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THE RADIO *Radio* HANDBOOK

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The "Radio" Handbook

Steve Sholand
W9RLP

By

FRANK C. JONES

and the

Technical Staff of "Radio"

1938

EDITION

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Chapter Contents

Foreword

THE EDITORS of RADIO long have been convinced of the need for a radio handbook that is authoritative technically, yet one which is journalistically sound and substantially new, one that represents far *more* than a mere condensation of previously published magazine articles with the same illustrations, the same mathematics.

The history of this handbook, now in its fourth edition, gratifyingly has supported this view. Within the short period during which it has been published, sales have approached closely the 100,000 mark, and this despite the fact that changes in the book's title have occurred twice. Called last year the *Jones Radio Handbook* by reason of its being a separate publishing venture, this issue the book returns to its former title, RADIO HANDBOOK.

This fourth edition of the handbook comes in an enlarged and revised form. No chapter remains unchanged; all, we believe, are improved. With patience and perseverance Frank C. Jones, the principal author, and the editors of RADIO have sought to determine the clearest methods of presenting all technical information. Even the fundamentals of the theory have been simplified, made more understandable. The new mathematical formulae, based upon laboratory experience, are more clear and far more workable.

As the reader turns through these pages he will find chapter after chapter of vital information.

New methods have been evolved for the presentation of the buffers and amplifiers. By means of them the reader will be able to select the oscillator, buffer, and doubler or final amplifier he prefers, regardless of the type of tube he has or desires to use. This will permit the design of a transmitter employing one of several suitable combinations of the respective units. It is no longer necessary to adhere to one complete set of instructions in constructing a transmitter unless the reader wishes to do so. For those who do so desire, several pages devoted to completely-built transmitters also will be found.

Taken in all, no effort has been spared in this attempt to compile a more comprehensive source of reference than has ever been published previously. We are confident that this edition will meet with the reader's approval.

THE PUBLISHERS.

LOS ANGELES, CALIFORNIA.
November, 1937

The authors' appreciation for helpful advice and cooperation is extended to Prof. F. E. Terman of Stanford University, Mr. Clayton F. Bane, D. B. McGowan, and to the Radio Corporation of America for its permission to reprint certain of the formulae in the theoretical pages of the handbook.

Chapter 1

Fundamental Electrical Principles and Radio Theory

IT IS difficult for anyone to advance in the study of radio without a first-hand knowledge of electrical phenomena. *Electricity* can be considered as a movement of extremely minute negative charges; an understanding of electricity can therefore be acquired from a knowledge of the action and nature of infinitesimal units. These small particles of energy are known as *electrons.*

● The Electron

Our food, clothing, houses, our entire world—in fact, the human being himself—is a combination of approximately ninety-two substances, called *elements.* In spite of this large number of elements, each in turn is composed of two basic units, the positive *proton* and the negative *electron.* The difference between iron and copper, for example, lies not in the basic units of which they are composed, but rather in the *quantity* and the *position* of these units.

In combination, these electrons and protons are known as *atoms.* The proton (one or more) represents the central or neuclear *positive charge,* while the electron (or electrons) represents the outer or *negative charge.* These electrons revolve around the central unit in an elliptical path or orbit, in much the same manner as the planets in our solar system revolve about the sun. The atoms which make up the various elements differ mainly in the fact that some have several "rings" of electrons, rather than a single ring.

The electrons in the orbits which surround the positive nucleus have a charge that is exactly equal to the central unit, and, since they are opposite in *polarity,* a perfect state of balance exists. It is this same general state of balance which exists throughout nature, generally speaking.

It is important to understand that an atom (or atoms) containing several orbits of electrons around the central portion (nucleus) will have many of its electrons at a considerable distance from the nucleus, and consequently these electrons will not be so strongly held as those in the nearer orbits.

In relative size the proton is considered to be approximately 1,845 times larger than the electron. Any attempt to visualize the actual physical mass of either is quite impossible, the realization becoming evident when it is considered that countless billions upon billions of electrons and protons make up a tiny piece of copper wire.

When this enormous quantity of atoms in any particular object is taken into consideration, it is easier to understand why, when electrons in some far-removed orbit are not so strongly held by their central positive proton, such electrons are very apt to be attracted by some other atom which has previously lost its outer electron. This is precisely what happens.

As was previously related, the atom at all times seeks to maintain a state of balance; this is accomplished only when an atom has the proper number of electrons. If one electron is lost to some other atom, balance is quickly restored by attracting another. Consequently, there is a continuous helter-skelter movement of electrons, a constant shifting from one atom to another. The electrons which move about in a substance are called *free electrons,* and it is these free electrons that make possible the *electric current.*

● Insulators and Conductors

If the atomic structure of a certain material is such that all of the electrons in an individual atom are tightly held by their positive proton and tend to remain within their own orbits, the material or substance will have very few free electrons and becomes what is known as an *insulator.* Mica, glass, porcelain, and dry air are examples of such insulators. On the other hand, materials that have a large number of free electrons are known as *conductors*. Most metals, such as copper, silver and aluminum are conductors. The ability of a material to pass an electric current is known as its *conductivity*. Metals which have high conductivity may be said to have low *resistance* to the flow of an electric current.

● The Electric Current

The free electrons in a conductor move constantly about and change their position in a haphazard manner. If, however, the conductor is connected between the positive and negative terminals of a battery, there will be a steady movement of electrons from the negative to positive terminal, in *addition* to the irregular movement of the electrons. This flow constitutes an *electric current*, but as soon as the battery is removed, the current will cease.

In explanation, it can be said that when the battery was first connected to the wire, there existed a shortage of electrons at one terminal, which the electrons at the other terminal attempted to supply.

It must always be remembered that the constant *movement* of electrons in a definite direction creates an electric current. In the previous example, the constant electron movement was brought to a halt when the battery was disconnected, since the surplus electrons immediately supplied the deficiency existing at one end and established a balance throughout the entire conductor.

● Resistance

The molecular structure of certain metals is such that when the free electrons are made to flow in a definite direction, there are frequent collisions between them and the individual atoms in the material. The result of these collisions is to *decrease* the total number of electrons flowing out of the material. This ability of a substance to resist the steady electron flow is called its *resistance*.

It will require a greater *electromotive force* to produce a given current through a substance with high resistance than to produce the same current in a good conductor. In the case of the conductor, virtually all of the electromotive force is effective in producing current, whereas in the resistor a portion is wasted in the form of lost energy, due to electron collisions. These collisions cause the material to become heated, and part of the initially-applied electromotive force is thus ultimately lost in the form of heat. This same phenomenon of heat is exhibited when a metal is repeatedly struck by a hammer.

The resistance of a uniform length of material is directly proportional to its length, and inversely proportional to its cross-section. A wire with a certain resistance for a given length will have twice as much resistance if the length of the wire is doubled. For a given length, doubling the size (cross section) of the wire will *halve* the resistance. It is also important to note that the resistance of most materials will increase as the temperature is increased. Thus, the resistance of the filament in a vacuum tube, or in a tungsten electric lamp, is many times higher when brought to operating temperature than when it is cold.

The resistance of a material or circuit can be expressed by a constant, *R*, which is equal to the ratio of the applied electromotive force to the current produced. Expressed as an equation:

$$R = \frac{\text{electromotive force}}{\text{current}}$$

This equation constitutes the basis for *Ohm's Law*, which is treated at length in the succeeding text.

The commonly-used unit of resistance is the *ohm*, although the expression *megohm* (1,000,000 ohms) is sometimes used when very large quantities are involved.

● The Ampere

The strength of an electric current depends upon the rate at which electrons pass a given point. The units of measurement are the *ampere* and the *coulomb*, one ampere being equal to 6.28×10^{18} electrons passing a given point in one second. The generally-used term in electrical practice is the ampere, in which the time element is already implied and need not be stated, as would be the case when referring to current in terms of coulombs (coulombs per second).

● The Volt

The electrons are driven through the wires and components of a circuit by a force called an *electromotive force*, usually abbreviated *e.m.f.* or *EMF*. The unit that denotes this force is called the *volt*. This force or pressure is measured in terms of the difference in the number of electrons at one point with respect to another. This is known as the *potential difference*. The relationship between the electromotive force (voltage) to the flow of current (amperes), and the resistance which impedes the flow of current (ohms), is very clearly expressed in a simple but highly valuable law, known as *Ohm's Law.*

Ohm's Law

This law states that the current in amperes is equal to the voltage divided by the resistance in ohms. Expressed as an equation:

$$I = \frac{E}{R}$$

If the voltage (E) and resistance (R) are known, the current (I) can be readily found. If the voltage and current are known, and the resistance is unknown, the resistance (R) is equal to $\frac{E}{I}$. When the voltage is the unknown quantity, it can be found by multiplying I × R. These three equations are all secured from the original by simple transposition. The expressions are here repeated for quick reference:

$$I = \frac{E}{R} \qquad R = \frac{E}{I} \qquad E = IR$$

where I is the current in amperes.
R is the resistance in ohms,
E is the electromotive force in volts.

Practical Problems

A typical example for the application of Ohm's law would be a resistance-coupled amplifier whose plate resistor has a value of 50,000 ohms, with a measured current through this resistor of 5 milliamperes. The problem is to find the actual voltage applied to the plate of the tube. From Ohm's law, the resistance *R* is 50,000 ohms. The current *I* is given as 5 milliamperes; milliamperes must, therefore, first be converted into amperes; .005 amperes equals 5 milliamperes. The electromotive force or voltage, *E*, is the unknown quantity. Ohm's law is applied as follows:

Formula: E = I × R
R = 50,000 ohms
I = .005 amperes

Solution: .005 × 50,000 = 250 volts drop across the resistor.

If the power supply delivers 300 volts, the actual voltage on the plate of the tube would be only 50 volts. This means that 250 volts of the supply voltage would be consumed in forcing a current of .005 amperes through the 50,000 ohm plate resistor.

Example (2)

Given the same amplifier, suppose it is desirable in this case to have a voltage of 150 on the plate of the tube. The known quantities are a plate current of 10 milliamperes (.010 amperes), and a supply voltage of 300 volts. It is desired to find the value of plate resistor to provide this drop in voltage.

It is obvious from the foregoing that with 300 volts plate supply available, the voltage that must be consumed across the plate resistor is 150 volts, so that 150 volts will remain at the plate of the tube. The problem is solved as follows:

From Ohm's law, $R = \frac{E}{I}$

E in the above example is equal to the *difference* between supply and desired voltages, or the "*voltage drop*" across the resistor, *R*.

Therefore:

$$R = \frac{150}{0.010}, \text{ or } 15,000 \text{ ohms.}$$

Example (3)

The given supply voltage is 300, and the (measured) voltage on the plate of the tube is 100 volts. Find the current flowing through the plate resistor of 20,000 ohms.

From Ohm's law, $I = \frac{E}{R}$. *E* again equals the *difference* between supply and measured plate voltages.

Therefore:

$$I = \frac{200}{20,000},$$

I = .01 amperes, or 10 milliamperes.

Resistances in Series

The *total* resistance of several resistances in series is equal to the sum total of the individual resistances. A 50,000-ohm resistance in *series* with a 25,000-ohm resistance would give a total resistance of 75,000 ohms.

Formula: $R_1 + R_2 = R$.

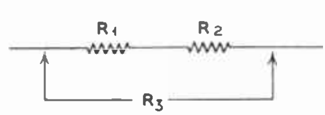


Figure 1

Resistances in Parallel

When *two* resistances of *equal* value are connected in *parallel,* the total resistance will be one-half the resistance of one. Two 100,000-ohm resistances connected in parallel would have a total resistance of only 50,000 ohms.

When two or more resistances are connected in parallel, the effective total is always *less* than the value of the lowest resistance in the group. The value of three or more *unequal* resistances in parallel is solved from the following formula:

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

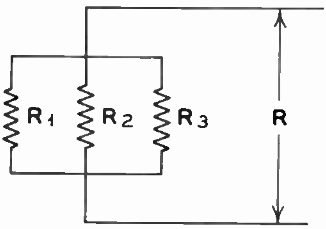


Figure 2

Three or More Parallel Resistors All Having the Same Value

When three or more resistors of the *same value* are connected in parallel, the effective resistance is the common value divided by the number of resistances connected in parallel.

Examples:

Three resistances of 75,000 ohms each, connected in parallel, would have an effective resistance of $\frac{75{,}000}{3}$ *or only 25,000 ohms.*

Four resistances of 200 ohms each, connected in parallel, would have an effective resistance of $\frac{200}{4}$, *or only 50 ohms.*

Two Unlike Resistances In Parallel

When two resistances have the *same* value, the above formula applies. When the resistances are of *unequal* values, the following formula is used:

$$R = \frac{R_1 \times R_2}{R_1 + R_2},$$

where R is the unknown quantity,
R_1 is the resistance of the first resistor,
R_2 is the resistance of the second resistor.

A typical example would be an a.v.c. resistor of 500,000 ohms, which is to be shunted (paralleled) with another resistor of some value, in order to bring the *effective* resistance value *down* to a value of 300,000 ohms. Substituting these values in the equation for two unequal resistances in parallel:

$$300{,}000 = \frac{500{,}000 \times R_2}{500{,}000 + R_2}.$$

By transposition, factoring and solution, the effective value of R will be 750,000 ohms. Thus a 750,000-ohm resistance must be connected across the 500,000-ohm resistance in order to secure an effective resistance of 300,000 ohms.

In solving for values other than those given, the simplified equation becomes:

$$R_2 = \frac{R_1 \times R}{R - R_1},$$

where R is the resistance present,
R_1 is the resistance to be obtained,
R_2 is the value of the unknown resistance necessary to give R_1 when in parallel with R.

Resistances in Series-Parallel

Resistances in series-parallel can be solved from the equation:

$$R = \frac{1}{\frac{1}{R_1 + R_2} + \frac{1}{R_3 + R_4} + \frac{1}{R_5 + R_6}}$$

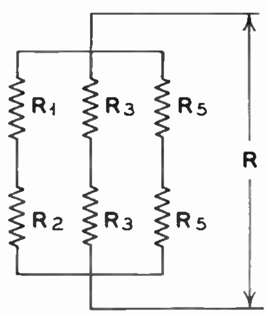


Figure 3

Power Measurements and Formulas for Resistive Circuits

It was previously stated that when a voltage causes a given current to flow through a resistor, heat is generated or dissipated by the resistor. This loss is attributable to the molecular structure of the material through which the current is made to pass. In other words, if the constant flow of electrons is always coming into contact with the atoms of the material through which the electrons flow, there will be countless collisions and the electrons must, therefore, be forced through in order that a given number will constantly move from the conducting medium. This phenomenon results in heating of the conductor, and this heating results in a loss of *power* or *energy*.

From Ohm's law, E = I × R, it can readily be seen that if the resistance of a circuit is doubled, it will require twice the voltage to maintain the same current flow through the added resistance. This expenditure of power can be considered as the product of the voltage and current in the circuit and is expressed in *watts*. Hence, W (watts) = E × I. Since it is very convenient to express power in terms of the resistance and current, a substitution of I × R for E (E = I × R) in the above formula, gives: W = IR × I, or I^2R.

In terms of voltage and resistance, $W = \frac{E^2}{R}$. Here $I = \frac{E}{R}$ and when this was substituted for I, the formula became $W = E \times \frac{E}{R}$ or $W = \frac{E^2}{R}$. These three expressions are repeated for quick reference:

$$W = E \times I, \quad W = I^2 \times R, \quad W = \frac{E^2}{R}$$

where W is the power in watts,
E is the electromotive force or voltage,
I is the current in amperes.

This equation is used in a typical example, as follows: The voltage drop across a cathode resistor in a power amplifier stage is 50 volts; the plate current flowing through the resistor is 150 milliamperes. The number of watts the resistor will be required to dissipate is found from the formula: W (watts) = E × I, or 50 × .150 = 7.5 watts. (.150 amperes is equal to 150 milliamperes). From the foregoing it is seen that a 7.5-watt resistor will safely carry the required current, yet a 10- or 20-watt resistor would ordinarily be used to provide a safety factor.

In another problem, the conditions being similar to those above, but with resistance and current being the *known* factors, the solution is obtained as follows: $W = I^2 \times R = .0225 \times 333.33+ = 7.5$.

If only the voltage and resistance are known, $W = \frac{E^2}{R} = \frac{2500}{333.33} = 7.5$ watts. It is seen that all three equations give the same result; the selection of the particular equation depends only upon the known factors.

• Voltage Dividers

A voltage divider is exactly what its name implies: a resistor or a series of resistors, connected across a source of voltage from which various lesser values of voltage may be obtained by connection to various points along the resistor. A voltage divider serves a most useful purpose in a radio receiver, transmitter or amplifier, because it offers a simple means of obtaining plate, screen and bias voltages of different values from a common power supply source. It may also be used to obtain very low voltages of the order of .01 to .001 volts with a high degree of accuracy, even though a means of measuring such voltages is lacking. The procedure for making these measurements can best be given in the following example:

It is assumed that an accurately calibrated 0-150 voltmeter is available and that the source of voltage is exactly 100 volts. This 100 volts is then impressed through a resistance of exactly 1,000 ohms. It will then be found that the voltage along various points on the resistor, with respect to the grounded end, will be exactly proportional to the resistance at that point. From Ohm's law, the current would be 0.1 ampere; this current remains unchanged, since the original value of resistance (1,000 ohms) and the voltage source (100 volts) are unchanged. Thus, at a 500-ohm point on the resistor (half its entire resistance), the voltage will likewise be halved or reduced to 50 volts.

The equation gives the proof: E = 500 × 0.1 = 50. At the point of 250 ohms on the resistor, the voltage will be one-fourth the total value or 25 volts (E = 250 × 0.1 = 25). Continuing with this process, a point can be found where the resistance measures exactly one ohm, and where the voltage equals 0.1 volt. It is, therefore, obvious that if the original source of voltage and resistance can be measured, it is a simple matter to predetermine the voltage at any point along the resistor, provided that the current remains constant.

Bleeder Resistors

Resistors are often connected across the output terminals of power supplies in order to "bleed off" a constant value of current or to serve as a constant, fixed load. The regulation of the power supply is thereby improved and the voltage is maintained at a more or less constant value, regardless of load conditions. When the load is entirely removed from a power supply, the voltage may rise to such a high value as to ruin the filter condensers. The amount of current which can be drawn from a power supply depends upon the current rating of the particular power transformer in use. If a transformer will carry a maximum safe current of 100 milliamperes, and if 75 milliamperes of this current is required for operation of a radio receiver, there remains 25 milliamperes of current available to be "wasted" in the bleeder resistor.

An example for calculating bleeder resistor values for safe wattage rating is as follows: The power supply delivers 300 volts. The power transformer can safely supply 75 milliamperes of current, of which 60 milliamperes will be required for the receiver. The problem is to find the correct value of resistance to give a bleeder current of 15 milliamperes. Ohm's law gives the solution:

$$R = \frac{E}{I} = \frac{300}{.015} = 20{,}000 \text{ ohms.}$$

(15 milliamperes is equivalent to .015 ampere.) Therefore, it is seen that the bleeder resistor should have a resistance of 20,000 ohms.

Another problem would be to find the required safe wattage rating of the bleeder, under the same conditions as given in the previous example. The answer is secured as follows: $W = E \times I = 300 \times .015 = 4.5$ watts. It is considered good practice to allow an overload factor of at least 100 per cent, since the voltage will increase somewhat when all load except the bleeder is removed. Therefore, a 10-watt resistor should be chosen.

Design of Voltage Dividers

The design of a voltage divider for any type of radio equipment is a relatively simple matter. The first consideration is the amount of bleeder current to be drawn, which is dictated largely by the examples previously given. In addition, it is also necessary that the desired voltage and the exact current at each tap on the voltage divider be known. The current does not flow from the tap-on point through the resistor to ground or negative terminal, but rather from the positive side, then out through the tap, then through the device to ground. This explanation can be more easily followed by referring to figure 4, wherein the arrows indicate the direction of current flow through the external load.

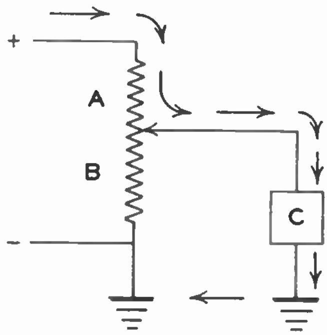


Figure 4

The device which secures current from the voltage divider is indicated as *C*. The current drawn by *C* flows through section *A* of the bleeder resistor, then through *C*. and back to ground. The bleeder current, however, flows through the entire divider, i.e., through both *A* and *B*. Therefore, it becomes apparent that when a tap-on point is chosen to give the voltage desired, it is necessary to consider not only the current drawn by the device *C*, but also the bleeder current.

The design of more complex voltage dividers can best be illustrated by means of the following problems:

A power supply delivers 300 volts and is conservatively rated to supply all needed current for the receiver and still allow a bleeder current of 10 milliamperes. The following voltages are wanted: 250 volts at 20 milliamperes for the plates of the tubes. 100 volts at 5 milliamperes for the screens of the tubes, and 75 volts at 2 milliamperes for the detector tube. The voltage drop from the 300-volt value to the required 250 volts would be 50 volts; for the 100-volt value, the drop will be 150 volts; for the 75-volt value, the drop will be 225 volts. These values are shown in the diagram of figure 5. The respective current values are also indicated.

Tabulating the above:

$$A = \frac{\text{Voltage Drop}}{\text{Current}} = \frac{50}{.037} = 1{,}351 \text{ ohms.}$$

Dissipation = .037 × 50 = 1.85 watts.

$$B = \frac{\text{Voltage Drop}}{\text{Current}} = \frac{150}{.017} = 8{,}823 \text{ ohms.}$$

Dissipation = .017 × 150 = 2.25 watts.

$$C = \frac{\text{Voltage Drop}}{\text{Current}} = \frac{26}{.012} = 2{,}083 \text{ ohms.}$$

Dissipation = .012 × 25 = 0.3 watts.

$$D = \frac{\text{Voltage Drop}}{\text{Current}} = \frac{75}{.010} = 7{,}500 \text{ ohms.}$$

Dissipation = .010 × 75 = 0.75 watts.

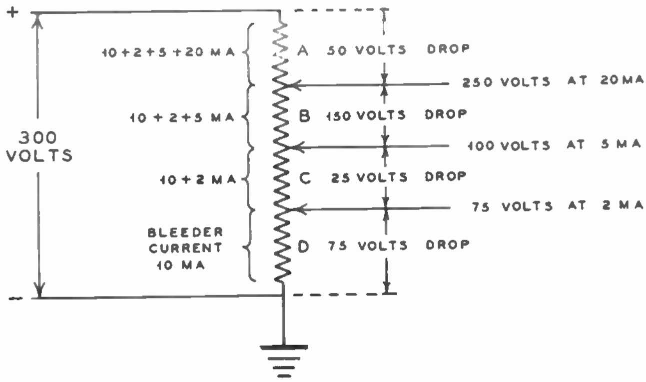


Figure 5

The total resistance of the divider is 19,757 ohms; this value is secured by adding together the four resistance values of 1,351, 8,823, 2,083 and 7,500 ohms. A 20,000 ohm resistor with three sliding taps will, therefore, be of the approximately-correct size and therefore would ordinarily be used because of the difficulty in securing four separate resistors of the exact, odd values indicated, and because no adjustment would be possible to compensate for any slight error in estimating the probable currents through the various taps.

Although the wattage dissipation across all the individual sections is only 5.15 watts, the selection of a single resistor, such as a large resistor with several sliders, should be based not only on the wattage rating but also on the current that it will safely carry. In the above example, the wattage of the section carrying the heaviest current is only 1.85 watts. The maximum dissipation of any particular section is 2.25 watts. Yet, if a 5-watt resistor were selected, it would very soon burn up. The reason for this is that *part* of the divider must handle 37 ma. The selection for wattage rating is therefore made on the basis of *current*, because wattage rating of resistors assumes uniform current distribution. Most manufacturers rate their resistors in this manner; if not, it can be calculated from the resistance and wattage rating.

Once the sliders on the resistor are set to the proper point, as in the above example, the voltages will remain constant at the values shown as long as the current remains a constant value. One of the serious disadvantages of the voltage divider becomes evident when the current drawn from one of the taps changes. It is obvious that the voltage drops are inter-dependent and, in turn, the individual drops are in proportion to the current which flows through the respective sections of the divider resistor. The only remedy lies in providing a heavy, steady bleeder current, so as to make the individual currents so small a part of the total current that any change in current will result in only a slight change in voltage. This can seldom be realized in practice because of the excessive values of bleeder current which would be required.

When a power supply is used for C-bias service, still another factor must be taken into consideration. The rectified grid current from the amplifier stages will flow through the divider, in addition to the bleeder current. If this current changes, the voltage applied to the grid will also correspondingly change. When adjustments of a C-bias supply are made, the amplifier should be operated in the condition where it draws its proper amount of grid current; otherwise, the C-bias resistor setting will be greatly in error. Heavy bleeder currents are thus required for C-bias supplies, especially where the grid current is changing and the bias must remain constant, as in certain types of phone transmitters.

Resistances for Operating Filaments in Series

When computations are made for the operation of vacuum tube filaments or heaters in series-connection, it should be remembered that each has a definite resistance and that Ohm's law here again holds true, just as it does in the case of a conventional resistance.

No particular problem is involved when two exactly similar tubes of the same voltage and current rating are to be operated with their filaments or heaters connected in series in order to operate them from a source of voltage twice as high as is required for the tubes. If two six-volt tubes, each requiring 0.5 ampere for heater operation, are connected in series across a 12-volt power source, each tube will have the same voltage drop (6 volts), and the total current drawn from the power supply will be the same as for one tube or 0.5 ampere. By making this connection, the resistance has actually been doubled; yet, because the voltage is doubled, each tube automatically secures its proper voltage drop. In this example, the resistance of each tube would be 12 ohms (6 divided by 0.5). In series, the resistance would be twice this value or 24 ohms. The current I would then equal $\frac{12}{24}$ or 0.5 amperes, from which it can be seen that the current drawn from the supply is the same as for a single tube.

It is important to understand that in a series connection the sum of the voltage drops across all of the tubes in the circuit cannot be more than the voltage of the supply. It is not possible to connect six similar 6-volt tubes in series across a 32-volt supply and expect to realize 6 volts on the filaments of each, since the sum of the various voltage drops is equal to 36 volts. The tubes can, however, be connected in such a manner that the correct voltage drop will be secured, as will be explained later.

The following examples and diagrams give all needed design information for series- and series-parallel connections:

Example—One 6F6 and one 6L6 tube are to be operated in a low-power aeroplane transmitter. The power supply delivers 12.6 volts. The problem is to connect the heaters of the two tubes in such a manner that each tube will have exactly the same voltage drop across its heater terminals. The *tube tables* show that a type 6F6 tube draws 0.7 ampere at 6.3 volts. Its resistance, accordingly, equals $R = \frac{E}{I} = \frac{6.3}{0.7} = 9$ ohms.

The 6L6 tube draws 0.9 ampere at 6.3 volts, and its resistance equals $\frac{6.3}{0.9} = 7$ ohms.

If these tubes are connected in series without precautionary measures, the total resistance of the two will be 16 ohms (9 + 7). A potential of 12.6 volts will pass a current of 0.787 amperes through this value of 16 ohms. The drop across each separate resistor is found from Ohm's law, as follows: $9 \times 0.787 = 7.083$ volts, and $7 \times 0.787 = 5.4$ volts. Thus, it is seen that neither tube will have the correct voltage drop. One of the resistor values must, therefore, be changed so that it will be equal to the other, in order that the voltage drop will be equal across both tubes. If the larger of the two resistors is taken, and another resistor connected in parallel across it, the value of the larger resistor can then be brought down to that of the smaller.

Substituting these values in an equation previously given, $R = \frac{7 \times 9}{7 - 9} = 31.5$ ohms.

By connecting a resistance of 31.5 ohms in parallel with the 9-ohm resistance, the effective resistance will be exactly 7 ohms or equal to that of the other resistor.

The problem is made more simple by the following procedure:

If the tubes are regarded on the basis of their respective current ratings, it will be

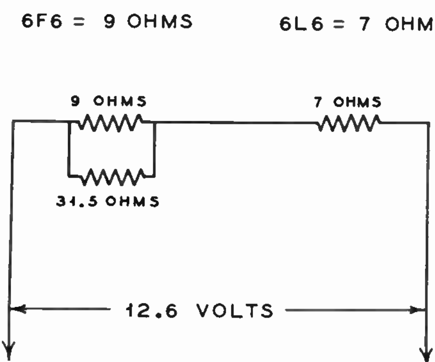


Figure 6

found that the 6L6 draws 0.9 ampere and the 6F6 0.7 ampere, or a difference of 0.2 ampere. If the resistance of the 6F6 is made equal to that of the 6L6, both tubes will draw the same current. Simply take the difference in current, 0.2 amperes, and divide this value into the proper voltage drop, 6.3 volts; the answer will be 31.5 ohms, which is the exact same value which was obtained in the previous round-about method of calculation.

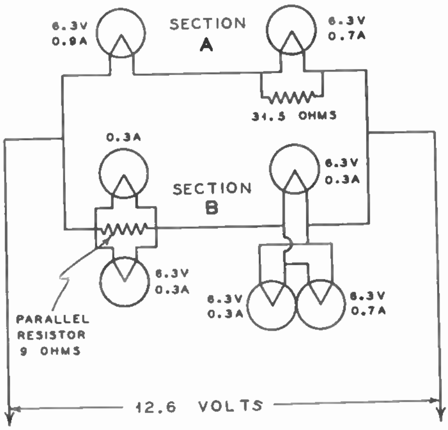


Figure 7

The diagram in figure 7 shows other possible connections for tubes of dissimilar heater or filament current ratings. Although section *B* in figure 7 appears formidable, it is a simple matter to make the necessary calculations for operating the tubes from a common source of supply. In section *B* there are three tubes, with their heaters connected in parallel. The current, therefore, will be 0.3 + 0.3 + 0.7 = 1.3 amps. The two tubes in parallel draw 0.3 + 0.3 = 0.6 amps. The difference between 1.3 and 0.6 is 0.7 amps. The drop across each section is the same or 6.3 volts; therefore, $\frac{6.3}{0.7}$ = 9 ohms. This value of resistance across the two parallel-connected tubes gives their sections the same resistance as that of the three tubes; consequently, all tubes secure the proper voltage.

When tube heaters or filaments are operated in series connection, the current is the same throughout the entire circuit. The resistance of all tube filaments must then be made the same if each is to have the same voltage drop across its terminals. The resistance of a tube heater or filament should never be measured when cold, because the resistance will be only a fraction of the resistance present when the tube functions at proper heater or filament temperature. The resistance can be satisfactorily calculated by using the current and voltage ratings given in the tube tables.

Conversion Table for Volts, Amperes and Watts.

1 kilovolt = 1,000 volts.
1 volt = 1/1000 kilovolt, 10^{-3} kilovolts, or .001 kilovolts.
1 millivolt = 1/1000 volt, 10^{-3} volts, or .001 volts.
1,000 millivolts = 1 volt.
1 microvolt = 1/1,000,000 volt, 10^{-6} volts, or .000001 volts.
1,000,000 microvolts = 1 volt.
1,000 microvolts = 1 millivolt, or 10^{-3} volts.
1 milliampere = 1/1,000 ampere, 10^{-3} amperes, or .001 amperes.
1,000 milliamperes = 1 ampere.
1 microampere = 1/1,000,000 ampere, 10^{-6} amperes, or .000001 amperes.
1,000 microamperes = 1 milliampere, or 10^{-3} amperes.
1 kilowatt = 1,000 watts.
1 watt =1/1,000 kilowatt, 10^{-3} kilowatts, or .001 kilowatts.
1 milliwatt = 1/1,000 of a watt, 10^{-3} watts, or .001 watts.
1,000 milliwatts = 1 watt.
1 microwatt = 1/1,000,000 of a watt, 10^{-6} watts, or .000001 watts.
1,000 microwatts = 1 milliwatt or 10^{-3} watts.

● Alternating Current

In all previous portions of this text, consideration was given only to a steady flow of electrons in one direction. Such currents are known as *uni-directional* or *direct currents,* abbreviated *d.c.* Radio and electrical practice also makes use of another and altogether different kind of current, known as *alternating current* abbreviated *a.c.*

An alternating current begins to flow in one direction, meanwhile changing its amplitude from zero to a maximum value, then down again to zero, from which point it changes its direction, and again goes through the same procedure. Each one of these zero-maximum-zero amplitude changes in a given direction is called a *half cycle*. The complete change in two directions is called a *cycle*. The number of times per second that the current goes through a complete cycle is called the *frequency*. The frequency of common house-lighting alternating current is generally 60 cycles, meaning that it goes through 60 complete cycles (120 reversals) per second.

High radio-frequency currents, on the other hand, go through so many of these changes per second that the term *cycle* becomes unwieldy. As an example, it can be said that a certain station is operating on 14,000,000 cycles. However, it is simpler to say 14,000 *kilocycles*, or 14 *megacycles*. A conversion table for simplifying this terminology is given here:

1,000 *cycles* = 1 *kilocycle. The abbreviation for kilocycle is kc.*
1 *cycle* = 1/1,000 *of a kilocycle*, .001 *kc. or* 10^{-3} *kc.*
1 *megacycle* = 1,000 *kilocycles, or* 1,000,000 *cycles*, 10^{-3} *kc. or* 10^{-6} *cycles.*
1 *kilocycle* = 1/1,000 *megacycle*, .001 *megacycles, or* 10^{-3} *Mc. The abbreviation for megacycles is Mc.*

Ohm's Law Applied to Alternating Current

Ohm's law applies equally to direct or alternating current, *provided* that the circuits under consideration are purely resistive, i.e., circuits which have neither inductance (coils) nor capacitance (condensers). Problems which involve tube filaments, drop resistors, electric lamps, heaters or similar resistive devices can be solved from Ohm's law, regardless of whether the current is direct or alternating. When a condenser or a coil is made a part of the circuit, a property common to each, called *reactance*, must be taken into consideration. Reactance will be treated under a separate heading.

Electromagnetic Effects

When an electric current flows through a conductor, the moving electrons which comprise this current set up *lines of force* in the surrounding medium. These are termed *lines of magnetic force*, and they extend outwardly from the conductor in a plane at right angles to its direction. It is these lines of magnetic force that make up the *magnetic flux*. In drawing an analogy of voltage, current and resistance in terms of magnetic phenomena, magnetic flux might be termed *magnetic current; magneto-motive force, or magnetic voltage*. The *reluctance* of a magnetic circuit can be thought of as the resistance of the magnetic path. The relation between the three is exactly the same as that between current, voltage and resistance (Ohm's law).

The magnetic flux depends upon the material, cross-section, and length of the magnetic circuit, and it varies directly as the current flowing in the circuit. The *reluctance* is dependent upon the length, cross-section, permeability, and air-gap, if any, of the magnetic circuit.

In the electrical circuit, the current would equal the voltage divided by the resistance, and so it is in the magnetic circuit.

$$\text{Magnetic Flux } (\phi) = \frac{\text{magneto-motive force (m.m.f.)}}{\text{reluctance } (r)}$$

Permeability

Permeability describes the difference in the magnetic properties of any magnetic substance as compared with the magnetic properties of air. Iron, for example, has a permeability of around 2,000 times that of air, which means that a given amount of magnetizing effect produced in an iron core by a current flowing through a coil of wire will produce 2,000 times the *flux density* that the same magnetizing effect would produce in air. The permeabilities of different iron *alloys* vary quite widely and permeabilities up to 100,000 can be obtained, if required.

Permeability is similar to *electric conductivity*. There is, however, one important difference: the permeability of iron is not independent of the magnetic current (flux) flowing through it, although electrical conductivity is usually independent of electric current in a wire. After a certain point is reached in the flux density of a magnetic conductor, an increase in the magnetizing field will not produce a material increase in flux density. This point is known as the *point of saturation*. The inductance of a choke coil whose core is saturated declines to a very low value.

The magnetizing effect of a coil is often described in *ampere turns*. *Two amperes* of current flowing through *one turn* is equal to *two ampere turns*. From this it can be seen that the flux can be increased by either increasing the current through the conductor or by making the conductor into the form of a coil of many turns. As a means of showing why the flux is increased when the conductor is put into the form of a coil, two figures are given here:

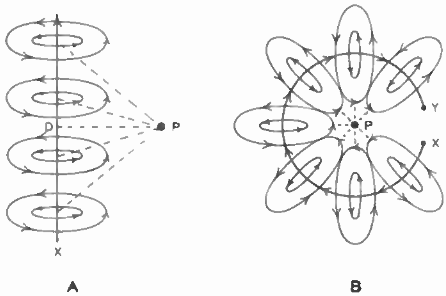


Figure 8-A Figure 8-B

In *A* of figure 8, an arbitrary point "*P*" is chosen to represent a point at some fixed distance from a straight conductor, *X-Y*. Upon examination, it will be seen that the maximum effect will be exerted on *X-Y* by the lines of force which are nearest this point, or at *D*. The field intensity at the fixed point is the resultant or vector sum of all the fields due to the individual electron flow along the conductor. Other fields than those at the shortest distance will then have less and less effect as they lie farther along the conductor. If the conductor is arranged in the shape shown in *B* of figure 8, it will readily be seen that all of the fields along the conductor will act equally on the central point, *P*, with the result that the field is greatly strengthened.

When a conductor is wound into a number of turns in the form of a coil, the flux which encircles the current flowing through an individual *turn* also links the turns adjacent to it. Thus, in a multi-turn coil, the magnetic field which is produced will be much greater than if only a single turn were used. This flux increases or decreases in direct proportion to the change in the current. The ratio of the change in flux to the change in current has a constant value, known as the *inductance* of a coil.

It is a fundamental law of electricity that when lines of force cut across a conductor, a voltage is induced in that conductor. Therefore, it can be readily seen that in the case of the coil previously mentioned, the flux lines from one turn cut across the adjacent turn, and a *voltage* is induced in that turn. The effect of these induced voltages is to create a voltage across the entire coil of opposite polarity or in the opposite direction to the original voltage. Such a voltage is called *counter e.m.f.* or *back e.m.f.*

If a direct current potential such as a battery is connected across a multi-turn coil or inductance, the back e.m.f. will exist only at the instant of connection, at which time the flux is rising to its maximum value. While it is true that a current is flowing through the turns of the coil and that a magnetic field exists around and through the center of the inductance, an induced voltage may only be produced by a *changing flux*. It is only such a changing flux that will cut across the individual turns and induce a voltage in them. By a changing flux is meant a flux that is increasing or decreasing, as would occur if the e.m.f. across the coil were alternating or changing its direction periodically.

As the current increases, the back e.m.f. increases; as the current decreases, the back e.m.f. decreases. This back voltage is always *opposite* to the exciting voltage and, hence, always acts to resist any *change* in current in the inductance. This property of an inductance is called its *self inductance* and is expressed in *henrys,* the henry being the unit of inductance. A coil has an inductance of one henry when a voltage of one volt is induced by a current change of one ampere per second. The unit, henry, is too large for reference to inductance coils such as those used in radio-frequency circuits; *millihenry* or *microhenry* are more commonly used, in the following manner:

1 *henry* = 1,000 *millihenrys, or* 10^3 *millihenrys.*

1 *millihenry* = 1/1,000 *of a henry, or* .001 *henry, or* 10^{-3} *henry.*

1 *microhenry* = 1/1,000,000 *of a henry, or* .000001 *henry, or* 10^{-6} *henry.*

One-one-thousandth of a millihenry = .001 *or* 10^{-3} *millihenrys.*

1,000 *microhenrys* = 1 *millihenry.*

● Mutual Inductance

When two inductances are so placed in relation to each other that the lines of force encircling one coil are interlinked with the turns of the other, a voltage will be set up or *induced* in the second coil. As in the case of self-inductance, the *induced voltage* will be opposite in direction to the exciting voltage. This effect of linking two inductances is called *mutual inductance*, abbreviated *M*, and is also expressed in henrys. Two circuits thus joined are said to be *inductively coupled*. The magnitude of the mutual inductance depends upon the shape and size of the two circuits, their positions and distances apart, and the permeability of the medium. The extent to which two inductances are coupled is expressed by a relation known as *coefficient of coupling*. This is the ratio of the mutual inductance actually present to the maximum possible value.

• Inductances in Parallel

Inductances in parallel are combined exactly as are resistors in parallel, provided that they are far enough apart so that the mutual inductance is entirely negligible, i.e., if the coupling is very loose.

• Inductances in Series

Inductances in series are additive, just as are resistors in series, again provided that no mutual inductance exists. In this case, the total inductance *L* is:

$$L = L_1 + L_2 + \ldots\ldots\ldots\ldots\text{etc.}$$

Where mutual inductance does exist:

$$L = L_1 + L_2 + 2M,$$

where M is the mutual inductance.

This latter expression assumes that the coils are connected in such a way that all flux linkages are in the same direction, i.e., additive. If this is not the case, and the mutual linkages *subtract* from the self linkages, the following formula holds:

$$L = L_1 + L_2 - 2M,$$

where M is the mutual inductance.

• Formulas for Calculating Inductance

The inductance of coils with magnetic cores can be determined with reasonable accuracy from the formula:

$$L = 1.257 \times N^2 \times P \times 10^{-8}$$

where

L is the inductance in henrys,
N is the number of turns,
P is the permeability of the core material.

From this formula it can be seen that the inductance is proportional to the square of the number of turns, *as well as to the permeability*. Thus, it is possible to secure greater values of inductance with a given number of turns of wire wound on an iron core than would be possible if an air-core coil were used.

Ordinary magnetic cores cannot be used for radio frequencies because the *eddy current losses* in the core material become enormous as the frequency is increased. The principal use for magnetic cores is in the audio frequency range below approximately 15,000 cycles, whereas at very low frequencies (50 to 60 cycles) their use is mandatory if an appreciable value of inductance is desired.

An air core inductor of only one henry in inductance would be quite large in size, yet values as high as 100 henrys are commonly available in small, iron core chokes. The inductance of a coil with a magnetic core will vary with the amount of direct current which passes through the coil. For this reason, iron core chokes that are used in power supplies have a certain inductance rating at a *predetermined value of d.c.*

One exception to the statement that metal core inductances are highly inefficient at radio frequencies is in the *powdered* iron cores used in some types of intermediate frequency transformers. These cores are made of very *fine particles* of powdered iron, which is first treated with an insulating compound so that each particle is insulated from the other. These particles are then molded into a solid core, around which the wire is wound. Eddy current losses are greatly reduced, with the result that these special iron cores are entirely practical in circuits which operate up to 1,500 kc. in frequency.

The inductance of an air core coil is proportional to the square of the number of turns of wire, provided that the length and diameter remain constant as the turns are changed (actually an impossibility, strictly speaking). The formula for inductance of air core coils is given with good accuracy, as follows:

$$L = N^2 \times d \times F.$$

where

L = inductance in microhenrys,
d = diameter of coil, measured to center of wire,
F = a constant, dependent upon the ratio of length-to-diameter.

This formula is explained under the heading of *Coil Calculation*, where a graph for the constant *F* is given.

• Mutual Conductance

The unit of conductance is the *mho*, which can be recognized as *ohm* spelled backward. Transconductance, or mutual conductance, is expressed in *micromhos;* the latter is 1/1,000,000 of a mho. A mutual conductance of 5,000 micromhos would be .005 mhos.

● Energy Stored in a Magnetic Field

The stored energy in a magnetic field is expressed in joules, and is equal to $\frac{L \times I^2}{2}$.

● Transformers: Primary—Secondary

When two coils are placed in such inductive relation to each other that the lines of force from one cut across the turns of the other and induce a voltage in so doing, the combination can be called a *transformer.* The name is derived from the fact that energy is transformed from one coil into another. The inductance in which the original flux is produced is called the *primary;* the inductance which *receives* the induced voltage is called the *secondary.* In a radio receiver power transformer, for example, the coil through which the 110-volts a.c. passes is the *primary,* and the coil from which a higher or lower voltage than the a.c. line potential is obtained is the *secondary.*

Transformers can have either air or magnetic cores, depending upon whether they are to be operated at radio or audio frequencies. The reader should thoroughly impress upon his mind the fact that current can be transferred from one circuit to another *only* if the primary current is changing or alternating. From this it can be seen that a power transformer cannot possibly function as such when the primary is supplied with non-pulsating d.c.

A power transformer usually has a magnetic core which consists of laminations of iron, built up into a square or rectangular form, with a center opening or "window." The secondary windings may be several in number, each perhaps delivering a different voltage. The secondary voltages will be proportional to the number of turns and to the primary voltage.

If a primary winding has an a.c. potential of 110 volts applied to 220 turns of wire on the primary, it is evident that this winding will have two turns per volt. A secondary winding of 10 turns, wound on an adjacent "leg" of the transformer core, would have a potential of 5 volts. If the secondary winding has 500 turns, the potential would be 250 volts, etc. Thus a transformer can be designed to have either a step-up or step-down ratio, or both simultaneously. The same applies to air core transformers for radio-frequency circuits.

● Inductive Reactance

It was previously stated that when an alternating current flows through an inductance, a back- or counter-electromotive force is developed; this force opposes any change in the initial e.m.f. The property of an inductance to offer opposition to a change in current is known as its *reactance* or *inductive reactance.* This is expressed as X_L:

$$X_L = 2\pi fL,$$

where X_L = inductive reactance expressed in ohms,
$\pi = 3.1416$ ($2\pi = 6.283$),
f = frequency in cycles,
L = inductance in henrys.

Since it is very often necessary to compute inductive reactance at radio frequencies, the same formula may be used, except that the units in which the inductance and the frequency are expressed will be changed. Inductance can, therefore, be expressed in *millihenrys* and frequency in *kilocycles.* For higher frequencies and smaller values of inductance, frequency is expressed in *megacycles* and inductance in *microhenrys.* The basic equation need not be changed, since the multiplying factors for inductance and frequency appear in numerator and denominator, and hence are cancelled out. However, it is not possible, in the same equation, to express *L* in millihenrys and *f* in cycles without conversion factors.

When it becomes desirable to know the value of inductance necessary to give a certain reactance at some definite frequency, a transposition of the original formula gives the following:

$$L = \frac{X_L}{2\pi f}$$

or, when X_L and L are known:

$$f = \frac{X_L}{2\pi L}$$

● Capacity; Condensers

When two metallic plates are separated from each other by a thin layer of insulating material (called a *dielectric*, in this case), the combination becomes a *condenser*. When a source of d.c. potential is momentarily applied across these plates, they may be said to become *"charged."* If the same two plates are then joined together momentarily, by means of a wire, the condenser will *"discharge."*

When the potential was first applied, electrons immediately started to flow from one plate to the other through the battery or such source of d.c. potential as was applied to the condenser plates. However, the circuit from plate-to-plate in the condenser was *incomplete* (the two plates being separated by an insulator) and thus the electron flow ceased, meanwhile establishing a shortage of electrons on one plate and a surplus of electrons on the other.

It will be recalled that when a deficiency of electrons exists at one end of a conductor, there is always a tendency for the electrons to move about in such a manner as to re-establish a state of balance. In the case of the condenser herein discussed, the surplus quantity of electrons on one of the condenser plates cannot move to the other plate, because the circuit has been broken; i.e., the battery or d.c. potential was removed. This leaves the condenser in a *"charged"* condition; the condenser plate with the electron *deficiency* is *positively* charged, the other plate being *negative*. In this condition, a considerable stress exists in the insulating material (dielectric) which separates the two condenser plates, due to the mutual attraction of two unlike potentials on the plates. This stress is known as *electrostatic* energy, as contrasted with *electromagnetic* energy in the case of an inductance. This charge can also be called *potential energy*, because it is capable of performing work when the charge is released through an external circuit.

When the external circuit of the two condenser plates is completed by joining the terminals together with a piece of wire, the electrons will immediately rush from one plate to the other through the external circuit and establish a state of equilibrium. This latter phenomenon explains the *discharge* of a condenser. The amount of stored energy in a charged condenser is dependent upon the charging potential, as well as a factor which takes into account the *size* of the *plates, dielectric thickness, nature* of the dielectric, and the *number* of plates. This factor, which is determined by the foregoing, is called the *capacity* of a condenser and is expressed in farads.

$$\text{Stored energy in } joules = \frac{C \times E^2}{2},$$

where C = unit of capacity, the *farad*,
E = potential in volts.

The *farad* is such a large unit of capacity that it is rarely used in radio calculations, and the following more practical units have, therefore, been chosen:

1 *microfarad* = 1/1,000,000 *of a farad, or* .000001 *farad, or* 10^{-6} *farads.*
1 *micro-microfarad* = 1/1,000,000 *of a microfarad, or* .000001 *microfarad, or* 10^{-6} *microfarads.*
1 *micro-microfarad* = *one-million-millionth of a farad, or* .000000000001 *farad, or* 10^{-12} *farads.*

If the capacity is to be expressed in *microfarads* in the equation just given, the factor C would then have to be divided by 1,000,000, thus:

$$\text{Stored energy in joules} = \frac{C \times E^2}{2 \times 1{,}000{,}000}.$$

This storage of energy in a condenser is one of its very important properties, particularly in those condensers which are used in power supply filter circuits.

Dielectric Constant

The capacity of a condenser is largely determined by the thickness and nature of the dielectric separation between plates. Certain materials offer a greater capacity than others, depending upon their physical makeup. This property can be expressed by a constant *K*, called the *dielectric constant*. A table for some of the commonly-used dielectrics is given here:

Material	*Dielectric Constant*
Air	1.00
Mica	2.94
Hard rubber	2.50 to 3.00
Glass	4.90 to 7.00
Bakelite derivitives	3.50 to 6.00
Celluloid	4.10
Fiber	4 to 6
Wood (without special preparation):	
Oak	3.3
Maple	4.4
Birch	5.2
Transformer oil	2.5
Castor oil	5.0
Porcelain	4.4

Breakdown in Dielectric

The nature and thickness of a dielectric has a very definite bearing on the amount of charge of a condenser. If the charge becomes too great for a given thickness of dielectric, the condenser will break down, i.e., the dielectric will "puncture." It is for this reason that condensers are rated in the manner of the amount of voltage they will safely withstand. This rating is commonly expressed as the *d.c. working voltage.*

Calculation of Capacity

The capacity of two parallel plates is given with good accuracy by the following formula:

$$C = 0.2244 \times K \times \frac{A}{t},$$

where C = capacity in micro-microfarads,
K = dielectric constant of spacing material,
A = area of dielectric in square inches,
t = thickness of dielectric in inches.

An examination of this formula will show that the capacity is directly proportional to the area of the plates, and inversely proportional to the thickness of the dielectric (spacing between the plates). This simply means that when the area of the plate is doubled, the spacing between plates remaining constant, the capacity will be doubled. Also, if the area of the plates remains constant, and the plate spacing is doubled, the capacity will be reduced to half. The above equation also shows that capacity is directly proportional to the dielectric constant of the spacing material. A condenser that has a capacity of 100 in air would have a capacity of 500 when immersed in castor oil, because the dielectric constant of castor oil is 5.0, or five times greater than the dielectric constant of air.

In order to determine the capacity of a parallel plate condenser, the following transposition is of value when the spacing between plates is known:

$$A = \frac{C \times t}{0.2244 \times K},$$

where A = area of plates in square inches,
K = dielectric constant of spacing material,
C = capacity in micro-microfarads,
t = thickness of dielectric (plate spacing) in inches.

Where the area of the plates is definitely set, and when it is desired to know the spacing needed to secure a required capacity:

$$t = \frac{A \times 0.2244 \times K}{C},$$

where all units are expressed just as in the preceding formula. This formula is not confined to condensers having only square or rectangular plates, but also applies when the plates are circular in shape. The only change will be the calculation of the *area* of such circular plates; this area can be computed by squaring the *radius* of the plate, when multiplying by 3.1416, or "pi". Expressed as an equation:

$$A = 3.1416 \times r^2,$$

where r = radius in inches.

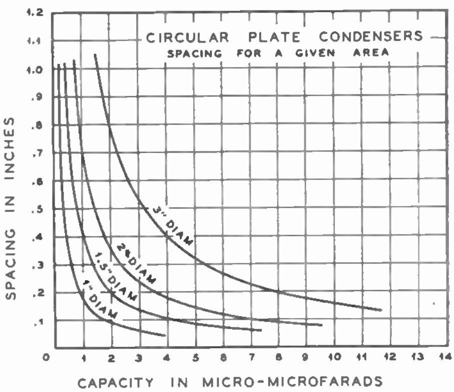


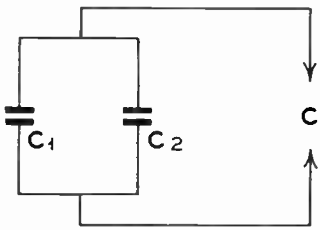
Figure 9

Multi-plate condenser capacity can be calculated by taking the capacity of one section and multiplying this by the number of dielectric spaces. In such cases, however, the formula gives no consideration to the effects of "edge capacity," so that the capacity as calculated will not be entirely accurate. These additional capacities will be but a small part of the effective total capacity, particularly when the plates are reasonably large, and the final result will, therefore, be within practical limits of accuracy.

Condensers in Parallel

Equations for calculating capacities of condensers in *parallel* connection are the same as those for resistors in *series:*

$$C = C_1 + C_2, \text{ etc.}$$

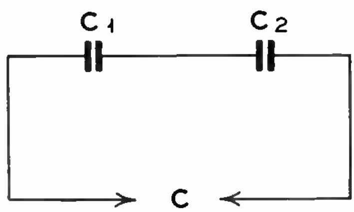


CONDENSERS IN PARALLEL

Figure 10

Condensers in Series

Again, as in resistor calculations, condensers in *series* connection are calculated in the same manner as are resistors in *parallel.*



CONDENSERS IN SERIES

Figure 11

The formulas are repeated: (1) For two or more condensers of *unequal* capacity in series:

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}, \text{ or } \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

(2) *Two* condensers of *unequal* capacity in series:

$$C = \frac{C_1 \times C_2}{C_1 + C_2}$$

(3) Three condensers of *equal* capacity in series:

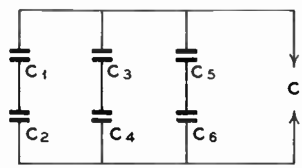
$$C = \frac{C_1}{3}, \text{ where } C_1 \text{ is the common capacity.}$$

(4) Three or more condensers of *equal* capacity in series:

$$C = \frac{\text{Value of common capacity}}{\text{Number of condensers in series}}$$

(5) Condensers in series parallel:

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}} + \frac{1}{\frac{1}{C_3} + \frac{1}{C_4}} + \frac{1}{\frac{1}{C_5} + \frac{1}{C_6}}$$



CONDENSERS IN SERIES - PARALLEL

Figure 12

Voltage Rating of Series Condensers

A well-made paper dielectric filter condenser has such a high internal resistance (indicating a good dielectric) that the exact resistance will vary considerably from condenser to condenser even though they are made by the same manufacturer and are of the same rating. Thus, when 1000 volts d.c. is connected across two 1-μfd. 500-volt condensers, the chances are that the voltage will divide unevenly and one condenser receive more than 500 volts and the other less than 500 volts. By connecting a half-megohm 1-watt carbon resistor across each condenser, the voltage will be equalized, because the resistors act as a voltage divider and the internal resistances of the condensers are so much higher (many megohms) that they have but little effect in disturbing the voltage divider balance.

Because carbon resistors of the inexpensive type are not particularly accurate (not being designed for precision service), it is advisable to check several on an accurate ohmmeter to find two that are as close as possible in resistance. The exact resistance is unimportant, just so it is the same for the two resistors used.

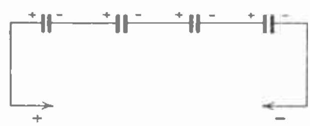
When two condensers are connected in series, *alternating* current pays no heed to the relatively high internal resistance of each condenser, but divides across the condensers in inverse proportion to the *capacity*. Because, in addition to the d.c. across a capacitor in a filter or audio amplifier circuit, there is usually an a.c. or a.f. voltage component, it is inadvisable to series-connect condensers of unequal capacitance, even if dividers are provided to keep the d.c. within the ratings of the individual capacitors. For instance, if a 500-volt 1-μfd. capacitor is used in series with a 4-μfd. 500-volt condenser across a 250-volt a.c. supply, the 1-μfd. condenser will have 200 volts a.c. across it and the 4-μfd. condenser only 50 volts. An equalizing divider to do any good in this case would have to be of very low resistance, because of the comparatively low impedance of the condensers *to a.c.* Such a divider would draw excessive current and be impracticable.

The safest rule to follow is to use only condensers of the same capacity and voltage rating and to install matched, high resistance proportioning-resistors across the various condensers to equalize the d.c. voltage drop across each condenser. This holds regardless of how many capacitors are series-connected.

Similar electrolytic capacitors, of the same capacity and made by the same manufacturer, have more nearly uniform (and much lower) internal resistance, though it still will vary considerably. However, the variation is not nearly as great as encountered in paper condensers, and an odd compensating effect automatically puts the lowest voltage across the weakest electrolytic condensers of a series group.

As an electrolytic capacitor begins to show signs of breaking down from excessive voltage, the leakage current goes up, which tends to heat the condenser and aggravate the condition. However, when used in series with one or more others, the lower resistance (higher leakage current) tends to put less d.c. voltage on the weakening condenser and more on the remaining ones. Thus the capacitor with the *lowest* leakage current, usually the *best* capacitor, has the highest voltage across it. For this reason, dividing resistors are not essential across series-connected electrolytic capacitors.

Electrolytic condensers use a very thin film of oxide as the dielectric and are "polarized"; that is, they have a positive and a negative terminal which must be properly connected in a circuit; otherwise, the oxide will boil, and the condenser will no longer be of service. When electrolytic condensers are connected in series, the positive terminal is always connected to the positive lead of the power supply; the negative terminal of the condenser connects to the positive terminal of the *next* condenser in the *series* combination. The method of connection is illustrated in figure 13.



POLARIZED CONDENSERS, (ELECTROLYTIC) IN SERIES

Figure 13

● Condensers in a. c. and d. c. Circuits

When a condenser is connected into a direct current circuit, it will "block" the d.c. or stop the flow of current. Beyond the initial movement of electrons during which the condenser is charged, there will be no flow of current, because the circuit is effectively broken by the dielectric of the condenser. Strictly speaking, a very small current may actually flow, because the dielectric of the condenser may not be a perfect insulator. This minute current flow is the "leakage current" previously referred to and is dependent upon the internal d.c. resistance of the condenser. This leakage current is usually quite noticeable in most types of electrolytic condensers.

When an alternating current is applied to a condenser it will charge and discharge a certain number of times per second in accordance with the frequency of the alternating voltage. The electron flow in the charge and discharge of a condenser when an a.c. potential is applied constitutes an alternating current, in effect. It is for this reason that a condenser will pass an alternating current, yet offer practically infinite opposition to a direct current. These two properties are repeatedly in evidence in a radio circuit.

Capacitive Reactance

It has been explained that inductive reactance is the ability of an inductance to oppose a change in an alternating current. Condensers have a similar property, although in this case the opposition is to the *voltage* which acts to charge the condenser. This action is called *capacitive reactance* and is expressed as follows:

$$X_c = \frac{1}{2\pi fC}.$$

where X_c = capacitive reactance in ohms,
π = 3.1416,
f = frequency in cycles,
C = capacity in farads.

Here again, as in the case of inductive reactance, the units of capacity and frequency can be converted into smaller units for practical problems encountered in radio work. The equation may be written:

$$X_c = \frac{1{,}000{,}000}{2\pi fC},$$

where f = frequency in megacycles,
C = capacity in micro-micro-farads.

In the design of filter circuits, it is often convenient to express frequency (f) in *cycles* and capacity (C) in *microfarads*, in which event the same formula applies.

Comparison of Inductive to Capacitive Reactance with Changing Frequency

From the equation for *inductive* reactance, it is seen that as the frequency becomes greater the reactance increases in a corresponding manner. The reactance is doubled when the frequency is doubled. If the reactance is to be very large when the frequency is low, the value of inductance must be very large.

The equation for capacitive reactance shows that the reactance varies *inversely* with frequency and capacity. With a fixed value of capacity, the reactance will become less as the frequency increases. When the frequency is fixed, the reactance will be greater as the capacity is lowered. In order to have high reactance, it is necessary to have low capacitance, although in power filter circuits the reactance is always made low so that the alternating current component from the rectifier will be bypassed. The capacitance must be made large in this case, because the frequency is quite low (60-120 cycles).

A comparison of the two types of reactance, inductive and capacitive, shows that in one case (inductive) the reactance *increases* with frequency, whereas in the other (capacitive) the reactance *decreases* with frequency.

Reactance and Resistance in Combination

When a circuit includes a capacity or an inductance or both, in addition to a resistance, the simple calculations of Ohm's law will *not* apply when the total a.c. resistance of the circuit is to be determined. Reference is here made to the passage of an alternating current through the circuit; the reactance must be considered in addition to the d.c. resistance, because reactance offers an opposition to the flow of alternating current.

When alternating current passes through a circuit which contains only a condenser, the voltage and current relations are as follows:

$$E = I X_c \text{ and } I = \frac{E}{X_c},$$

where E = voltage,
I = current in amperes,
X_c = capacitive reactance or $\frac{1}{2\pi fC}$
(expressed in ohms).

When the circuit contains inductance only, yet with the same conditions as above, the formula is as follows:

$$E = I X_L \text{ and } I = \frac{E}{X_L}.$$

where E = voltage,
I = current in amperes,
X_L = inductive reactance or $2\pi fL$
(expressed in ohms).

When a circuit has resistance, capacitive reactance and inductive reactance in *series*, the effective total opposition to the alternating current flow is known as the *impedance* of the circuit. Stated in another manner, the impedance of a circuit is the vector sum of the resistance and the difference between the two reactances. This is expressed:

$$Z = \sqrt{r^2 + (X_L - X_c)^2} \text{ or}$$

$$Z = \sqrt{r^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}$$

where Z = impedance in ohms,
r = resistance in ohms,
X_L = inductive reactance ($2\pi fL$) in ohms,

X_c = capacitive reactance $\frac{1}{2\pi fC}$ in ohms.

An example will serve to clarify the relationship of resistance and reactance to the total impedance. If a 10-henry choke, a 2-μfd. condenser, and a resistance of 10 ohms (which is represented by the d.c. resistance of the choke) are all connected in *series* across a 60-cycle source of voltage:

for reactance $X_L = 6.28 \times 60 \times 10 =$ 3,750 ohms (approx.),

$$X_c = \frac{1{,}000{,}000}{6.28 \times 60 \times 2} =$$

1,300 ohms (approx.)

r = 10 ohms

Substituting these values in the impedance equation:

$Z = \sqrt{10^2 + (3750 - 1300)^2} = 2450$ ohms. This is nearly 250 times the value of the d.c. resistance of 10 ohms. The subject of impedance is more fully covered under *Resonant Circuits.*

Again recalling previous text, an alternating current is one which rises to a maximum, then decreases to zero from that point, and then goes through a negative-maximum-to-zero in the opposite direction. This continual change of amplitude and direction is maintained as long as the current continues to flow. The number of times that the current changes direction in a given length of time is called the frequency of change, or more generally, it is simply called the *frequency.* Alternating currents which range from nearly zero to many millions of cycles per second are commonplace in radio applications. Such a current is produced by the rotating machine which generates the common 60-cycle house-lighting current; it is likewise produced by oscillatory circuits for the high radio frequencies. A machine that produces alternating current for house-lighting, industrial and other purposes is called an *alternator.* It is also commonly referred to as an *a.c. generator.*

Figure 14 shows an alternator in its very basic form. It consists of two permanent magnets, *M*, the opposite poles of which face each other, and the poles being machined so that they have a common radius. Between these two poles, *north* (N) and *south* (S). magnetic lines of force exist; these lines of force constitute a *magnetic field.* If a conductor in the form of *C* is so suspended that it can freely rotate between the two poles,

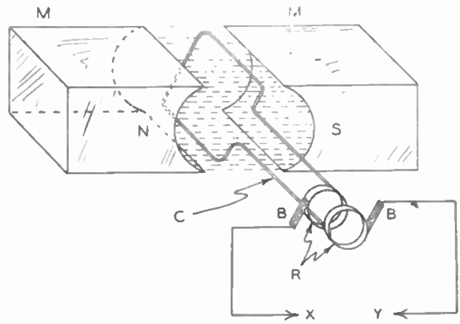


Figure 14

and if the opposite ends of conductor *C* are brought to collector rings, *R*, which are contacted by brushes, there will be a flow of alternating current when conductor *C* is rotated. This is the basic method of producing alternating current.

When the conductor loop is rotated so that it cuts or passes through the magnetic lines of force between the pole pieces (magnets), a current will be induced in the loop, and this current will flow out through the collector rings *R* and brushes *B* to the external circuit, *X-Y*. As the rotation continues, the current becomes increasingly greater as the center of the pole pieces are approached by the loop. The field intensity of the magnets is greatest at the center, and gradually falls to a low value either side of center.

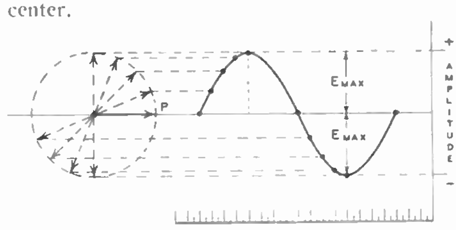


Figure 15

Figure 15 will serve to clarify the operation of the alternator. The point *P* is taken as the revolving conductor, which is *C* in figure 14. As point P is revolved in a circular manner, the change in field intensity with consequent change in voltage can be visualized. It will be seen that as the conductor *P* begins its rotation, it starts through the lesser field intensity, gradually coming into the maximum field, then away again to another field of minimum intensity. The conductor then cuts the magnetic field in the *opposite* direction, going through the same varying intensity as previously related, then reaching a maximum, and then falling away to zero, from which point the current again increases in the original direction. When the conductor has completed its 360° rotation, two complete changes—or *one cycle*—will have been completed.

The voltage does *not* increase directly as the angle of rotation, but rather as the *sine* of the angle; hence, such a current has the mathematical form of a *sine wave.* Although most electrical machinery does not produce a strictly pure sine curve, the departures are usually so slight that the assumption can be regarded as fact for all practical purposes.

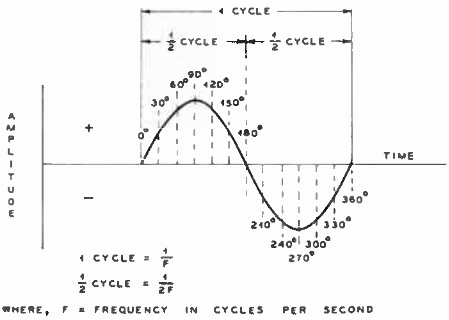


Figure 16

Referring to figure 16, it will be seen that if a curve is plotted for an alternating voltage, such a curve would assume the shape of a sine wave and by plotting amplitude against time, the voltage at any instant could be found. When dealing with alternating current of sine wave character, it becomes necessary to make constant use of terms which involve the number of changes in *polarity* or, more properly, the *frequency* of the current. The instantaneous value of voltage at any given instant can be calculated as folllows:

$$c = E_{max} \sin 2\pi ft,$$

where c = the instantaneous voltage.
sin = the sine of the angle formed by the revolving point *P* at the instant of time, t.
E = maximum crest value of voltage (figure 16).

The term $2\pi f$ should be thoroughly understood, because it is of basic importance.

Returning again to the rotating point *P* (figure 15), it can be seen that when this point leaves its horizontal position and begins its rotation in a counter-clockwise direction, through a complete revolution back to its initial starting point, it will have traveled through 360 electrical degrees. Instead of referring to this movement in terms of degrees, mathematical treatment dictates that the movement be expressed in *radians.* If radians must be considered in terms of

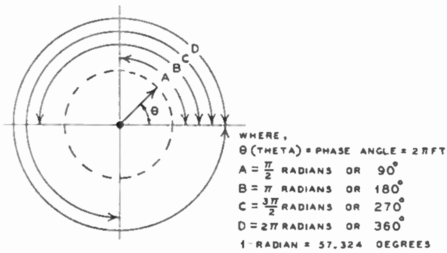


Figure 17

degrees, there are approximately 57.32 degrees to one radian. In simple language, the radian is nothing more than a unit for dividing a circle into many parts. In a complete circle (360 degrees) there are 2πradians. Figure 17 shows lesser divisions of a circle in radians.

When the expression *2πradians* is used, it implies that the current or voltage has gone through a complete circle of 360 electrical degrees; this rotation represents two complete changes in direction during one cycle, as was previously shown. $2\pi f$ then represents one cycle, multiplied by the number of such cycles per second or the frequency of the alternating voltage or current. The expression *$2\pi ft$* is a means of showing how far point *P* has traveled from its zero position toward a possible change of *2πradians* or 360 electrical degrees. In the case of an alternating current with a frequency of 60 cycles per second, the current must pass through *120* changes in polarity in the same length of time. This "time" can be expressed as:

$$\frac{1}{2f}.$$

However, the only consideration at this point is one-half of one alternation, and because the wave is symmetrical between 0-and-90-degrees rising, and from 90-degrees-to-zero when falling, the expression therefore becomes:

$$\frac{1}{4f}.$$

The actual time t in the formula is seen to be only a fractional portion of a second: a 60-cycle frequency would make $\frac{1}{4f}$ equal to $\frac{1}{240}$ of a second at the maximum value. and correspondingly less at lower amplitudes. $2\pi ft$ represents the *angular velocity*. and since the instantaneous voltage or current is proportional to the *sine* of this angle, a definite means is secured for calculating the voltage at any instant of time, provided that the wave very closely approximates a sine curve.

Current and voltage are synonymous in the foregoing discussion, since they both follow the same laws. The instantaneous current can be found from the same formula, except that the maximum current would be used as the reference, viz.:

$$i = I_{max} \sin 2\pi ft,$$

where i = instantaneous current,
I = maximum or peak current.

Effective Value of Alternating Voltage or Current

The fact that an alternating voltage or current in an a.c. circuit is rapidly changing in direction and that since it requires a definite amount of time for the indicator needle on a d.c. measuring instrument to show a deflection, such instruments cannot be used to measure alternating current or voltage. Even if the needle had such negligible damping that it could be made to follow the a.c. changes, it would merely vibrate back and forth near the zero point on the meter scale.

Alternating and direct current can be expressed in similar terms from the standpoint of heating effect. In other words, an alternating current will have the same value as a direct current in that it produces the same heating effect. Thus, an alternating current or voltage will have an equivalent value of one ampere when it produces the same heating effect in a resistance as does one ampere of direct current. This is known as the *effective value;* it is neither the maximum nor the instantaneous value, but an entirely different value.

This effective value is derived by taking the instantaneous values of current over a cycle of alternating current, then squaring these values, then taking an average of this value, and then taking the square-root of the average thus obtained. By this procedure, the *effective* value becomes known as the *root mean square* or *r.m.s.* This is the value that is read on alternating current voltmeters and ammeters. The r.m.s. value is approximately 70 per cent of the peak or maximum instantaneous value and is expressed as follows:

$$E_{eff} = 0.707 \times E_{max}, \text{ or}$$
$$I_{eff} = 0.707 \times I_{max},$$

where E_{max} and I_{max} are peak values of voltage and current, respectively, and E_{eff} and I_{eff} are effective or r.m.s values.

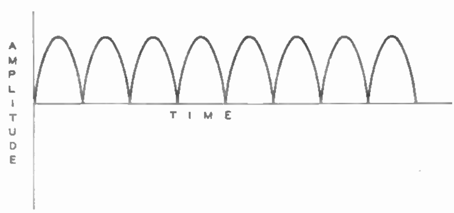
The following relations are extremely useful in radio and power work:

$$E_{rms} = 0.707 \times E_{max},$$
$$E_{max} = 1.414 \times E_{rms}.$$

In order to find the peak value when the effective or r.m.s. value is known, simply multiply the r.m.s. value by 1.414. When the peak value is known, multiply it by 0.707 to find the r.m.s. value.

Rectified Alternating Current or Pulsating Direct Current

When an a.c. current is passed through a full-wave rectifier, it emerges in the form of a current of *varying amplitude* which flows in *one* direction only. Such a current is known as *rectified a.c.* or *pulsating d.c.* A typical wave form of a current of this nature is shown in figure 18.



OUTPUT FROM FULL-WAVE RECTIFIER

Figure 18

A d.c. measuring instrument will not read the peak or instantaneous maximum value of the pulsating d.c. output from the rectifier; it will read only the *average* value. This can be explained by assuming that it could be possible to cut off some of the peaks of the waves, using the cut-off portions to fill in the spaces that are open, thereby obtaining an *average* d.c. value. A milliammeter and voltmeter connected to the adjoining circuit, or across the output of the rectifier, will read this average value.

It is related to *peak* value by the following expression:

$$E_{avg} = 0.636 \times E_{max}.$$

It is thus seen that the average value is approximately 63 per cent of the peak value.

• Phase

When an alternating current flows through a purely resistive circuit, it will be found that the current will go through maximum and minimum in perfect step with the voltage. In this case the current is said to be in step or in *phase* with the voltage. For this reason, Ohm's law will apply equally well for a.c. or for d.c. where pure resistances are concerned. provided that the *effective* values of a.c. are used in the calculations.

When a circuit has capacity or inductance, or both, in addition to resistance, the current does not reach a maximum at the same instant as the voltage: Ohm's law will, therefore, *not* apply. It has been stated that inductance tends to resist any change in current: when an inductance is present in a circuit through which an alternating current is flowing, it will be found that the current will reach its maximum *behind* the voltage. In electrical terms, the current will *lag* the voltage or, conversely, the voltage will *lead* the current. If the circuit is *purely* inductive, i.e., if it contains neither resistance nor capacitance, the current does not start until the voltage has first reached a maximum: the current therefore *lags* the voltage by 90 degrees as in figure 19. The angle will be less than 90 degrees if resistance is present in the circuit.

When pure capacity alone is present in an a.c. circuit (no inductance or resistance of any kind), the opposite effect to inductance will be encountered; the current will reach a maximum at the instant the voltage is starting and, hence, will *lead* the voltage by 90 degrees. The presence of resistance in the circuit will tend to decrease this angle.

• Power Factor

It should now be apparent to the reader that in such circuits that have reactance as well as resistance, it will not be possible to calculate the power as in a d.c. circuit, or as in an a.c. circuit in which current and voltage are in phase. The reactive components cause the voltage and current to reach their maximum at different times, as was explained under *"phase."*

The *power factor* in a resistive-reactive

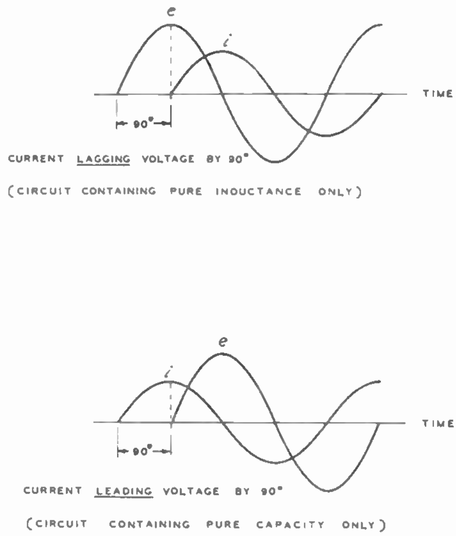


Figure 19

a.c. circuit may be expressed as the *actual* watts (as measured by a wattmeter), divided by the product of voltage and current or:

$$\frac{W}{E \times I}$$

where W = watts as measured,
E = voltage (r.m.s.),
I = current in amperes (r.m.s.).

Stated in another manner:

$$\frac{W}{E \times I} = \cos\theta$$

The character θ is the angle of phase difference between current and voltage. The product of volts times amperes gives the *apparent* power of the circuit, and this must be multiplied by $\cos\theta$ to give the *actual* power. This factor $\cos\theta$ is called the *power factor* of the circuit.

When the current and voltage are in phase, this factor is equal to 1. Resonant or purely resistive circuits are then said to have unity power factor, in which case

$$W = E \times I, \quad W = IR, \quad W = \frac{E}{R}$$

• Resonant Circuits

Before proceeding with this text, the reader is advised to review the subject matter on inductance, capacity, and alternating current in order that he may gain a complete understanding of the action of resonant circuits. Once the basic conception of the foregoing has been mastered, the more complex circuits in which they appear in combination will present no great problem.

The accompanying diagram shows an inductance, a capacitance, and a resistance arranged in series, with a variable frequency source *E* of a.c. applied across the combination.

Figure 20

Resistance is always present in a circuit, because it is possessed in some degree by both the inductance and capacitance. If the frequency of the alternator *E* in figure 20 is varied from nearly zero to some high frequency, there will be one particular frequency at which the inductive reactance and capacitive reactance will be equal. This is known as the *resonant frequency*, and in a series circuit it is the frequency at which the circuit current will be a maximum. Such series resonant circuits are chiefly used when it is desirable to allow a certain frequency to pass through the circuit (low impedance to this frequency), while at the same time the circuit is made to offer considerable opposition to currents of other frequencies.

If the values of inductance and capacity both are fixed, there will be only one resonant frequency. If, however, both the inductance and capacitance are made variable, the circuit may then be changed or *"tuned,"* so that an unlimited number of combinations of inductance and capacitance can resonate at the same frequency. This can be more easily understood when one considers that inductive reactance and capacitive reactance travel in opposite directions as the frequency is changed. For example, if the frequency were to remain constant, and the values of inductance and capacitance are then changed, the following combinations would have the same *reactance:*

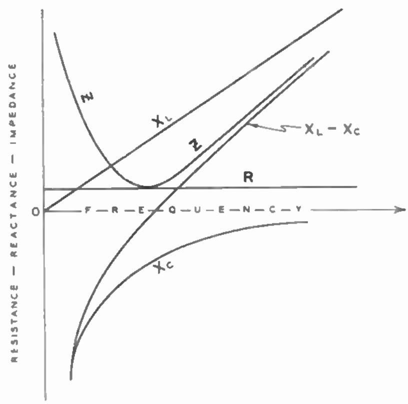
Frequency is constant at 60 cycles.

L is expressed in henrys

C is expressed in microfarads (.000001 farad).

L	X_L	C	X_C
.265	100	26.5	100
2.65	1,000	2.65	1,000
26.5	10,000	.265	10,000
265.00	100,000	.0265	100,000
2,650.00	1,000,000	.0026	1,000,000

In the above table there are five radically different ratios of L to C (inductance to capacitance) each of which satisfies the resonant condition, $X_L = X_C$. When the frequency is constant, *L* must increase and *C* must decrease in order to give equal reactance. Figure 21 shows how the two reactances change with frequency; this illustration will greatly aid in clarifying this discussion.



SERIES CIRCUIT REACTANCE VARIATION WITH CHANGE OF APPLIED FREQUENCY

Figure 21

For mechanical reasons it is advisable to change the capacitance rather than the inductance when a circuit is "tuned," yet the inductance can be made variable, if desired.

• Formula for Frequency

From the formula for frequency, where $2\pi fL = \frac{1}{2\pi fC}$, the resonant frequency can readily be solved. In order to isolate *f* on one side of the equation, merely multiply both sides by $2\pi f$, thus giving:

$$4\pi^2 f^2 L = \frac{1}{C}.$$

Dividing by the quantity $4\pi^2 L$, the result is: $f^2 = \frac{1}{4\pi^2 LC}$.

Then by taking the square-root of both sides: $f = \frac{1}{2\pi\sqrt{LC}}$,

where f = frequency in cycles,
L = inductance in henrys,
C = capacity in farads.

It is more convenient to express *L* and *C* in smaller units, especially in making radio-frequency calculations; *f* can also be expressed in megacycles or kilocycles. A very useful group of such formulas is:

$$f^2 = \frac{25{,}330}{LC} \text{ or } L = \frac{25{,}330}{f^2C} \text{ or } C = \frac{25{,}330}{f^2L},$$

where f = frequency in megacycles,
L = inductance in microhenries,
C = capacity in micro-microfarads.

In order to clarify the original formula, $f = \frac{1}{2\pi\sqrt{LC}}$, take two values of inductance and capacitance from the previously given chart and substitute these in the formula. It was stated that the frequency is 60 cycles; therefore, f = 60. Substituting these values to check this frequency:

$$60 = \frac{1}{2\pi\sqrt{LC}};\ 3{,}600 = \frac{1}{4\pi^2LC};$$

$$L = \frac{1}{3600 \times 4\pi^2 \times .000026}.$$

$$L = 0.265$$

The significant point here is that the formula calls for *C* in *farads*, whereas the capacity was actually in microfarads. Recalling that one microfarad equals .000001 farad, it is, therefore, possible to express 26 microfarads as .000026 farads. This consideration is often overlooked when computing for frequency and capacitive reactance, because capacitance is expressed in a totally-impractical unit, viz.: the *farad*.

• Impedance of Series Resonant Circuits

The impedance across the terminals of a series resonant circuit is

$$Z = \sqrt{r^2 + (X_L - X_C)^2},$$

where Z = impedance in ohms,
r = resistance in ohms,
X_C = capacitive reactance in ohms,
X_L = inductive reactance in ohms.

From this equation it can be seen that the impedance is equal to the vector sum of the circuit resistance and the *difference* between the two reactances. Since at the resonant frequency X_L equals X_C, the difference between them is obviously zero, so that at resonance the impedance is simply equal to the resistance of the circuit . . . and, because the resistance of most normal radio-frequency circuits is of a very low order, the impedance is also low.

At frequencies higher and lower than the resonant frequency, the difference between the reactances will be a definite quantity and will add with the resistance to make the impedance higher and higher as the circuit is tuned off the resonant frequency.

• Current and Voltage in a Series Resonant Circuit

Formulas for calculating series resonance are similar to those of Ohm's law.

$$I = \frac{E}{Z}.\quad E = IZ.$$

The complete equations:

$$I = \frac{E}{\sqrt{r^2 + (X_L - X_C)^2}}.$$

$$E = I\sqrt{r^2 + (X_L - X_C)^2}$$

A careful consideration of the above formulas will show the following to apply to series resonant circuits: When the impedance is low, the current will be high; conversely, when the impedance is high, the current will be low.

Since it is known that the impedance will be very low at the resonant frequency, it follows that the current will be a maximum at this point. If a graph is plotted of the current against the frequency either side of resonance, the resultant curve becomes what is known as a *resonance curve*. Such a curve is shown in figure 22.

Several factors will have an effect on the shape of this resonance curve, of which resistance and L-to-C ratio are the important considerations. The curves *B* and *C* in figure 22 show the effect of adding increasing values of resistance to the circuit. It will be seen that the peaks become less and less prominent as the resistance is increased: thus, it can be said that the *selectivity* of the circuit is thereby *decreased*. Selectivity in this case can be defined as the ability of a circuit to discriminate against frequencies adjacent to the resonant frequency.

Again referring to figure 22, it can be seen from curve *A* that a signal, for instance, will drop from 19 to 5, or more than 10 decibels, at 50 kc. off resonance. Curve *B*, which represents considerable resistance

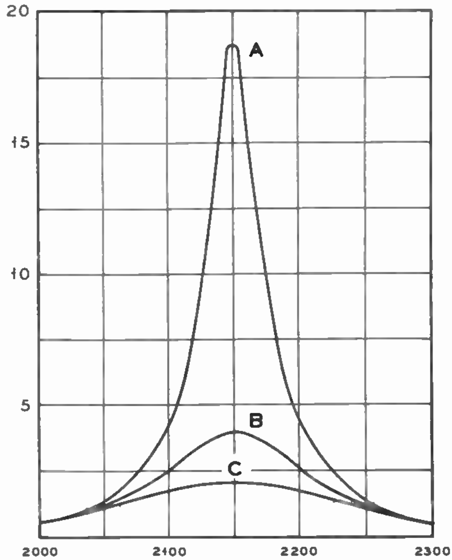


Figure 22

in the circuit, shows a signal drop of from 4 to 3, or approximately 2.5 decibels, when the signal is also 50 kilocycles removed from the resonant point. From this it becomes evident that the steeper the resonant curve, the greater will be the change in current for a signal removed from resonance by a given amount. The effect of adding more resistance to the circuit is to flatten-off the peaks, without materially affecting the sides of the curve. Thus, signals far removed from the resonance frequency give almost the same value of current, regardless of the amount of resistance present.

• Voltage Across Coil and Condenser in Series Circuit

For the reason that the a.c. or r.f. voltage across a coil and condenser is proportional to the reactance (for a given current), the actual voltages across the coil and across the condenser may be many times greater than the *terminal* voltage of the circuit. Furthermore, since the individual reactances can be very high, the voltage across the condenser, for example, may be high enough to cause flash-over, even though the applied voltage is of a value considerably below that at which the condenser is rated.

• Circuit "Q"

An extremely important property of an inductance is its factor-of-merit, more generally called its *Q*. This factor can be expressed as the ratio of the reactance to the resistance, as follows:

$$Q = \frac{2fL}{R},$$

where R = total d.c. and r.f. resistances.

The actual resistance in a wire or inductance can be far greater than the d.c. value when the coil is used in a radio-frequency circuit; this is because the current does not travel through the entire cross-section of the conductor, but has a tendency to travel closer and closer to the surface of the wire as the frequency is increased. This is known as the *skin effect*. The actual current-carrying portion of the wire is decreased, therefore, and the resistance is increased. This effect becomes even more pronounced in square or rectangular conductors, because the principal path of current flow tends to work outwardly toward the four edges of the wire.

An examination of the equation for *Q* may give rise to the thought that even though the resistance becomes greater with frequency, the inductive reactance does likewise, and that the *Q* might be a constant. In actual practice, however, the resistance usually increases more rapidly with frequency than does the reactance, with the result that *Q* normally decreases with frequency.

• Parallel Resonance

Parallel resonance is more frequently encountered than series resonance, in radio circuits; in fact, it is the basic foundation of receiver and transmitter circuit operation. A circuit is shown in figure 23.

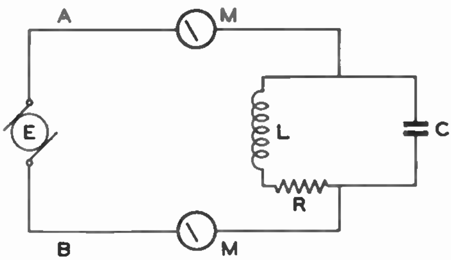


Figure 23

In this circuit, as contrasted with a circuit for series resonance, *L* (inductance) and *C* (capacitance) are connected in *parallel*, yet the *combination* can be considered to be in series with the remainder of the circuit. This combination of *L* and *C*, in conjunction with *R*, the resistance which is principally included in L, is sometimes called a "*tank circuit*," because it effectively functions as a storage "tank" when incorporated in vacuum tube circuits.

Contrasted with series resonance, there are two kinds of current which must be considered in a parallel resonant circuit: (1) the line current, as read on the indicating meters *M*, and, (2) the circulating current which flows within the parallel L-C-R portion of the circuit. See figure 23.

At the resonant frequency, the line current (as read on the meters *M*) will drop to a very low value, although the circulating current in the L-C circuit may be quite large. It is this line current that is read by the milliammeter in the plate circuit of an amplifier or oscillator stage of a radio transmitter, and it is because of this that the meter shows a sudden "*dip*" as the circuit is tuned through its resonant frequency. The current is, therefore, a minimum when a parallel resonant circuit is tuned to resonance, although the *impedance* is a *maximum* at this same point. Therefore, it is interesting to note that the parallel resonant circuit, in this respect, acts in a distinctly opposite manner to that of a series resonant circuit, in which the current is at a maximum when the impedance is minimum. It is for this reason that in a parallel resonant circuit the principal consideration is one of impedance, rather than current. It is also significant that the *impedance* curve for *parallel* circuits is very nearly identical to that of the *current* curve for *series* resonance. The impedance at resonance is expressed as:

$$Z = \frac{(2\pi fL)^2}{R},$$

where Z = impedance in ohms,
L = inductance in henrys,
f = frequency in cycles,
R = resistance in ohms.

The curves illustrated in figure 22 can be applied to parallel resonance, in addition to the purpose for which they are illustrated.

Reference to the impedance curve will show that the effect of adding resistance to the circuit will result in both a broadening-out and a lowering of the peak of the curve. Since the voltage of the circuit is directly proportional to the impedance, and since it is this voltage that is applied to the grid of the vacuum tube in a detector or amplifier circuit, the impedance curve must have a sharp peak in order for the circuit to be *selective*. If the curve is broad-topped in shape, both the desired signal and the interfering signals at close proximity to resonance will give nearly equal voltages on the grid of the tube, and the circuit will then be *non-selective*, i.e., it will tune broadly.

Effect of L/C Ratio In Parallel Circuits

In order that the highest possible voltage can be developed across a parallel resonant circuit, the impedance of this circuit must be very high. The impedance will be greater when the ratio of inductance-to-capacitance is great, i.e., when *L* is large as compared with *C*. When the resistance of the circuit is very low, X_L will equal X_C at resonance and, of course, there are innumerable ratios of *L* and *C* that will have *equal* reactance at a given resonant frequency, exactly as is the case in a series resonant circuit. Contrasted with the necessity for a high *L/C* ratio for high *impedance*, the capacity for maximum *selectivity* must be *high*, and the *inductance low*. While such a ratio will result in lower *gain*, it will offer greater *rejectivity* to signals adjacent to the resonant signal.

In practice, where a certain value of inductance is tuned by a variable capacitance over a fairly wide range in frequency, the *L/C* ratio will be small at the lowest frequency and large at the high frequency end. The circuit, therefore, will have unequal selectivity at the two ends of the band of frequencies which is being tuned. At the low frequency end of the tuning band, where the capacitance predominates, the selectivity will be greater and the gain less than at the high frequency end, where the opposite condition holds true. Increasing the *Q* of the circuit (lowering the series resistance) will obviously increase *both* the selectivity and gain.

Circulating Tank Current at Resonance

The *Q* of a circuit has a definite bearing on the circulating tank current at resonance. This tank current is very nearly the value of the line current multiplied by the circuit *Q*. For example: an r.f. line current of 0.050 amperes, with a circuit *Q* of 100, will give a circulating tank current of approximately 5 amperes. From this it can be seen that the inductance and connecting wires in a circuit with a high *Q* must be of ample proportions, particularly in the case of high power transmitters, if heat losses are to be held to a minimum.

• Effect of Coupling on Impedance

When a parallel resonant circuit is coupled to another circuit, such as an antenna output circuit, the impedance of the parallel circuit is decreased as the coupling becomes closer. The effect of closer (tighter) coupling is the same as though an actual resistance were added to the parallel circuit. The resistance thus coupled into the tank circuit can be considered as being *reflected* from the output or load circuit to the driver circuit. If the load across the parallel resonant tank circuit is purely resistive, just as it might be if a resistor were shunted across part of the tank inductance, the load will not disturb the resonant setting. If, on the other hand, the load is reactive, as it could be with a too-long or too-short antenna for the resonant frequency, the setting of the tank tuning condenser would have to be changed in order to restore resonance.

• Tank Circuit Flywheel Effect

When the plate circuit of a class-B or class-C operated tube is connected to a parallel resonant circuit, the plate current serves to maintain this *L/C* circuit in a state of oscillation. If an initial impulse is applied across the terminals of a parallel resonant circuit, the condenser will become charged when one set of plates assumes a positive polarity, the other set a negative polarity. The condenser will then discharge through the inductance; the current thus flowing will cut across the turns of the inductance and cause a counter-e.m.f. to be set up, charging the condenser in the opposite direction.

In this manner an alternating current is set up within the *L/C* circuit and the oscillation would continue indefinitely with the condenser charging, discharging, and charging again if it were not for the fact that the circuit possesses some resistance. The effect of this resistance is to dissipate some energy each time the current flows from inductance to condenser and back, so that the amplitude of the oscillation grows weaker and weaker, eventually dying out completely.

The frequency of the initial oscillation is dependent upon the *L/C* constants of the circuit. If energy is applied in short spurts or pushes at just the right moments, the *L/C* circuit can be maintained in a constant oscillatory state. The plate current pulses from class-B and class-C amplifiers supply just the desired kind of "kicks."

Whereas the class-B plate current pulses supply a kick for a longer period, the short pulses from the class-C amplifier give a pulse of very high amplitude, thus being even more effective in maintaining oscillation. So it is that the positive half cycle in the tank circuit will be reinforced by a plate current kick, but since the plate current of the tube only flows during a half cycle or less, the *missing* half cycle in the tank circuit must be supplied by the discharge of the *condenser*. Since the amplitude of this half cycle will depend upon the charge on the plates of the condenser, and since this in turn will depend upon the capacitance, the value of capacitance in use is very important. Particularly is this true if a distorted wave shape is to be avoided, as would be the case when a transmitter is being modulated. The foregoing applies particularly to single-ended amplifiers. If push-pull were employed, the negative half cycle would secure an additional "kick," thereby greatly lessening the necessity for the use of higher *C* in the *L/C* circuit.

• Impedance Matching: Impedance, Voltage, and Turns-Ratio

It is a fundamental law of electricity that the maximum transfer of energy results when the impedance of the load is equal to the impedance of the driver. Although this law holds true, it is not necessarily a desirable one for every condition or purpose. In many cases where a vacuum tube works into a parallel resonant circuit load, it is desirable to have the load impedance considerably higher than the tube-plate impedance, so that maximum power will be dissipated by the load, rather than in the tube. On the other hand, one of the notable conditions for which the law holds true is in the matching of transmission lines to an antenna impedance.

A vacuum tube circuit often requires that the plate impedance of a driver circuit be "matched" to the grid impedance of the tube being driven. When the driven tube operates in such a condition that it draws grid current, such as in all transmitter r.f.

amplifier circuits, the grid impedance may well be lower than the plate tank impedance of the driver stage. In this case it becomes necessary to tap down on the driver tank coil in order to select the proper number of turns that will give the desired impedance. If the desired working load impedance of the driver stage is 10,000 ohms, for example, and if the tank coil has 20 turns, the grid impedance of the driven stage being 5,000 ohms, it is evident that there will be required a step-down *impedance* ratio of $\frac{10,000}{5,000}$, or 2-to-1. This impedance value is *not* secured when the driver inductance is tapped at the center. It is of importance to stress the fact that the impedance is decreased *four times* when the number of turns on the tank coil is *halved*. The following equations will prove this fact:

$$\frac{N_1}{N_2} = \sqrt{\frac{Z_1}{Z_2}} \text{ or } \frac{N_1^2}{N_2^2} = \frac{Z_1}{Z_2},$$

where $\frac{N_1}{N_2}$ = turns ratio,

$\frac{Z_1}{Z_2}$ = impedance ratio

In the foregoing example, a step-down *impedance* ratio of 2-to-1 would require a *turns* step-down ratio of the square-root of the impedance or 1.41. Therefore, if the inductance has 20 turns, a tap would be taken on the 6th turn down from the "hot" end or 14 turns up from the "cold" end. This is arrived at by taking the resultant for the turns-ratio, i.e., 1.41, and then dividing it into the total number of turns, as follows:

$$\frac{20}{1.41} = 14 \text{ (approx.)}$$

Either an impedance step-up or step-down ratio can be secured from a parallel resonant circuit. One popular type of antenna impedance matching device utilizes this principle. Here, however, two condensers are effectively in series across the inductance; one has a quite-high capacitance (500 $\mu\mu$fd., the other is a conventional-size condenser, used principally to restore resonance. The theory of the device is simply that the impedance is proportional to the reactances of the condensers, and, by changing the ratio of the two, the antenna is effectively connected into the tank circuit at impedance points which reach higher or lower values as the ratio of the condensers is changed.

In practice, however, it is usually necessary to change the value of inductance in order to maintain resonance while still correctly matching it to the antenna or feeder. This method is discussed at greater length elsewhere in these pages.

As the impedance step-down ratio becomes larger, the voltage step-down becomes correspondingly great. Such a condition takes place when a resonant circuit is tapped down for reasons of impedance matching; the voltage will be stepped-down in direct proportion to the turn step-down ratio. The reverse holds true for step-up ratios. As the step-up ratio is increased, the voltage is increased. This principle applies in the case of an *auto transformer* illustrated in Figure 24.

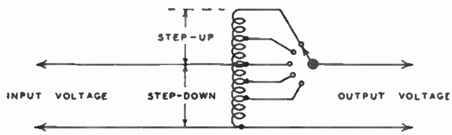


Figure 24

The type of transformer in figure 24 when wound with heavy wire and over an iron core is a common device in primary power circuits for the purpose of increasing or decreasing the line voltage. In effect, it is merely a continuous winding with taps taken at various points along the winding, the

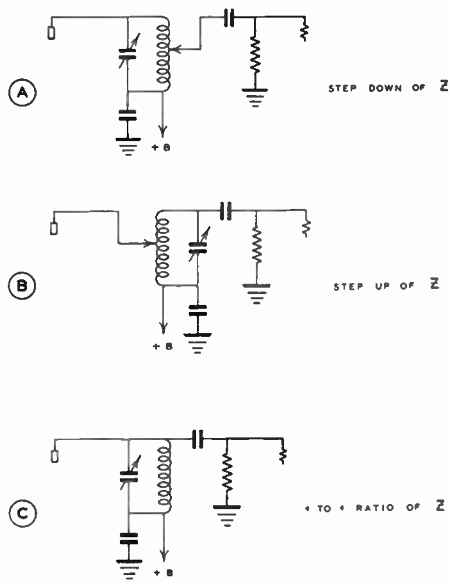


Figure 25

input voltage being applied to the bottom and also to one tap on the winding. If the output is taken from this same tap, the voltage ratio will be 1-to-1, i.e., the input voltage will be the same as the output voltage. On the other hand, if the output tap is moved down toward the common terminal, there will be a step-down in the turns-ratio with a consequent step-down in voltage. The opposite holds true if the output terminal is moved upward from the middle input terminal; there will be a voltage step-up in this case. The initial setting of the middle input tap is chosen so that the number of turns will have sufficient reactance to keep the no-load primary current at a reasonably low value.

In the same manner as voltage is stepped-up and down by changing the number of turns in a winding, so can impedance be stepped up or down. Figure 25(A) shows an application of this principle as applied to a vacuum tube circuit which couples one circuit to another.

Assuming that the grid impedance may be of a lower value than the plate tank impedance of the preceding stage, a step-down ratio will be necessary in order to give maximum transfer of energy. In (*B*) of figure 25, the grid impedance is very high as compared with the tank impedance of the driver stage, and thus there is required a step-up ratio to the grid. The driver plate is tapped-down on its plate tank coil in order to make this impedance step-up possible. A driver tube with very low plate impedance must be used if a good order of plate efficiency is to be realized.

In (*C*) of figure 25, the grid impedance very closely approximates the plate impedance and no transformation is required, therefore. The grid and plate impedances are not generally known in many practical cases and the adjustments, hence, are made on the basis of maximum grid drive consistent with maximum safe input to the driver stage.

• Inductive Coupling

Inductive coupling is often used when two circuits are to be coupled. This method of coupling is shown in figures 26A and 26B.

The two inductances are placed in such inductive relation to each other that the lines of force from the primary coil cut across the turns of the secondary coil, thereby inducing a voltage in the secondary. As in the case of capacitive coupling, impedance transformation here again becomes of importance. If two parallel tuned circuits are coupled very closely together, the circuits

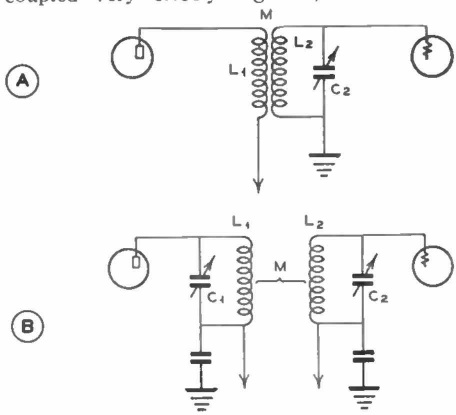


Figure 26

can in reality be "over-coupled." This is illustrated by the curve in figure 27.

The dotted-line curve *A* is the original curve or that of the primary coil *alone.* Curve *B* shows what takes place when two circuits are over-coupled; the resonance curve will have a definite "dip" on the peak, or a "double hump." This principle of over-coupling is advantageously utilized in band-pass circuits where, as shown in *C*, the

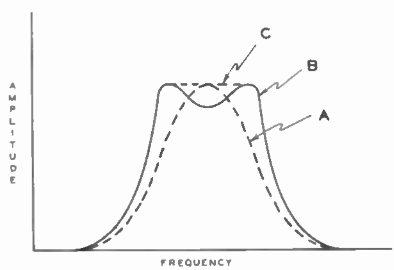


Figure 27

coupling is adjusted to such a value as to reduce the peak of the curve to a virtual flat-top, with no dip in the center as in *B*.

Some undesirable capacitive coupling will result when circuits are closely or tightly coupled; if this capacitive coupling becomes a factor, the tuning of the circuits will be affected. The amount of capacitive coupling can be reduced by so arranging the physical shape of the inductances as to enable only a minimum surface of one to be presented to the other. Another method of accomplishing the same purpose is by electrical means. A "curtain" of closely-spaced parallel wires or bars, connected together only at one end, and with this end connected to ground, will allow electromagnetic coupling, but *not* electrostatic coupling. Such a device is called a *Faraday screen* or *shield*.

Still another method of decreasing capacitive coupling is by means of a *coupling link* circuit between two parallel resonant circuits. The capacity of the coupling link, with its one or two turns, is so small as to be negligible.

● Link Coupling

Link coupling is widely used in transmitter circuits because it adapts itself so universally and eliminates the need of a radio-frequency choke, thereby reducing a source of loss. Link coupling is very simple; it is diagrammed in figure 28.

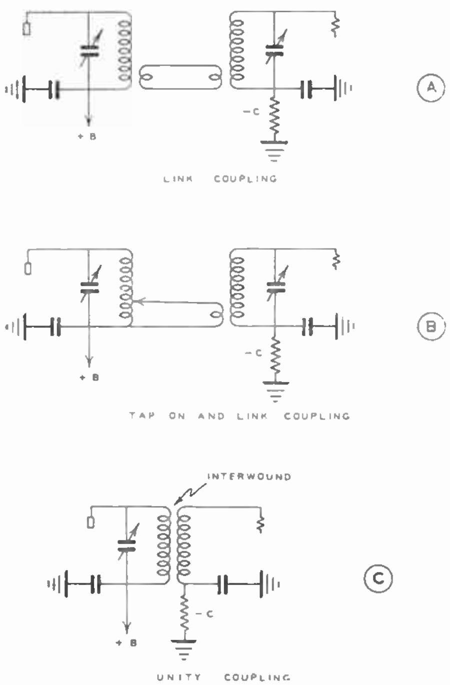


Figure 28

In *A* of figure 28, there is an impedance step-down from the primary coil to the link circuit. This means that the line which connects the two links or loops will have a low impedance and can, therefore, be carried over a considerable distance without introduction of appreciable loss. A similar link or loop is at the output end of the line; this loop is coupled to the grid tank of the driven stage.

Still another link coupling method is shown in *B* of figure 28. It is similar to that of *A*, with the exception that the primary line is tapped on the coil, rather than being terminated in a link, or loop.

● Unity Coupling

Another type of commonly-used coupling is that known as *unity coupling*, by reason of the fact that the turns-ratio between primary and secondary is one-to-one. This method of coupling is illustrated in *C* of figure 28. Only one of the windings is tuned, although the interwinding of the two coils gives an effect in the untuned winding as though it were actually tuned with a condenser. Unity coupling is used in some types of ultra-high frequency circuits, although the mechanical considerations are somewhat difficult. The secondary, when it serves as the grid coil, is placed inside of a copper tubing coil; the latter serves as the primary or plate coil.

● Transformer Action: Reflected Impedance

When two inductances are coupled to each other, the result is a transformer in basic form. The two inductances can be wound on separate air-core forms, or, as in an audio of power transformer, on iron or magnetic cores. Power transformers are treated in a separate chapter of this *Handbook;* radio-frequency transformers have already been treated, and thus this treatise will be confined to audio frequency transformers:

For all audio frequency circuit applications, it is only necessary to refer to the *tube tables* in this book in order to find the recommended load impedance for a given tube and a given set of operating conditions. For example, the table shows that a type 42 pentode tube requires a load impedance of 7,000 ohms. Audio transformers are always rated for both their primary and secondary impedance, which means that the primary impedance will be of the rated value *only* when the secondary is terminated in its rated impedance.

If a 7,000-ohm plate load is to work into a 7-ohm loudspeaker voice coil, the impedance ratio of the transformer would be $\frac{7,000}{7} = 1,000$-to-1. Hence, the turns-ratio

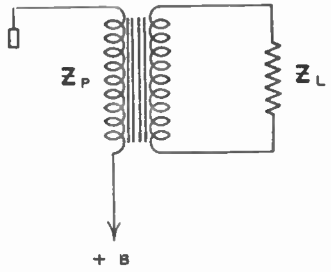


Figure 29—The reflected impedance Z_P varies directly in proportion to Z_L and the square of the turns ratio

will be the square-root of 1,000 or 31.6. This does not mean that the primary will have only 31.6 turns of wire and only one turn on the secondary. The primary must have a certain *inductance* in order to offer a high impedance to the lower audio frequencies. Consequently, it must have a large number of turns of wire in the primary winding. The *ratio* of total primary turns, to total secondary turns must remain constant, regardless of the number of turns in the primary, if the correct primary impedance is to be maintained.

The foregoing can be summarized by stating that a certain transformer will have a certain impedance-ratio (determined by the square of the turns ratio) which will remain constant. If the transformer is terminated with an impedance or resistance *lower* than the original rated value, the reflected impedance on the primary will also be lower than the rated value. If the transformer is terminated in an impedance *higher* than rated, the reflected primary impedance will be higher.

For push-pull amplifiers the recommended primary impedance is stated as some certain value, *plate-to-plate;* this refers to the impedance of the total winding without consideration of the center-tap. The reflected impedance across the total primary will follow the same rules as previously given for single-ended stages. The voltage relationship in primary and secondary is the same as the turns-ratio. For a step-down turns-ratio of 10-to-1, the corresponding *voltage* step-down would be 10-to-1, though the *impedance* ratio would be 100-to-1.

Bibliography, Formulas, and Notes

Chapter 2

Vacuum Tube Theory and Practice

Vacuum tubes are widely used for the generation, detection and amplification of audio and radio-frequency currents; electron tubes also serve as power rectifiers to convert alternating current into direct current, and in special cases for controlling and inverting electric power.

The performance of a thermionic tube depends upon the emission of electrons from a metallic surface and the flow of these electrons to other surfaces; the transition constitutes an electric current.

An electron tube consists essentially of an evacuated glass or metal envelope in which is enclosed an electron emitting surface, called a *cathode*, and one or more additional electrodes. The connections for the various elements are carried through the tube envelope to special connectors.

• Electron Emission; Cathodes

The rate of electronic motion in every atom increases if the molecular constituents of any material are subjected to thermal agitation. Hence, by heating certain metallic conductors the motion of electrons becomes so rapid that some of them break away from their parent atoms and are set free in space. In the absence of any external attraction, the electrons escaping from the emissive surface repel each other because they are all negatively charged. Therefore, the number of electrons leaving the emitter is limited because the "free" negatively charged electrons counteract the escape function of new electrons.

The point of electronic saturation is called the "*space charge effect.*" When this condition is reached no further electrons will leave the emitter regardless of how much higher the temperature of the emitting surface is increased.

In all modern vacuum tubes the surface of the cathode material is chemically treated in order to increase electronic emission. The two principal types of surface treatment include "thoriated tungsten" filaments, as used in medium and high-powered transmitter tubes, and "oxide coated" filaments or cathode sleeves, such as used in most receiver tubes. Pure tungsten filaments are practically obsolete, and are only being manufactured for some types of high-power transmitter tubes in which sufficient vacuum cannot be maintained for operating properly a thoriated tungsten type of filament.

• Cathode Current

When a heated cathode and a separate metallic plate are placed in an evacuated envelope, it is found that a few of the electrons thrown off by the cathode will leave with sufficient velocity to reach the plate. If the plate is electrically connected back to the cathode, the electrons will flow from cathode to plate, and through the external circuit back to cathode, due to the potential difference between plate and cathode. This small current flow is called *plate current.*

If a battery or other source of d.c. voltage is placed in the external circuit between the plate and cathode, so that the battery voltage places a positive potential on the plate, the flow of current from the cathode to plate will be increased. This is due to the strong attraction offered by the positively charged plate for any negatively charged electrons. If the positive potential on the plate is increased, the flow of electrons between the

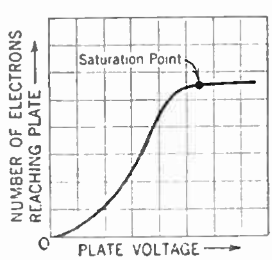


Figure 1 — Curve showing emission from a cathode

cathode and plate will also increase, up to the point of *saturation*. Saturation current flows when all of the electrons leaving the cathode are attracted to the plate, and no increase in plate voltage can increase the number of electrons being attracted to the plate.

Operating a cathode at a temperature materially above its normal rating will shorten the life of the emitting surface. In the case of thoriated tungsten emitters, which are rather sensitive to changes in filament temperature, it is advisable to have a close control over the filament voltage. If there is doubt about the filament voltage, it is better to operate the filament slightly higher than normal, rather than below normal, especially if the tube is operating with high plate current.

• Rectification

It has been stated that when the potential of the plate is different from that of the cathode, electrons will be attracted to the plate and a current will therefore flow in the external circuit. If, on the other hand, the plate is made negative, the electron flow in the external circuit will cease, due to the repulsion of the electron stream within the tube back to its cathode. From this is derived a valuable property, namely the ability to pass current in one direction only, as in a *rectifier*. Figure 2-A shows a half-wave rectifier circuit. For convenience of explanation a conventional power rectifier is chosen, although the same diagram and explanation will apply to diode rectification in a radio receiver.

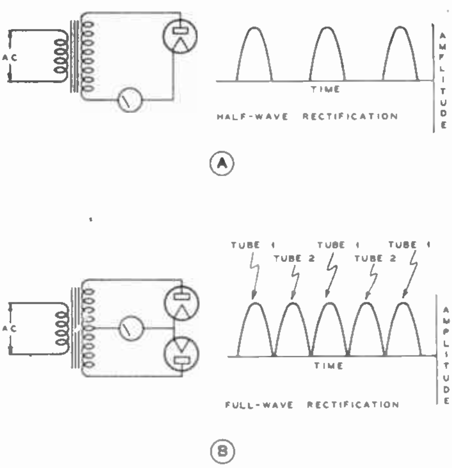


Figure 2

When a sine wave voltage is induced in the secondary of the transformer, the rectifier is made alternately positive and negative as the polarity of the alternating-current changes. Electrons are attracted to the plate from the cathode when the plate is positive, and current then flows in the external circuit. On the succeeding half cycle the plate becomes negative with respect to the cathode, and no current flows. Thus there will be an interval before the succeeding half cycle occurs when the plate again becomes positive. Under these conditions, plate current once more begins to flow and there is another pulsation in the output circuit. For the reason that one-half of the complete wave is absent in the output, the result is what is known as *half-wave rectification*. The output power is the average value of these pulsations; it will therefore be of a low value because of the interval between pulsations.

In a *full wave* circuit (figure 2B) the plate of one tube is positive when the other plate is negative; although the current changes its polarity, one of the plates is always positive. One tube therefore operates effectively on each half cycle, but the output current is in the same direction. In this type of circuit the rectification is complete and there is no "gap" between plate current pulsations. This output is known as *rectified a.c.*, or *pulsating d.c.*

• Gaseous Conduction; Mercury Vapor Rectifiers

If a two-element electron tube is evacuated and then filled with a gas, such as mercury vapor, its characteristics and performance will differ radically from that of an ordinary high-vacuum diode tube.

The principle upon which the operation of a gas-filled rectifier depends is known as the phenomenon of *ionization*. Investigation has shown that the electrons emitted by a hot cathode in a mercury vapor tube are accelerated toward the anode (plate) with great velocity. These electrons move in the electrical force-free space between the hot cathode and the anode, in which space they collide with mercury vapor molecules.

If the moving electrons attain a velocity so great as to enable them to break through a potential difference of more than 10.4 volts (for mercury), they will literally "knock the electrons out of the atoms" with which they collide. When an electron is separated from its normal orbit it does not leave in the form of an electron, but rather as a *positive ion.* The positive ion thus freed will therefore be neutralized by the acquisition of a free electron. Finally, the free electron will be attracted to the anode, or plate, as will the positive ions which have been separated from the mercury atoms; collectively, this constitutes the flow of current in the tube.

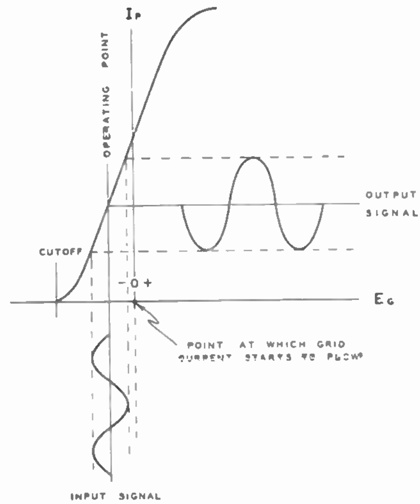
As more and more atoms are broken up by collision with electrons, the mercury vapor within the tube becomes *ionized* and transmits a considerable amount of current. The ions are repelled from the anode when it is positive; they are then attracted to the cathode, thus tending to neutralize the negative space charge as long as saturation current is not drawn. This effect neutralizes the negative space charge to such a degree that the voltage drop across the tube is reduced to a very low value; furthermore, the reduction in heating of the diode plate as well as an improvement in the voltage regulation of the load current is achieved. The efficiency of rectification is thereby increased because the voltage drop across any rectifier tube represents a waste of power.

• The Vacuum Tube As An Amplifier

The rectifier tube is essentially a two-element device. A third element can be added to the tube as a means of controlling the plate current. A third element of this type is called a *grid.* It is a mesh-like structure which surrounds the cathode, interposed between cathode and plate in such a manner that the passage of electrons to the plate must travel through the grid on the way.

If this grid is made negative with respect to the cathode, the negatively-charged electrons will be repelled back to the cathode. Plate current can be entirely stopped when the grid is made sufficiently negative, even though there is a positive voltage on the plate, that would ordinarily attract electrons. Thus it can be seen that the grid acts as a "valve" in its control of the plate current; it is for this reason that vacuum tubes are termed "valves" in Britain, Australia and Canada. When there is less negative voltage on the grid than that necessary to cut-off the plate current, a steady value of plate current will flow. The value of fixed negative voltage on the grid of a vacuum tube is referred to as *bias.*

A graph of values of plate current for various values of grid voltage can be plotted as shown in figure 3.



CLASS A OPERATION

Figure 3

A suitable "operating point" is chosen on the static characteristic curve; this point is dictated by the service to which the tube is to be subjected. The bias determines the operating point, and a signal causes the grid to vary back-and-forth about this point in exact accordance with the wave shape of the input signal. This is the condition under which a Class-A amplifier functions. The fluctuation in grid potential results in a corresponding fluctuation in plate current. When this current flows through a suitable load device it produces a varying voltage drop, which is a replica of the original input voltage, although considerably greater in amplitude.

• Properties of Vacuum Tubes; Amplification Factor; Mutual Conductance; Plate Resistance

The amplification factor, or "mu" (μ) of a vacuum tube is the ratio of the ability of the plate voltage to control plate current, to the ability of the grid voltage to likewise control the plate current. Expressed as an equation:

$$\mu = \frac{dE_p}{dE_g}$$

The μ can be determined experimentally by making a slight change in the plate voltage, thus slightly changing the plate current. The plate current is then returned to its original value by a change in grid voltage. The ratio of the increment in plate voltage to the increment in grid voltage is the μ of the tube. The foregoing assumes that the experiment is conducted on the basis of rated voltages as shown in the manufacturers' tube tables.

The plate resistance can also be determined by the previous experiment. By noting the change in plate current as it occurs when the plate voltage is changed, and by dividing the latter by the former, the plate resistance can then be determined. Expressed as an equation:

$$R_p = \frac{dE_p}{dI_p}$$

The mutual conductance, also referred to as *transconductance*, is the ratio of the amplication factor (μ) to the plate resistance:

$$S_m = \frac{\mu}{R_p} = \frac{\frac{dE_p}{dE_g}}{\frac{dE_g}{dI_p}} = \frac{dI_p}{dE_p}$$

The amplification factor is the ability of the tube to amplify or increase the voltages applied to the grid. The amount of voltage amplification that can be obtained from a tube is expressed as follows:

$$\frac{\mu Z}{R_p + Z}$$

where Z = ohmic load in the plate circuit.

In the case of a type-6F5 tube with a plate resistor of 50,000 ohms, the voltage amplification as calculated from the previous equation would be:

$$\frac{100 \times 50{,}000}{50{,}000 + 66{,}000} = 43.$$

From the foregoing it is seen that an input of 1-volt to the grid of the tube will give an output of 43 volts (a.c.).

• Class-A Amplifier

The expression, "Class-A," is simply a means of classifying the operating conditions of an amplifier stage. It was previously explained how the fixed bias applied to the grid of an amplifier determines the operating point from which the signal input varies. From the characteristic curve in figure 3 it will be seen that this curve is not a perfectly straight line, but is curved toward its base, with an additional curvature at the top, due to filament saturation. If an amplifier is to be designed so that it will faithfully reproduce the character of the input signal, the operating point on the curve must be set in the center of the straight-line portion. Furthermore, the amplitude of the input signal must be such that the peaks do not exceed the straight-line portion of the characteristic curve.

If the signal is permitted to go too far negative, the negative half cycle in the plate output will not be the same as the positive half cycle. In other words, the output wave shape will not be a duplicate of the input, and a *distortion* in the output will therefore result. The fundamental property of Class-A amplification is that both the bias voltage and input signal level must not advance beyond the point of zero grid potential, otherwise the grid itself will become positive. Electrons will then flow into the grid and through its external circuit in much the same manner as if the grid were actually the plate. The result of such a flow of grid current is a lowering of the input impedance of the tube, so that power is required to drive it.

Class-A amplifiers are never designed to draw grid current; in other words, the grid is never permitted to become positive. Class-A amplifiers do not realize the optimum capabilities of any individual tube; it can therefore be said that the efficiency of such amplifiers is low. They are used because they give very little distortion, even though it requires larger tubes and higher plate voltage to obtain a given audio output power than when some grid current is permitted to flow. The correct bias for Class-A operation is given in the *Tube Tables.*

● Load Impedance; Dynamic Characteristic

The plate current in an amplifier increases and decreases in proportion to the value of applied input signal. If useful power is to be realized from such an amplifier, the plate circuit must be terminated in a suitable resistance or impedance, across which the power can be developed. As soon as the increasing and decreasing plate current flows through a resistor or impedance, the voltage drop across this load will constantly change, because the plate current is constantly changing. The actual value of voltage on the plate will vary in accordance with the *IZ* drop across the load, even though a steady value of direct current may be applied to the load impedance; hence for an alternating voltage on the grid of the tube there will be a constant change in the voltage at the anode.

The static characteristic curves give an indication of the performance of the tube for only one value of plate voltage. If the plate voltage is changed, the characteristic curve will shift. This sequence of change can be plotted in a form that permits a determination of tube performance; it is customary to plot the plate current for a series of permissible values of plate voltage, at some fixed value of grid voltage. The process is repeated for a sufficient number of grid voltage values in order that adequate data will be available. A group or "family" of plate voltage-plate current curves, each for a different grid potential, makes possible the calculation of the correct load impedance of the tube. Dynamic characteristics include curves for variations in amplification factor, plate resistance, transconductance and detector characteristics.

The correct value of load impedance for a rated power output is always specified by the tube manufacturer. The plate coupling device must always reflect this impedance to the tube. This subject was treated under *Impedance Matching.*

● Tubes in Parallel and Push-Pull

Two or more tubes can be connected in parallel in order to secure greater power output; two tubes in parallel will give twice the output of a single tube. Since the plate resistances of the two tubes are in parallel, the required load impedance will be half that for a single tube.

When power is to be increased by the use of two tubes, it is generally advisable to connect them in push-pull; in this connection the power output is doubled and the *harmonic content,* or *distortion,* is reduced. The input voltage applied to the grids of two tubes is 180° out of phase, the voltage usually being secured from a center-tapped secondary winding with the center-tap connected to the source of bias and the outer ends of the winding connected to each grid. The plates are similarly fed into a center-tapped winding and plate voltage is introduced at the center-tap. The signal voltage supplied to one grid must always swing in a positive direction when the other grid swings negatively. The result is an increase in plate current in one tube with a consequent decrease in plate current in the other at any given instant; one tube *"pushes"* as the other *"pulls"*; hence the term: *push-pull.*

● Voltage and Power Amplification

Virtually all amplifiers can be divided into two classifications, *voltage amplifiers* and *power amplifiers.* In a voltage amplifier it is desirable to increase the voltage to a maximum possible value, consistent with allowable distortion. The tube is not required to furnish *power,* because the succeeding tube is always biased to the point where no grid current flows. The selection of a tube for voltage amplifier service depends upon the voltage amplification it must provide, upon the load that is to be used, and upon the available value of plate voltage. The varying signal current in the plate circuit of a voltage amplifier is expended in the plate load solely in the production of *voltage* to be applied to the grid of the following stage. The plate voltage is always relatively high, the plate current small.

A *power amplifier,* in contrast, must be capable of supplying a heavy current into a load impedance that usually lies between 2,000 and 10,000 ohms. Power amplifiers normally furnish excitation to power-consuming devices, such as a loud-speaker. They also serve as drivers for other larger amplifier stages whose grids require power from the preceding stage. Power amplifiers are common in modulator systems for radiotelephone transmitters.

The difference between the plate power output and plate input is dissipated in the tube in the form of heat, and is known as the *plate dissipation*. Tubes for power amplifier service therefore have larger plates and heavier filaments than those for a voltage amplifier. High-power audio circuits for commercial broadcast transmitters call for tubes of such proportions that it becomes necessary to cool their plates by means of water jackets or air-cooling systems.

• Interstage Coupling

Common methods of coupling one stage to another are shown in figure 4.

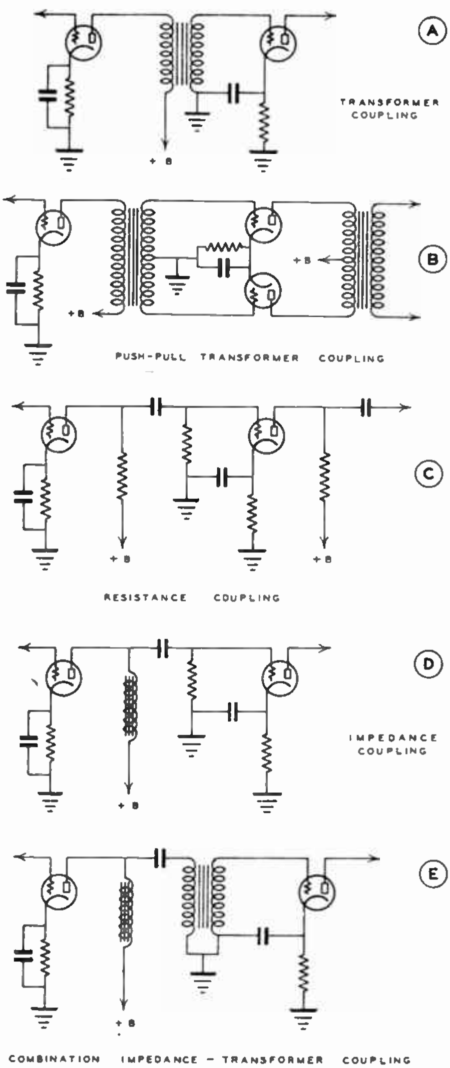


Figure 4 — Five Common Methods of A.F. Interstage Coupling.

Transformer coupling for a single-ended stage is shown in *A*; coupling to a *push-pull* stage in *B*; *resistance coupling* in *C*; *impedance coupling* in *D*. A combination impedance-transformer coupling system is shown in *E*: this arrangement is generally chosen for high permeability audio transformers of small size, and where it is necessary to prevent the plate current from flowing through the transformer primary. The plate circuit in the latter is *shunt-fed*.

• The Class-AB Amplifier

In a Class-AB amplifier the fixed grid bias is made higher than would be the case for a push-pull Class-A amplifier. The static plate current is thereby reduced and higher values of plate voltage can be used without exceeding the rated plate dissipation of the tube. The result is an increase in power output.

Class-AB amplifiers can be subdivided into Class-AB$_1$ and Class-AB$_2$. There is no flow of grid current in a Class-AB$_1$ amplifier, i.e., the peak signal voltage applied to each grid does not exceed the negative grid bias voltage. In a Class-AB$_2$ amplifier the grid signal is greater than the bias voltage on the peaks and grid current flows.

The Class-AB amplifier should be operated in push-pull if distortion is to be held to a minimum. Class-AB$_2$ will furnish more power output for a given pair of tubes than will Class-AB$_1$. The grids of a class-AB$_2$ amplifier draw current, which means that a power driver stage must be used.

• Class-B Amplifier

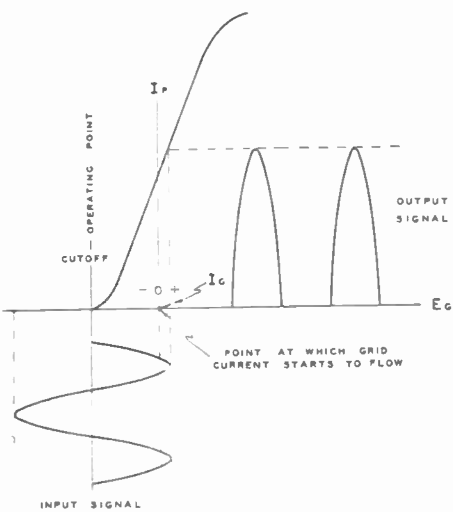
A Class-B audio amplifier operates with two tubes in push-pull. The bias voltage is increased to the point where but very little plate current flows. This point is called the *cut-off* point. When the grids are fed with voltage 180° out of phase, i.e., one grid swinging in a positive direction and the other in a negative direction, the two tubes will alternately supply current to the load. When the grid of tube no. 1 swings in a positive direction, plate current flows in this tube. During this process, grid no. 2 swings negatively beyond the point of cut-off, hence no current flows in tube no. 2. On the other half-cycle, tube no. 1 is idle, and tube no. 2 furnishes current. Each tube operates on one-half cycle of the input voltage, so that the complete input wave is reproduced in the plate circuit. Since the plate current is at a very low value when no signal is applied, the plate efficiency is considerably higher than in a Class-A amplifier.

There is a much higher steady value of plate current flow in a Class-A amplifier, regardless of whether or not a signal is present. The average plate dissipation or plate loss is therefore much greater than in a Class-B amplifier of the same power output capability.

For the reason that the plate current rises from a low to a very high peak value on input swings in a Class-B audio amplifier, the demands upon the power supply are quite severe; a power supply for Class-B amplifier service must have good *regulation*. A high capacity output condenser must be used in the filter circuit to give sufficient storage to supply power for the high peaks, and a choke-input filter system is required for good regulation.

Radio-Frequency Amplifier

Class-B radio-frequency amplifiers are used primarily as *linear amplifiers* whose function is to increase the output from a modulated Class-C stage. The bias is adjusted to the cut-off value. In a single-ended stage, the r.f. plate current flows on alternate half cycles. The power output in Class-B r.f. amplifiers is proportional to the square of the grid excitation voltage. The grid voltage excitation is doubled in a



CLASS B OPERATION

Figure 5

linear amplifier at 100% modulation, the grid excitation voltage being supplied by the modulated stage, and hence the power output on modulation peaks in a linear stage is increased four times in value. In spite of the fact that power is supplied to the tank circuit only on alternate half cycles, the "fly-wheel" effect of the tuned tank circuit supplies the missing half cycle, and the complete wave form is therefore reproduced in the output to the antenna.

Class-C R. F. Amplifier

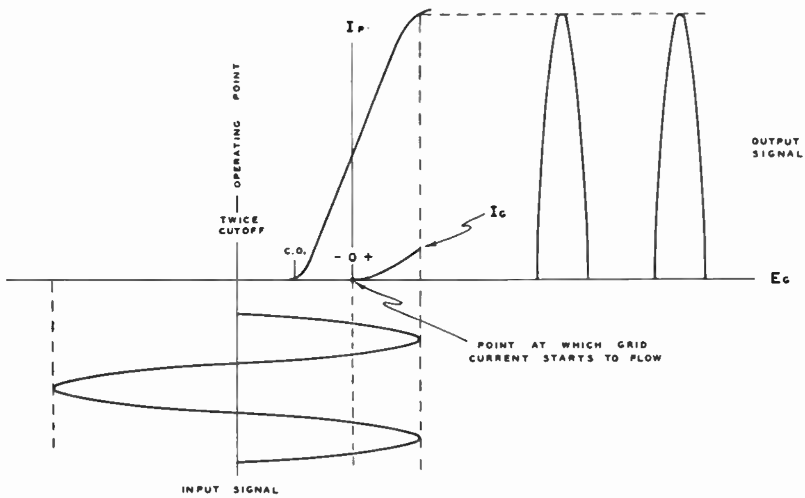
The Class-C amplifier differs from others in that the bias voltage is increased to a point well beyond cut-off. When a tube is biased to cut-off as in a Class-B amplifier, it draws plate current for a half cycle, or 180°. As this point of operation is carried beyond cut-off, i.e., when the grid bias becomes more negative, the angle of plate current flow decreases. Under normal conditions the optimum value for Class-C amplifier operation is approximately 120°. The plate current is at zero value during the first 30° because the grid voltage is still approaching cut-off. From 30° to 90° the grid voltage has advanced beyond cut-off and swings to a maximum in a region which allows plate current to flow. From 90° to 150° the grid voltage returns to cut-off, and the plate current decreases to zero. From 150° to 180° no plate current flows, since the grid voltage is then beyond cut-off.

The plate current in a Class-C amplifier flows in pulses of high amplitude, but of short duration. Efficiencies up to 75% are realized under these conditions. It is possible to convert nearly all of the plate input power into r.f. output power (approximately 90% efficiency) by increasing the excitation, plate voltage and bias to extreme values.

The r.f. plate current is proportional to the plate voltage, hence the power output is proportional to the square of the plate voltage. Class-C amplifiers are invariably used for plate modulation because of their high efficiency, and because they reflect a pure resistance load into the modulator. The plate voltage of the Class-C stage is doubled on the peaks at 100% modulation, and the power output at this point is consequently increased four times.

Oscillation

The ability of an amplifier tube to control power enables it to function as an *oscillator* in a suitable circuit. When part of



CLASS C OPERATION

Figure 6

the amplified output is coupled back into the input circuit, sustained oscillations will be generated, provided the input voltage to the grid is of the proper magnitude and phase with respect to the plate.

The voltage that is fed back and applied to the grid must be 180° out of phase with the voltage across the load impedance in the plate circuit. The voltage swings are of a frequency depending upon circuit constants.

When a parallel resonant circuit consisting of an inductance and a capacitance is inserted in series with the plate circuit of an amplifier tube and a connection is made so that part of the potential drop is impressed on the grid of the same tube 180° out of phase, amplification of the potential across the L/C circuit will result. The potential would increase to an unrestricted value were it not for the limited plate voltage and the limited range of linearity of the tube characteristic, which causes a reversal of the process after a certain point is reached. The rate of reversal is determined by the time constant or resonant frequency of the tank circuit.

The frequency range of an oscillator can be made very great; thus by varying the circuit constants, oscillations from a few cycles per second up to many millions can be generated. A number of different types of oscillators are treated in detail elsewhere in this *Handbook.*

• Harmonic Distortion

It can be said that distortion exists when the output wave shape of an amplifier departs from the shape of the input voltage wave. The flywheel effect in an r.f. amplifier tends literally to iron out the irregularities in the plate circuit wave, but unless the ratio of capacitance is high as compared to the value of inductance the foregoing does not hold entirely true. Distortion is present in the form of *harmonics,* i.e., voltages existing simultaneously with the fundamental at frequencies 2, 3, 4, 5, etc. times this fundamental frequency. The lower order of harmonics, namely those whose frequencies are twice and three times that of the fundamental frequency, are generally the strongest. The presence of strong harmonics in an audio frequency amplifier gives rise to speech or music distortion, plainly apparent to the human ear. The average ear can tolerate a certain amount of distortion, and audio amplifiers are therefore rated in percentage of *harmonic content.* The value of 5% is generally accepted as being the maximum permissible total harmonic distortion from an average audio amplifier.

The effect of harmonics in a c.w. telegraph transmitter is objectionable, for the reason that frequencies in addition to those for the desired transmission may be radiated if means are not taken to suppress them or keep them from reaching the antenna. This is thoroughly covered in later chapters.

● Detection

Detection is the process by which the audio component is separated from the modulated radio-frequency signal carrier at the receiver. Detection always involves either rectification or non-linear amplification of an alternating current.

Two general types of amplifying detectors are used in radio circuits:

(1) *Plate Detector.* The plate detector, or *bias detector,* sometimes improperly called a *power detector,* amplifies the radio-frequency wave and then rectifies it and passes the resultant audio signal component to the succeeding audio amplifier. The detector operates on the lower bend in the plate current characteristic, because it is biased close to the cut-off point . . . and could therefore be called a single-ended Class-B amplifier. The plate current is quite low in the absence of a signal and the audio component is evidenced by an increase in the average unmodulated plate current. See figure 7.

(2) *Grid Detector.* The grid detector differs from the plate detector in that it rectifies in the grid circuit and then amplifies the resultant audio signal. The only source of grid bias is the grid-leak, so that the plate current is maximum when no signal is present. This form of detector operates on the upper, or saturated bend of its characteristic curve, at a high plate voltage, and the demodulated signal appears as an audio frequency decrease in the average plate current. However, at *low* plate voltage most of the rectification takes place as the result of the *curvature* in the grid characteristic. By proper choice of grid-leak and plate voltage, distortion can be held to a reasonably small value. In extreme cases the distortion can reach a very high value, particularly when the carrier signal is modulated to a high percentage. In such cases the distortion can reach $\frac{100\%}{4}$, or 25%.

The grid detector will absorb some power from the preceding stage because it draws grid current. It is significant to relate that the higher gain through the grid detector does not necessarily indicate that it is more sensitive. Detector sensitivity is a matter of *rectification efficiency* and amplification, not amplification alone. Grid-leak detectors are often used in regenerative detector circuits because smoother control of *regeneration* is possible than in other forms of plate and bias detectors.

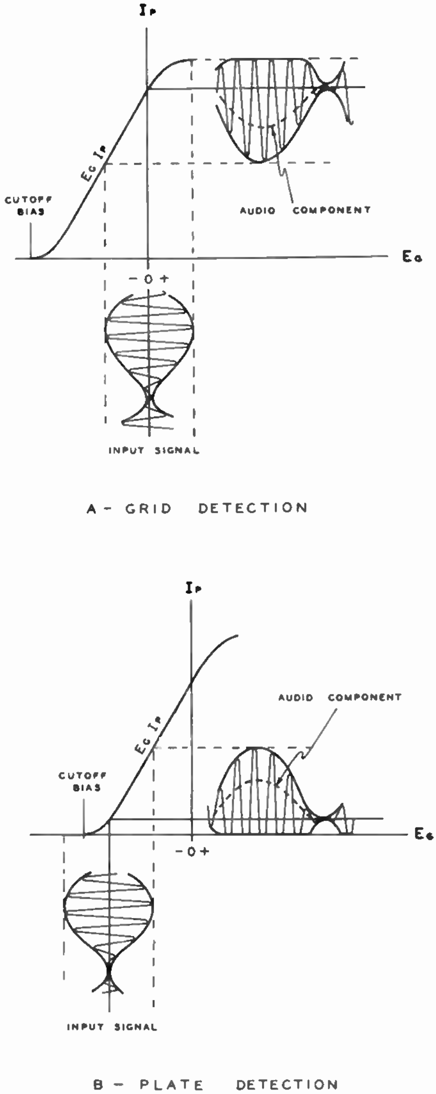


Figure 7

● Tetrodes

When still another grid is added to a vacuum tube between the control grid and plate, the tube is then called a *tetrode,* meaning that it has four elements. Such tubes are more familiarly known as *screen-grid* tubes, since the additional element is called a *screen.* The interposition of this screen between grid and plate serves as an electrostatic shield between these two elements, with the consequence that the grid-to-plate capacitance is reduced. This effect is accomplished by establishing the screen at r.f. ground potential by by-passing it to ground with a fairly-large condenser. The grid-plate capacitance is then so small that the amount of feedback voltage from plate to grid is normally insufficient to start oscillation. The advent of the screen-grid tube eliminated the necessity for "lossers" and neutralization previously required to prevent a triode r.f. amplifier stage from oscillating.

In addition to the shielding effect, the screen-grid serves another very useful purpose. Since the screen is maintained at a positive potential it serves to increase or accelerate the flow of electrons to the plate. There being large openings in the screen mesh, most of the electrons pass through it and on to the plate. Due also to the screen, the plate current is largely independent of plate voltage, thus making for high amplification. When the screen is held at a constant value it is possible to make radical changes in plate voltage without appreciably affecting the plate current.

• Secondary Emission; Pentodes

If the electrons from the cathode travel with sufficient velocity they may dislodge electrons from the plate when they strike the latter. This effect of *bombarding* the plate with high-velocity electrons, with the consequent dislodgement of other electrons from the plate, is known as *secondary emission.* This effect can cause no particular difficulty in a triode tube because the secondary electrons so emitted are eventually attracted back to the plate. In the screen-grid tube, however, the screen is close to the plate and is maintained at a positive potential. Thus the screen will attract these electrons that have been knocked from the plate, particularly when the plate voltage falls to a lower value than the screen voltage, with the result that the plate current is lowered and the amplification is decreased.

This effect is eliminated when still another element is added between the screen and plate. This additional element is called a *suppressor*, and tubes in which it is used are called *pentodes.* The suppressor grid is sometimes connected to cathode within the tube, sometimes it is brought out to a connecting pin on the tube base, but in any case it is established negative with respect to the minimum plate voltage. The secondary electrons that would travel to the screen, if there were no suppressor, are diverted back to the plate. The plate current is therefore not reduced and the amplification possibilities are increased.

Pentodes for audio applications are designed so that the suppressor increases the limits to which the plate voltage may swing; the consequent power output and gain can therefore be very great. Pentodes for radio-frequency service function in such a manner that the suppressor allows high voltage gain, at the same time permitting fairly-high gain at low plate voltage. This holds true even if the plate voltage is the same or slightly lower than the screen voltage.

• Beam Power Tubes*

A beam power tube makes use of a new method for suppressing secondary emission. In this tube there are four electrodes: a cathode, a grid, a screen, and a plate, so spaced and placed that secondary emission from the plate is suppressed without actual power. Because of the manner in which the electrodes are spaced, the electrons which travel to the plate are slowed down when the plate voltage is low, almost to zero velocity in a certain region between screen and plate. For this reason the electrons form a stationary "cloud," a *space charge.* The effect of this space charge is to repel secondary electrons emitted from the plate

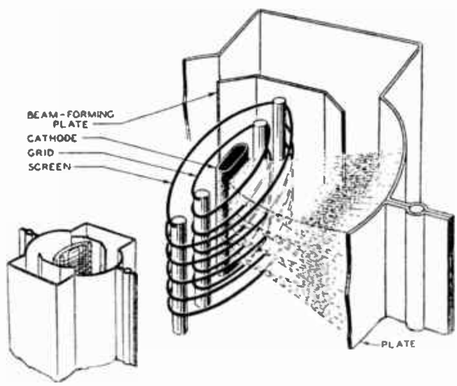


Figure 8—Internal Structure of Beam Power Tube

*Explanation and illustration courtesy RCA Radiotron Co., Inc.

and thus cause them to return to the plate. In this way secondary emission is suppressed.

Another feature of the beam power tube is the low current drawn by the screen. The screen and the grid are spiral wires wound so that each turn in the screen is shaded from the cathode by a grid turn. This alignment of the screen and the grid causes the electrons to travel in "sheets" between the turns of the screen, so that very few of them flow to the screen. Because of the effective suppressor action provided by the space charge, and because of the low current drawn by the screen, the beam power tube has the advantages of high power output, high power sensitivity and high efficiency. The 6L6 is such a beam power tube.

• Pentagrid Converters

A pentagrid converter is a multiple-grid tube so designed that the functions of superheterodyne oscillator and mixer are combined in one tube. One of the principal advantages of this type of tube in superheterodyne circuits is that the coupling between oscillator and mixer is automatically done: the oscillator elements effectively modulate the electron stream and in so doing the conversion conductance is high. The principal disadvantage of these tubes lies in the fact that they are not particularly suited for operation at frequencies much above 20 Mc., because of difficulties encountered in the oscillator section.

• Conversion Conductance

Conversion conductance is a term applied to mixer circuits in superheterodyne receivers and may be considered as a *factor of merit* for such stages.

• Special Tube Types: Twin Triodes; Frequency Converters

Some of the commonly-known vacuum tubes are in reality two tubes in one, i.e., in a single glass or metal envelope. Twin triodes, such as the types 53, 6A6 and 6N7, are typical examples. A feature of the twin triode tube is its common cathode.

Of a different nature is the 6H6 twin diode tube: the cathode is a separate element in this tube, thus making it a true dual-tube in one envelope. Other types combine the functions of double diode and triode in a common envelope, as well as a similar combination with a pentode section instead of a triode. Still other types offer a triode and a pentode in a common envelope.

Notable among the special purpose multiple grid tubes is the 6L7, used principally as a frequency converter or mixer in superheterodyne circuits. This tube has *five* grids: control grid, screens, suppressor, and a special injection grid for oscillator input. Oscillator coupling to control grid and screen grid circuits of ordinary pentodes is effective as far as mixing is concerned, but has the disadvantage of considerable interaction between oscillator and mixer. Oscillator injection into the suppressor grid of an ordinary pentode also is not particularly successful.

The 6L7 has a special *injection grid* so placed that it has reasonable effect on the electron stream without the disadvantage of interaction between the screen and control-grid. The principal disadvantage is that it requires fairly high oscillator input in order to realize its high conversion conductance. It may also be used as an r.f. pentode amplifier.

Data and Notes on Newly Released Tubes

Chapter 3

DECIBELS AND LOGARITHMS

● Technique and Practical Application

The *decibel* unit as used in radio engineering and virtually universal in all power and energy measurements is actually a unit of amplification expressed as a common logarithm of a power or energy ratio. One decibel is 1/10th of a bel. One bel or 10 decibels indicates an amplification by 10, the common logarithm of 10 being 1. Similarly, 2 bels or 20 db means amplification by 100; 30 db. means amplification by 1,000, and so on. The power ratio for one decibel is expressed as

$$\frac{P_1}{P_2} = 10^{\cdot 1} \qquad (1)$$

where P_1 is the power input; P_2, the power output. The number of decibels represents a power gain or loss, depending upon whether the relation P_1/P_2 is greater or less than 1.

Expressions for various power ratios are now commonly employed in communication engineering at audio and at radio frequencies. To express a ratio between any two amounts of power, it is convenient to use a logarithmic scale. A table of logarithms facilitates making conversions in positive or negative directions between the number of decibels and the corresponding power, voltage and current ratios.

● The Logarithmic Table

A table of logarithms is here presented. This table does not differ essentially from any other similar table except that here no proportional parts are given and the figures are stated to only three decimal places; this arrangement has been found to be satisfactory for all practical radio purposes. A complete exposition on logarithms is without the scope of this Handbook; however, the very essentials together with the practical use of the tables and their application to decibels is given herewith. Thus, a person need not be concerned with the study of logarithms other than their direct employment to decibels.

The logarithm of a number usually consists of two parts: a whole number called the *characteristic,* and a decimal called the *mantissa.* The characteristic is the integral portion to the *left* of the decimal point (see examples below), and the mantissa is the value placed to the *right.* The mantissa is all that appears in the table of logarithms.

In the logarithm the mantissa is independent of the position of the decimal point, while the characteristic is dependent only on the position of the number with the relation to the decimal point. Thus, in the following examples:

	Number		Logarithm
(a)	4021.	=	3.604
(b)	402.1	=	2.604
(c)	40.21	=	1.604
(d)	4.021	=	0.604
(e)	.4021	=	—1.604
(f)	.04021	=	—2.604

It will be seen that the characteristic is equal, algebraically, to the number of places minus one, which is the first significant figure to the left of the decimal point.

In (a) the characteristic is 3; in (b) 2; in (d) 0; in (e) —1; and in (f) —2. The following should be remembered: (1) that for a number greater than 1, the characteristic is *one less* than the number of significant figures in the number; and (2), that for a number wholly a decimal, the characteristic is *negative* and is numerically *one greater* than the number of ciphers immediately following the decimal point. Notice (e) and (f) in the above examples.

● Finding a Logarithm

To find a common logarithm of any number simply proceed as directed herewith: Suppose the number to be 5576. First, determine the characteristic. An inspection will show that this number will be three. This figure is placed to the *left* of a decimal point. The mantissa is now found by referring to the logarithm table. Proceed selecting the first two numbers which are 55, then glance down the N column until coming to these figures. Advance to the right until coming in line with the column headed 7; the number will be 746. (Note that the column headed 7 corresponds to the *third* figure in the number 5576). Place the mantissa 746 to the *right* of the decimal point making the number now read 3.746. This is the logarithm of 5576. *Important:* do not consider the last figure, 6, in the number 5576 when looking for the mantissa; in fact, disregard all digits beyond the first three when determining the mantissa; however, be doubly sure to include *all* figures when ascertaining the magnitude of the *characteristic.*

Practical applications of logarithms to decibels will follow. Other methods of using logarithms will be discussed as the subject develops.

• Power Levels

In the design of radio devices and amplifying equipment the standard power level of six milliwatts (.006w) is the arbitrary reference level of zero decibels. All power levels above the reference level are designated as "plus" quantities, and below as "minus." The figure is always prefixed by a plus (+) or minus (—) sign indicating the direction in which the quantity is to be read.

• Power to Decibels

The power output (watts) of any amplifier may be easily converted into decibels by the following formula, assuming that the input and output impedances are equal:

$$N_{db} = 10 \, Log_{10} \frac{P_1}{P_2} \qquad (2)$$

where N_{db} is the desired power level in decibels; P_1, the output of the amplifier; and P_2, the reference level of 6 milliwatts. The subnumeral, 10, affixed to the logarithm indicates that the log is to be extracted from a log table using 10 as the base.

Substituting values for the letters shown in the above formula, take the following illustration:

An amplifier using a 2A5 tube is said to deliver an undistorted output of three watts. How much is this in decibels?

Solution by formula (2)

$$\frac{P_1}{P_2} = \frac{3}{.006} = 500$$

and Log 500 = 2.69

therefore 10 × 2.69 = 26.9 DECIBELS.

By placing other values for those shown in the solution any output power may be converted into decibels *provided* that the decibel equivalent is *above* the zero reference level or the power is *not less* than 6 milliwatts.

To solve almost all problems to which the solution will be given in minus decibels, a simple understanding of algebraic adding is required. To add algebraically, it is necessary to observe the plus and minus signs of expressions. (Do not confuse these signs with decibels.) In the succeeding illustrations notice that the result was caused sometimes by addition and at other times by subtraction.

Three Place Logarithms

N	0	1	2	3	4	5	6	7	8	9
00	000	000	000	000	000	000	000	000	000	000
10	000	004	008	012	017	021	025	029	033	037
11	041	045	049	053	056	060	064	068	071	075
12	079	082	086	089	093	096	100	103	107	110
13	113	117	120	123	127	130	133	136	139	143
14	146	149	152	155	158	161	164	167	170	173
15	176	179	181	184	187	190	193	195	198	201
16	204	206	209	212	214	217	220	222	225	227
17	230	233	235	238	240	243	245	248	250	252
18	255	257	260	262	264	267	269	271	274	276
19	278	281	283	285	287	290	292	294	296	298
20	301	303	305	307	309	311	313	316	318	320
21	322	324	326	328	330	332	334	336	338	340
22	342	344	346	348	350	352	354	356	358	359
23	361	363	365	367	368	371	372	374	376	378
24	380	382	383	385	387	389	390	392	394	396
25	397	399	401	403	404	406	408	409	411	413
26	415	416	418	420	421	423	424	426	428	429
27	431	433	434	436	437	439	440	442	444	445
28	447	448	450	451	453	454	456	457	459	460
29	462	463	465	466	468	469	471	472	474	475
30	477	478	480	481	482	484	485	487	488	490
31	491	492	494	495	496	498	499	501	502	503
32	505	506	507	509	510	511	513	514	515	517
33	518	519	521	522	523	525	526	527	528	530
34	531	532	534	535	536	537	539	540	541	542
35	544	545	546	547	549	550	551	552	553	555
36	556	557	558	559	561	562	563	564	565	567
37	568	569	570	571	572	574	575	576	577	578
38	579	580	582	583	584	585	586	587	588	599
39	591	592	593	594	595	596	597	598	599	601
40	602	603	604	605	606	607	608	609	610	611
41	612	613	614	616	617	618	619	620	621	622
42	623	624	625	626	627	628	629	630	631	632
43	633	634	635	636	637	638	639	640	641	642
44	643	644	645	646	647	648	649	650	651	652
45	653	654	655	656	657	658	659	659	660	661
46	662	663	664	665	666	667	668	669	670	671
47	672	673	673	674	675	676	677	678	679	680
48	681	682	683	683	684	685	686	687	688	689
49	690	691	692	692	693	694	695	696	697	698
50	699	699	700	701	702	703	704	705	705	706
51	707	708	709	710	711	712	713	713	715	715
52	716	716	717	718	719	720	721	722	722	723
53	724	725	725	726	727	728	729	730	730	731
54	732	733	734	734	735	736	737	738	738	739
N	0	1	2	3	4	5	6	7	8	9

Three Place Logarithms

N	0	1	2	3	4	5	6	7	8	9
55	740	741	741	742	743	744	745	746	747	747
56	748	749	749	750	751	752	752	753	754	755
57	755	756	757	758	758	759	760	761	761	762
58	763	764	764	765	766	767	767	768	769	770
59	770	771	772	773	773	774	775	776	776	777
60	778	778	779	780	781	781	782	783	783	784
61	785	786	786	787	788	788	789	790	791	791
62	792	793	793	794	795	795	796	797	798	798
63	799	800	800	801	802	802	803	804	804	805
64	806	806	807	808	809	810	810	811	811	812
65	813	813	814	814	815	816	816	817	818	818
66	819	820	820	821	822	822	823	824	824	825
67	826	826	827	828	828	829	829	830	831	831
68	832	833	833	834	835	835	836	837	837	838
69	838	839	840	840	841	842	842	843	843	844
70	845	845	846	847	848	848	849	849	850	850
71	851	851	852	853	853	854	854	855	856	856
72	857	857	858	859	859	860	860	861	861	862
73	863	863	864	865	865	866	866	867	868	868
74	869	869	870	871	871	872	872	873	873	874
75	875	875	876	876	877	877	878	879	879	880
76	880	881	882	882	883	883	884	884	885	885
77	886	887	887	888	888	889	889	890	891	891
78	892	892	893	893	894	894	895	896	896	897
79	897	898	898	899	899	900	900	901	902	902
80	903	903	904	904	905	905	906	906	907	907
81	908	909	909	910	910	911	911	912	912	913
82	913	914	914	915	915	916	917	917	918	918
83	919	919	920	920	921	921	922	922	923	923
84	924	924	925	925	926	926	927	927	928	928
85	929	929	930	930	931	932	932	933	933	934
86	934	935	935	936	936	937	937	938	938	939
87	939	940	940	941	941	942	942	943	943	944
88	944	945	945	946	946	946	947	947	948	948
89	949	949	950	950	951	951	952	952	953	953
90	954	954	955	955	956	956	957	957	958	958
91	959	959	960	960	960	961	961	962	962	963
92	963	964	964	965	965	966	966	967	967	968
93	968	968	969	969	970	970	971	971	972	972
94	973	973	974	974	975	975	975	976	976	977
95	977	978	978	979	979	980	980	980	981	981
96	982	982	983	983	984	984	985	985	985	986
97	986	978	987	988	988	989	989	989	990	990
98	991	991	992	992	993	993	993	994	994	995
99	995	996	996	996	997	997	998	998	999	999
00	000	004	008	012	017	021	025	029	033	037
N	0	1	2	3	4	5	6	7	8	9

(a)	(b)	(c)	(d)
+2	—4	—4	+4
—4	—2	+2	+2
—2	—6	—2	+6

The terms used in (c) are those that apply to decibel calculations.

When a solution to a problem involving logarithms will be in minus decibels, note particularly that the characteristic of the logarithm will be prefixed by a minus sign (—). This sign only affects the characteristic; the mantissa remains positive. The mantissa *always* remains positive, regardless of whether the solution of the problem brings the sign of the characteristic as negative or positive. A prefix —1 to a logarithm means that the first figure of the number which it represents will be the *first place* to the *right* of the decimal; —2 will occupy the second place to the right, while a cipher fills the first place; —3, the third place with two ciphers filling the first and second places, and so on.

To multiply a *minus* characteristic and a *positive* mantissa by 10, each part must be considered separately, multiplied by 10, and then the products added algebraically; thus, in the following illustration:

An amplifier using a 199 tube has an output of 5 milliwatts. How much is this in decibels?

Solution by formula (2):

$$\frac{P_1}{P_2} = \frac{.005}{.006} = .83$$

Log .83 = —1.9 (actually —1.920)

Therefore 10 × —1.9 = —1 DECIBEL (10 × —1 = —10; and 10 × .9 = +9, hence, adding the products algebraically = —1).

By substituting the other values for those in the above solution, any output power *below* 6 milliwatts or the zero reference level may be converted into decibels.

Determining Db Gain or Loss

In using amplifiers it is a prime requisite to be able to indicate gain or loss in *decibels*. To determine the gain or loss in db employ the following formula:

$$\text{(gain) } N_{db} = 10 \text{ Log } \frac{P_o}{P_i} \qquad (3)$$

$$\text{(loss) } N_{db} = 10 \text{ Log } \frac{P_i}{P_o} \qquad (4)$$

where N_{db} is the number of db gained or lost; P_i, the input power, and P_o, the output power.

Applying, for example, formula (3): Suppose that an intermediate amplifier is being driven by an input power of 0.2 watts, and after amplification, the output is found to be 6 watts.

$$\frac{P_o}{P_i} = \frac{6}{.2} = 30$$

Log 30 = 1.48

Therefore 10 × 1.48 = 14.8 DB POWER GAIN.

Amplifier Ratings

The technical specifications or rating on power amplifiers must contain the following information: the overall gain in decibels; the power output in watts; the value of the input and output impedances; the input signal level in db; the input signal voltage; and the power output level in decibels.

If the specifications on an amplifier include only the input and output signal levels in db, it then is necessary to calculate how much these values represent in power. The methods employed to determine power levels are not similar to those used in previous calculations. Caution should, therefore, be taken in reading the following explanations, with particular care and attention being paid to the minor arithmetical operations.

The Anti-logarithm

To determine a power level from some given decibel value, it is necessary to invert the logarithmic process formerly employed in converting power to decibels. Here, instead of looking for the log of a number, it is now necessary to find the *anti-logarithm* or number corresponding to a given logarithm.

In deriving a number corresponding to a logarithm it is important that these simple rules be committed to memory: (1) that the figures that form the original number from a corresponding logarithm depend entirely upon the mantissa or decimal part of the log; (2), that the characteristic serves only to indicate where to place the decimal point of the original number; and (3), that if the original number was a whole number the decimal point would be placed to the extreme right.

The procedure of finding the number corresponding to a logarithm is explained as follows: Suppose the logarithm to be 3.574. First, search in the table under any column from 0 to 9 for the numbers of the mantissa 574. If the exact number cannot be found, look for the next *lowest* figure, which is nearest to, but less than, the given mantissa. After the mantissa has been located, simply glance immediately to the left to the N column and there will be read the number, 37. This number comprises the first two figures of the number corresponding to the antilog. The third figure of the number will appear at the head of the column in which the mantissa was found. In this instance the number heading the column will be 5. If the figures have been arranged as they have been found, the number will now be 375. Now since the characteristic is 3, there must be four figures to the *left* of the decimal point; therefore, by annexing a cipher the number becomes 3750; this is the number that corresponds to the logarithm 3.574. If the characteristic were 2 instead of 3, the number would be 375. If the logarithm were —3.574 or —1.574, the antilogs or corresponding numbers would be .00375 and .375 respectively. After a little experience a person can obtain the number corresponding to a logarithm in a very few seconds.

Converting Decibels to Power

It is always convenient to be able to convert a decibel value to a power equivalent in order to determine the ratio difference. The formula used for converting decibels into watts is similar in many respects to equation (2), the only difference being that the factor P_1 corresponding to the power level is not known. Usually the formula for converting decibels into power is written as:

$$N_{db} = 10 \text{ Log } \frac{P_1}{.006} \qquad (5)$$

In practice it has been found that it is too difficult to derive the solution to the above equation because of the expression being written in the reverse. However, by re-arranging the various factors, the expression can be simplified to permit easy visualization, thus:

$$P = .006 \times \text{antilog } \frac{N_{db}}{10} \qquad (6)$$

where P is the desired power level; .006, the reference level in milliwatts; N_{db}, the decibels to be converted; and 10, the divisor.

To determine the power level, P, from a decibel equivalent, simply divide the decibel value by 10, then take the number comprising the antilog and multiply it by .006, the product gives the power level of the decibel value.

NOTE: In all problems dealing with the conversion of *minus* decibels to power, it often happens that the decibel value $-N_{db}$, is not always equally divisible by 10. When this is the case, the numerator in the factor $-N_{db}/10$ must be made evenly divisible by the denominator in order to derive the proper power ratio. Note that the value $-N_{db}$ is negative; hence, when dividing by 10, the negative signs must be observed and the quotient labeled accordingly.

To make the numerator in the value $-N_{db}$, equally divisible by 10, proceed as follows: Assume $-N_{db}$ to be the logarithm —38 with a zero mantissa; hence, in order to make —38 divisible by 10 simply annex as many units as is necessary from the zero mantissa and add them to the —38 until the figure can be equally divided. An examination will show it was only necessary to add two units to bring —38 up to —40. *Carefully note* that every unit borrowed from the zero mantissa must be returned to it as a positive quantity multiplied by 10. Thus, the two units borrowed to bring —38 up to —40 is returned as 20, making what was a zero mantissa now have a value of 20. The numerator $-N_{db}$, now becomes —40.20; this figure can now be equally divided by 10.

While the above discussion applies strictly to negative values, the following examples will clearly show the technique to be followed for almost all practical problems.

(a) The output level of a popular velocity ribbon microphone is rated at —74 db. What is the equivalent in milliwatts?

Solution by equation (6)

$$\frac{-N_{db}}{10} = \frac{-74}{10} \quad \text{(not equally divisible by 10)}$$

Routine:

$$\begin{array}{rl} -74 & \text{mantissa} \\ +6 & 60 \ (6 \times 10) \\ \hline -80 & 60 \end{array}$$

$$\frac{-N_{db}}{10} = \frac{-80.60}{10} = -8.6$$

Antilog —8.6 = .00000004

.006 × .00000004 = .000000000240 or 240 Micromicrowatts

(b) This example differs somewhat from that of the foregoing one in that the mantissas are added differently. A low powered amplifier has an input signal level of —17.3 db. How many milliwatts does this value represent?

Solution by equation (6)

$$-N_{db} = \frac{-17.3}{10} = -2.33$$

$$\begin{array}{r} -17 \ . \ \ 3 \\ +\ 3 \ . \ 30 \\ \hline -20 \ . \ 33 \end{array}$$

(The mantissas were added as 30 plus 3, and *not* .3 plus .30.)

Antilog —2.33 = .0214

.006 × .0214 = .000128 or .128 Milliwatts.

● Voltage Amplifiers

When plans are being drafted contemplating the design of power amplifiers, it is essential that the following data be determined: First, the input and output signal levels to be used; second, the size of the power tubes that would adequately deliver sufficient undistorted output, and third, the input signal voltage that must be applied to the amplifier to deliver the desired output. This last requirement is the most important in the design of voltage amplifiers.

The voltage step-up in a transformer-coupled amplifier depends chiefly upon the μ of the tubes and the turns ratio of the inter-stage coupling transformers. The step-up value in any amplifier is calculated by multiplying the step-up factor of each voltage amplifying or step-up device. Thus, for example, if an amplifier were designed having an output transformer with a ratio of 3:1 coupled to a tube having a μ of 7, the voltage step-up would be approximately 3 times 7, or 21. It is seldom that the total product will be exactly the figure derived because it is not quite possible to realize amplification equal to the full μ of the tube.

From the voltage gain in an amplifier it is possible to calculate the input and output signal levels and at the same time be able to determine at what level the input signal must be in order to obtain the desired output. By converting voltage ratios into decibels, power levels can be determined. Hence, to find the gain in db when the input and output voltages are known, the following expression is used:

$$\text{(gain) } N_{db} = 20 \text{ Log} \frac{E_1}{E_2} \qquad (7)$$

where E_1, is the output voltage; and E_2, the input voltage.

Employing the above equation in a practical problem, note that the logarithm is multiplied by 20 instead of by 10 as in previous examples. For instance:

A certain one-stage amplifier consists of the following parts: 1 input transformer, ratio 2:1, and 1 output tube having a μ of 95. Determine the gain in decibels with an input voltage of 1 volt.

Solution by equation (7)

2 × 95 = 190 voltage gain

$$\text{therefore, } \frac{E_1}{E_2} = \frac{190}{1} = 190$$

Log 190 = 2.278

20 × 2.278 = 45.56 DECIBELS GAIN

To reverse the above and convert decibels to voltage ratios, use the following expression:

$$E\ (\text{gain}) = \text{antilog}\,\frac{N_{db}}{20} \qquad (8)$$

where E is the voltage gain (power ratio); N_{db}, the decibels, and 20, the divisor.

To find the gain, simply divide the decibels by 20, then extract the antilog from the quotient; the result gives the voltage ratio.

Input Voltages

In designing power amplifiers, it is paramount to have *exact* knowledge of the magnitude of the input signal voltage necessary to drive the output power tubes to maximum undistorted output.

To determine the input voltage, take the *peak voltage* necessary to drive the grid of the last class A amplifier tube to maximum output and divide this figure by the total overall gain *preceding this stage.*

Microphone Levels

Practically all acoustic-electric apparatus used to energize amplifiers have output levels rated in decibels. The output signal levels of these devices vary considerably, as may be noted from the table below:

	Decibels	Average
Phonographic pickup.	0 to —30	—15
Carbon microphones..	—30 to —60	—45
Piezo-electric microphones	—55 to —80	—60
Dynamic microphones	—75 to —95	—85
Condenser microphones	—80 to —100	—90
Velocity microphones.	—70 to —110	—85

In general, the lower the output signal level, the higher will be the acoustic fidelity over the entire audio spectrum.

The output levels of microphones and phonograph pickups have the same power values ascribed to them as those derived from calculating power output levels of amplifiers. Therefore, the same equations employed in connection with power ratios are similarly applied when converting output signal levels to power levels.

Computing Specifications

From the preceding explanations the following data can be computed with a very high degree of accuracy:

(1) Voltage amplification
(2) Overall gain in db
(3) Output signal level in db
(4) Input signal level in db
(5) Input signal level in watts
(6) Input signal voltage

Push-Pull Amplifiers

To double the output of any cascade amplifier, it is only necessary to connect in push-pull the last amplifying stage and replace the interstage and output transformers with push-pull types.

To determine the voltage gain (voltage ratio) of a push-pull amplifier, take the ratio of one *half* of the secondary winding of the push-pull transformer and multiply it by the μ of one of the output tubes in the push-pull stage; the product, *when doubled,* will be the voltage amplification or step-up.

Acoustically, that is, from the loudspeaker standpoint, it takes approximately one db before any change in the volume of sound is noted. This is because the intensity of sound as heard by the ear varies logarithmically with the acoustic power. For practical purposes it is only necessary to remember that if two sounds differ in physical intensity by less than one db they sound alike. If they are much more than one decibel apart, one sounds slightly louder than the other.

Pre-Amplifiers

Pre-amplifiers are employed to raise low input signal levels up to some required input level of another intermediate or succeeding amplifier. For example: If an amplifier was designed to operate at an input level of —30 db and instead a considerably lower input level were used, a pre-amplifier would then have to be designed to bring the low input signal up to the rated input signal level of —30 db to obtain the full undistorted output from the power tubes in the main amplifier. The amount of gain necessary to raise a low input signal level up to another level may be determined by the following equation:

$$E\ (\text{gain}) = \text{antilog}\,\frac{N_{db1} - N_{db2}}{20} \qquad (9)$$

where E is the voltage step-up or gain; N_{db1}, the input signal level of the pre-amplifier or the new input signal level; N_{db2}, the input signal level to the intermediate amplifier; and 20, the divisor.

Chapter 4

LEARNING THE CODE

THE FOLLOWING is addressed more or less personally to those who contemplate taking up amateur radio as a hobby. To secure an amateur license from the Federal Communications Commission, it is necessary that the applicant submit to an examination, the first part of which is a code transmitting and receiving test. The *Continental Code* is used for radio communication; it consists of combinations of dots and dashes. It differs from the *American Morse Code* in that the latter includes the use of "spaces" in addition to the dots and dashes in the formation of certain letters. Thus, for instance, the letter "r" in the *Morse Code* is: *dot-space-dot-dot.* In the *Continental Code* the same letter is made as follows: *dot-dash-dot.* The *Morse Code* is used principally for land-line telegraphic communication in North America, while the *Continental Code* is used for both radio and ocean-cable communication.

The *Continental Code* is the more simple of the two because it uses only dots and dashes. The fact that the letters and numerals are free from "spaces" simplifies the learning of this code, because one is less likely to interpret as two letters the characters intended as a single letter.

The applicant for an amateur license must be able to send and receive the *Continental Code* at a speed of 13 words per minute, with an average of 5 characters to the word. Thus 65 characters must be copied consecutively without error in one minute. Similarly, 65 consecutive characters must be transmitted without error in that time. The applicant, however, is given sufficient opportunity to pass this code test, since sending and receiving tests are both five minutes in length. If 65 consecutive characters, at the required rate, are copied correctly somewhere during the first five-minute period, the applicant may then attempt a transmission. Again, if 65 consecutive characters are sent correctly somewhere during this second period, a passing mark is received.

The mastering of the code has been a stumbling-block to perhaps 30 per cent of the total number of applicants who appear for amateur license examinations. The code test is given first at any of the several offices of the Federal Communications Commission; if the applicant passes it, he is permitted to proceed with the remaining portions of the examination (technical questions and radio laws). Failure to pass the code test results in a three month "rest period" during which the applicant can improve his mastery of the code; thereafter, he may again appear for another try.

Many of those who fail to pass the code test, or experience difficulty in mastering the code, are handicapped because of their method of attempting to learn it. The old-line operators, who have graduated from the school of hard-knocks, are almost unanimously of the opinion that the surest method of learning the code consists of becoming familiar with the combinations of short and long *sounds* that represent the dots and dashes needed to make up the various letters. The beginner is cautioned against regarding the code as being made up of dots and dashes, but rather as consisting of *sounds,* the dot sounding as a *"did,"* the dash as a *"daw"*.

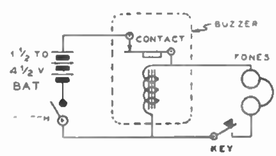


Figure 1—The Simplest Code Practice Set—a Key, Buzzer, Battery and Headphones. The Buzzer Operates Continuously, but Signals are Heard in the Headphones Only When the Key Is Depressed.

The code, then, becomes a series of *dids* and *daws,* precisely as it sounds when one listens-in on a receiver of radio-code signals. The code letter *A,* for example, is not *"dot-dash"*; it is *"did-daw"*.

Study the *code chart* for a few moments. Memorize the first three groups of characters which make up the letters *A, B,* and *C.* Repeat these characters to yourself thus: *"did-daw"*, *"daw-did-did-did"*, and *"daw-did-daw-did"*. The three letters, *A, B,* and *C,* are thus represented as they sound when heard on a code receiver.

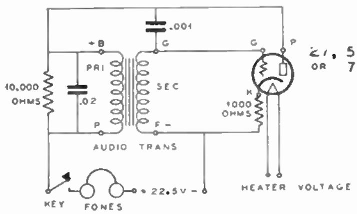


Figure 2—Code Practice Oscillator Using Heater Tube. The Tone Can Be Varied by Changing the Values of Condenser Capacity.

Do not attempt to memorize too many letters of the alphabet at one time. Take a group of four, such as the letters *E*, *I*, *S*, and *H*. These letters consist of nothing but *dids* (dots). *E* is *"did"*; I is *"did-did"*; *S* is *"did-did-did"*; *H* is *"did-did-did-did"*. On the other hand *T*, *M*, and *O*, are comprised solely of *"daws"* (dashes). *T* is *"daw"*; *M* is *"daw-daw"*, and *O* is *"daw-daw-daw"*.

Next memorize the letters which consist of combinations of dots and dashes, such as the letters *N*, *U*, and *W*. *N* is *"daw-did"*; *U* is *"did-did-daw,"* and *W* is *"did-daw-daw"*. It is best to memorize one group of letters before proceeding to another group.

In sending it is obvious that some space must exist between successive dots or dashes. The spacing is determined by the time necessary for the key to come up and then close again. No more time should be employed. To the ear, the letter *A*, previously denoted as *"did-daw"*, for the purpose of clarifying the use of the "dids" and "daws", actually sounds like *"diddaw"* when this amount of spacing is used. There is no pause between "did" and "daw"; they are completely run together into one character. If these code elements were separated ("did" "daw"), the combination might easily be interpreted as consisting of two separate letters of the alphabet, since *E* is "did" and *T* is "daw". (See code chart.)

Spaces, however, are inserted between the letters which comprise a single word and between the words themselves. To clarify this statement, a typical example is given here:

Study the above test group. The "dids" and "daws" which comprise the various letters of the alphabet used in this sentence are printed under the letters. There is a short *space* between each letter and a *longer space* between each word. The space between *letters of a word* is equivalent to the length of time required to telegraph a single dash or three dots, whereas the space between *words* is equivalent to the length of time required to send *five* dots. Obviously, it is necessary that the spacing between the letters of a word be less than the spacing between the words themselves.

Many successful radio telegraphers have found it easier to learn the code by first memorizing a single letter of the alphabet, such as the letter "A", *diddaw*. Firmly affixing this sound in their memories by continually repeating it, they then tune a short-wave receiver until a slow-sending code transmitter is heard. Each time the *diddaw* is heard and recognized, it is written on a piece of paper. Another letter is then memorized and the process of picking it out of some code transmission again repeated. It is interesting to note the number of times the memorized letters can be heard and recognized. If this system is tried, pick the most used letters first.

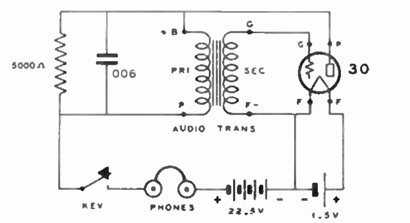
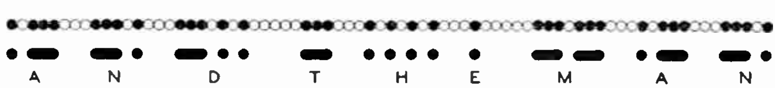


Figure 3—Code Practice Oscillator Using Triode Filament-Type Tube. Equally Desirable as the Method Shown in Figure 2.

Another method of learning the code is with the aid of a code-practice buzzer or oscillator, or by means of any one of the several types of automatic code-sending machines which are commercially available. The latter can be adjusted so as to send the code at any desired speed.

A code oscillator is perhaps the most suit-



Dash Equal to Three Dots.
Spacing Between Letters Equal to One Dash.
Spacing Between Words Equal to Five Dots.

THE RADIO TELEGRAPH CODE

A	· —
B	— · · ·
C	— · — ·
D	— · ·
E	·
F	· · — ·
G	— — ·
H	· · · ·
I	· ·
J	· — — —
K	— · —
L	· — · ·
M	— —
N	— ·
O	— — —
P	· — — ·
Q	— — · —
R	· — ·
S	· · ·
T	—
U	· · —
V	· · · —
W	· — —
X	— · · —
Y	— · — —
Z	— — · ·

Numerals, Punctuation Marks, Etc.

· — — — —	1
· · — — —	2
· · · — —	3
· · · · —	4
· · · · ·	5
— · · · ·	6
— — · · ·	7
— — — · ·	8
— — — — ·	9
— — — — —	Ø

· · · — — — · · ·	INTERNATIONAL DISTRESS SIGNAL
· · · · · ·	PERIOD
· — · — · —	COMMA
· · — — · ·	INTERROGATION
· — · · — ·	QUOTATION MARKS
— — · · — —	EXCLAMATION
— — — · · ·	COLON
— · — · — ·	SEMICOLON
— · — — · —	PARENTHESIS
— · · — ·	FRACTION BAR
· — · · ·	WAIT SIGN
— · · · —	DOUBLE DASH (BREAK)
· · · · · · · ·	ERROR (ERASE) SIGN
· — · — ·	END OF MESSAGE
· · · — · —	END OF TRANSMISSION

able device for the student. It consists of a vacuum tube, a conventional audio transformer, several small resistors and paper-type condensers, a small transformer for supplying current to the heater of the tube, a telegraph key, a pair of headphones, a filament transformer, and a "B" battery. Two vacuum tube oscillators are shown in the accompanying circuit diagrams, figures 2 and 3. Either is a satisfactory device. The oscillator shown in figure 2 uses a cathode-heater type tube and functions in what is known as a "Hartley" oscillating circuit. Tubes with either 2.5 volt or 6.3 volt heaters can be substituted with equal success, providing the proper type of filament transformer for the particular tube is used. The audio transformer can be of any commonly-used turns-ratio, the customary type having a ratio of one-to-three. The telegraph key is in series with the headphones and plate ("p") terminal of the audio transformer. The pitch of the note can be varied by merely increasing or decreasing the "B" voltage.

The capacity of the two fixed condensers shown in the diagram in figure 2 also will have an effect on the resultant tone from the oscillator; almost any desirable tone can be secured by changing these values, though those shown in the circuit diagram have proven generally satisfactory.

This vacuum tube code practice oscillator is far more practical than the simple buzzer-device shown in figure 1 because it emits a more stable tone, which can be varied to suit the taste of the individual.

● The Successful Telegrapher

Not all telegraphers are good operators. Each telegrapher acquires what is known as a "fist", i. e., his own individual style of sending on a telegraph key either of the hand-type or the automatic variety. The latter key is known as a "bug", "speed key", or "automatic key" and should not be employed by the beginner until he has become thoroughly adept in sending the code by means of a standard hand-type key.

The adjustment of a hand-type key is almost as important as its actual use. It is advisable that beginners have the telegraph key adjusted by an experienced amateur or other telegraph operator. The "feel" of the key is all-important. It determines to a large extent the nature of the characters which the operator is sending. If the key is opened too wide, the sending will be "choppy"; if not opened sufficiently wide, the sending will sound "sloppy". Neither

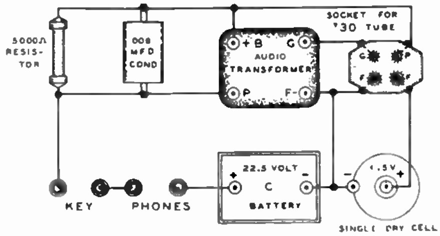


Figure 4—Pictorial Wiring Diagram of Code Practice Oscillator Shown Schematically in Figure 3.

is desired, nor to be tolerated. The key should be so adjusted that the spacing between its contact, when ready for use, is approximately 1/16-inch.

The telegraph key should be firmly secured to the operating table or mounted on a board. The tension of the spring on the lever of the key should be adjusted so that no effort is encountered in depressing the key. If the spring is made too stiff in adjustment, the operator will soon tire his hand; however, the tension must be sufficient in order that the key will snap back instantly when released.

To use a telegraph key properly one's arm should rest on the table, in the manner shown in the accompanying sketch. The third and index fingers are placed on the flat portion of the knob of the key, the thumb being permitted to touch gently the *side* of the knob in such a position that it literally "floats". This is much preferred to placing the thumb securely under the key knob.

The wrist must be permitted to move freely in an upward-and-downward motion, with the arm comfortably at ease on the table, and the third and index fingers lightly

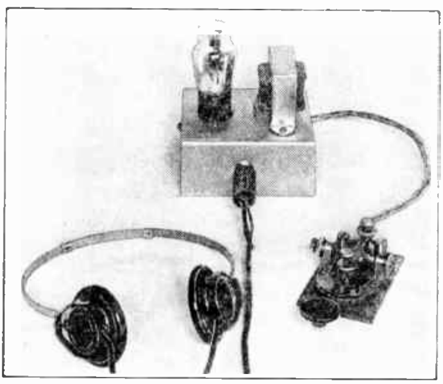
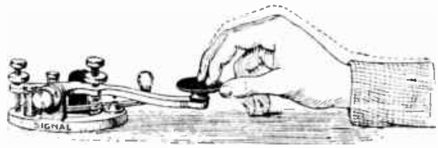


Figure 5—Code Practice Ensemble Consisting of Vacuum Tube Oscillator, Telegraph Key and Headphones, as Shown in Figures 2 and 3.

resting atop the key knob, the thumb "floating" at the side of the knob as indicated above. Do not grasp the key as though it were ready to walk off the table. *Grasp it gently*, making no effort of the task of handling the key.

Place the *Code Chart* on the table near the telegraph key. Connect the code practice set and send a few preliminary "dids" and "daws" to get the feel of the key. Then send the letter "A" on the key. Send "did-daw", letting the combination "roll into itself". Remember never to send it as "did daw" with a noticeable space between the "did" and the "daw'. Learn the knack of "rolling the characters into one another". This is what is known as "smooth sending". You will not succeed in mastering this technique if the tension of the key is too great or if the contacts are spaced too far. Con-



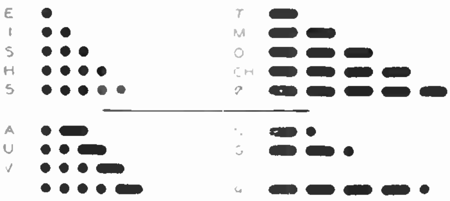
Correct Position for Arm and Wrist, and Showing How Third and Forefinger and Thumb are Placed on Key Knob.

tinue to practice sending the letter "A" until you have full control of the "touch" of the key, and until you can send this letter over and again without error. Send "diddaw", then a short pause, then another "diddaw", and repeat the process with a slight pause following each "diddaw".

Do not send too fast. Send cautiously, steadily, so that you can distinguish every character you make upon the key. If you cannot distinguish the characters while you are sending them, how could it be expected of another to copy what you are sending? *Too many students make the mistake of attempting to send faster than they can receive.*

After you have succeeded in sending the entire code from *A* to *Z* without error, making sure that you have paused between each letter of the alphabet, continue your practice by sending words, then complete sentences. A slight pause should exist between each of the letters making up a word, then a longer pause between the words in the sentence. Therein lies the secret of good, clean telegraphing.

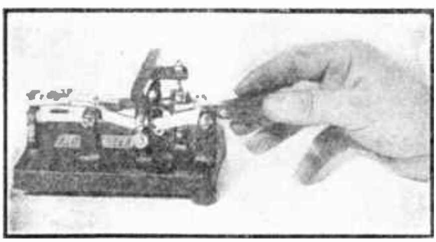
It is advisable to attempt to interest a friend in practicing the code with you. However, first acquaint yourself with the characters of each letter of the alphabet, without



Dots Alone, Dashes Alone, and Combinations of Dots and Dashes are Found in the Code Groups Above. These are the More-Easily Memorized Combinations in the Radio Telegraph Code.

assistance from others, so that you can send them upon the key without reference to the code chart. Attempt to relax when sending or receiving. Calmly make the characters in an effortless manner. When receiving, relax in your chair. If someone is sending to you on a practice set, write down the characters as you intercept them. If a letter is sent which you do not instantly recognize from memory, ask the sending operator to "break", or pause, until you have recalled the character from memory, or ask the operator to repeat the character until you have recalled it. If this fails, refer back to the code chart to determine it. Do not permit a letter to skip by. It is better either to pause or to ask for a repeat, because by this means the hard-to-learn combinations will be more quickly mastered.

The method of learning the code advocated here has become known as the "*sound*" system by reason of the fact that the characters are memorized in the form of sounds ("dids" and "daws") and not as dots and dashes. Repeat these "dids" and "daws" to yourself throughout the day or in your spare moments. Intone signs conveniently located nearby; send familiar phrases and sentences by means of your tongue. It will



Correct "Grip" and Position of Wrist for Operating Automatic Key ("Bug").

A Typical Automatic Code-Practice Ensemble.

surprise you to realize how quickly and easily you can learn the entire code by thus utilizing spare moments.

The art of properly spacing letters and words is even more complex than that of learning the code itself and of the utmost importance in the training of a good telegrapher. For this reason it is well to memorize such difficult combinations as those which are made up entirely of dashes. The sentence: *Tom To Otto*, for example, consists of nothing but dashes, with spacing between the letters and words. Another group: *She Is His,* consists entirely of dots, with proper spacing between letters and words. The paramount considerations for clean-cut telegraphing are repeated and summarized as follows:

(1) The key contacts should be spaced no more than 1/16 inch.

(2) The tension of the spring on the key should be quite light.

(3) Send slowly until you have mastered the code, then improve your speed.

(4) A dot is made with one rapid depression of the key.

(5) A dash should be approximately three times as long as a dot.

(6) "Roll" the characters of a single letter together, with no pause between them.

(7) Pause slightly between letters of a word. (Approximately one dash.)

(8) Pause a bit longer between words. (Approximately five dots.)

Log of Amateur Stations Currently Sending Code Practice Lessons

Call	*Frequency*	*Times*	*Comment*

Chapter 5

Antennas, Feed Systems, and Coupling Methods

A RADIO wave in space can be compared to a wave in water. The wave, in either case, has peaks and troughs; one peak and one trough constitute a *full wave* or *one wavelength.*

The radio wave consists of condensations and rarefactions of the energy as it travels through space, and this wave induces electrical energy into an antenna in the case of reception. When the antenna is used for transmission, it *radiates* radio waves, due to the varying intensity of the electrical field surrounding the wire.

The antenna is simply an electrical conductor which either receives or transmits radio-frequency energy. The phenomena of receiving is similar to that of transmission and an antenna can, therefore, be used with equal effectiveness for either purpose.

An antenna is somewhat similar to a tuned circuit; it has a *fundamental* or *resonant* frequency which is dependent upon the distributed capacity and inductance of the wire. The antenna is most efficient for transmission and reception when it is receiving or transmitting on its resonant *frequency.*

Radio waves travel with approximately the speed of light, which is 300,000,000 meters per second. The frequency of a radio wave can be expressed in terms of wavelength, from the formula:

$$F = \frac{300,000,000}{\lambda}$$

where *F* is the frequency in cycles per second,

λ is the wavelength in meters.

The physical dimensions of a transmitting antenna at resonance bear a direct relationship to the wavelength of the radio wave, as does an organ pipe. A long, straight wire in space is said to be "one half wavelength" long when it is electrically resonant on the "fundamental." The actual physical length of the wire is about 5 per cent less than the physical length of one half the radio wave, due to *"end effects"* of the antenna wire and because the radio energy travels at a lower speed in the wire than it does in space.

A tuned circuit is always resonant to a half wavelength, so that the *fundamental* wavelength or resonant frequency of an antenna or tuned circuit is equivalent to approximately twice the antenna length. An antenna is also resonant to the frequencies which are harmonically related to the fundamental resonant frequency. Compare the "overtone" oscillations of a guitar string. The fundamental frequency is known as the *first harmonic;* twice this frequency is the *second harmonic;* three times becomes the third harmonic, etc.

From the formula of frequency and wavelength previously given, it is apparent that one is proportional to the reciprocal of the other. The fundamental wavelength is known as a *half wave,* and the second harmonic would, therefore, be a *full wave.* The third harmonic would be three half-wavelengths, etc.

Nearly all forms of antennas used by amateurs for general coverage are of either the *Hertz* or *Marconi* type. The Hertz antenna consists of a wire suspended above the earth and insulated from it; it is of such a length as to be some multiple of a half wave.

A Marconi antenna is usually one quarter or three quarters of a wave in length and is connected to the earth or to a ground screen for the purpose of obtaining resonance. The ground acts as a mirror in effect and takes the place of the extra quarter wave that would be required to resonate the wire were it not grounded.

Marconi antennas are normally used for longer wavelengths, where the physical length of a half-wave antenna wire makes such an antenna impractical.

Hertz antennas usually are more efficient because there is a power loss due to the resistance of the ground connection required with a Marconi radiator. The Marconi antenna is connected to ground at a *current* *peak;* the resistance of this connection to earth often causes an excessive loss in power when transmitting or receiving.

● Radiation Field

A wire connected to any source of oscillating electrical energy will radiate radio waves due to the varying intensity of the electrical field surrounding the wire. The field closest to the wire is called the *induction field;* that part of the field which escapes forms the energy in the radiated field, which is urged outward and diffused in all directions through space. Any wire supported in space and within range of the radiated field will intercept the energy and will have induced in it a radio-frequency voltage, which is detectable as an incoming signal by receiving apparatus.

Radio waves are transmitted from an antenna through space in two general types of waves. One is called the *ground wave,* which follows approximately along the surface of the ground and is rapidly attenuated for very short waves. The ground wave is useful in long-wave radio communication and for very short distance work on ultra-short wavelengths. Best broadcast reception is always obtained when the receiver picks up only the ground wave, which means that, normally, it must be within a 100-mile radius of even a high power transmitter. *Fading effects* take place at greater distances, due to the interference between the ground wave and the sky waves.

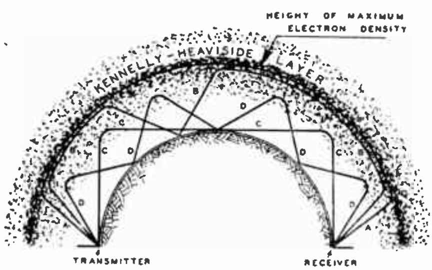


Figure 1—Reflection of Radio Waves from the Kennelly-Heaviside Layer Around the Earth

That portion radiated upward from the antenna is known as the *sky wave,* since it is reflected back to earth by ionized layers in the upper atmosphere known as The *Kennelly-Heaviside Layers,* as shown in figure 1.

At very low angles of radiation, the waves start out practically tangent to the earth's surface, penetrate into the ionized layers, and are bent back to the earth at a very distant point. Higher angles of radiation are bent back to the earth at shorter distances until a certain high angle is reached at which radiations will not be bent back to earth. This angle varies with the season of the year, frequency, and time of day. At angles slightly less than this value at which the layers are penetrated, the radio waves can be carried around one of the upper layers to extremely great distances before being bent back to earth.

The Kennelly-Heaviside Layers are strata of ionized air molecules; their ionization is due to the ultra-violet and similar extremely high-frequency radiations from the sun. The refracting layers lie above the earth at distances from about fifty up to several hundred miles elevation. The relative density of the layers is not constant, but varies from year to year and seems to depend upon sun-spot activity.

The time required for the sky waves to reach the receiver varies in accordance with the number of reflections to and from earth and the density of ionization in the Kennelly-Heaviside Layers. Obviously, the time required for a ground wave to reach the receiver will be less than that of a high-angle sky wave. When two or more waves from these different paths arrive at the same instant (*in-phase*), the signal strength will be greatest. If the time lag is great enough so that one wave tends to neutralize another (*out-of-phase*), the signal intensity will decrease, resulting in the phenomenon known as *fading.*

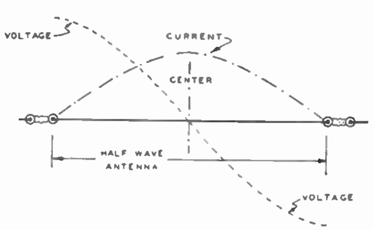
The rate of fading varies with frequency, and even a slightly different frequency sometimes has an entirely different rate of fading. A modulated wave from a radiophone station consists of a band of frequencies being transmitted; variation of fading within this narrow band results in distortion in the received signal. This effect is known as *selective fading,* because certain side-band frequencies may be stronger than others at the receiving point, resulting in bad distortion of audio quality in the output of the receiver.

● Electrical Properties

A wire stretched out into space has *inductance* of the same type as that produced by wire wound into a coil. This antenna wire also has a *distributed capacity* to nearby objects, such as the ground. As in any electrical circuit, inductive reactance and capacitive reactance impede the flow of current in either a transmitting or receiving antenna. At resonance, the inductive reactance is equal and opposite to the capacitive reactance, with the result that the electrical current is limited only by the resistance.

The resistance consists of several components, such as wire resistance, dielectric losses from nearby objects, ground resistance, insulator losses, and *radiation resistance*. The latter is a fictitious term which is useful in expressing the power radiated by the antenna. It is that resistance which would consume the same amount of power that is radiated into space by the antenna; the power lost in other forms of resistance is wasted. Shortwave antennas generally have a very high ratio of radiation resistance to loss resistance and are, therefore, very efficient.

In a resonant antenna, *standing waves* of current and voltage exist. In a typical half-wave antenna, the current is maximum at the center and zero at the ends. The radio-frequency voltage is maximum at the ends and minimum at the center. These standing waves exist because an impressed radio wave will travel out to the end of the antenna and be reflected back toward the center, since the end is an open circuit corresponding to a large mismatch of impedance. The resonant antenna is of such length that the reflected wave will be in-phase with each succeeding impressed wave or oscillation, resulting in a standing wave along the antenna wire. Standing waves produce more actual radiated power into space from an antenna than when the values of voltage and current are uniform and of lower value all along the antenna wire. Radio-frequency feeders to an antenna are generally designed for uniform distribution of current and voltage along their entire length (no standing waves). In other words, the feeders should *not* radiate because the antenna proper should alone be the radiating medium.



SHOWING HOW STANDING WAVES EXIST ON A RESONANT ANTENNA CURRENT IS MAXIMUM AT CENTER — VOLTAGE IS MAXIMUM AT ENDS

Figure 2

The *impedance* along a half-wave antenna varies from a minimum at the center to a maximum at the ends. The impedance is that property which determines the antenna current at any point along the wire for the value of radio-frequency voltage at that point. The main component of this impedance is the radiation resistance; normally, the latter is referred to the center of the half-wave antenna where the current is a maximum. The square of the current multiplied by the radiation resistance is equal to the power radiated by the antenna, for convenience these values are usually referred to the center of a half-wave section of antenna.

The curves in figure 3 indicate the theoretical center point radiation resistance of a half-wave horizontal antenna for various heights above ground. These values are of some importance in matching radio-frequency feeders to the antenna in order to obtain both a good impedance match and an absence of standing waves on the feeders.

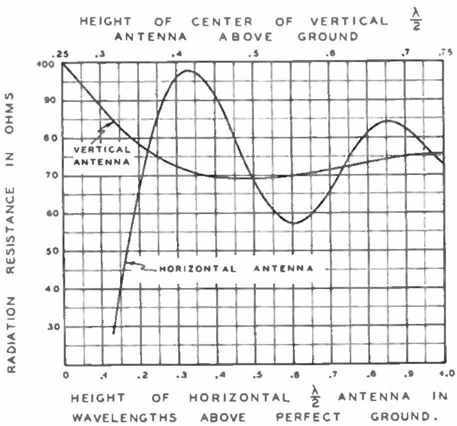


Figure 3—Effect of Height on the Radiation Resistance of a Dipole

A transmitting antenna usually consists of a wire of definite length either grounded, ungrounded, or connected to a *counterpoise*. A ground made by either a direct or capacitive connection acts as a "mirror" to the antenna wire, thereby completing the circuit. With a direct ground connection, the antenna may be either an electrical quarter wavelength or an odd multiple of a quarter wavelength. A very short wire can be loaded to resonate as a Marconi by means of a loading coil to ground; a wire slightly over a quarter wave long can be resonated as a Marconi by means of a series condenser to ground. In other words, if a Marconi is not an exact odd number of electrical quarter waves long, the reactance can be tuned out by means of a tapped coil or variable condenser, depending upon whether the antenna is too long or too short. If the antenna is not resonant and presents an inductive reactance, we insert just the right amount of capacitive reactance. If it offers capacitive reactance, we insert just the right amount of inductive reactance to establish resonance.

• Counterpoise

A counterpoise will often reduce the losses incurred in a ground connection when a Marconi antenna is used. A counterpoise consists of one or more wires insulated from the ground and supported a few feet above ground. A counterpoise network, such as shown in figure 4, will act as a condenser plate with high capacity to earth; it will eliminate the resistance loss of a high-resistance ground connection.

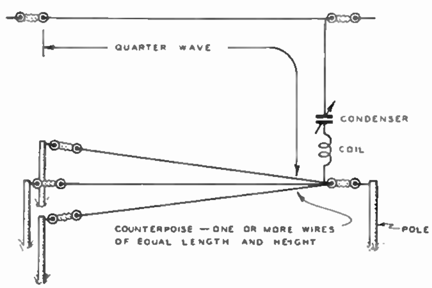


Figure 4—Typical Counterpoise System with Loading Coil and Series Tuning Condenser

The counterpoise wires can be of any length, preferably about a quarter wavelength at the frequency of operation. The network should spread-out over a wide area under the antenna and in as many directions as possible. The physical construction often depends upon the space available. Above about two megacycles, a counterpoise (especially a single wire one) takes on the aspects of a radiator, rather than a condenser plate.

• Low Resistance Grounds

Vertical antennas with heights of a quarter to five-eighths wavelength are often used in connection with an elaborate ground wire system, as shown in figure 5.

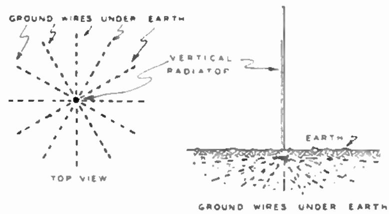


Figure 5—Ground System For Vertical Radiator.

Wires of any size, from No. 14 to No. 8 gauge, are run out in all directions and buried a few inches under the surface of the earth. These wires should extend outward about a quarter to one half wavelength from the base of the antenna. As many as 120 radial wires are sometimes used in order to reduce the resistance of the ground return which may represent a very appreciable power loss with any form of Marconi antenna.

• Directional Properties

A simple vertical antenna is non-directional in a horizontal plane. All horizontal antennas produce a radiation field which is more intense in certain directions than in others. The radiation field around a horizontal antenna depends upon its height above ground for different "vertical" angles of radiation, and upon the length of antenna and the tilt or angle of the wire with respect to ground.

The approximate radiation patterns of a horizontal half-wave antenna for various heights above ground are shown in figure 6. The relative energy is indicated for various vertical angles above the surface of the earth, for both broadside- and end-radiation from the antenna wire.

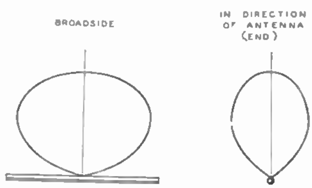
• Angle of Radiation

The *Heaviside Layer* reflects the short-wave and broadcast signals back to earth. This effect is used for long distance short-wave transmission and reception. When the major portion of the transmitted energy is directed at a particular angle above the horizon (some vertical angle), the signal will be stronger at the receiving point. The best angle of radiation depends upon the distance between stations, the frequency, and the condition of the *Heaviside Layer.*

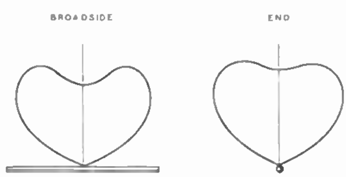
Low-angle radiation is preferable for extremely long distances because the transmitted wave does not go through as many reflections from the *Heaviside Layer* and surface of the earth between the transmitter and receiver. A certain high critical angle above the earth will sometimes allow the signal to travel through the *Heaviside Layer* to the distant receiving point, without ground reflections. However, this type of communication is not reliable, due to changing conditions of the *Heaviside Layer*. Intermediate vertical angles of radiation tend to reflect the signals back to earth at shorter distances.

These higher angles of radiation are suitable for intermediate distances of communication. Each time the signal is reflected from the surface of the earth to the *Heaviside Layer* the signal strength is reduced, due to losses which arise from the fact that the earth is not a perfect reflector. These *"earth reflection losses"* are not as great when the path between radio stations is over salt water.

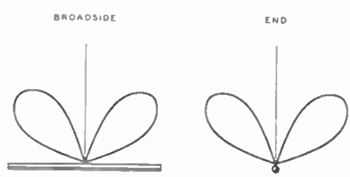
The major radiation from vertical antennas is at low vertical angles above the earth, as shown in figure 7.



QUARTER WAVE ABOVE GROUND

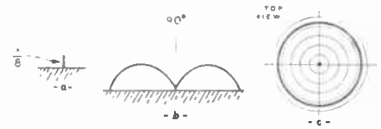


$\frac{3}{8}$ WAVE ABOVE GROUND

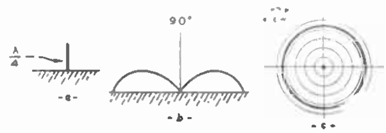


HALF WAVE ABOVE GROUND

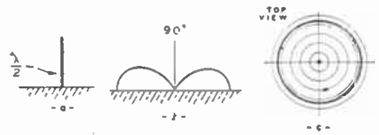
Figure 6—Horizontal Half-Wave Antenna Radiation Patterns.



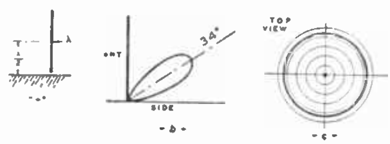
Short: [Vertical Antenna Over Perfect Ground Gives Low Angle Radiation.



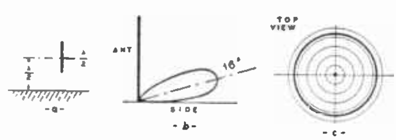
Quarter-Wave Grounded Antenna Concentrates More of the Radiation at a Low Angle Than the ⅛-Wave Antenna Does.



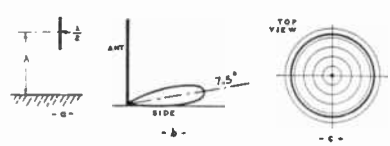
Half-Wave Antenna Above Perfect Ground.



Full-Wave Antenna Gives Maximum Radiation Upward at an Angle of 34 Degrees from the Horizon.



Half-Wave Antenna, Bottom a Quarter Wave Above Average Earth.



Increasing Height of Antenna Above Average Type Ground Lowers Angle of Radiation to 7.5 Degrees, as Shown.

FIGURE 7—ANGLE OF RADIATION OF HALF-WAVE VERTICAL ANTENNAS DEPENDS UPON CHARACTER OF EARTH OVER WHICH ANTENNA IS PLACED.

The earth acts as a reflector and prevents the vertical radiator from transmitting a wave outwardly exactly parallel to the surface of the earth, unless the vertical antenna is high above the earth. The radiation from the vertical antenna in a horizontal direction is uniform, as shown by the perfect circles in the right-hand patterns of figure 7.

Horizontal antennas, when placed at certain heights above the earth, will be most efficient at certain vertical angles, as shown in figure 6.

● Antenna Impedance

A *resonant antenna* is one which has an impedance equal to the resistance, which in this case is largely *radiation resistance.* The radiation resistance varies along the antenna wire and reaches a minimum value at the *voltage node* or *nodes.* The radiation resistance at the center of a half-wave antenna is approximately 73 ohms, and at the ends approximately 2400 ohms if the antenna is high above the earth.

Antenna feeders can be connected in such a manner that they can be terminated with any value of impedance between 73 and 2400 ohms in order to obtain *impedance matching* for maximum power transfer from the transmitter to the antenna proper.

A *non-resonant r.f. feeder* of infinite length has a *characteristic surge impedance* which is a function of the wire diameter and spacing between the wires, in the case of a two-wire feeder. Short r.f. lines, such as used for coupling transmitters to the antenna, can be made to act as lines of infinite length by terminating the far end of the feeder in an impedance that will match this characteristic surge impedance of the feeder. In a *non-resonant r.f. feeder* that is properly terminated, the r.f. current is of a constant value throughout the length of the feeder (there are no standing waves of voltage and current on the feeder).

In actual practice, there is always a small variation of r.f. current along a non-resonant feeder due to difficulties in matching impedances properly and in irregularities in the line, such as bends in the wire, spacing insulators, etc.

Concentric line feeders, twisted-pair feeders, two-wire and four-wire matched-impedance feeders, and single-wire feeders are some of the so-called "non-resonant" feeder systems.

Resonant feeders are those which have standing waves of voltage and current along the feeder line; this type of feeder must, therefore, be tuned (or cut) to resonance. The lines are prevented from radiating energy by using two wires spaced only a few inches apart, and in which the field of one wire tends to cancel that of the other. These feeders essentially consist of "folded" resonant sections of the antenna proper. Center-fed and end-fed Zepp. feeders and matching stubs are types of resonant r.f. feeders.

● Single-Wire-Fed Antenna

A single-wire feeder has a characteristic surge impedance of from 500 to 600 ohms, depending upon the diameter of the feeder wire. This type of feeder makes use of the earth as a return circuit through the earth's capacity effect to the antenna and feeder. The actual earth connection to the transmitter may have a relatively high resistance without causing appreciable loss of r.f. energy. The impedance of the feeder of 500 to 600 ohms is a great many times more than the 5 to 30 ohms resistance of a Marconi antenna at the ground connection. The additional resistance of a few ohms at the earth connection produces a large power loss in the latter case, and relatively little loss in the case of single-wire feeder.

The single-wire feeder should be tapped to either side of a *current loop* in a resonant antenna at a point of impedance matching.

The current loop occurs at the center of a half-wave antenna and at the center of each half-wave "section" in a long-wire antenna. The impedance at this current loop is approximately 73 ohms for most half-wave antennas (varying with height above ground). In order to match the 500- or 600-ohm impedance of the feeder, it is necessary to connect it to the antenna at a point approximately 1/6th or 1/7th of the total length of the antenna wire either side of center. There will be no standing waves on the feeder when the impedances are perfectly matched, and maximum efficiency will then result.

This point of perfect impedance match unfortunately is not suitable for harmonic operation of the antenna. By having a small impedance mismatch at the fundamental frequency, the single-wire-fed antenna can be used on several harmonically related shortwave bands. The feeder should be connected to the antenna at a point 1/6th, rather than 1/7th, of the total length of the antenna

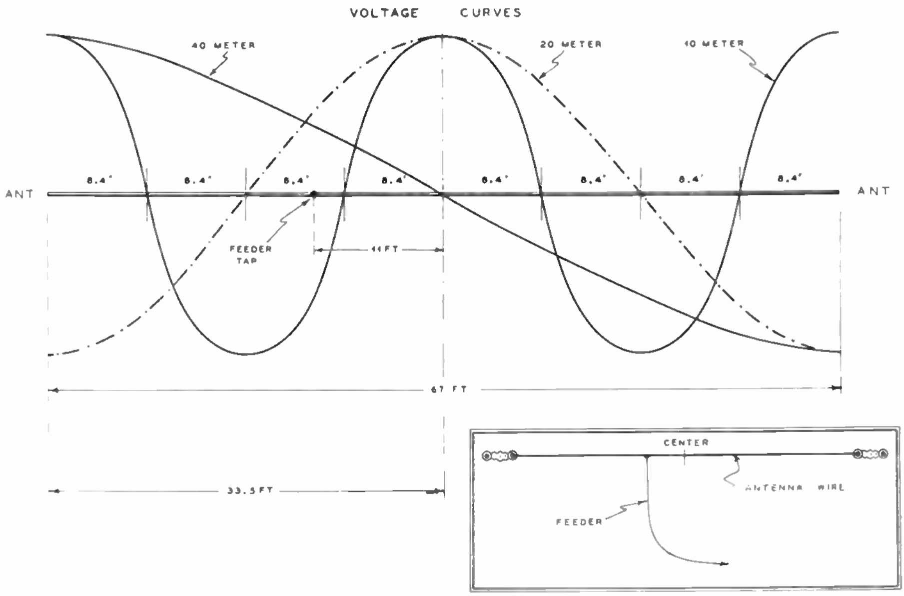


Figure 8—Single Wire Fed Antenna for All-Band Operation. An antenna of this type for 40-, 20- and 10-meter operation would have a wire 67 feet long, with the feeder tapped 11 feet off center. The feeder can be 33, 66, or 99 feet long. The same type of antenna for 80-, 40-, 20- and 10-meter operation would have a wire 134 feet long, with the feeder tapped 22 feet off center. The feeder can be either 66 or 132 feet long. This system should be used only with those coupling methods which provide good harmonic suppression.

wire either side of center. A simple manner in which to find this point is to divide the antenna into three equal lengths, and then connect the feeder to the antenna at a point which is 1/3rd of the total length from either end.

This all-wave type of antenna feeder connection results in a slight mismatch (not enough to be serious) on the fundamental frequency of operation.

In a perfectly matched design at the fundamental frequency of operation, the impedance mismatch is very great when the antenna is operated on its harmonics. It is better to compromise by connecting the feeder to the antenna as shown in figure 8, so that the system will operate efficiently in the harmonically related bands.

The effect of the small standing wave on the feeder can be practically eliminated by making the feeder some multiple of quarter waves in length. The impedance at the station end will then be purely resistive and no detuning effect will be evident in the final amplifier circuit when the feeder is either connected or disconnected from the amplifier. The formula for calculating a feeder length in feet is:

$$l = \frac{234{,}000}{f_1}$$

where l is the feeder length in feet,
f_1 is the lowest frequency of operation in kilocycles.

The length of the antenna wire in figure 8 is also a compromise for all-band operation. The harmonics of an antenna wire for any given length are not exact multiples, due to the *end effects* of the antenna. The end effect shortens each free end of the antenna by approximately 2½ per cent of a half wave. This means that a half-wave antenna has a physical length approximately 5 per cent less than the length of the radio wave in free space. In a long antenna which has several half-wave sections, the intermediate half-wave wire lengths have no end effects and, consequently, they are almost as long as the actual radio wave in space.

In this case, only the two quarter-wave sections at each end of the wire are shortened, which results in less than 5 per cent total shortening of the entire wire length when working on harmonics. This means that a wire cut for 3,600 kc. will be a little short for operation as a full wave antenna on 7,200 kc. which is the second harmonic of 3,600 kc. Fortunately, the single-wire-fed antenna can be operated satisfactorily over a band of frequencies wide enough that this effect is no handicap.

The antenna wire should be cut so that it will resonate at the *middle of the highest frequency band desired* on its fourth harmonic, because this gives the best compromise for operation in three harmonically related bands.

The formula for calculating the length of the antenna wire for all-band operation is:

$$L = \frac{(K - .05)\ 492{,}000}{f_2}$$

where L is the antenna length in feet,
f_2 is the frequency in kilocycles of the chosen middle band of operation in a three-band antenna,
K is the number of half wavelengths at that frequency.

These multi-band single-wire-fed antennas are generally designed for three bands of operation, such as 80, 40 and 20, or 40, 20 and 10 meters.

The single-wire feeder for all-band operation should preferably be some multiple of a quarter wave (of the lowest frequency band) in length; however, it can be made any length (up to several thousand feet). For single-band operation, the feeder can be any length, *provided it is attached to the antenna at the point of exact impedance match.* In any event, the feeder should run at right angles to the antenna wire proper for a distance of at least a quarter wavelength at the lowest frequency of operation. A good "earth" ground connection should be made to the transmitter for most effective operation of a single-wire feeder.

• Coupling the Single-Wire Feeder to the Final Amplifier

The simplest way to connect a single-wire feeder to the final amplifier is to tap the feeder directly to the final amplifier tank coil, at a point on the coil which causes the amplifier to draw its normal d.c. plate current. A high-voltage mica condenser should be connected in series with the feeder and tank coil for the purpose of keeping d.c. plate voltage off the feeder, thus avoiding possible electric shock to persons touching the antenna or feeder. The mica condenser can be of any capacity, from .001 to .006 μfd., and should be rated to stand the plate voltage (plus modulation peaks if phone). This mica condenser is not required with a shunt-fed final amplifier, as no d.c. appears on the plate tank coil with this method of plate voltage feed.

This simple antenna coupling method does not prevent the radiation of harmonics from the final amplifier. The single-wire-fed antenna offers practically no discrimination against harmonics and, therefore, very effectively radiates these harmonics. The circuits shown in figures 9 and 10 practically eliminate harmonic radiation and provide a balanced load to the final amplifier.

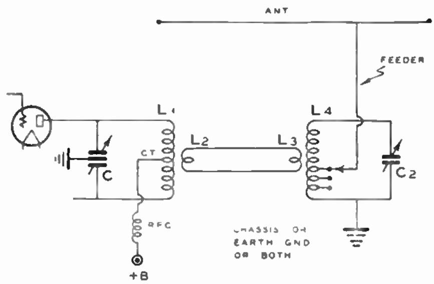


Figure 9—Single Wire Feeder Coupling to Final Amplifier.

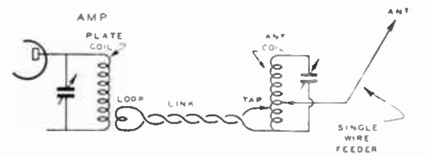


Figure 10—Alternate Method of Coupling Single-Wire Fed Antenna by Tapping the Link Line Directly to the Antenna Coil. The Lower End of the Antenna Coil Should be Grounded.

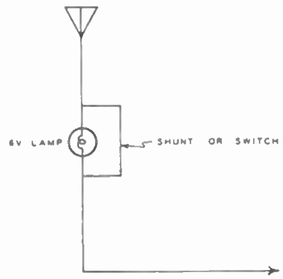
Direct connection of the feeder to the amplifier tank coil generally causes an unbalance, especially in a push-pull r.f. amplifier. The tuned antenna circuit is tuned to the same frequency as the tank circuit; it can be made of similar coils and condensers, with approximately 10 per cent fewer turns on the antenna coil then on the plate coil. The antenna coil should have a series of taps, soldered to various turns on the coil, in order to connect the feeder to the point which gives correct impedance match to the tuned-antenna circuit. The point of connection depends upon the L-C ratio in this antenna tank circuit and can be found only by experiment. The bottom end of the antenna coil should be connected to a good "earth" ground.

A small thermo-couple meter can be connected in series with the feeder, or a small flashlight globe can be shunted across a few inches of the feeder wire for indicating the comparative current flowing through the feeder to the antenna, as shown in figure 11.

Single-Wire-Fed Antenna Tuning Procedure

Referring to figure 9, the amplifier tank circuit L_1-C is tuned to its resonant dip with the link coupling circuit *removed* from the tank circuit. Plate voltage should be reduced in order to prevent flashover in condenser C. The antenna tank circuit L_4-C_2 can be checked for the correct number of turns in L_4 by holding this tuned antenna circuit close to the amplifier tank coil, then tuning it in the same manner as a wave-meter is tuned. The plate current in the final amplifier will rise sharply when the circuit L_4-C_2 is tuned to resonance (with the antenna feeder removed). The antenna tank circuit can then be placed in its permanent location a few feet from the transmitter and coupled to the final amplifier coil by means of one or more turns of wire around coil L_1 and L_4 in the link coupling circuit.

Figure 11 Resonance Indicator



The feeder should be connected to various experimental taps on the coil L_4 and the antenna tank then tuned to resonance. The proper tap connection is usually found at a point about ¼th of the total number of turns from the grounded end of L_4.

The adjustment procedure for tuning the system consists of always keeping the amplifier tank circuit tuned to *minimum plate current*, then making other adjustments which finally brings the d.c. plate current to its normal value *at the point of lowest dip in plate current when tuning condenser C.* The lamp indicator in the feeder must be observed while adjustments of link coupling, feeder tap connection and tuning of C_2 are made in order to arrive at the point of maximum antenna power at the point of normal plate current in the final amplifier. *Maximum current in the r.f. feeder denotes greatest power input to the antenna at that frequency.*

The circuit C_2-L_4 is automatically tuned to resonance during this tuning procedure, since condenser C_2 should be tuned to the point which draws maximum plate current in the final amplifier. Just remember to tune C for minimum plate current and C_2 for maximum. Too many link-coupling turns around either or both coils will make it very difficult to tune the condenser C_2 without greatly affecting the amplifier tank condenser (C) setting at its adjustment of minimum plate current. Insufficient link coupling will not enable normal amplifier current to be drawn, even when the antenna tank circuit and feeder tap adjustments are correctly made.

Two-Wire Matched Impedance-Fed Antenna

A two-wire non-resonant feeder is somewhat more efficient than a single-wire feeder, though the principle of operation is the same. The two-wire matched-impedance-fed antenna is suitable for one-band operation only. A half-wave antenna is connected to the feeder by means of a matching section Y in figure 12.

The two-wire line has a spacing of several inches between wires, and, in order to match its impedance of several hundred ohms at the antenna, it must be fanned-out to each side of center of the antenna. The distance between T and T_1 and the length Y, figure 12, can be easily calculated for any desired frequency of operation.

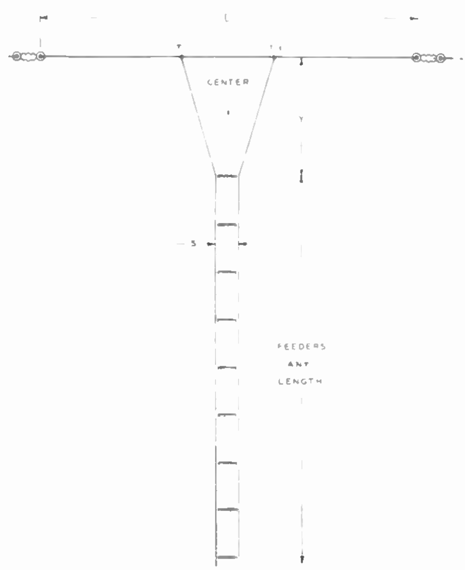


Figure 12—Matched Impedance "Y" System

The characteristic surge impedance of a two-wire line can be found from the formula.

$$Z = 276 \log_{10} \frac{b}{a}$$

where Z is the surge impedance in ohms,

a is the radius of the wire,

b is the distance between the centers of the two wires.

The spacing of a two-wire line is normally chosen at approximately 600 ohms. The spacing can be calculated by the approximate formula of

$$S = 150 \times r.$$

where S is the distance between wires,

r is the radius of the wires.

A typical two-wire line consists of No. 12 wires, spaced 6 inches, and supported every few feet by ceramic feeder spacers.

The length of the half-wave antenna can be calculated from the formula:

$$L = \frac{468{,}000}{f}.$$

where L is the length in feet.

f is the transmitter frequency in kilocycles.

The portion of the antenna between the two taps T and T_1, (figure 12) can be calculated from this formula:

$$X = \frac{118{,}000}{f}.$$

where X is the distance T to T_1 in feet.

f is the transmitter frequency in kilocycles.

The impedance-matching section Y in feet can be computed from

$$Y = \frac{147{,}000}{f}.$$

This type of antenna is often used for the shortwave bands, such as 5, 10 and 20 meters. The transmission line should be at right angles to the antenna for a distance of at least one-third the antenna length. Careful adjustment of the feeder connections T and T_1 in each antenna installation will give correct impedance match and a minimum of standing waves along the feeder. No sharp bends should be tolerated in the feeder.

Standing waves can be detected in a two-wire feeder by means of a *standing wave detector*, illustrated in figures 13 and 14.

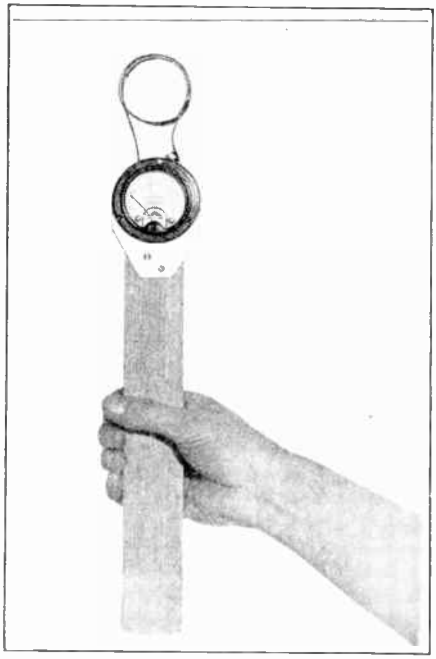


Figure 13—"Standing Wave Detector" and Field Strength Meter. The Device Is Moved Along the Feeder or Antenna, Held Close to the Wire in the Same Relative Position. A Variation of Current Denotes Standing Waves.

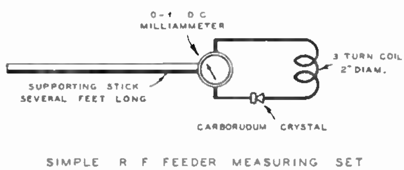


Figure 14—Simple Circuit Diagram of Device Illustrated in Figure 13.

A variation in meter reading as the coupling loop is moved along the feeder line at a constant distance from one of the wires indicates the presence of standing waves of feeder current. If the transmitter has suffi-

Two-Conductor Open-Wire-Line Impedance.

No. 12 Ga. Wire Line Impedance in Ohms	No. 14 Ga. Wire Line Impedance in Ohms	No. 16 Ga. Wire Line Impedance in Ohms	Wire Spacing in Inches
470	500	525	2
550	580	600	4
600	630	660	6

cient power output, a neon bulb can be touched to the feeder and the relative amount of glow in the bulb will indicate the variation in feeder voltage. Any non-resonant r.f. feeder should have nearly constant current and voltage throughout its entire length.

● Zepp Fed Antenna

When resonant r.f. feeders are connected to the end of a resonant antenna, the system is called a *zepp.* antenna, as shown in figure 15.

Resonant feeders can be connected into the center of a half-wave antenna, as shown in figure 16. In this case the system is known as a *center-fed zepp.*

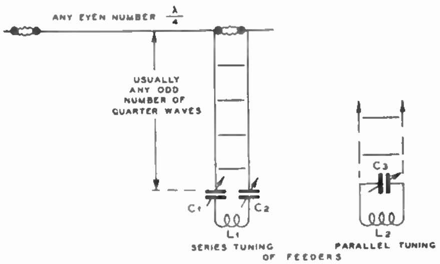


Figure 15—Zepp. Antenna System and Feeder Tuning.

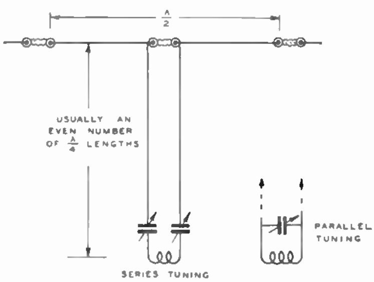


Figure 16—Center-Fed Zepp. Antenna.

End-fed zepp. feeders must be some odd multiple of quarter waves in length in order to be resonant. The actual length of the feeders can be varied to some extent by series or parallel tuning of the antenna coupling coil L_1 or L_2 in figure 15. The number of turns in the coupling coil depends upon the size of tuning condensers and the actual length of the feeder wires.

The center-fed zepp. antenna in figure 16 requires feeders an even number of quarter waves in length. A common value is a half wavelength, so that the antenna and feeders will be of the same total length.

Approximate feeder lengths and tuning methods for end-fed zepp. antennas are given in the accompanying charts.

Zepp. Feeder Tuning Chart.

Length of Feeders	Type of Feeder Tuning to Use
Up to One Quarter Wave	Parallel Tuning
Between One and Two Quarter Waves	Series Tuning
Between Two and Three Quarter Waves	Parallel Tuning
Between Three and Four Quarter Waves	Series Tuning
Between Four and Five Quarter Waves	Parallel Tuning
Between Five and Six Quarter Waves	Series Tuning

For	
5 meters one quarter wave is	4 ft.
10 meters one quarter wave is	8 ft.
20 meters one quarter wave is	16 ft.
40 meters one quarter wave is	33 ft.
80 meters one quarter wave is	66 ft.
160 meters one quarter wave is	132 ft.

Band	Length of Flat-Top
160 meters	250 feet
80 meters	130 feet
40 meters	66 feet
20 meters	33 feet
10 meters	16.5 feet
5 meters	8 feet

The flat top portion of a zepp. antenna can be calculated from the formula:

$$L = \frac{468{,}000}{f},$$

where L is the length of the antenna in feet, f is the transmitter frequency in kilocycles.

Another simple formula is:

$$L = 1.56 \times \lambda,$$

where L is the antenna length in feet, λ is the wavelength in meters.

Variations of approximately 10 per cent in the length of the radiating portion can be tolerated when resonant feeders are used. The tuning system at the lower end of the feeders will compensate for errors in antenna length up to 10 per cent without serious radiation from the feeders.

Non-resonant fed antennas must be cut to more nearly the exact length, which is affected considerably by presence of nearby objects, such as trees, houses, power lines, etc.

When zepp. feeders are tuned, their electrical length is varied. If the physical length of the feeders plus the inductance of the coupling coil is slightly less than an electrical quarter wave or odd number of quarter waves, it is necessary to use parallel tuning. If the physical length is slightly greater, the feeders must be tuned with a series condenser.

Zepp. antennas can be operated on harmonically related bands by tuning the system to resonance for each band of operation. This advantage is sometimes more than offset by losses in the resonant feeder system, in comparison to some of the other non-resonant lines. Zepp. feeders are usually spaced approximately 6 inches apart and held in position with ceramic insulators tied to the wires at intervals of from 2 to 4 feet.

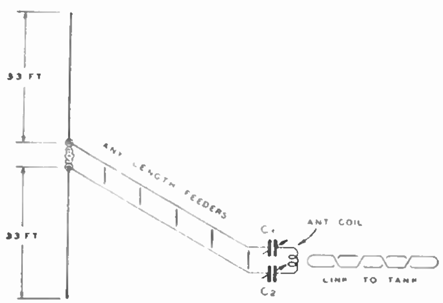


Figure 17—20- and 40-Meter Vertical Antenna with Zepp. Feeders. C1-C2 Are .00025 μfd. Condensers.

When zepp. feeders are connected to the end of an antenna, the arrangement is often called *voltage fed*, since this is a point of high r.f. voltage and low current. When the feeders are connected into the center of a half-wave antenna, the method is sometimes called *current fed*. The r.f. voltage in the antenna is at a minimum at this point, the current at a maximum. A point of maximum current is known as a *current loop*.

Comparative RF Feeder Losses

Frequency	D. B. loss per 100 ft.	Type of Line
7 mc. 14 mc. 30 mc.	0.9 1.5 3	150 ohm impedance, rubber insulated twisted pair with outer covering of braid.
7 mc. 30 mc.	0.4 0.9	W. E. 3/8" concentric pipe feeder with inner wire on bead spacers. Impedance - 70 ohms.
7 mc. 30 mc.	0.05 0.12	Open 2-wire line no. 10 wire. Impedance - 440 ohms.
7 mc. 14 mc. 30 mc.	3 4½ 8	Twisted no. 14 solid weather proof wire, weathered for six months (telephone wire).

• Impedance Matching Stubs

A quarter- or half-wave resonant line is often used as an *impedance matching stub*. It is a special application of zepp. feeders and is extensively used with directive antenna arrays. The sliding bar or jumper used at the bottom end of a *stub* in certain applications permits tuning the antenna system to exact resonance. A non-resonant feeder system can be connected across the stub at a point of correct impedance match for coupling the antenna system to the transmitter or receiver.

Matching stubs are often applied to simple antenna systems, as shown in figures 18, 19, 20, 21, and 22.

The feeder arrangement illustrated in figure 18 can be used in place of long zepp. feeders if the antenna is several hundred feet from the station. The losses in non-resonant feeders connected to a matching stub will be much lower than in zepp. feeders of similarly great lengths.

The antennas shown in figures 18 to 21 are suitable for operation on one band only. When the matching stub is connected in series with the current loop of the antenna and tuned by means of a shorting bar, the shorted stub must be a half wave in length. The stub can be shortened to a quarter wavelength and left *open*, as shown in figure 20, providing the stub wires are trimmed to exact length for tuning the antenna to resonance with the transmitter frequency.

The arrangement in figure 21 is often used; it is a well-balanced antenna system because both sides of the stub are connected to separate half-wave antennas. The impedance at the free end of a quarter-wave

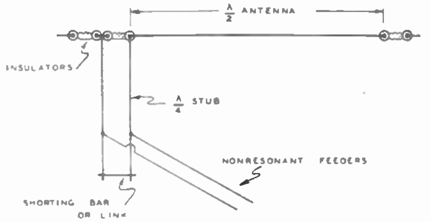


Figure 18—Half-Wave Antenna with Quarter-Wave Matching Stub.

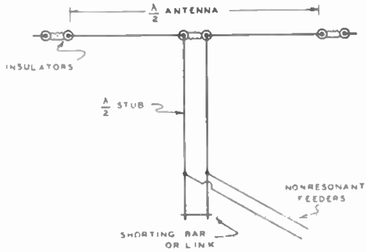


Figure 19—Center-Fed Half-Wave Antenna with Half-Wave Matching Stub.

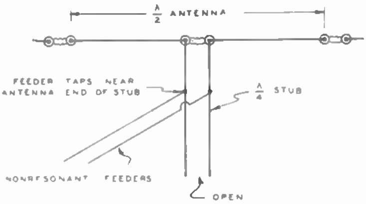


Figure 20—Center-Fed Half-Wave Antenna with Stub Line Cut to Exact Length Without Shorting Bar.

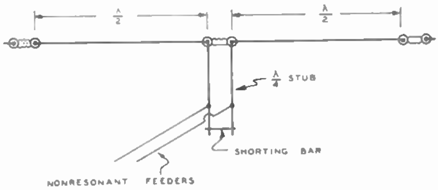


Figure 21—Two Half-Wave Sections in Phase with Quarter-Wave Stub.

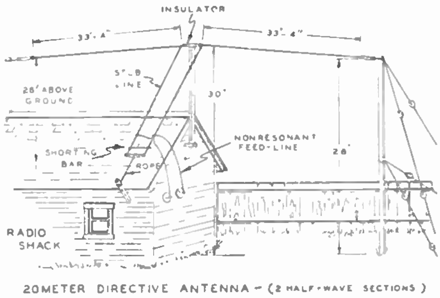


Figure 22—Pictorial of Figure 21, Showing Simplicity of 20-Meter Antenna Installation.

stub is very high and reaches a minimum at the center of the shorting bar, just as in any half-wave antenna. The quarter-wave stub is, in reality, a half-wave antenna folded together in order to prevent radiation from that portion of the antenna.

A simple 20-meter directional antenna is shown in figure 22, in which two half-wave antennas are operated in phase by means of a stub approximately 17 feet long. The stub is tuned to exact resonance by sliding the shorting link or bar along the two feeder wires. The current is high at the shorting bar; the connection to the two wires should, therefore, be soldered permanently in position once the proper point of connection has been found. The radiators should be at *least* 28 feet above earth, preferably higher (35 or 40 feet).

• Shorted Stub Tuning Procedure

When the antenna requires a shorted stub (odd number of quarter waves if the antenna is voltage fed; even number of quarter waves if radiator is current fed), the tuning procedure is as follows:

Shock excite the radiator (or one of the half-wave sections if harmonically operated) by means of a makeshift doublet strung directly underneath where possible and just off the ground a few inches, connected to the transmitter by means of any kind of twisted pair handy.

With the feeders and shorting bar disconnected from the stub, slide along an r.f. milliammeter or low current dial light at about where you calculate the shorting bar should be and find the point of maximum current (in other words use the meter or lamp as a shorting bar). It is best to start with reduced power to the transmitter until you see how much of an indication you can expect; otherwise the meter or lamp may be blown on the initial trial. The leads on the lamp or meter should be no longer than necessary to reach across the stub.

After finding the point of maximum current, remove the lamp or meter and solder a piece of wire across the stub at that point.

Starting at a point about a quarter of a quarter wave (8 feet at 40 meters) from the shorting bar, connect the feeders to the stub. Then move the feeders up and down the stub until the standing waves on the line are at a minimum. The makeshift doublet should, of course, be disconnected and the regular feeders connected to the transmitter instead during this process.

In checking for standing waves, take readings no closer than several feet to the stub, as the proximity of the stub will affect the reading of the standing wave indicator and lead one to false conclusions.

• Open-Ended Stub Tuning Procedure

When the antenna requires an open stub (even number of quarter waves if the antenna is voltage fed; odd number of quarter waves if radiator is current fed) the tuning procedure is as follows:

Shock excite the radiator as described for tuning a shorted stub system, feeders disconnected from the stub and the stub cut slightly longer than the calculated value. Place a field strength meter (the standing wave indicator can be very easily converted into one by addition of a tuned tank) close enough to one end of the radiator to get a reading, and as far from the makeshift exciting antenna as possible. Now start cutting off the stub wires together, a couple of inches at a time, until you pass the peak as registered on the field meter and the reading starts to drop. This means you have "passed" the point, but there is no way to determine the correct length without first cutting off a little too much. Solder on a few inches to each of the stub wires to correspond to the point of maximum field strength meter reading.

Now attach the feeders to the stub as described for the shorted stub system, but, for the initial trial connection, the feeders will attach more nearly ¾ of a quarter wave from the end of the stub instead of ¼ of a quarter wave as is the case for a shorted stub. After attaching the feeders, move them along the stub as necessary to remove standing waves on the line. If sliding the feeders along the stub a few inches makes the standing waves worse, it means the correct connecting point is in the other direction.

• Johnson "Q" Antenna

A popular half-wave antenna for 5-, 10- and 20-meter operation is the *Johnson "Q."* This antenna has a special quarter-wave matching "transformer" in the form of a quarter-wave section of two rods or a four-wire closely spaced "cage" line. The usual arrangement has two aluminum tubes, as shown in figure 23. Figture 24 shows the complete system.

The aluminum tubing is ½ inch in diameter, spaced 1.6 inches apart, in order to obtain an impedance of about 200 ohms. This value is the geometric mean between the antenna center impedance of 73 ohms and the 600-ohm impedance of the two-wire nonresonant line. The matching "transformer" introduces a negligible loss and eliminates the fanned-out section of a two-wire matched impedance feed system, such as the one described in figure 12.

Figure 23—Pictorial Sketch of Johnson "Q."

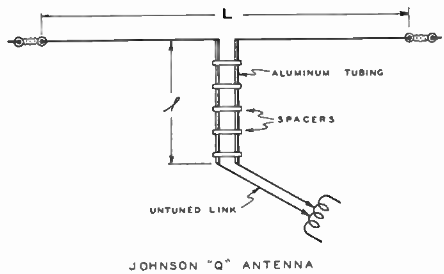


Figure 24

The 600-ohm non-resonant line from the end of the matching "transformer" to the transmitter can be any length. The design formulas for the *Johnson "Q"* are given here:

$$L = \frac{468,000}{f},$$

$$l = \frac{246,000}{f},$$

where L is the antenna length in feet,
l is the length of the matching section in feet,
f is the transmitter frequency in kilocycles.

• Collins Multi-Band Antenna

A special form of center-fed Zepp. antenna will operate with low feeder loss on several harmonically related amateur bands if the feeders are designed in such a manner as to have a low surge impedance. When the antenna is operated on the fundamental, the center impedance is approximately 73 ohms; when the same antenna is operated in the next higher frequency band, it becomes a full-wave antenna with a center impedance of approximately 1,200 ohms. Consequently, the "compromise" feeder is designed to have an impedance which is the geometric mean of these two values or 300 ohms.

Parallel Tubing Surge Impedance for Matching Sections

Center to Center Spacing in Inches	Impedance in Ohms for ½" Diameters	Impedance in Ohms for ¼" Diameters
1	170	250
1.25	188	277
1.5	207	298
1.75	225	318
2	248	335

●

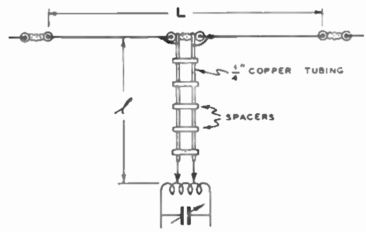
Correct Values of Surge Impedance of λ/4 Matching Sections for Different Lengths of Antennas.

Antenna Length in Wave-length	Surge Impedance for Connection Into Two-Wire Open Lines with Impedances of		
	500 Ohms	580 Ohms	600 Ohms
½	190	210	212
1	210	230	235
2	235	252	257
4	255	277	282
8	280	300	305

Matching section connects into center a current loop such as middle of a half-wave section.

This value of 300 ohms can be obtained by using a line made up of two ¼-inch copper tubes, spaced 1½ inches apart. The impedance mismatch between 300 ohms and 73 ohms, or 1200 ohms, is four-to-one, which is not great enough to cause an excessive intensity of standing waves on the feeders. The line is made a multiple of quarter waves in length, which results in a resistive impedance of 73 or 1,200 ohms at the station end of the line. A simple untuned pickup coil will couple the line to the transmitter or receiver.

Figures 25 and 26 show details of this type of feeder.



COLLINS MULTI-BAND ANTENNA

Figure 25

Design formulas are as follows:

$$L = \frac{(k-.05)\,492{,}000}{f},$$

$$l = \frac{234{,}000\ m}{f},$$

Chart for Collins Multi-Band Antenna.

Antenna	A	B	C	D	E	F	G
Antenna Length in Feet	136	136	275½	250	67	67	103
Feeder Length in Feet	66	115	99	122	65	98	82½
Frequency Range in Megacycles	3.7—4.0 7.0—7.3 14.0—14.4	3.7—4.0 14.0—14.4	1.7—2.0 3.7—4.0 7.0—7.3 14.0—14.4	1.7—2.0 3.7—4.0	7.0—7.3 14.0—14.4 28.0—29.0	7.0—7.3 14.0—14.4 28.0—29.0	3.7—4.0 7.0—7.3 14.0—14.4
Nominal Input Impedance in Ohms	1200 all bands	75 all bands	1200 160—80—20M., and 75 on 40M.	1200 all bands	75 on 40M. 1200 on 20 and 10M.	1200 all bands	1200 all bands

where L is the antenna length in feet,
l is the feeder length in feet,
k is the number of half wavelengths in the antenna,
f is the transmitter frequency in kilocycles,
m is the number of quarter wavelengths in the feeder.

Refer to the design chart for the *Collins Multi-Band Antenna.*

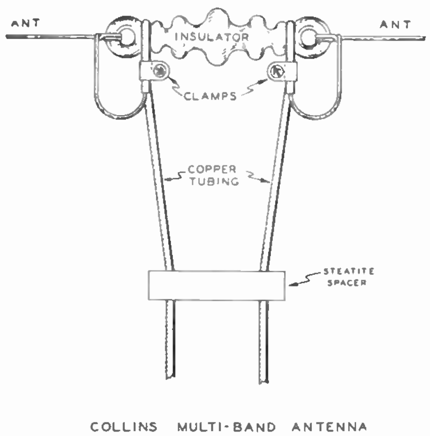


Figure 26—Close-Up of Center of Antenna, Showing Feeder Connections.

• Multi-Wire Lines

An inexpensive 200-ohm matching section for a "Q" antenna or a 300-ohm feeder for a Collins "Multiband" system can be had by using a *four* wire feeder or matching section in order to bring down the surge impedance without resorting to heavy tubing for the conductors. The four wires are equally spaced in the form of a square, and the *opposite* wires (*not* the adjacent ones) are connected together at each end of the feeder or stub and considered as a single wire. Celluloid curtain rings or embroidery hoops, or hard rubber "X" spacers made of 1-inch strips of proper length and bolted together in the center can be used every few feet to hold the wires in position.

Following is constructional data (wire size and spacing) for both 200- and 300-ohm four-wire lines or matching sections:

For a 200-ohm line, the ratio of spacing-to-wire radius is 50; for instance, if No. 12 wire were used (radius .040"), the spacing between adjacent wires would be 50 times this or 2". Similarly, for a 300-ohm line, the ratio of spacing to wire radius is about 210. In this case, with No. 16 wire (radius .025"), the spacing for a 300-ohm line would be 5.25" between adjacent wires. Knowing these two factors (50 and 210) of wire spacing to radius, it is possible to calculate the dimensions of any line of these surge impedances.

• Twisted-Pair Fed Antenna

A single-band antenna for transmitting and receiving, which consists of a half-wave flat top with a twisted-pair feeder, is shown in Figure 27.

The impedance of the twisted-pair feeder depends upon the spacing and diameter of the two wires and is usually of a low value —between 60 and 175 ohms, so that the feeder can be connected directly into the center of a half-wave antenna without serious mismatch.

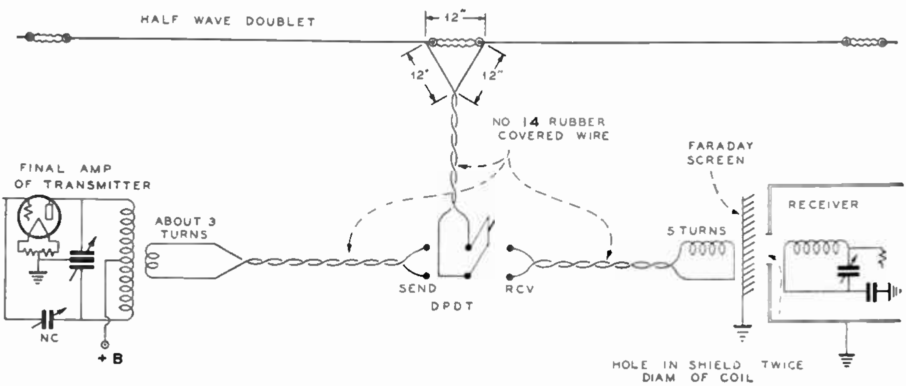


Figure 27—One-Band Doublet Antenna With Twisted-Pair Feeders for Transmitting and Receiving.

The feeders are often fanned-out into a small triangle, as shown in Figure 27; they can be of any length, carried over or near surrounding objects, or run underground. The losses in the line depend upon the dielectric losses in the insulation around the wires. Available for this purpose are special twisted-pair conductors which will safely handle transmitter powers up to 1 kw. Type "*EO*-1" cable, available from radio dealers, is designed with a characteristic impedance of 75 ohms and is suitable for any power the amateur is lawfully permitted to use.

Twisted-pair fed antennas are suitable for operation on one band only because second harmonic operation will result in very bad impedance mismatch and power loss. The efficiency is good on the lower frequencies, but the losses go up with frequency, becoming quite high on 5 and 10 meters unless the feeder is short.

• Length of Any Half-Wave Antenna

Any simple half-wave antenna can be cut to the theoretically correct length by consulting the following formulas:

$$L = 1.56\,\lambda.$$

or

$$L = \frac{468{,}000}{f}.$$

where L is the length of the antenna in feet,
λ is the transmitter wavelength in meters,
f is the transmitter frequency in kilocycles.

These formulas do not hold good for "long wire" antennas.

The antenna length may be slightly modified by the presence of nearby objects, such as the earth, power lines, chimneys, masts, trees, buildings, etc.; these objects may require that the wire be shortened by as much as 10 per cent in order to maintain the electrical length at an exact half wavelength.

The accompanying chart gives theoretical antenna lengths for various amateur bands.

• Marconi Antennas

A quarter-wave antenna connected to a ground or counterpoise system is generally called a *Marconi Antenna*. The ground or counterpoise completes the half wavelength necessary for resonance at the desired frequency. The antenna may be less than a quarter wave in length and then brought to this value electrically by means of a *loading coil*. These antennas, such as shown in Figures 28, 29 and 30, are often used in the 160-meter amateur band because of the difficulty in getting up a half-wave radiator at that frequency.

The total length of the antenna wire can be from 90 to 160 feet for 160-meter operation. The system is tuned to resonance by connecting series tuning coils and condensers to a ground or counterpoise. For best results, make the radiator as long as possible (up to 150 or 160 feet).

The radiation resistance of a quarter-wave *Marconi Antenna* at the point of connection to earth is less than 35 ohms. Therefore, the ground connection should have a very low resistance in order to prevent excessive loss of power.

Figure 31 shows how a *Marconi Antenna* for aeroplanes or small boats is coupled to the transmitter.

Coupling methods for various *Marconi Antennas* are described in the pages which follow.

Chart Showing Theoretical Length of Half-Wave Antennas, Such as Single-Wire Fed, Collins, Johnson "Q," Matched Impedance, Twisted Pair, and Zepp.

BAND	Frequency	Antenna Length
1¼ Meter	224 mc 232 mc 240 mc	25" 24" 23.5"
2½ Meter	112 mc 116 mc 120 mc	4' 2" 4' 3' 10"
5 Meter	56 mc 58 mc 60 mc	8' 4" 8' 1" 7' 10"
10 Meter	28 mc 29 mc 30 mc	16' 8" 16' 1" 15' 6½"
20 Meter	14.05 mc 14.15 mc 14.25 mc 14.35 mc	33' 4" 33' 1" 32' 10" 32' 8"
40 Meter	7.02 mc 7.10 mc 7.20 mc 7.28 mc	66' 7" 65' 9" 64' 11" 64'
80 Meter	3550 kc 3600 kc 3700 kc 3800 kc 3950 kc	131' 6" 129' 10" 126' 4" 123' 118' 4"
160 Meter	1750 kc 1850 kc 2000 kc	267' 252' 233'

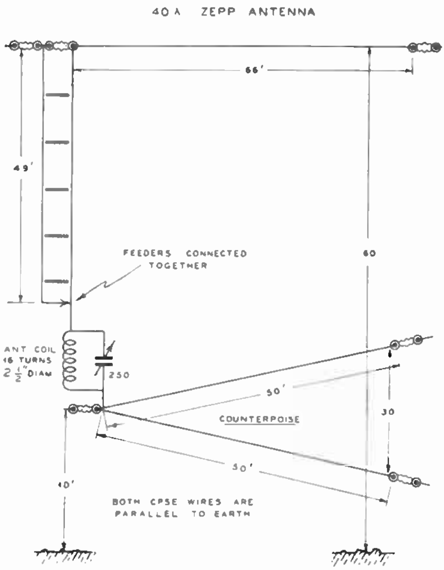


Figure 28—160 Meter Operation From a 40-Meter Zepp. Antenna. Where space is limited, the 40-meter zepp.-fed Hertz antenna illustrated above will give satisfactory operation on 160 meters. The zepp. feeders are connected together at the station end and attached to one side of the tuning condenser and coil, as shown in the diagram. The remaining ends of the coil and condenser connect to the counterpoise.

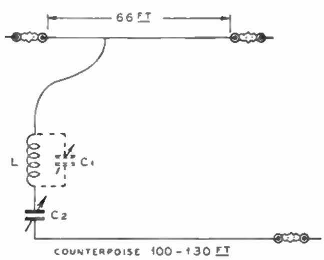


Figure 29—40-Meter Single-Wire-Fed Hertz for 160-Meter Operation. If "L" has sufficient turns, C1 is not required. "L" is coupled to the plate tank circuit.

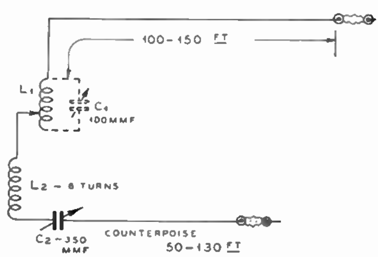


Figure 30—System for Loading Any Antenna for 160-Meter Operation.

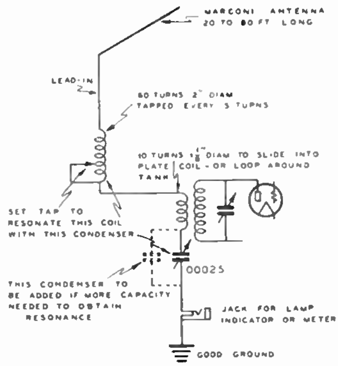


Figure 31—Loading System for Short Marconi Antenna for Boats, Aeroplanes, Etc.

• Antenna Coupling Devices

The antenna system must be *coupled* to a final r.f. amplifier of a radio transmitter in such a manner as to transfer most efficiently the power into useful output. One- and two-wire feeder systems can be directly coupled to the final amplifier, as shown in figures 32 and 33.

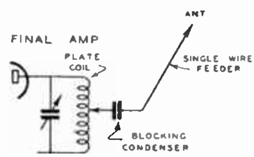


Figure 32

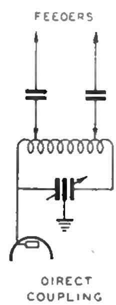


Figure 33

A blocking condenser of some value, such as .002 μfd., should be connected in series with the feeder in order to prevent d.c. plate voltage from reaching the antenna and endangering human life. The feeder is tapped to the final amplifier tank coil at a point which causes the amplifier to draw normal d.c. plate current when the tank condenser is tuned for greatest dip in plate current.

● Inductive Coupling

160-meter antenna systems should be inductively coupled to the final tank coil in the manner shown in figures 34 and 35.

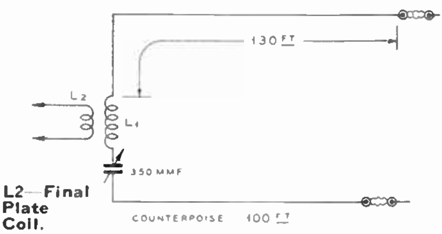


Figure 34

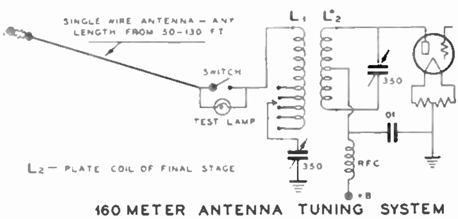


Figure 35—The circuit shows a tuning lamp in series with the antenna and a shorting switch for bridging the lamp after the antenna is tuned. Another method is to wrap a turn or two of the lead-in wire around a 2-turn loop connected to the lamp. The former system is best adapted for low power, the latter for medium or high power.

The antenna circuit is tuned to resonance as indicated by maximum r.f. current in the antenna or counterpoise, and the coupling between coils L_1 and L_2 is adjusted to a position which will cause normal plate current to flow in the r.f. amplifier. The antenna tuning circuit will often affect the setting of the r.f. tank circuit condenser, which will then require readjustment for greatest plate current dip.

Twisted-pair feeders can be inductively coupled to the final tank circuit with from one to four turns of well-insulated wire wound over the *voltage node* of the tank coil. The *voltage node* is the point of *minimum r.f. voltage* and is the center of the coil in a plate-neutralized or push-pull amplifier or the B-supply end of the coil in a grid-neutralized or screen-grid amplifier stage. The number of coupling turns determines the degree of coupling for each band of operation.

● Pi Coupler

The *Collins Pi Coupler* consists of one or two coils and two variable condensers connected in the form of a low-pass pi-filter, as shown in figures 36, 37 and 38.

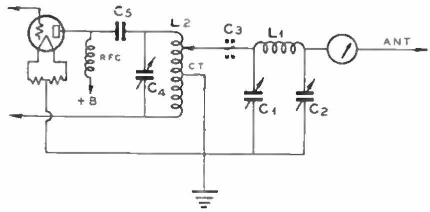


Figure 36—Single-Wire Feed Line—Single Section Plate Tuning Condenser—Shunt Feed. C1 and C2 in All Circuits Are .00035 μfd.

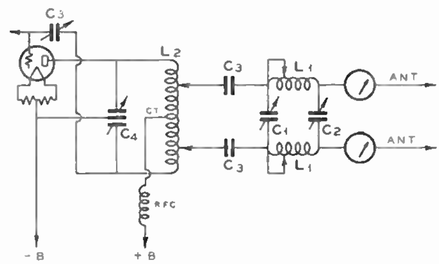


Figure 37—Two-Wire Line from Single-Endep Amplifier. Split-Stator Tuning and Series Feed.

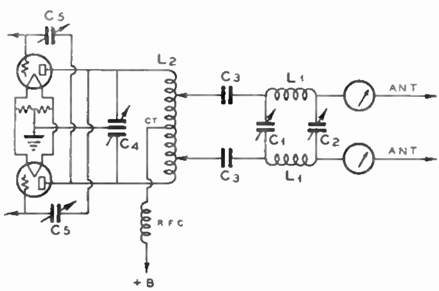


Figure 38—Coupling a Two-Wire Line to a Push-Pull Final Amplifier. Single-Wire Line Out of a Push-Pull Final Through a Pi Network is Not Recommended.

The coupler permits adjustment of the antenna load across the r.f. amplifier; when *correctly adjusted* it tends to attenuate the higher-frequency harmonics. The coupler is tuned to the frequency of the transmitter by varying the condensers C_1 and C_2 and by adjusting the tap on the coil or coils. The impedance of the antenna feeders is matched to that of the final amplifier by connecting the coupler across a portion of the amplifier tank circuit and by adjusting the ratio of the capacities of C_1 and C_2. This system can be used with zepp. feeders which have sufficiently high impedance. It is also suitable for connection to single-wire or two-wire feeders, or end-fed antennas. It should not be used for connection to twisted-pair feeders, concentric feeders, or quarter-wave *Marconi Antennas,* because the capacity required at C_2 would be too high in value for practical use.

The plate tank of the r.f. amplifier must be tuned to resonance with the pi network disconnected and the dial setting of the final tank condenser should *not be changed thereafter.* The pi network can then be connected to the tank coil and antenna, and the two condensers adjusted until maximum antenna or feeder current is obtained at normal values of amplifier plate current. The condenser C_1 is used for obtaining resonance (minimum plate current) for any particular setting of the impedance-matching condenser C_2. The amount of inductance in the pi network coils must be determined by experiment.

A simplified version of the pi network is shown in figure 39, with circuit constants

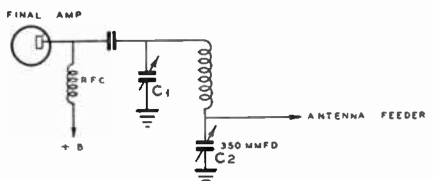


Figure 39—Simplified Pi Antenna Coupling System. The 350-$\mu\mu$fd. condenser is an ordinary receiving type variable condenser.

given for 160-meter operation. This simplified circuit eliminates one tank circuit. The matching network serves the dual purpose of tank circuit and antenna-impedance matching system. This type of circuit can be used at any frequency, especially for screen-grid r.f. and grid-neutralized triode amplifiers. It is particularly suited for use in low power portables or emergency gear, where simplicity and versatility are required and some harmonic radiation can be tolerated.

• Link Coupling

Any kind of antenna or antenna feeder can be connected to an antenna tuning circuit which has a tank coil and one or more tuning condensers. This circuit can then be *link-coupled* to the final amplifier with one or two turns of well-insulated wire over the *voltage node* of the amplifier and from one to five turns around the antenna tuning circuit. Figure 40 shows a method of link coupling to a zepp. feeder tuned circuit.

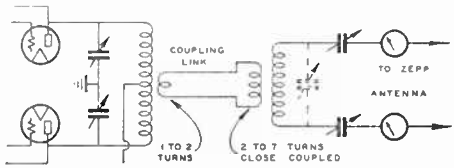


Figure 40

The link around the antenna coil is sometimes omitted, being then connected across a few turns of the antenna tuning coil. The link can consist of a pair of No. 14 or No. 12 rubber-covered wires of any reasonable length.

Figure 41 shows a method of link coupling commonly used to work into an end-fed antenna. Sometimes the system will tune up better if the center of the antenna coil is grounded. The end-fed antenna can be any multiple of half wavelengths long.

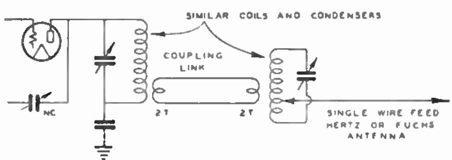


Figure 41—Link Coupling for End-Fed or Single-Wire Feeders.

Figure 42 shows how to link-couple a 160-meter antenna to a final tank coil. This circuit is often slightly modified by connecting the link in series with the bottom end of the antenna loading coil, rather than to coil L_3. A short antenna can be made to resonate by using more turns in the coil L_4.

The circuits in figure 43 are typical for coupling to zepp. antennas, matched imped-

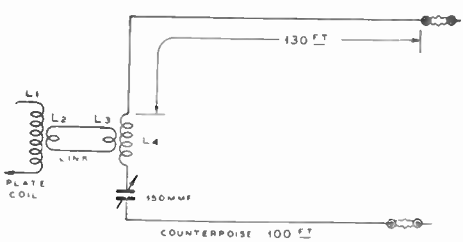


Figure 42—Link Coupling to 160-Meter Antenna System.

ance feeders, single-wire-fed antennas and end-fed antennas. The ground connection is optional.

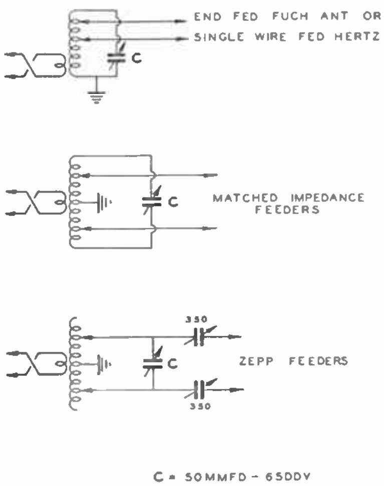


Figure 43—Link Coupling from Final Amplifier to Tuned-Antenna Circuits.

Directive Antennas

All antennas have directional properties and these can be increased by properly combining the antenna elements. The various forms of half-wave antennas already described have maximum radiation at right angles to the direction of the wire, but the directional effect is not very great.

If this radiation can be confined to a narrow beam, the signal intensity can be increased a great many times in the desired direction of transmission. This is equivalent to increasing the power output of the transmitter. It is more economical to use a directive antenna than to increase transmitter power if more than a few watts power is being used.

Directive antennas can be designed to give as high as 23 db gain over that of a single half-wave antenna. However, this high gain (nearly 200 times as much power) is confined to such a narrow beam that it can be used only for commercial applications in point-to-point communication.

The increase in radiated power in the desired direction is obtained with a corresponding loss in all other directions. Gains of 3 to 10 db seem to be of more practical value for amateur communication because the angle covered by the beam is wide enough to sweep a fairly large area. 3 to 10 db means the equivalent of increasing power from 2 to 10 times. For example, an amateur living in the center of the United States would want his beam to be wide enough to cover all of Europe in one direction and New Zealand in the opposite direction. His beam should be centered about 45° north-of-east and about 35° wide. Similarly, a 20° beam width, 50° south-of-east, would cover South America and the Orient. Another 35° beam pointing east and west would cover Australia and South Africa. In San Francisco, two beam antennas, could be made to cover all dx sections fairly well; a 30° beam, 35° south-of-east for South America and the Orient, and another 35° to 40° beam, 45° north-of east for Europe, New Zealand and Australia.

In this discussion, all antenna arrays are assumed to have two main lobes of radiation in opposite directions (no reflector system). Directions in which the antennas could be pointed can be figured as the Great Circle shortest distance direction with the aid of a globe of the world. Day and night directions in some cases are different, due to the skip distance effects of some of the high-frequency bands, because the signals may go around the world in one direction in the morning, and in the other direction in the evening, to points near the opposite sides of the world.

Four to six half-wave antennas or their equivalent are apparently about all that can be used without securing too much directivity, unless the operator is aiming at one locality of relatively small area. With wavelengths below 10 meters, the problem of rotating the beam antenna is simplified and more directional effects with greater power are desirable. Reflector systems can be set up for increasing the beam in one direction and preventing radiation in the opposite direction.

Tables of wire lengths for several arrays and directional types of antennas are given. Surroundings will modify these values, but for most purposes the wires can be cut to the values listed, and satisfactory results obtained.

The most simple method of feeding many types of directional antennas (if near the transmitter) is by means of zepp. feeders which are generally some odd multiple of quarter waves in length. In all cases where the system is much more than a wavelength from the transmitter to the feed point, a non-resonant two-wire feeder and quarter-wave matching stub should be employed. The problem is greatly simplified in most cases by the use of zepp. feeders, since the feeders can be tuned at the transmitter just as with any zepp. half-wave antenna. A simple field strength meter coupled to the antenna system will readily indicate correct feeder tuning.

All directional resonant antenna systems, other than a single long-wire system, operate on the one frequency for which they are designed. The "V" beam can be operated on two bands with fair satisfaction, although the correct angle δ between the arms of the "V" can only be made for one frequency. A type is generally chosen from a consideration of available space. The "V" beams are less critical in mechanical design; if space is available for pointing the open or closed end of the "V" in the desired direction, this type is excellent.

Horizontal and Vertical Directivity

The horizontal directivity of any antenna system is that shape of the radiated beam or beams shown looking down at the earth from a point above the antenna system. For example, a beam having a width of 30° horizontally would spread out enough to cover a whole continent, such as Europe, from points in the United States. *Vertical Directivity* is the expression for defining the angle above the horizon at which the major portion of the radiation goes out from the antenna. Directional antenna systems are generally made to have a very low angle of radiation, so that the vertical directivity is outward toward the horizon, rather than upward at a high angle.

Polarization

Radio waves are *polarized* in that they will induce a greater signal in the receiving antenna when the plane of that antenna is parallel to the plane of polarization. For example, a vertical transmitting antenna will produce a vertically-polarized wave which can best be received by a vertical receiving antenna over relatively short distances, such as in the ultra-high-frequency region. Wavelengths between 10 and 100 meters can be transmitted with either vertical or horizontal antennas, resulting in the wave starting out with a *vertical* or *horizontal* polarization. By the time it reaches the distant receiving antenna it is apt to be mainly *horizontally* polarized. Reflection and refraction effects in the Heaviside Layer tend to twist the wave polarization so that in most cases a horizontal receiving antenna will give best results.

For ultra-short wavelengths, vertically polarized waves are not reflected upward by the surface of the earth as easily as those of horizontally polarized nature. As only the ground wave is useful on wavelengths below 10 meters, vertical transmitting and receiving antennas have thus proven most satisfactory at these frequencies.

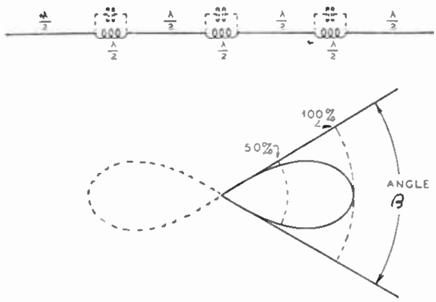
With ultra-short wavelengths, the plane of polarization may be twisted by such objects as hills or buildings, so that occasionally a horizontal antenna will very efficiently receive signals transmitted by a vertical antenna.

Directive Factors

Directional antenna systems operate on the principle that the radiation fields add or subtract in space. When several radiating elements, such as half-wave antennas, are in close proximity to one another, the radiated fields may aid or oppose each other in different directions. In those directions in which opposition or cancellation occur, the signal is attenuated; similarly in those directions in which the fields aid each other, or add, the signal is increased. All directive antennas depend upon this phenomenon. The fields are said to be *in phase* when they are additive, and *out of phase* when they cancel each other. Antenna directivity results from phasing the radiation from adjacent antenna elements so as to neutralize the radiation in the undesired directions, and to reinforce the radiation in the desired direction. Directivity can be obtained in either horizontal or vertical planes. In transmission, directive antennas concentrate energy much like reflectors and lenses concentrate light rays.

Co-Linear Antennas

Franklin or *co-linear* antennas are widely used by amateurs. The radiation is broadside to the antenna. The antenna consists of two or more half-wave radiating sections with the current *in-phase* in each section. This is accomplished by quarter-wave stubs between each radiating section or by means of a tuned coil and condenser or resonant loading coil between each half-wave radiating section. The quarter-wave stub is a folded half-wave wire in which the wires are sufficiently together so that the radiation is neutralized.



ANGLE β = 72° FOR 1 RADIATOR SECTION
" " = 42° " 2 " "
" " = 32° " 4 " "
" " = 14° " 8 " "

FRANKLIN ANTENNA

Figure 44

Two half waves *in-phase* will give a gain of approximately 2.5 db with respect to a single half-wave antenna; three sections will give a gain of approximately 4 db. Additional half-wave sections increase this power gain approximately one db. per section.

Various feeder systems are shown in the accompanying sketches. A zepp. feeder can be used in place of a quarter-wave stub and 600-ohm line. The latter will allow a two-section *co-linear* antenna to be operated as a single section half-wave antenna (center-fed zepp.) on the next longer amateur wave band. For example, an antenna of this type would be a half-wave antenna on 40 meters and a two-section *co-linear* antenna on 20 meters. The direction of current at a given instant and the location of the current nodes are indicated in the sketches by means of arrowheads and dots, respectively.

Co-Linear Antenna Design Chart

Band	Frequency in mc.	L_1	L_2	L_3
10 Meters	30 29 28	16' 16' 6" 17' 1"	16' 5" 17' 17' 7"	8' 2" 8' 6" 8' 9"
20 Meters	14.4 14.2 14.0	33' 4" 33' 8" 34' 1"	34' 3" 34' 7" 35'	17' 1" 17' 3" 17' 6"
40 Meters	7.3 7.15 7.0	65' 10" 67' 68' 5"	67' 6" 68' 8" 70' 2"	33' 9" 34' 4" 35' 1"
75 Meters	4.0 3.9	120' 123'	123' 126'	61' 6" 63'
80	3.6	133'	136' 5"	68' 2"

A *table* of wire length for the L_1, L_2, and L_3 sections is given for various amateur bands.

The radiation resistance at any voltage node in a *co-linear* antenna is shown in the *co-phase antenna curve,* figure 45. This curve is for an antenna in free space, but is sufficiently correct for satisfactory operation so long as the antenna is more than a quarter wave above earth.

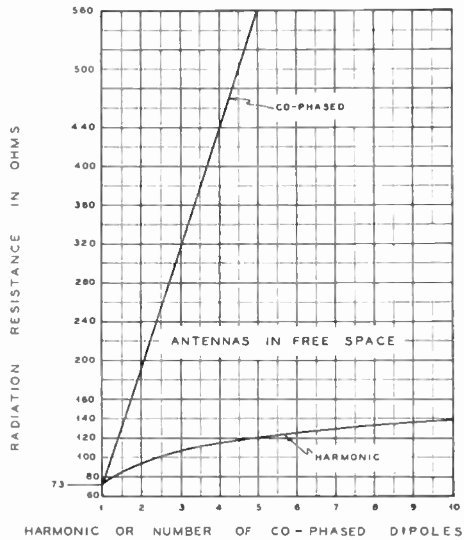


Figure 45—Radiation resistance (at a voltage node) versus harmonic or co-phased elements

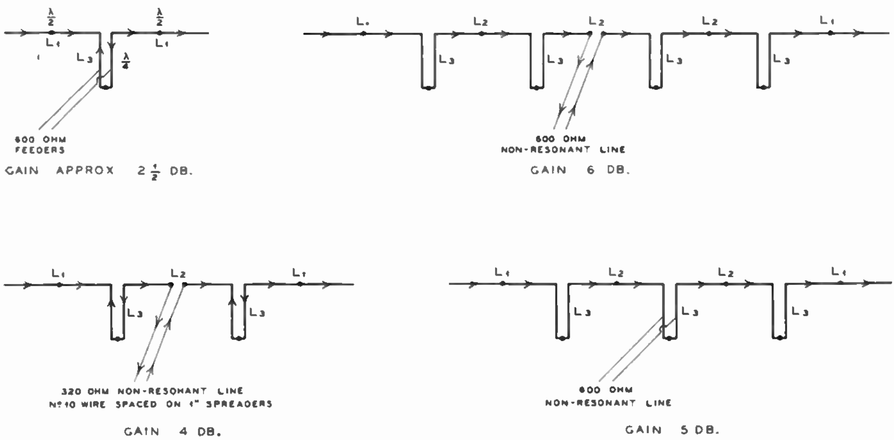
The radiation resistance increases rapidly with the number of in-phase sections, so that an antenna with five sections can be current-fed directly with a 600-ohm non-resonant line, as shown in one of the sketches. This curve sheet can be used to calculate the impedance of current feeders for any number of *co-linear* or *co-phased* sections. A *Collins multi-band* feeder of two parallel copper or aluminum tubes or a simple four-wire "cage" feeder can be designed to match into impedances of from 250 to 400 ohms.

Tables for parallel-tubing surge impedance for operation as matching sections are given on page 77.

Co-linear antennas with 2, 3, 4, and 5 sections are shown in Figure 46.

• Long-Wire Antennas

A single long wire can be operated either as a fundamental half-wave radiator or on any of its harmonics. One of the most practical methods of feeding a long wire antenna is to bring one end of it into the



FRANKLIN OR CO-LINEAR ANTENNAS
HORIZONTAL POLARIZATION BROADSIDE RADIATION

FIGURE 46

radio room for direct connection to a tuned-antenna circuit which is link-coupled to the transmitter. The antenna can be tuned to exact resonance for operation on any harmonic by means of the tuned circuit which is connected to the end of the antenna. This tuned circuit corresponds to an adjustable, non-radiating half-wave section of the antenna. A ground connection is sometimes made to the center of the tuned coil.

Zepp. feeders may be connected to one end of a long wire antenna if the operating room is close to the ground or far removed from the antenna.

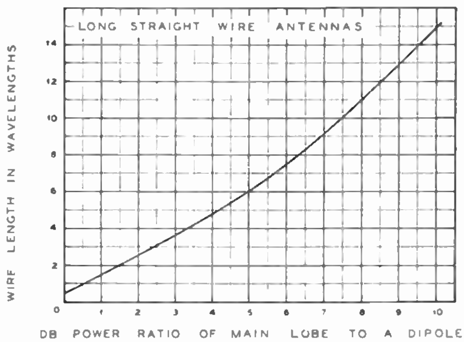


FIGURE 47

Long Antenna Design Chart

Length in Feet. End Fed Antennas.

Frequency in mc.	1λ	1½λ	2λ	2½λ	3λ	3½λ	4λ	4½λ
30	32	48	65	81	97	104	130	146
29	33	50	67	84	101	118	135	152
28	34	52	69	87	104	122	140	157
14.4	66½	100	134	169	203	237	271	305
14.2	67½	102	137	171	206	240	275	310
14.0	68½	103½	139	174	209	244	279	314
7.4	136	206	276	246	416	486	555	625
7.15	136½	207	277	347	417	487	557	627
7.0	137	207½	277½	348	418	488	558	628
4.0	240	362	485	618	730	853	977	1100
3.9	246	372	498	625	750	877	1000	1130
3.8	252	381	511	640	770	900	1030	1160
3.7	259	392	525	658	790	923	1060	1190
3.6	266	403	540	676	812	950	1090	1220
3.5	274	414	555	696	835	977	1120	
2.0	480	725	972	1230	1475			
1.9	504	763	1020	1280				
1.8	532	805	1080					

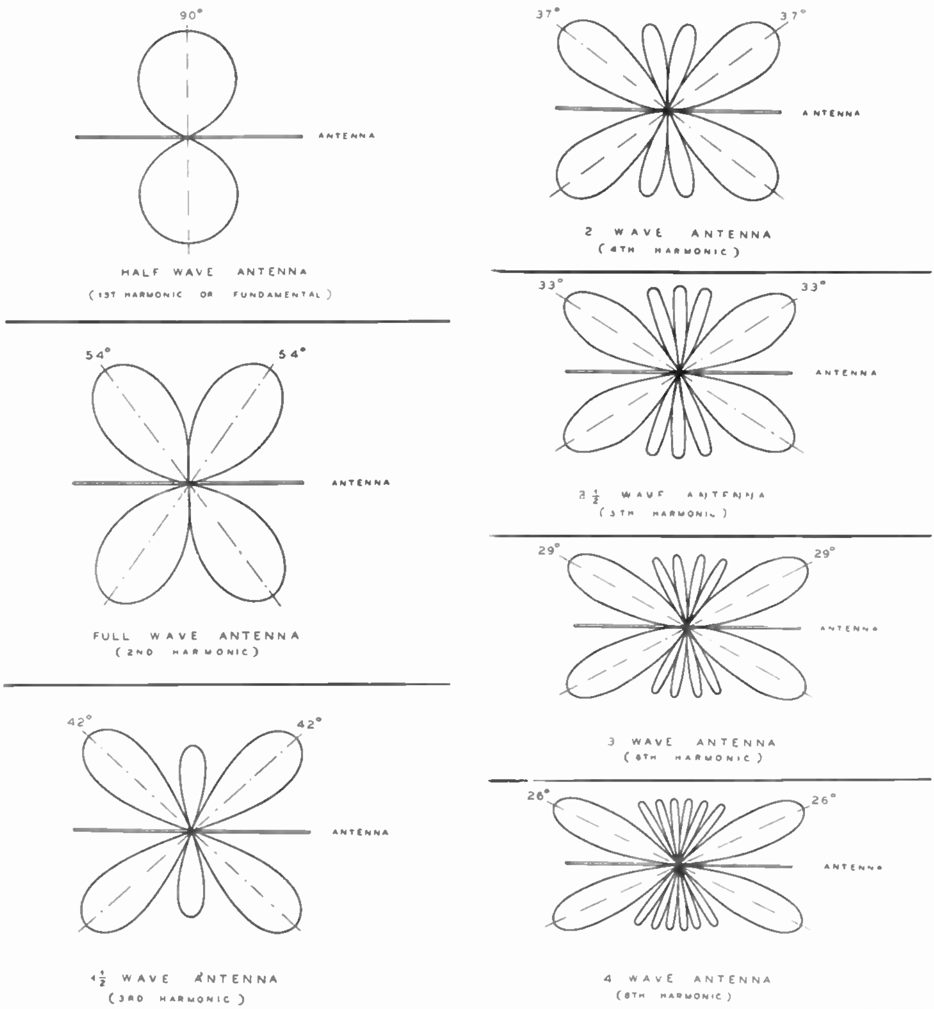


Figure 48—Radiation Patterns of Horizontal Antennas in Free Space.
The presence of the earth makes the antenna less directional than indicated in the above patterns, particularly in the direction of the antenna wire.

The long-wire antenna can be current-fed at a point of maximum *current* by means of a twisted-pair feeder or *concentric line*. The radiation resistance at any current node is shown in figure 45.

The proximity of the ground changes the values of radiation resistance to a certain extent. If the antenna were in free space, the radiation resistance would fall betwen 73 and 150 ohms, depending upon the length of the antenna wire, assuming that it is some multiple of half-waves in length. The ground may be ignored if the antenna is sufficiently high.

75-Meter Phone Antennas

Lengths in Feet

Frequency in Kilocycles	"Half Wave" ½λ	"Full Wave" 1λ	1½λ	2λ	2½λ
4000	117	240	362	485	618
3950	118	243	367	492	616
3900	119½	246	372	498	625

The gain in power in the optimum direction of radiation of a long-wire antenna over that of a half-wave antenna wire is shown in the curve of figure 47, which gives *db power ratio with respect to wire length.* It can be seen from this curve that an antenna eight waves long will have a gain of more than 6 db over that of a dipole.

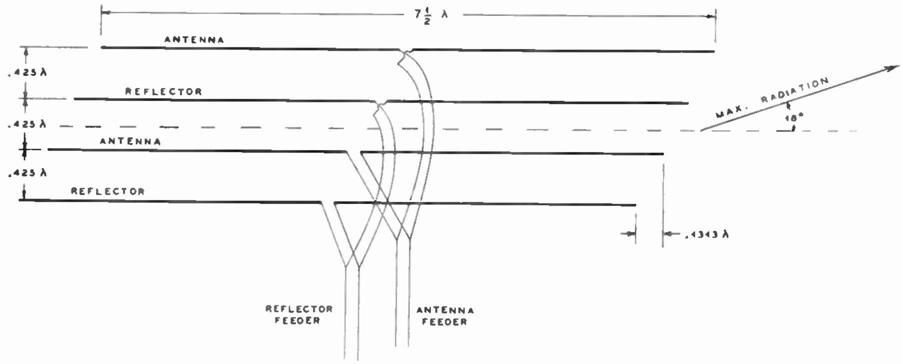
An antenna four waves in length has a gain of slightly more than 3 db. The greater lengths tend to make the antenna more directional out from the ends of the wire and also to lower the vertical angle of the main lobe of radiation.

The approximate lengths of wire resonant at the frequencies listed are shown in the *Long Antenna Design Chart.*

Long wire antennas can be connected into directional arrays in order to obtain great directivity and high gain. The horizontally-polarized long-wire array, shown in figure 49, gives a theoretical gain of 12.4 db over that of a half-wave antenna.

A more simple form of long wire antenna and reflector suitable for amateur service is shown in figure 50.

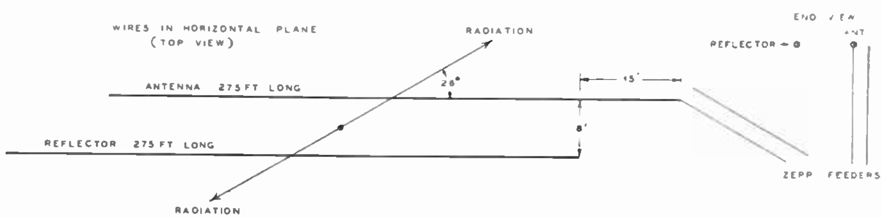
A wire 275 feet long can be suspended approximately 8 feet under a similar wire in order to act as a parasitic reflector and



HORIZONTALLY POLARIZED LONG WIRE ARRAY

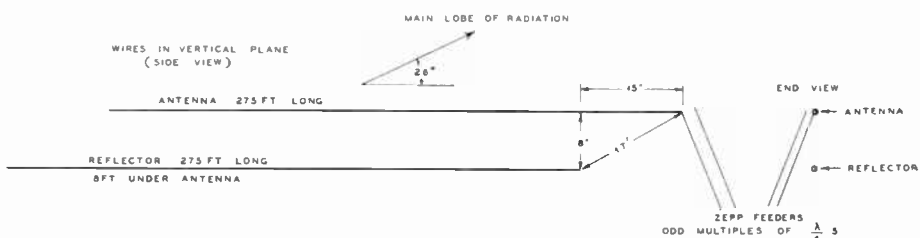
GAIN 12.4 DB OVER DIPOLE

FIGURE 49



BI-DIRECTIONAL WHEN ANTENNA AND REFLECTOR ARE IN HORIZONTAL PLANE

GAIN 6DB. OVER DIPOLE



14.2MC END-FIRE ANTENNA AT A VERTICAL ANGLE OF 26° ABOVE HORIZON

FIGURE 50

antenna, respectively. This antenna is suitable for 14 Mc. phone operation; the main lobe of radiation will be at a vertical angle of 26 degrees above the horizon. This lobe will be in the direction as indicated in the sketch and may be reversed 180 degrees by pulling the reflector wire along the axis of its length for a distance of 30 feet.

This antenna is practically uni-directional when the reflector is placed *under* the antenna. If the reflector is parallel to the antenna and of the same height above ground as the antenna, the radiation becomes bi-directional.

● RCA Broadside Antenna

This broadside radiator is not suitable for amateur practice because of the difficulty in adjusting the feeder shunt inductances, but is used commercially with excellent results. All parts of the parallel transmission line are kept *in-phase* by means of the shunt inductances which are connected across the line at each point where the radiators are attached. The waves are vertically polarized and a reflector can be placed a quarter wave behind the antenna in order to make the system unidirectional. The system is shown in figure 51.

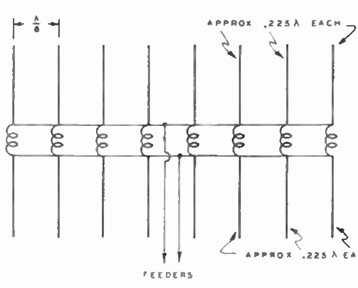


Figure 51

● Barrage Antenna

The *Barrage* antenna (figure 52) is an "in-between" system of the *stacked dipole* and the *Hawkins* antenna (figure 53). The two end sections L_3 are a quarter-wave long, the middle radiating elements L_2 a half-wave.

The two L_2 end sections have *out-of-phase* currents within the section, so that very little radiation takes place. The transposed L_2 sections do not radiate because of the close spacing between the two wires. The radiating sections of L_2 and L_3 can be mounted horizontally or vertically, as illustrated in the sketches.

The array transmits or receives broadside. The approximate gain of two horizontally-polarized arrays for amateur service, shown in the diagrams, is 6 and 8 db respectively. The theoretical wire lengths L_2 and L_3 are given in the *Barrage Array Antenna Design Chart.*

Barrage Array Antenna Design Chart.

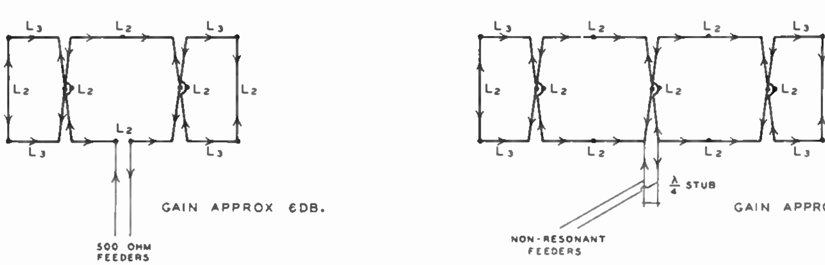
Band	Frequency in mc.	L_2	L_3
5 Meters	60 58 56	8′ 2″ 8′ 6″ 8′ 9″	4′ 1″ 4′ 3″ 4′ 5″
10 Meters	30 29 28	16′ 5″ 17′ 17′ 7″	8′ 2″ 8′ 6″ 8′ 9″
20 Meters	14.4 14.2 14	34′ 2″ 34′ 7″ 35′	17′ 17′ 3″ 17′ 6″

In commercial practice, several groups of these arrays are made into a large curtain in order to provide more gain and a sharper beam for point-to-point communication.

● Compact "H" Arrays

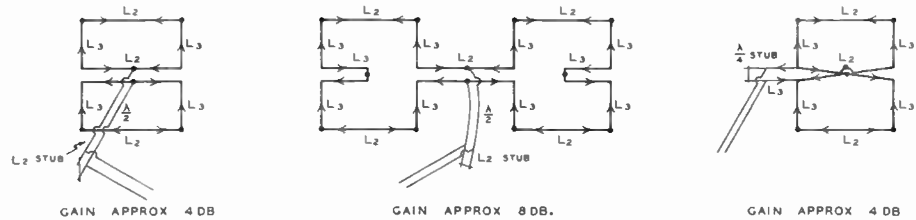
The "H" sections of a stacked dipole antenna can be rearranged into a more compact form, as illustrated in figure 53.

The top and bottom halves of each half



HORIZONTALLY POLARIZED BARRAGE BROADSIDE ANTENNAS.

FIGURE 52



HAWKINS BROADSIDE ANTENNAS — VERTICAL POLARIZATION

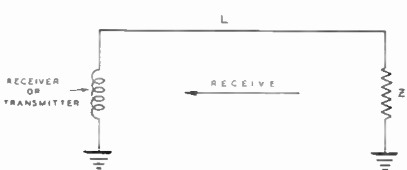
FIGURE 53

wave portion of an "H" section are bent over toward each other and connected together. This reduces the required vertical dimensions one-half. The reduction in gain due to cancellation of radiation in the bent-over portion of the half-wave sections is not very great. The calculations of the designer give the approximate gains as shown in figure 53.

The radiation is vertically polarized and broadside to the plane of the antenna. The L_3 sections may be made horizontal, if horizontally-polarized radiation is desired. These directional antennas should be mounted so that they clear the surface of the ground by a half wavelength, whenever possible. A reduction in height reduces the effectiveness and alters both the directional pattern and gain of the antenna.

The lengths L_2 and L_3 are the same as those shown in the *Stacked Dipole Chart* for L_2 and L_3 (page 92).

• The Beverage Antenna



BEVERAGE ANTENNA

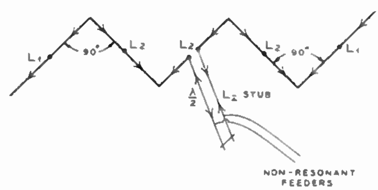
Figure 54

A very long wire of several wavelengths when terminated in a resistance equal to its characteristic impedance, becomes a *"Wave"* or *"Beverage"* antenna. This form of antenna is satisfactory for long-wave reception and is non-resonant.

The wire is usually suspended from 10 to 20 feet above the surface of the earth and should be pointed toward the stations whose signals are to be received. It is most effective when located over poorly-conducting earth, since the wave-front of the received signal is tilted more than when it travels over salt water or moist earth. This form of Beverage antenna is not recommended for short-wave reception.

• Chireix-Mesny Antenna

Numerous sections of tilted half-wave dipoles form the *Chireix-Mesny* array. The wires are arranged so as to form an angle of 45 degrees with respect to the earth, and 90 degrees with respect to each other, in a saw-tooth form.



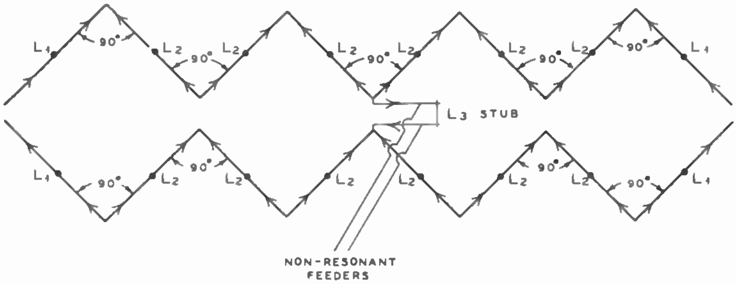
SIMPLE CHIREIX-MESNY ARRAY

Figure 55

The two sketches illustrate the design of this array. It transmits vertically-polarized waves. Any array section should be fed so that the current in the half-wave radiating sections will be fairly-well balanced. The antenna may be fed at a point of maximum current, as shown in the simple array, with

Chireix-Mesny Antenna Design Chart

Band	Frequency in mc.	L_1	L_2	L_3
2.5 Meters	120 116 112	4' 4' 1½" 4' 3"	4' 1" 4' 3" 4' 5"	24" 25" 26"
5 Meters	60 58 56	8' 8' 3" 8' 7"	8' 2" 8' 6" 8' 9"	4' 1" 4' 3" 4' 5"
10 Meters	30 29 28	16' 16' 6" 17'	16' 5" 17' 17' 7"	8' 2" 8' 6" 8' 9"
20 Meters	14.4 14.2 14	33' 4" 33' 8" 34' 1"	34' 2" 34' 7" 35'	17' 17' 3" 17' 6"



CHIREIX-MESNY ARRAY — VERTICALLY POLARIZED — GAIN APPROX 8 DB.

FIGURE 56

a half-wave matching stub or zepp. feeder of some multiple of half waves in length. If two bent wires are used as shown in the other Chireix-Mesny array, a quarter-wave matching stub can be connected across two points of high voltage.

The accompanying design chart gives the values for L_1, L_2 and L_3 for amateur practice.

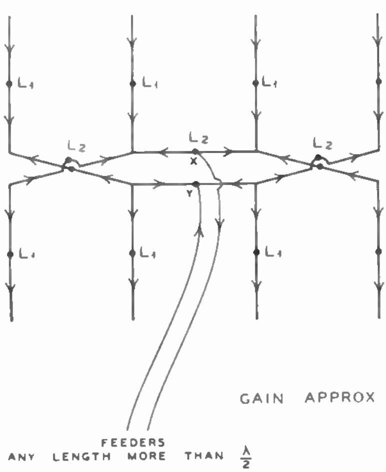
● Stacked Dipole Antennas

Several half-wave or dipole antennas can be arranged in a stacked form in order to provide a directional curtain system. The antennas are usually placed parallel in a plane, a half-wave apart in space. Similar half-wave sections may be stacked above or below the first sections in order to increase the physical size of the curtain. An increase in size, by the addition of half-wave sections, increases the directivity and gain of the antenna. Elaborate curtains with a gain of nearly 200 times are used in commercial practice. In such cases, a reflector curtain similar to the antenna proper is placed a quarter wavelength behind the antenna in order to make the system unidirectional, and thereby increasing the gain in the forward direction by 3 db as well.

Horizontal and vertical directivity can both be made very sharp with this type of directional array. The construction is more difficult than for a rhombic or "V" antenna; the wires must be correctly tuned, and the feeder system should be connected to points in the curtain which will provide a uniform current distribution in the antenna. This means that the feeders must be connected into several portions of the large curtains. A single point of connection for the feeder can be used in the less elaborate arrays illustrated in the accompanying sketches.

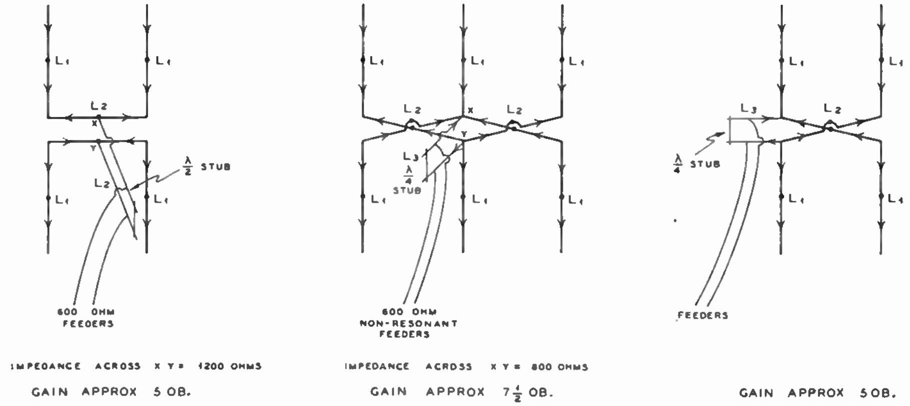
In these sketches the arrow-heads represent the direction of flow of current at a given instant; the dots represent the points of maximum current and lowest impedance. All arrows should point in the *same direction* in each portion of the radiating sections of the antenna in order to provide a field *in-phase* for broadside radiation.

If the arrows in adjacent half-way sections (which are spaced a half-wave apart) are in opposite directions, the system radiates in a direction *through* the plane of the wires, and is then called an *"end-fire radiator."* Figure 61 shows the directional pattern in a horizontal plane for two half-wave vertical antennas excited *out-of-phase*.



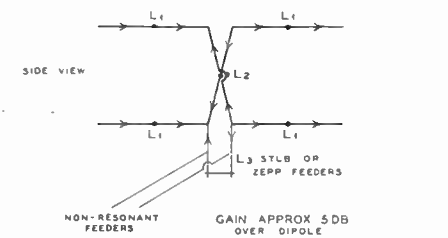
STACKED DIPOLE ANTENNA

Figure 57



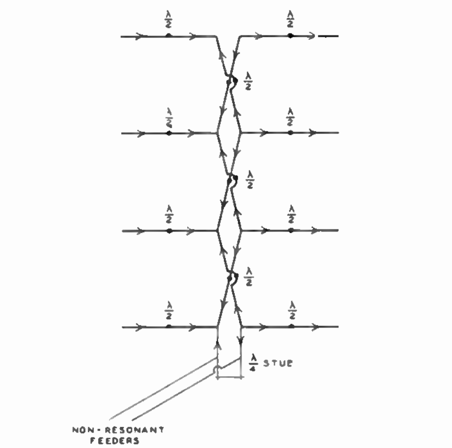
STACKED DIPOLE ANTENNAS — BROADSIDE RADIATION

FIGURE 58



BROADSIDE ARRAY WITH HORIZONTAL POLARIZATION

Figure 59



HORIZONTALLY POLARIZED BROADSIDE ARRAY SECTION

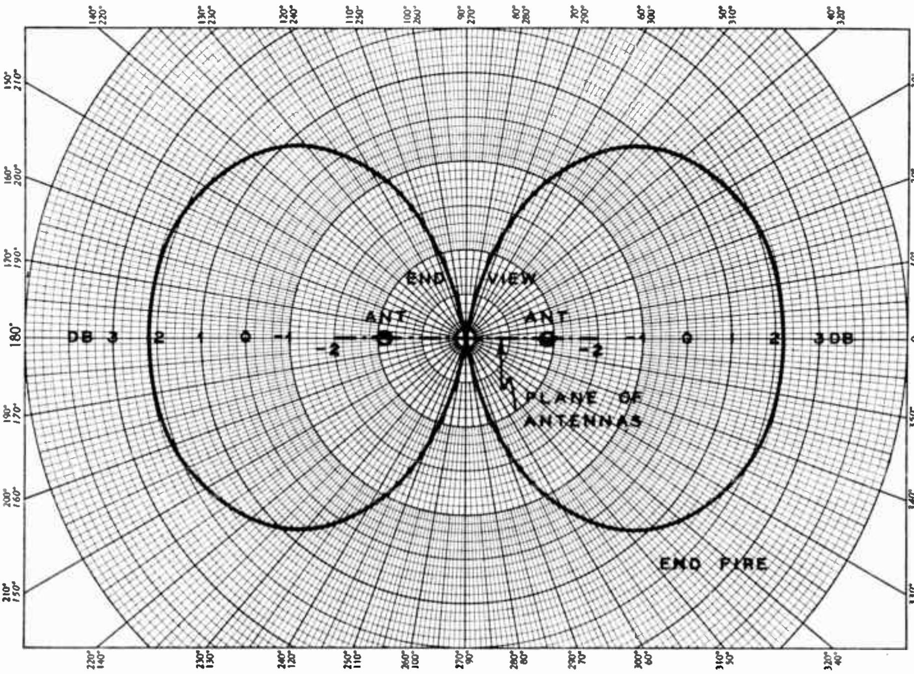
Figure 60

The broadside radiation from two similar antennas excited in-phase is shown in figure 62.

It can be seen that the maximum gain in the desired directions is approximately the same for either broadside or end-fire radiation; however, the beam in one case is sharper than in the other. In general, when antennas are connected to feeder systems in such a manner that the radiators are out of phase, they have a broader beam than when the antenna is excited in-phase for broadside radiation. The curves show the relative radiation in db, which emphasizes the difference in horizontal directivity of the two systems.

Stacked Dipole Antenna Design Chart

Band	Frequency in mc.	L_1	L_2	L_3
1.25 Meters	240 232 224	24" 25" 26"	24½" 25½" 26½"	12" 12½" 13"
2.5 Meters	120 116 112	4' 4' 1½" 4' 3"	4' 1" 4' 3" 4' 5"	24" 25" 26"
5 Meters	60 58 56	8' 8' 3" 8' 7"	8' 2" 8' 6" 8' 9"	4' 1" 4' 3" 4' 5"
10 Meters	30 29 28	16' 16' 6" 17'	16' 5" 17' 17' 7"	8' 2" 8' 6" 8' 9"
20 Meters	14.4 14.2 14	33' 4" 33' 8" 34' 1"	34' 2" 34' 7" 35'	17' 17' 3" 17' 6"
40 Meters	7.3 7.0	65' 10" 68' 2"	67' 6" 70'	33' 9" 35'



HORIZONTAL DIRECTIVITY 2 HALF WAVE ANTENNAS OUT OF PHASE SPACED $\frac{\lambda}{2}$

POWER GAIN OVER SINGLE VERTICAL DOUBLET

FIGURE 61

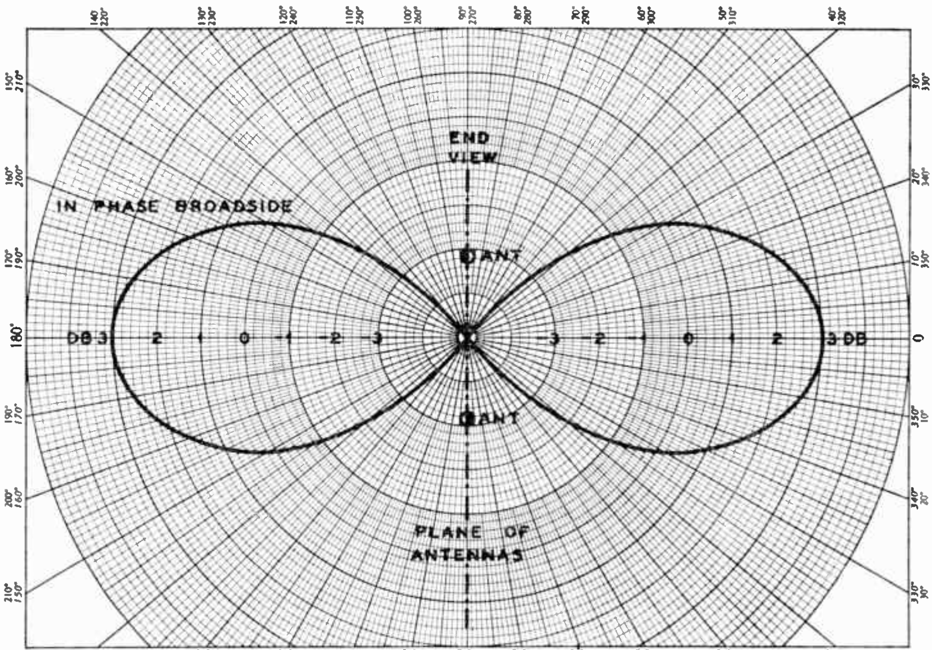
The radiating sections of half-wave wires may be either horizontal or vertical with respect to the surface of the earth, depending upon whether horizontally- or vertically-polarized transmission is desired. The currents in the L_1 sections are in-phase, with the result that they cause a radiation field which is additive in amplitude; more directivity and gain therefore result from the addition of radiating elements. The currents in the L_2 and L_3 sections are out-of-phase; since these wires are only a few inches apart there is no radiation, because the fields neutralize each other.

The theoretical lengths of the L_1, L_2 and L_3 elements are listed in the table for various amateur bands.

The L_1 sections are approximately 2.5 per cent shorter than a half-wavelength, due to the end effect, whereas the L_2 and L_3 sections are a full half-wave and quarter-wave in length, since both ends are terminated in additional elements. The values listed in the *Table* may be subject to modification if there are objects or conductors in the vicinity of the antenna.

Several forms of these stacked dipole antennas are shown in the sketches. Four radiating elements connected in the form of an "H" section will give a gain of approximately 5 db over that of single half-wave antenna. The "H" section can be fed as shown in either diagram of the "H" sections. The feeders must be connected so that the current will be in-phase if broadside radiation is desired. The "H" section, in which the quarter-wave matching stub is connected as shown in the sketch (L_3 being the length of the stub), can be converted into an end-fire radiator if the L_2 sections are not transposed.

In the other "H" section, the impedance across the points *X* and *Y* is approximately 1,200 ohms, which can be matched to a 600-ohm non-resonant line by means of a half-wave matching stub. When there are six radiating elements, the impedance across *X*-*Y* drops to 800 ohms, which could be



HORIZONTAL DIRECTIVITY 2 HALF WAVE ANTENNAS IN PHASE SPACED $\frac{\lambda}{2}$

POWER GAIN OVER SINGLE VERTICAL DOUBLET

FIGURE 62

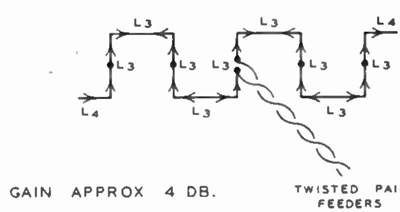
matched approximately by using very wide spacing in the feeders to the points X-Y. The quarter-wave matching stub, as shown in the sketch, gives a more accurate match. The gain from six wires, as illustrated, is approximately 7.5 db over that of a single dipole, and the horizontal directivity becomes more pronounced. The simple "H" section, or the section with six elements, will give as much horizontal directivity as can be used to practical advantage by the amateur.

A double "H" section with eight L_1 dipoles can be fed across the points X-Y with a 600-ohm non-resonant line, because the impedance across these points is 600 ohms. The approximate gain of this array is 10 db over that of a single antenna.

A similar antenna with horizontal wires is shown in the diagram of figure 59. It is fed with a quarter-wave matching stub, connected to a non-resonant feeder. Many sections of these types are mounted in large curtains, one above the other and end to end, in commercial practice. The problem of tuning such elaborate antenna systems is very complex.

• The Bruce Antenna

The Bruce antenna consists of quarter- and eighth-wave sections fed in such a manner that the current in adjacent vertical sections is in-phase. The radiation is vertically polarized and broadside to the antenna. The

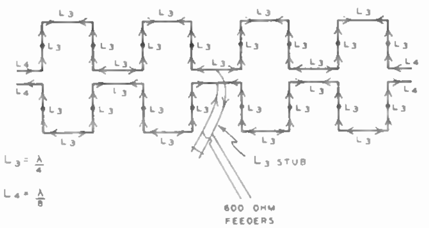


BRUCE ANTENNA VERTICALLY POLARIZED BROADSIDE RADIATION

Figure 63

current in the horizontal portions is out-of-phase, as illustrated in figure 63. Very little radiation takes place from the horizontal portions of the antenna.

For good horizontal directivity the overall length should be at least five wavelengths. A similar bent wire, placed a quarter wave behind the antenna, will act as a reflector and make the system unidirectional. The L_3 and L_4 sections of a Bruce antenna, in actual practice, are a continuous wire which can be mounted in a vertical plane by the use of insulators and additional sections of wire connected across the open-U-shaped portions of the bent wire.



MODIFIED BRUCE ANTENNA WITH VERY EFFICIENT FEEDER SYSTEM AND DOUBLE ROW OF BRUCE ELEMENTS.

GAIN APPROX 9 DB.

Figure 64

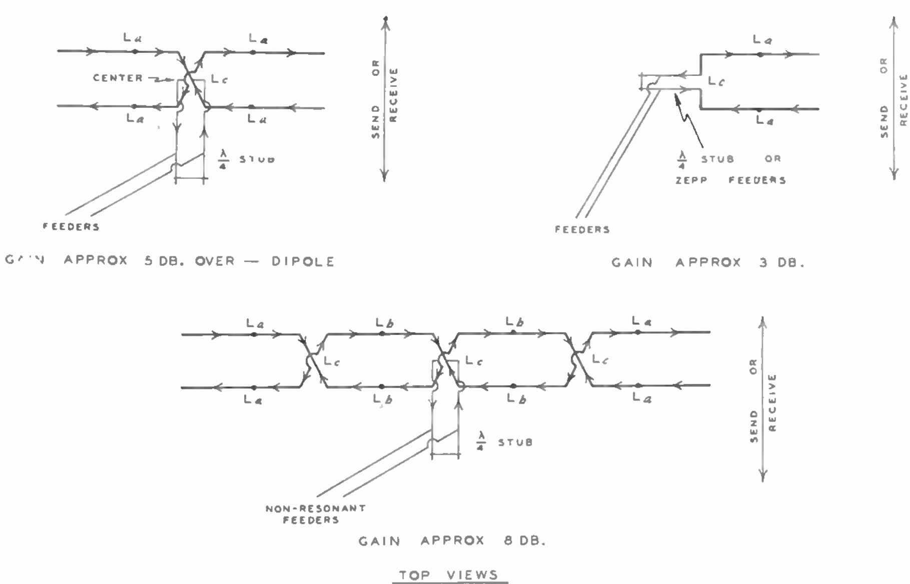
Bruce Antenna Design Chart

Band	Frequency in mc.	L_4	L_3
2.5 Meters	120	12″	24″
	116	12½″	25″
	112	13″	26″
5 Meters	60	2′	4′ 1″
	58	2′ 1″	4′ 3″
	56	2′ 2″	4′ 5″
10 Meters	30	4′	8′ 2″
	29	4′ 1½″	8′ 6″
	28	4′ 3″	8′ 9″
20 Meters	14.4	8′ 4″	17′
	14.2	8′ 5″	17′ 3″
	14.0	8′ 6″	17′ 6″

The two forms of the Bruce antenna suitable for amateur communication are shown in figures 63 and 64. A *Design Chart* is given for wire lengths for the 2.5-, 5-, 10- and 20-meter amateur bands.

● The Kraus "Flat-Top Beam"

This directive antenna, developed and first described in *RADIO* only recently by W8JK, has become perhaps the most popular directive system among amateurs be-



W8JK FLAT TOP "END-FIRE" ANTENNAS

FIGURE 65

W8JK Flat-Top Antenna Chart

Band	Frequency in mc.	L_a	L_b	L_c	Feeder Stub Length
10 Meters	30	14′	12′ 4″	4′	8′ 2″
	29	14′ 6″	12′ 10″	4′	8′ 6″
	28	15′	13′ 6″	4′	8′ 9″
20 Meters	14.35	29′ 4″	26′ 1″	8′	17′ 1″
	14.25	29′ 7″	26′ 5″	8′	17′ 2″
	14.15	29′ 10″	26′ 8″	8′	17′ 4″
	14.05	30′ 2″	27′	8′	17′ 6″
40 Meters	7.28	57′ 9″	51′ 4″	16′	33′ 7″
	7.20	58′ 6″	52′ 2″	16′	34′
	7.10	59′ 6″	53′	16′	34′ 6″
	7.02	60′ 5″	54′	16′	35′

cause of its simple construction and the excellent results it affords.

In its simplest form, the antenna consists of two horizontal, half-wave wires, spaced approximately one-eighth wavelength and bent in towards each other at one end, as shown in figure 65, to allow out-of-phase voltage feed. The "Signal Squisher," described later in this chapter, is a modified form of this arrangement which takes up less room and is, therefore, more readily rotated.

More directivity and gain can be provided by adding additional sections, as illustrated in figure 65. The wires are suspended in a manner similar to that of the old-time flat-top antenna systems.

The system is fed with either zepp. feeders or a matching stub and untuned line. The latter system is preferable when the radiator is located some distance from the transmitter. The stub may be either ¼ or ¾ wave long, the feeders attaching the same distance from the stub in either case. This point is determined as previously described under stub-matching sections.

The sketches show *top views* of the antenna. The two wires are parallel to the ground and cross over each half wavelength when more than one section is used. The accompanying table gives proper wire lengths for 10-, 20-, and 40-meter operation. The distances L_a and L_b refer to just the straight portions of the wire. Spacing where the wires cross over should be about 6 inches the entire distance.

While affording high gain when several elements are used, the beam is not particularly sharp and, therefore can be used to cover a wide area. A good portion of the gain comes from the lowered vertical angle of radiation.

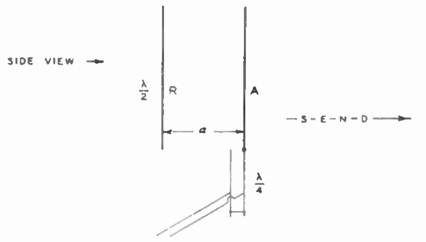
• The Yagi Antenna

A directive antenna system which is particularly useful for the ultra-high and micro-wave frequencies is the *Yagi*. It usually consists of a vertical half-wave antenna with several parasitically-excited reflector and director wires placed in vertical planes around the antenna. The rear reflector wire, which is on the side of the antenna opposite that of the desired directions of transmission, is normally spaced a quarter-wavelength behind the radiator. If side reflectors are used, they are spaced a half wavelength from the antenna.

A typical polar diagram of an antenna and three reflectors is shown in figure 68. This antenna has a theoretical gain of 6 db over that of the antenna wire alone. The beam is rather broad and covers an angle of nearly 90 degrees. The two small lobes do not detract from the power gain but do affect the discrimination.

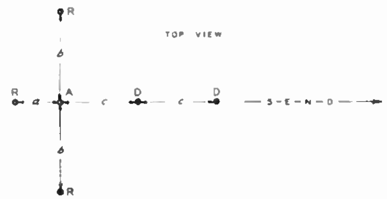
Reflector and Director Dimensions for Yagi Arrays

Freq.	A	R	D	a	b	c
224	25″	26″	23″	13″	26½″	20″
232	24″	25″	22″	12½″	25½″	19″
240	23½″	24″	21″	12″	24½″	18½″
112	4′2″	4′3″	45½″	26″	4′5″	39″
116	4′	4′1½″	44″	25″	4′3″	38″
120	3′10″	4′	43″	24½″	4′1″	37″
56	8′4″	8′7″	7′½″	4′5″	8′9″	6′7″
58	8′1″	8′3″	7′4½″	4′3″	8′6″	6′4″
60	7′10″	8′	7′1½″	4′1″	8′2″	6′2″
28	16′8″	17′2″	15′3″	8′9″	17′7″	13′2″
29	16′1″	16′6″	14′9″	8′6″	17′	12′8″
30	15′6½″	16′	14′3″	8′2″	16′5″	12′4″
14.05	33′4″	34′1″	30′5″	17′6″	35′	26′3″
14.15	33′1″	33′11″	30′2″	17′4″	34′8″	26′1″
14.25	32′10″	33′8″	30′	17′3″	34′6″	25′11″
14.35	32′8″	33′5″	29′10″	17′1″	34′3″	25′8″



PARASITIC REFLECTOR λ/4 IN BACK OF λ/2 ANTENNA
GAIN APPROX 3 DB.

Figure 66



2 PARASITIC DIRECTORS AND 3 REFLECTORS
GAIN APPROX 9 DB.

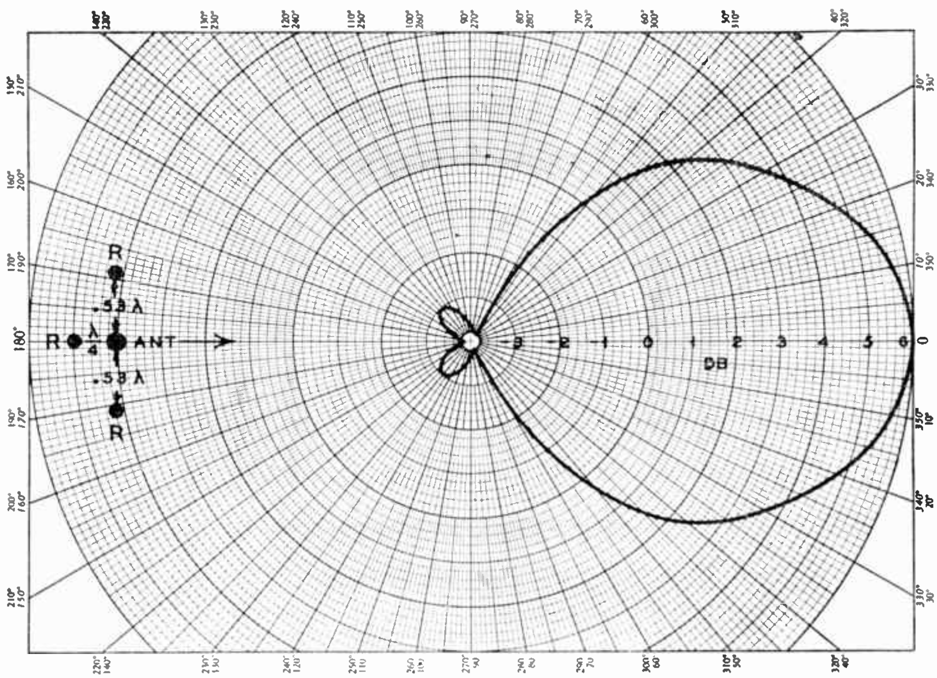
Figure 67

Greater directivity can be obtained with three reflector wires and two directors, figure 69.

The gain is approximately 9 db over that of a single antenna wire. The director wires are spaced about 3/8 wavelength each ahead of the antenna wire in the desired line of transmission.

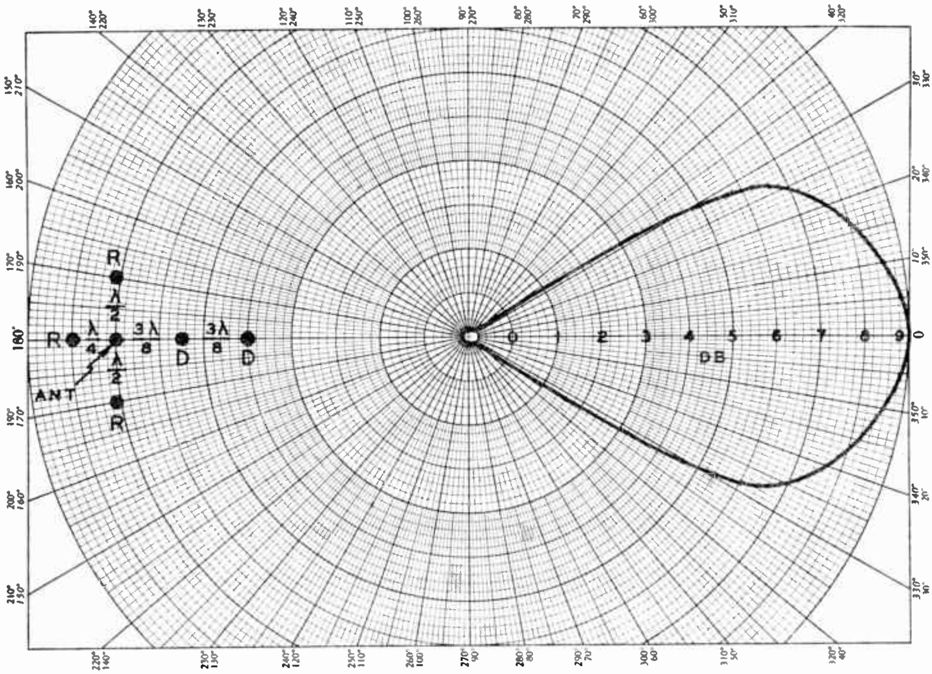
Typical reflector and director wire dimensions are listed in the table.

The elimination of the two side reflector wires results in a reduction in gain of 3 db in the forward direction and with the addition of two more lobes of radiation at right angles to the desired direction of transmission, as shown in figure 70. This effect is shown in the polar diagram of a single reflector and two director wires. The approximate gain of other simple *Yagi* are shown in figures 71, 72, and 73.



HORIZONTAL DIRECTIVITY
ANTENNA AND 3 PARASITIC REFLECTORS —
6 DB THEORETICAL GAIN OVER DIPOLE

FIGURE 68



EXPERIMENTAL RESULTS — HORIZONTAL DIRECTIVITY — YAGI ARRAY — 3 REFLECTORS — 2 DIRECTORS — $\frac{\lambda}{2}$ ANTENNA — 9 DB. GAIN OVER DIPOLE

FIGURE 69

• Operation of Parasitic Reflectors

A *parasitic reflector* consists of a wire approximately a half wavelength long, placed in the field of the antenna and parasitically excited by the radiation fields of the antenna. The energy from the antenna field is re-radiated by the reflector wire, so that the energy is reinforced in certain directions and cancelled in others. For example, if the reflector is spaced a quarter wave from the antenna, the resultant radiation field will be practically doubled in a direction opposite to that of the reflector wire in a line with the antenna.

Directly radiated and re-radiated fields tend to cancel in the opposite directions with the result that the radiation takes on a heart-shaped horizontal directivity pattern.

If the reflector wire is spaced a half wavelength from the antenna, the radiated field will be increased in *two directions* at *right angles* to the plane of the reflector and antenna.

When three reflector wires are supported around an antenna, one at the rear and two at the sides, with spacings of a quarter wavelength and half wavelength respectively, a radiation field such as the one shown in the polar diagram for the Yagi antenna will be produced.

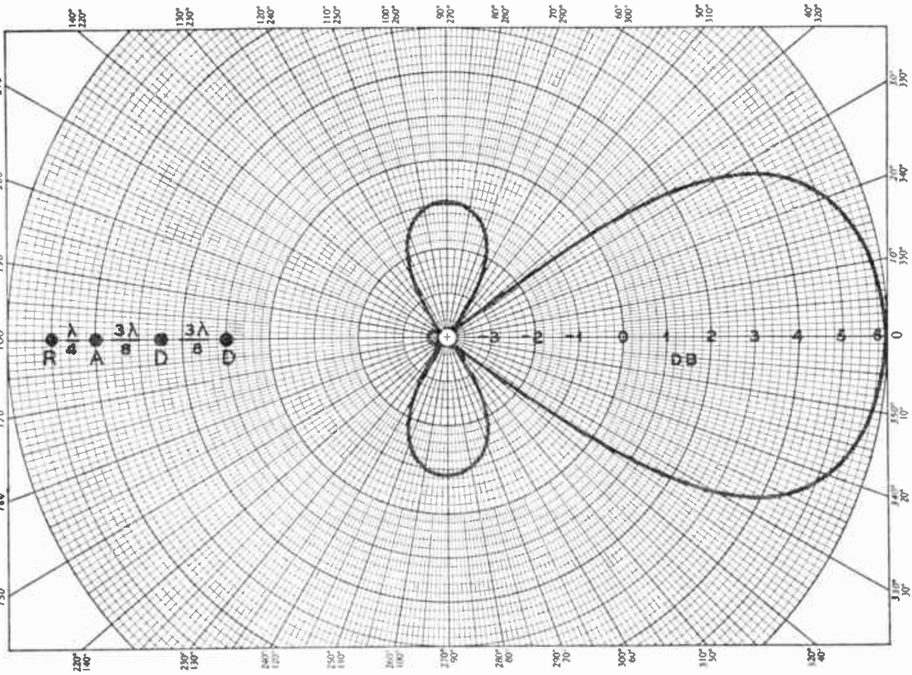
Combinations of reflector wires in the form of a curtain are sometimes placed a quarter wavelength behind a directional antenna system in order to increase the radiation in the forward direction and likewise prevent radiation from the rear.

Parasitic reflectors can be calculated from the formula:

$$L = 1.60 \times \lambda,$$

$$\text{or } L = \frac{492{,}000 \times 0.97}{f}$$

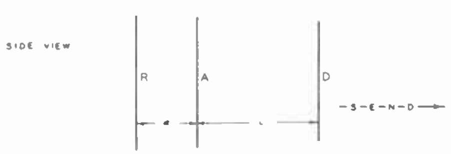
where L is the reflector length in feet,
λ is the transmitter wavelength in meters,
f is the transmitter frequency in kilocycles.



HORIZONTAL DIRECTIVITY OF YAGI ARRAY
ONE REFLECTOR — TWO DIRECTORS

6 DB. GAIN OVER DIPOLE

FIGURE 70



PARASITIC DIRECTOR AND REFLECTOR
GAIN APPROX $4\frac{1}{2}$ DB.

Figure 71

2 PARASITIC DIRECTORS AND ONE REFLECTOR
GAIN APPROX 6 DB.

Figure 72

• Operation of Parasitic Directors

A wire placed in front of an antenna in the desired direction of transmission or re-

3 PARASITIC DIRECTORS AND ONE REFLECTOR
GAIN APPROX $7\frac{1}{2}$ DB.

Figure 73

ception is known as a *director,* since it improves the transmission or reception in that direction. A parasitic director is normally made slightly shorter than the antenna proper and spaced ⅜ of a wavelength in front of the antenna. A parasitic *reflector* wire placed behind a radiator is normally made slightly longer than an electrical half wavelength. The antenna proper should always be resonant.

The length of director wires can be calculated from the following formulas:

$$L = 1.425 \times \lambda$$

$$\text{or } L = \frac{492{,}000 \times 0.87}{f}$$

where L is the director length in feet,
λ is the transmitter wavelength in meters,
f is the transmitter frequency in kilocycles.

• Rhombic Antennas

The terminated *rhombic* or *diamond* is probably the most effective directional antenna that is practical for amateur communication. This antenna is non-resonant, with the result that it can be used on three amateur bands, such as 10, 20 and 40 meters. When the antenna is non-resonant, i.e., properly terminated, the system is uni-directional and the wire dimensions are not at all critical. The rhombic antenna can be suspended over irregular terrain without greatly affecting its practical operation.

The tuned diamond antenna consists of two "V" antennas, end to end, and *without a free-end termination*, as shown in figure 74. The antenna is *bi-directional*, in which case the lengths are very critical, and the system must be tuned to exact resonance with the operating frequency. It has less gain than a properly terminated rhombic.

If the free end is terminated with a resistance of a value of from 700 to 800 ohms, as shown in figures 75, 76 and 77, the back-wave is eliminated, the forward gain is increased, and the antenna can be used on several bands without changes. The terminating resistance should be capable of dissipating one-third the power output of the transmitter. A bank of carbon and tungsten filament lamps can be connected in series-parallel for this purpose or heavy duty carbon rod resistances can be used. The latter can be procured from the Carborundum Co. For medium or low-power transmitters the non-inductive *"plaque"* resistors made by Ward-Leonard will serve as a satisfactory termination.

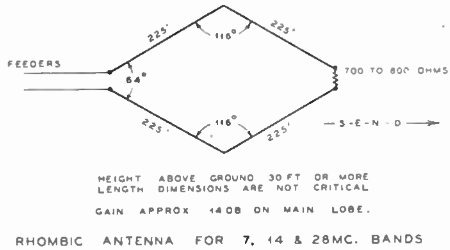


Figure 76

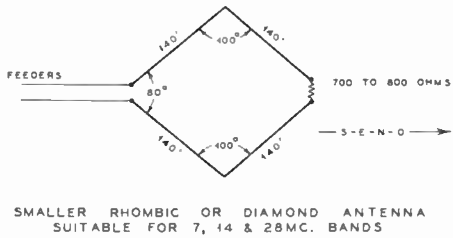


Figure 77

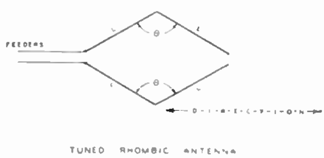


Figure 74

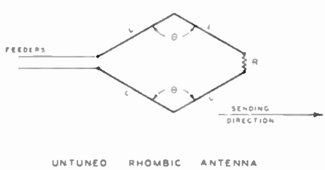


Figure 75

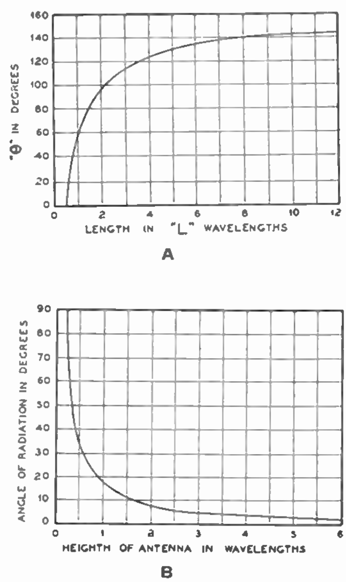


Figure 78—Diamond Antenna Design Chart.

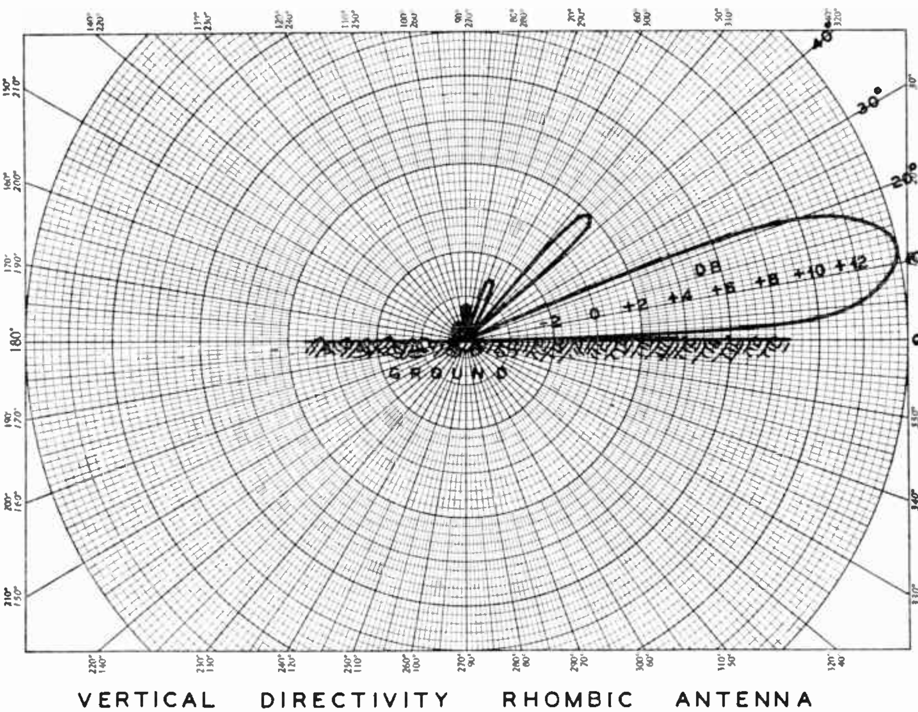
The antenna should be fed with a non-resonant line, preferably with an impedance of approximately 700 ohms. The four corners of the diamond can be suspended from poles or trees and, if possible, at least a half wavelength in height above ground at the lowest frequency of operation.

This antenna transmits a horizontally-polarized wave at a low angle above the horizon in the case of a large antenna. The approximate angle of radiation above the horizon is shown in chart B, figure 78, of *Diamond Antenna Design Curves.*

The vertical directivity of a typical rhombic antenna suitable for amateur communication is shown in the polar diagram, figure 79. This antenna will give a gain of approximately 14 db. over that of a vertical half-wave antenna. The horizontal directivity of the same antenna is shown in another polar diagram, figure 80. The smaller lobes of radiation prevent the antenna from being truly uni-directional; the amplitude, however, is relatively small in comparison to the main lobe of radiation. The sides of this diamond antenna are 3¼ wavelengths long, with the angle θ equal to 58 degrees. The correct angle θ for any length L of the wires in each leg is shown in chart A of *Diamond Antenna Design Curves,* figure 78.

• "V" Antennas

The "V" antenna consists of a long wire, folded in the center, so as to form a "V" toward or away from the desired direction of transmission. The antenna is bi-directional (two opposite directions) for the main lobes of radiation. Each side of the "V" can be made any odd or even multiple of quarter wavelengths, depending upon the method of feeding the apex of the "V." The complete system must be a multiple of half waves. If each leg is an even number of quarter waves long, the antenna must be voltage-fed; if an odd number of quarter waves long, current-feed must be used.

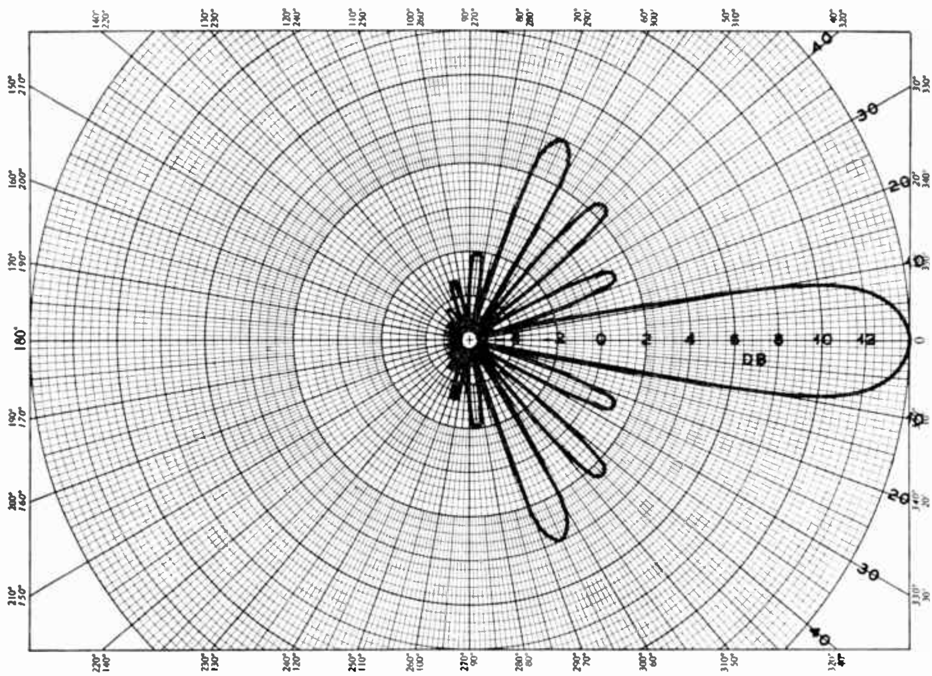


VERTICAL DIRECTIVITY RHOMBIC ANTENNA

$L = 3\frac{1}{4}\lambda$ $\Theta = 58°$ $H = \frac{\lambda}{2}$

14 DB. GAIN OVER VERTICAL HALF WAVE

FIGURE 79



HORIZONTAL DIRECTIVITY — RHOMBIC ANTENNA
$L = 3\frac{1}{4}\lambda$ $\Theta = 58^{\circ}$

14 DB. GAIN OVER DIPOLE

FIGURE 80

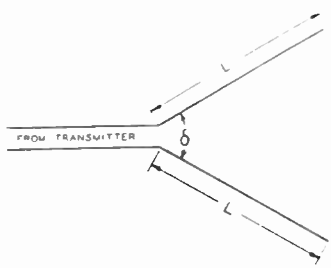


Figure 81

By choosing the proper angle δ, figure 81, the lobes of radiation from the two long wire antennas aid each other to form a bi-directional beam. Each wire by itself would have a radiation pattern similar to that shown for antennas operated on harmonics. The reaction of one upon the other removes two of the four main lobes, and increases the other two in such a way as to form two lobes of greater magnitude.

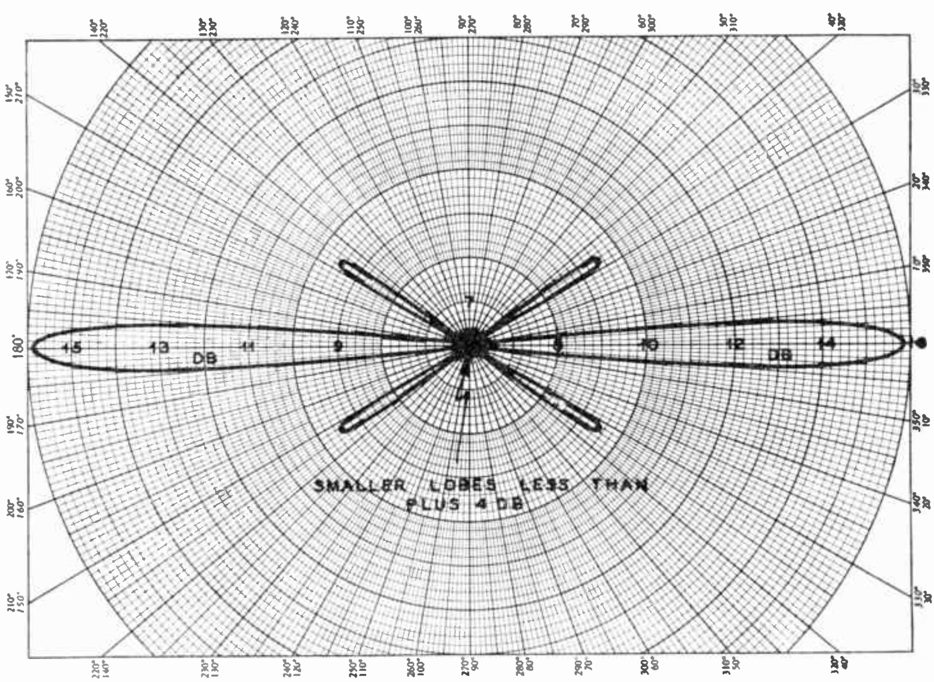
The correct wire lengths and the degree of the angle δ are listed in the "*V*" *Antenna Design Table* for various frequencies in the 10-, 20- and 40-meter amateur bands. These values must sometimes be reduced slightly if one of the wires is in the vicinity of some large object.

The horizontal directivity pattern for a typical "V" antenna for commercial practice is shown in the table. Each wire is made eight wavelengths long. The beam is very sharp, as shown in the polar diagram figure 82, and the gain over an ordinary half-wave antenna is theoretically 15.6 db. Four minor lobes occur.

The polar diagram of a very small "V" antenna with each of its sides one full wave in length is illustrated in figure 83. The main lobes give a gain of approximately 4 db over that of an ordinary half-wave antenna, but the two minor lobes are quite strong and radiate at right angles to the main beam a wave which is only slightly

"V" Antenna Design Table

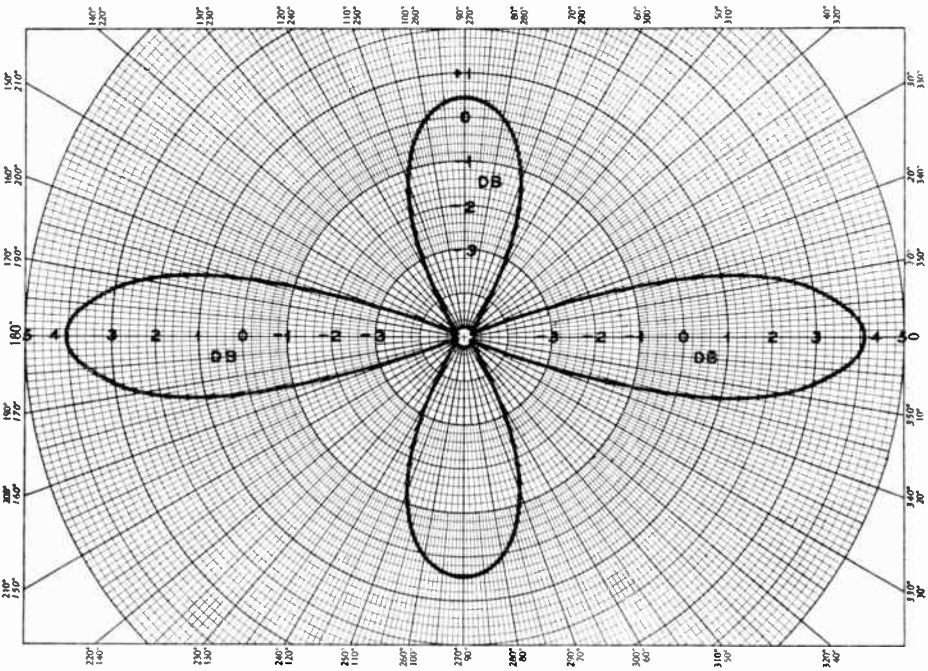
Frequency in Kilocycles	"Half Wave" Dipole	"Full Wave" $L = \frac{\lambda}{2}$ $\delta = 180°$	$L = \lambda$ $\delta = 104°$	$L = 2\lambda$ $\delta = 75°$	$L = 4\lambda$ $\delta = 52°$	$L = 8\lambda$ $\delta = 39°$
28000	16' 8"	17' 1"	34' 8"	69' 8"	140'	280'
28500	16' 4"	16' 9"	34' 1"	68' 6"	137' 6"	275'
29000	16' 1"	16' 6"	33' 6"	67' 3"	135'	271'
29500	15' 8"	16' 2"	33'	66' 2"	133'	266'
30000	15' 6½"	15' 11"	32' 5"	65'	131'	262'
14050	33' 4"	34'	69'	139'	279'	558'
14150	33' 1"	33' 10"	68' 6"	138'	277'	555'
14250	32' 10"	33' 7"	68' 2"	137'	275'	552'
14350	32' 8"	33' 5"	67' 7"	136'	273'	548'
7020	66' 7"	68' 2"	138' 2"	278'	558'	1120'
7100	65' 9"	67' 4"	136' 8"	275'	552'	1106'
7200	64' 11"	66' 5"	134' 10"	271'	545'	1090'
7280	64'	65' 8"	133' 4"	268'	538'	1078'



RADIATION PATTERN — HORIZONTAL DIRECTIVITY
"V" ANTENNA $L = 8\lambda$ $\delta = 17\frac{1}{2}°$ ANGLE

15.6 DB. GAIN OVER DIPOLE

FIGURE 82



RADIATION PATTERN IN A HORIZONTAL PLANE OF A "V" ANTENNA L = 1 λ δ = 110° ANGLE

4 DB. GAIN OVER DIPOLE

FIGURE 83

lower in amplitude. A longer "V" antenna, such as 2½ to 3½ wavelengths for each leg, will provide a radiation pattern intermediate between the two illustrated in the polar diagrams. Such a "V" antenna would be more suitable for amateur communication. Typical examples are shown in the accompanying sketches, figures 84, 85 and 86. The correct lengths and angle, as well as the approximate gain, are denoted on the sketches. These "V" antenna dimensions are suitable for operation in the 20-meter phone band.

An antenna of the "V" type can be used for receiving by constructing it as shown in figure 87. The center is the highest point, and the two ends slope toward the ground. The "V" antenna in this case is in a vertical, rather than a horizontal plane, and the angle θ is equal to 180 degrees minus δ. This form of receiving antenna is seldom used.

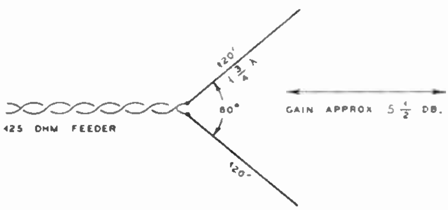


Figure 84—20 Meter "V" Antenna, Smallest Worthwhile Size

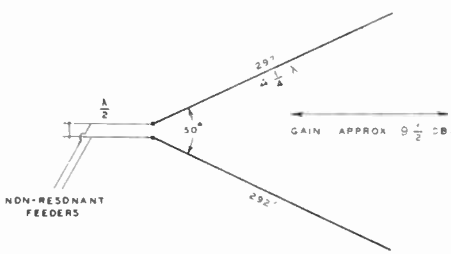


Figure 85—More Directive "V" Than Shown above, with More Efficient Method of Feed. Dimensions are for 20 Meters

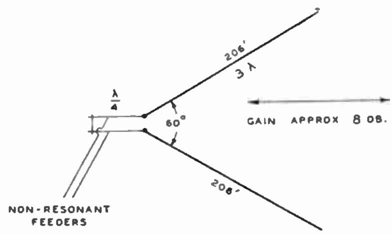
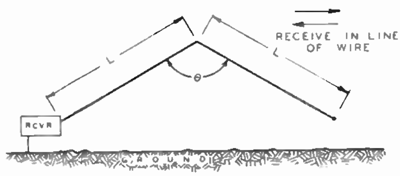


Figure 86—20 Meter "V" with Moderate Gain and Directivity, Best Suited for General Amateur Use



VERTICAL "V" ANTENNA

Figure 87

The vertical angle at which the wave is best transmitted or received from a horizontal "V" antenna depends largely upon the angle. The sides of the "V" antenna should be at least a half wavelength above ground; commercial practice dictates a height of approximately a full wavelength above ground.

● Tilt Antennas

A tilt antenna consists of a resonant length of wire, one end higher than the other, so that it forms an angle to the earth's horizon and thereby changes the effect of the ground reflection. The earth acts as a mirror and prevents the radiated wave from going out exactly in a plane to the horizon; it reinforces the radiation, however, at vertical angles above the earth's surface. Proper tilt of the wire will lower the effective radiation angle from the low end of the antenna, and reduce the radiation from the high end. An example of a tilt antenna is a half-wave radiator, which, in free space, does not radiate from its ends (see figure 88). The high end of a tilt antenna can be made to have an angle with respect to the surface of the earth such that the radiation is zero in the upper direction of the wire. Similarly, the antenna can be tilted so that the radiation can be made practically zero at any desired vertical angle in the direction of the higher end of the antenna.

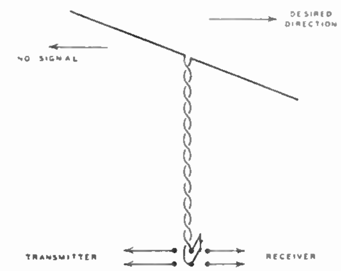


Figure 88—Tilt Doublet Antenna.

This phenomenon causes the tilt antenna to be of great value for short-wave communication because it can be oriented so as to cut down the interference from some particular part of the world; h.f. signals can be reduced as much as three to five *R* points with the proper tilt. The antenna is very nearly non-directional over an angle of 300°, as shown in the dotted curve of the polar diagram. It is also satisfactory for transmission.

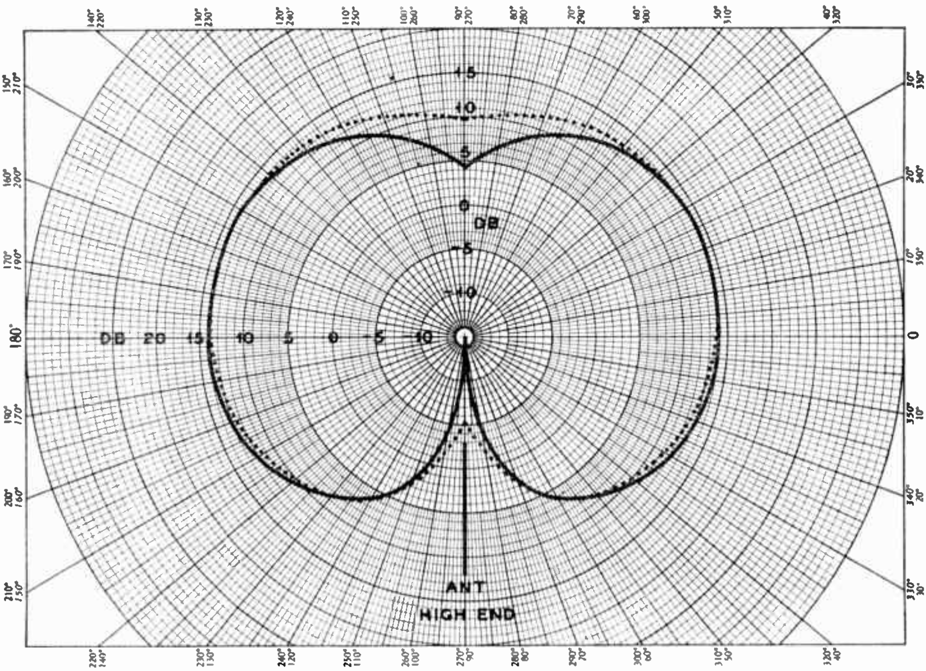
The dotted curve in the polar diagram, figure 89, shows the horizontal directivity pattern for a vertical angle of 10° above the horizon for an antenna tilt of approximately 18°. The same curve would apply to a 20° vertical angle for an antenna tilt of approximately 9°.

The solid curve shows the radiation at 10° above the horizon for a tilt of approximately 8°, which in this case is the optimum tilt for greatest reduction in signal from the high end of the antenna when used for reception. The gain in the opposite direction is not as great as for an 18° tilt, as shown in the dotted curve.

The angle of radiation for 10-meter operation should be approximately 10° above the horizon. The values shown in the polar diagram are suitable for a half-wave tilt antenna operated on 10 meters. For operation on 20 meters, the tilt should be slightly greater than for 10 meters for similar conditions of eliminating reception or transmission from the high end of the antenna.

The actual tilt angle of the wire with respect to the ground is somewhat less than the "null" angle, as for example: an 8° wire tilt eliminates a 10° radiation pickup by the antenna. An antenna operating on 40 meters would have a tilt of somewhat less than 30° if the 30° vertical angle reception is to be eliminated.

The actual vertical angle for optimum transmission and reception for any given



TILT HALF WAVE ANTENNAS

DOTTED CURVE = RADIATION AT 10° ABOVE HORIZON FOR TILT OF APPROX 18°. [APPROX SAME AS RADIATION AT 20° ABOVE HORIZON FOR TILT OF 9°].

SOLID CURVE = RADIATION AT 10° ABOVE HORIZON FOR TILT OF APPROX 8°.

FIGURE 89

frequency is not always *exactly* the same, though for all practical purposes it may be considered the same, and a great reduction of signal is possible by having the proper amount of tilt for the particular frequency in use. The reason why a signal cannot be attenuated more than a few *R* points is that the incoming wave does not come in toward the antenna at just one angle, such as exactly 30°.

Full wave, or even longer, antennas can be tilted to increase the radiation from the lower end and simultaneously greatly reduce that from the high end. Tilt antennas are very easily constructed, since it is possible to control simply and easily the tilt by means of the same rope and pulley which hoists the antenna wire to the top of the mast.

Figure 90 shows a tilt antenna for 20-meter operation. The actual angle of tilt can be easily varied for best results under actual operating conditions. The antenna can be fed with any form of non-radiating feeder. Any radiation or reception by the feeder will change the directivity pattern of the tilted portion of the antenna.

A tilt antenna can be used in conjunction with another receiving antenna in order to reduce the strength of *all* signals except those from one desired direction, as shown in figure 91.

The principle of operation is to adjust the pickup from both the regular receiving antenna and the tilt antenna so that the signals are coupled into the receiver with equal intensity and *opposite in phase*. The signals from the direction of upward tilt will be of very low amplitude in comparison to those coming from other directions, as regards the tilt antenna. If the regular receiving antenna is fairly non-directional, the un-

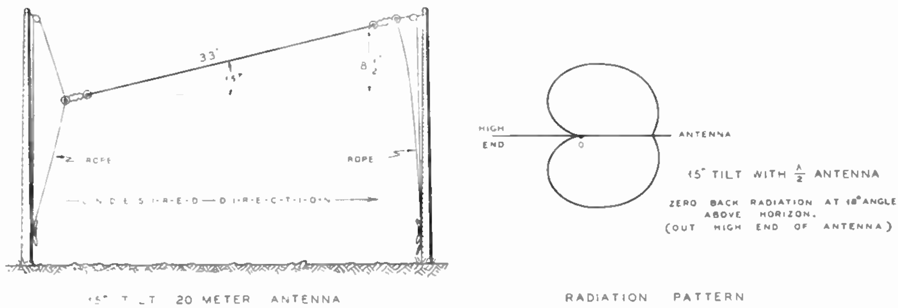


Figure 90

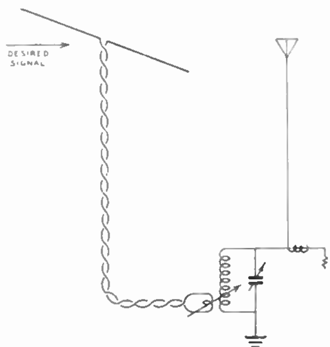


Figure 91—Tilt Bucking Antenna System.

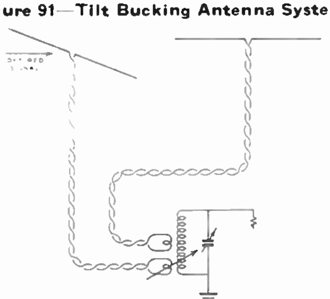


Figure 92—Directive Doublet Receiving Antenna System.

desired signals can be made to buck each other, thereby picking up only the signals from one direction. This idea can be utilized in reducing interference from relatively strong New Zealand and Australian signals when receiving European stations on the west coast.

Tests indicate that the undesired signals can be reduced from 2 to 3 *R* points over nearly 300 degrees by careful balance of the circuits. The coupling to both antenna systems should be made variable, or at least semi-variable, for proper balance. Two circuits are illustrated, one for any form of receiving antenna, another in connection with a horizontal doublet. This system can be used only in the frequency band designed for the tilt antenna.

Rotatable Arrays

• The Smith "Signal Squisher"

A compact, rotatable, bi-directional antenna giving low-angle radiation with optional polarization is shown in figure 93. It consists essentially of two half-wave radi-

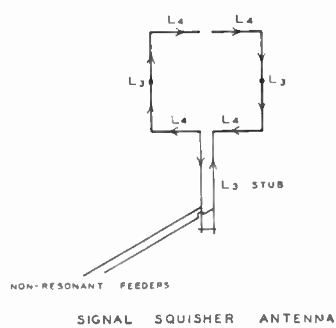


Figure 93

ators bent in the form of a square, voltage-fed by means of a matching stub and mounted horizontally for 20 and 10 meters and vertically for 5 meters. The main portion of the radiation is from the middle quarter-wave section of each half-wave radiator, giving directivity in a line through the two current nodes. Because of two minor lobes at right angles to the main lobes, the affair, when orientated horizontally, is little more directive than a horizontal doublet. Its chief advantage over a horizontal doublet is the fact that it is more compact and more easily rotated than a doublet and gives a favorable vertical angle of radiation for 10 and 20 meters regardless of height above the ground. Most of the radiation from a horizontal doublet is wasted on 10 meters, and a large part of it is wasted on 20 meters. This explains the increase in gain over a plain doublet on 10 and 20 meters, especially the former band.

For 5-meter work the radiating portion should be mounted *vertically* (as in figure 93), instead of horizontally. This gives low-angle radiation with vertical polarization and eliminates the two minor lobes (sends them straight up and down). The horizontal pattern measured on the ground with the antenna in this position (vertical) resembles a fat "figure 8," with no minor lobes.

The length L_3 is a quarter wave, L_4 an eighth wave. The feeder will attach closer to the shorting bar than is the case with most stub-matched antennas. The correct point for the shorting bar and feeder tap can be determined as previously described in this chapter.

Because it is bi-directional, the array need swing through but 180 degrees (140° is actually sufficient because the beam is not sharply defined and the direction need not be "on the nose").

This is the most widely used rotatable 20-meter antenna.

• Reinartz Rotary Beam Antenna

The John L. Reinartz compact directive antenna is shown in figures 94 and 95. It is suitable for 5- and 10-meter transmission and reception, and its field pattern shape is roughly similar to that of a half-wave vertical antenna with single reflector.

A 5-meter antenna consists of two 8-foot lengths of tubing, bent into a circle, with 2 in. to 3 in. spacing between the tubes. The circles are not closed; an opening of one inch remains, as shown in the diagram.

The loop can be placed in either a horizontal or vertical plane, depending upon whether horizontal or vertical polarization is desired. The actual power gain over that of a vertical half-wave antenna in the desired direction is only 18 per cent, but the power directivity is nearly 6-to-1.

16½-ft. rods can be used for 10-meter operation, 33-ft. rods for 20 meters. The spacing between the rods, or circles, need not be increased when the antenna is built for operation on the longer wavelengths.

The antenna should be arranged for 360° rotation. It is useful because of its *discrimination* (front-to-back ratio) rather than for the small power gain it provides.

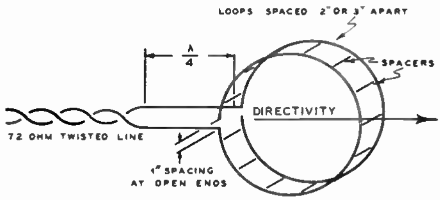


Figure 94—Reinartz Rotary Beam with Twisted-Pair Feeder and Stub.

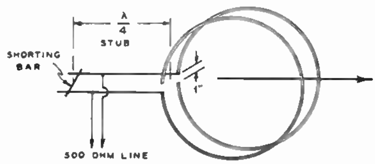


Figure 95—Reinartz Rotary Beam Antenna with Spaced Feeder and Stub.

• The "Signal Squirter"

A highly effective uni-directional affair that is not too unwieldy to be rotated on 20 meters and below consists of a half-wave radiator with a parasitically-excited reflector (Yagi) spaced a quarter wave to the rear. This system is not so compact as the Smith rotatable array, and it must be rotated through a full arc instead of half an arc. However, it will give excellent results for those in a position to put one up.

A kit of parts for this antenna, including everything from wire to rotating tower and mechanism, is available commercially under the trade name "Signal Squirter."

• Antennas for U.H.F. Operation

The only difference between antennas for ultra-high-frequency operation as compared with those for operation in other bands is in their physical size. The fundamental principles are unchanged.

Antennas for u.h.f. service are small in size, thus making them easily portable. In the u.h.f. field of communication, the direct or *ground wave* is used; for this reason the transmitting and receiving antennas are generally in visual range of each other. It is therefore necessary that the antennas be located as high above ground as possible. Low-angle radiation is necessary and antennas which radiate at low angles should always be used.

Vertically-polarized waves have less tendency for an upward bending. This, coupled with the fact that vertical antennas have a low angle of radiation to begin with, causes them to be generally employed.

A simple non-directional antenna for u.h.f. operation consists of a half-wave vertical wire or rod, fed with a two-wire matched impedance feeder, as shown in figure 96, or by means of a quarter-wave matching stub and two-wire non-resonant line, figure 97.

Zepp. feeders are seldom employed, because the antenna in most cases is located several wavelengths away from the transmitter or receiver in order to secure ample height above the ground.

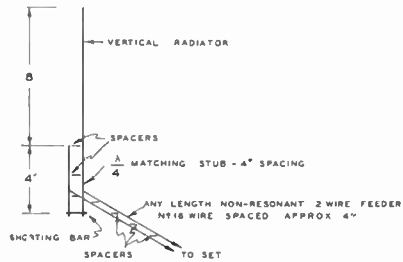
A *Concentric Feeder* is very effective for feeding either a half-wave antenna or a quarter-wave Marconi antenna, such as those used for mobile 5-meter work.

Directive antennas often prove of great value in the ultra-high-frequency region because the high power gain which is obtainable gives the same result as a great increase in transmitter power. The cost of increasing power is far more than that of a simple antenna array. Any of the directional antenna systems previously discussed can be used for u.h.f. communication, although those which give vertical polarization, such as the Stacked Dipole, Yagi, Vertical Franklin, or Bruce are best. A simple directional antenna is shown in figure 98.

• Types of Mobile U.H.F. Antennas

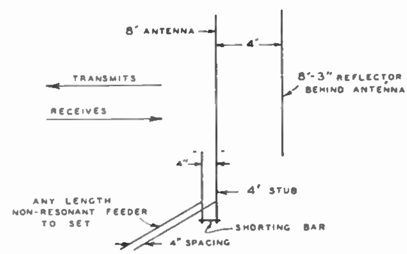
A quarter-wave vertical Marconi antenna (figure 100) is very convenient for automobile installations. A 4-foot rod with the bottom end grounded to the car body can be fed with a single-wire feeder several feet long; this feeder connects to the 5-meter set in the car.

Another 5-meter antenna consists of an insulated 4-foot rod, fed by either a twisted pair (solid conductors) or by a concentric



5 METER "J" ANTENNA

Figure 97



SIMPLE 5 METER DIRECTIONAL ANTENNA WITH REFLECTOR WHICH DOUBLES OUTPUT & SENSITIVITY

Figure 98

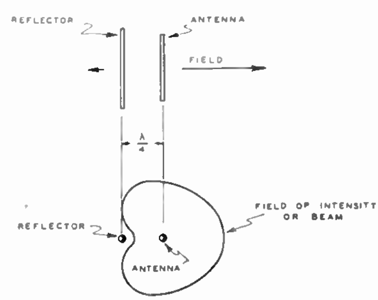


Figure 99—Directivity Pattern of Antenna Shown in Figure 98.

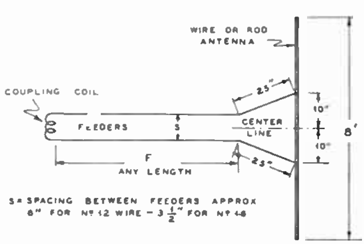
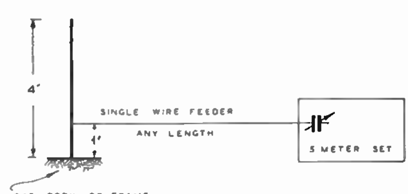


Figure 96—5-Meter Matched Impedance Antenna



SIMPLE 5 METER AUTO ANTENNA

Figure 100

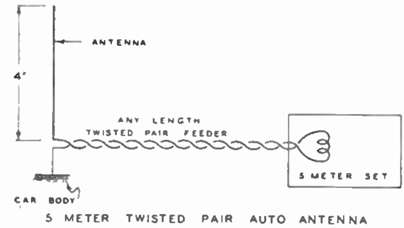


Figure 101

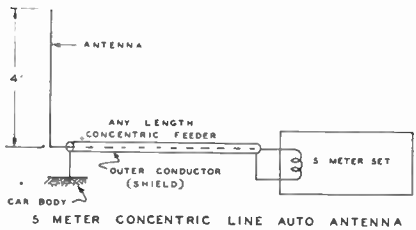


Figure 102

transmission line, figures 101 and 102. In the case of twisted-pair feeders, the impedance match is not very good, but this effect can be overcome to some extent by cutting the twisted pair to some particular length. This can best be determined by experiment, because a few inches more or less of feeder will provide a tuning effect and allow more efficient operation.

Quarter-wave rods can be mounted on the roof of an automobile, if some means of flexible coupling is built into the base of the rod so that the antenna can be swung down when it strikes an overhead obstacle, such as a garage entrance, etc. Sometimes the rod is mounted on the front or rear bumper of the car, on the radiator, running board, or fender. In many cases the antenna rod is mounted directly on a transmitter housed in the rear trunk of the automobile.

Mobile antenna installations for police radio work differ from the 5-meter types in that the antennas are somewhat longer because the frequency of operation is lower. The length can be calculated from the formula:

$$L_1 = \frac{492{,}000 \times 0.485}{f}$$

where L_1 = The quarter-wave antenna length in feet.

f = The transmitter frequency in kilocycles.

The length of a half-wave antenna is twice that of a quarter-wave antenna.

• Fixed Station 5-Meter Antennas

These antennas can be constructed from copper or aluminum rod, or wire. When a wire antenna is used, the wire can be supported on stand-off insulators attached to a vertical 2"x3" wood pole. The pole should be guyed, preferably with ropes, in order to keep metallic conductors away from the field of the antenna. The antenna should be as high as possible and well remote from surrounding objects.

These same types of antennas can be used for television reception by making the half-wave antenna resonant to the frequency of the television transmitter. In this case a twisted-pair feeder of solid wire, such as the *EO-1 Cable,* can be used in order to reduce automobile ignition interference, though the loss in a twisted-pair feeder at these frequencies is rather high.

Long wire antennas can be used on 5 meters providing the directional effects are taken into consideration. For example, a 20- or 40-meter single wire fed or zepp. antenna can be operated on 5 meters with fairly satisfactory results for both transmitting and receiving.

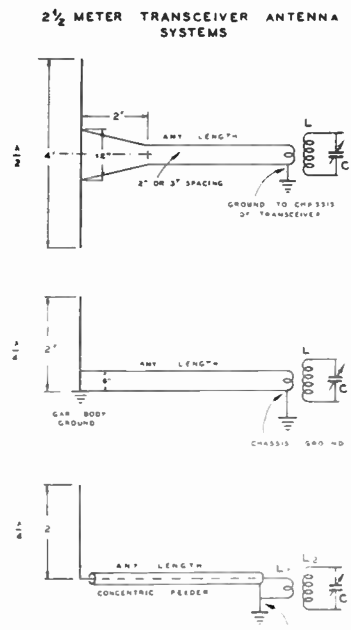


Figure 103

● 2½-Meter Antennas

Any of the antennas previously described, and which provide vertical polarization, are suitable for 2½-meter operation. Those shown in figure 103 are ideally suitable for use with a 2½-meter transceiver. The figures are self-explanatory, in that all dimensions are clearly shown. The Table showing *Antenna Array Dimensions* lists all of the data for the ultra-high-frequency bands, down to 1¼ meters. The Table, *Reflector and Director Dimensions*, shows the data for any form of Yagi or Parabolic Reflector system for wavelengths down to 1¼ meters.

● Micro-Wave Antennas

Antennas for operation in the vicinity of one meter, or less, are classified as *Micro-Wave Antennas*. Half-wave vertical rods are suitable for portable operation and in most cases they can be capacitively coupled at one end to the micro-wave transmitter or receiver. Directive arrays, especially those of the Yagi type, are easily constructed; they greatly improve the performance of micro-wave sets.

● Concentric Lines

A concentric transmission line is one of the most satisfactory means for carrying r.f. power from the transmitter to the radiating antenna. It has low losses and is weatherproof; the outer conductor is at ground potential. No radiation can occur, which is particularly important in a directional antenna system. The characteristic impedance ranges from 50 to 150 ohms, depending upon the ratio of inside diameter of the outer conductor to the outside diameter of the inner conductor. Its impedance can be calculated from the formula:

$$Z = 138 \times \text{Log}_{10} \frac{D}{d}$$

where D is the inside diameter of the outside conductor,
d is the outside diameter of the inner conductor.

The outer conductor can be grounded at any point. The inner conductor is insulated from the outer sheath by glass or isolantite beads which are placed at intervals along the line.

Concentric line feeders are used for coupling broadcast transmitters to the antenna, as well as in short-wave and u.h.f. installations. See figures 104 to 107. The impedance can be made to match exactly the center impedance of a half-wave antenna, or the impedance to ground of a quarter-wave antenna. A vertical quarter-wave antenna has an approximate radiation resistance of 37 ohms at the current loop (ground connection).

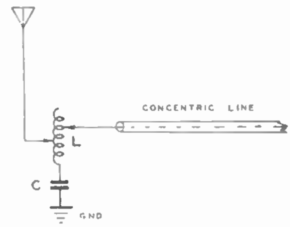


Figure 104

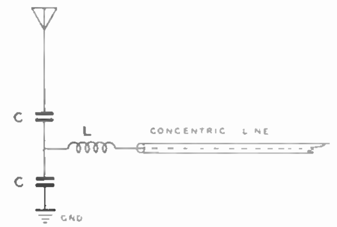


Figure 105

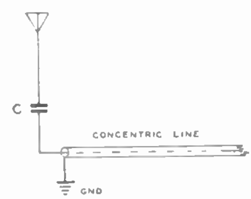


Figure 106
Concentric Feeder Systems for Broadcast Antennas with Various Terminations

Concentric Tube Transmission Line Impedance.

Impedance in Ohms	Ratio of Diameters
40	2
65	3
83	4
98	5
109	6
118	7
126	8
133	9
140	10

Inside of outer conductor diameter to outside diameter of inner conductor ratios.

FIGURE 107

Concentric lines can be buried underground and run for distances of several hundred yards without sacrificing appreciable amounts of r.f. power.

Antennas for Receiving

All of the transmitter antennas previously described are suitable for receiving; their directive properties are unchanged. All-wave receivers present a difficult problem from the standpoint of a suitable antenna that will cover the wide frequency range of the receiver.

Noise reduction is a decided factor in the design of an antenna for receiving all waves. The most prolific noise-creators are electrical devices, such as refrigerator units, violet-ray apparatus, thermostats, diathermy machines, battery chargers, electric signs, buzzers and doorbells, ignition systems of oil-burners and automobiles, elevators, street cars, electric motors, power-line disturbances which are carried along the line, telephone ringers, etc.

These disturbances are of a radio nature; however, their intensity dies away rapidly in open space. House wiring and metallic structures convey these electrical disturbances, and noise reduction can, therefore, be accomplished by locating the antenna in a clear space, also by using a lead-in of such type that pick-up on the lead-in is practically eliminated. The noise interference is sometimes so loud that it will seriously interfere with local reception. It becomes

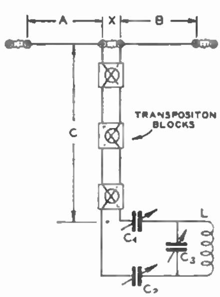


Figure 108—Noise-Reducing Shortwave Doublet Feeder System with Transposition Blocks.

A and B are 33 ft. each. C can be any length. The transposition blocks are spaced 2 feet apart. C1, C2 and C3 are 350 μμfd. variable condensers for tuning the system. L is the receiver coupling coil.

an even more troublesome factor in shortwave reception because the received signal strength is much lower than that from local broadcast stations.

Two general types of lead-ins are widely used with noise-reducing antenna systems. The shielded lead-in is effective in the broadcast range, but due to the high capacity between the shield and the lead-in conductor inside the shield, it is not often used for shortwave reception. For shortwave reception a balanced transposed line is more efficient, as shown in Fig. 108. Balanced lines consist of twisted-pair feeders or two-wire lines with transposition blocks. The latter can be tuned by means of a coil and variable condensers at the receiver in order to increase the signal energy for a comparatively wide range of frequencies.

Twisted-pair feeders cannot be easily tuned because standing wave effects will cause excessive dielectric losses. In order to cover a wide range of frequencies with twisted-pair feeders, combination *Doublet* antennas are connected through impedance-matching transformers to form an efficient all-wave antenna system. A single doublet with a twisted-pair feeder and without special transformers is suitable for operation over a very narrow band of only a few hundred kilocycles on the fundamental and third harmonic.

The design of the feeder transformers depends upon the impedance of the twisted-pair feeder, length of line and type of doublet antennas connected to the line. So many complications enter into the design of these feeder transformers that the home constructor cannot easily build them. Complete shortwave antenna kits with all proper components are available from many sources. The choice of an all-wave antenna for the home constructor is the tuned transposed feeder system, shown in Fig. 108. In noise-free locations, any single wire antenna will give good results.

Antennas for Automobiles

The efficiency of all antenna types for automobiles is comparatively low because the amount of available space around the body of the automobile is limited. Automobiles with all-metal tops prohibit the use of interior roof-antennas, so that other forms of antennas, such as shown in figures 109 and 110 are suspended under the running boards.

Under-car antennas, such as those illustrated, are located so close to the braking mechanism that they pick up an excessive amount of tire and brake static. The calcium chloride dust-laying compounds on roadbeds often cause destructive corrosion of the antenna.

Newer types of car antennas consist of chromium-plated top-of-car rods or "*whip*" antennas which have far greater signal pickup than older types of under-car antennas.

Some types of car antennas are equipped with a shielded lead-in and the receivers have a special shielded input transformer for reducing the interference from the car's ignition system. Modern developments have practically eliminated the need of spark plug suppressors.

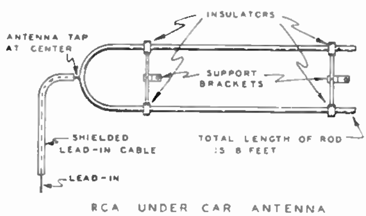


Figure 109

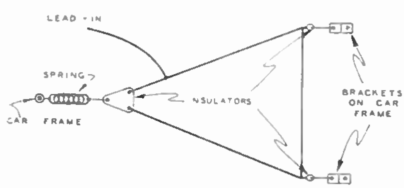


Figure 110—Triangular Antenna

• The Faraday Screen

An electrostatic shield between two coils is often used in receiver circuits in order to prevent capacitive coupling. One very effective arrangement is known as the *Faraday Screen*. It generally consists of a row of small wires, spaced from each other and connected together at one end in order to provide a connection to ground. Eddy current losses are prevented by grounding *only one end* of the wire, the other end remaining open; see figures 111 and 112.

A Faraday Screen can be constructed by winding a large number of turns of very small insulated wire on a piece of cardboard which has first been treated with insulating

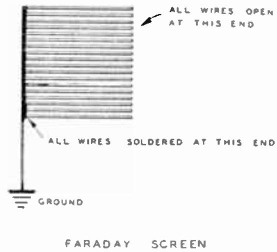


Figure 111

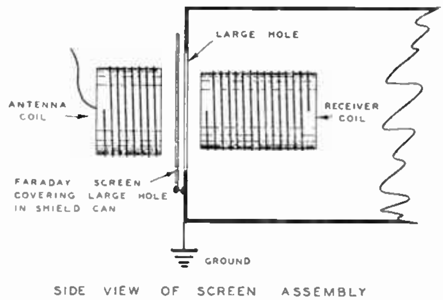


Figure 112

varnish. The wire is wound on, then a coating of insulating varnish is applied to the winding. After it has dried, one edge is trimmed with tin snips or heavy shears and the wires soldered together along the opposite edge as shown in the illustration.

• Aircraft Antennas

Antennas designed for aircraft must have a good "effective height" and very low wind resistance. The most efficient antenna electrically is a long trailing wire for both transmitting and receiving. It must be reeled-in when a landing is made, and it offers an excessive wind load at high speeds.

For beacon reception, a hollow streamlined metal rod approximately six feet in height and mounted on top of the fuselage is quite widely used. The rod must be insulated from the supporting structure. It has an effective height of about one meter, thus making it satisfactory for use with a sensitive receiver. Other forms of antennas, such as wires stretched across the wings, or from the tail to the ends of the wings, or from tail to cockpit, are satisfactory for both transmitting and receiving.

A short trailing wire, approximately 25 feet long, has less wind resistance than a rod or pole antenna.

● Marine Antennas

Single-wire antennas of the Inverted-L, T and Doublet types are used on shipboard. The wire is usually suspended between masts, or between mast and funnel. A separate antenna is widely used for short-wave reception, while for longer wave operation a break-in keying relay connects the receiver to the main transmitting antenna. Marconi antennas for small marine craft can be made more effective when more than one wire is used, such as in a cage or flat top antenna.

● Loop Antennas

When highly-directive transmission or reception is desired, loop antennas are used. A conventional type is shown in figure 113. Some are circular in shape, others are in the form of a rectangle or square.

The relative efficiency of loop antennas is very low and they are used only for such special applications as direction-finding. The directivity pattern has the same appearance as that of a half-wave dipole antenna. The response in the maximum direction (in line with the loop) is very broad, but the minima or zero signal setting is very sharp.

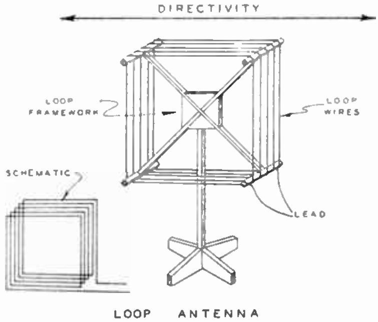
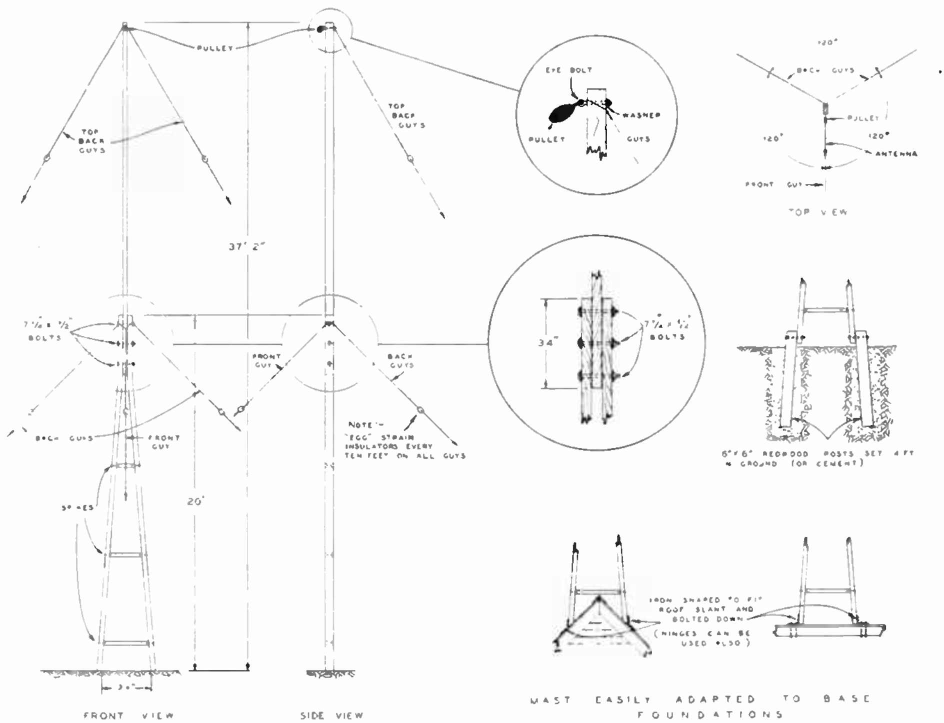


Figure 113

● Antenna Mast Construction

A practical and economical antenna mast is illustrated below. The mast is constructed of three pieces of 2x3, clear pine, each 20 feet long. The completed mast is light enough in weight for mounting on house tops, and it can be erected by two people. The mast is guyed at the top and center with three guys at each point. The guys should be broken about every ten feet with egg-type strain insulators. The illustrations give all of the necessary constructional data.



Chapter 6

Radio Receiver Theory

After radio waves are produced, the next step necessary to complete the transferring of intelligence is the *reception* of these waves. The radio receiver used for this purpose must abstract energy from the passing waves, separate the desired signal from all others, and then reproduce the modulation or code characters of the original signal. This latter function of the receiver usually entails amplification, since its output must be enormously greater than the energy obtained from the wave itself.

The antenna circuit plays an important part in this reception. Details of the antenna's function, however, are covered in another portion of this book. For the present, suffice it to say that making the antenna resonant to a particular frequency will also increase tremendously the energy received from waves of this frequency. This, in itself, assists in providing some separation between signals. Greater selectivity, however, can be made available by the use of properly arranged resonant circuits placed somewhere in the receiver in such a way as to discriminate strongly against all but the desired signal.

• Common Terms Defined

There are several important general properties of radio receivers which it is necessary to define: *selectivity, tuning, detection, sensitivity,* and *fidelity.*

The *Selectivity* of the receiver is its ability to discriminate between radio waves of different frequencies, between desired and undesired signals.

Tuning is the process of resonating r.f. circuits with the carrier frequency of a desired signal.

Detection is the process of reproducing the original signal from the radio frequency currents existing at the receiver; it is the process of *demodulation.*

The *sensitivity* of the receiver represents its ability to respond to small radio-signal voltages; it is the degree to which a receiver will respond to weak signals.

The *fidelity* of the receiver represents the accuracy with which the receiver reproduces the intelligence contained in the modulated radio wave; frequency distortion and harmonic distortion impair the fidelity.

• Basic Components

The fundamental parts of a simple radio receiver are the vacuum tube and the coupling circuits. The tube provides *amplification* and *detection,* while the r.f. coupling circuits provide the *selectivity* and determine the frequency at which the receiver will operate. Other coupling circuits in the receiver are used for supplying power to the electrodes of the vacuum tube, and also for coupling the audio-frequency amplifiers.

• Radio-Frequency Coupling

A small radio-frequency current is induced in an antenna by any radio wave which is intercepted by the antenna. This radio-frequency energy in the antenna can be made to energize a radio receiver by means of some form of *input coupling circuit.* When an inductance coil is connected in series with the antenna lead-in or feeder, the radio-frequency energy induced into the antenna will cause a small radio-frequency current to flow through coil L_1 in figure 1.

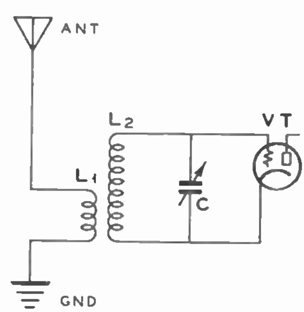


Figure 1

It will be recalled that the voltage induced across the coil is equal to the product of this current and the impedance of the coil. The *impedance* of the coil to the flow of current is made-up principally of its *reactance.* This is a function of the number of turns of wire in the coil, and the frequency of the radio signal.

In most cases, the antenna, ground and coil L_1 offer very little *selectivity,* which is always better obtained by means of *resonant tuned circuits.* As has been mentioned previously, the entire antenna system may be made resonant to the frequency of the radio signal, in which case the current flowing in the antenna circuit will be much greater. For purposes of simplicity, the standard circuit in figure 1 will be considered, in which resonant effects in the antenna usually are ignored. Selectivity is accomplished through the use of *parallel tuned circuits.* A typical circuit of this type is shown as L_2 and C, in figure 1. The current flowing through L_1 induces a current into L_2, providing the two coils L_1 and L_2 are coupled closely together. This is known as *inductive coupling.*

The antenna also may be coupled to the first tuned circuit in the radio receiver by means of capacitive coupling, as shown in figure 2.

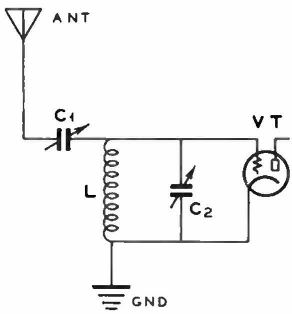


Figure 2

The capacity of condenser C_1 is very small, so that the desired amount of coupling between the antenna and the tuned circuit L-C_2 can be obtained. Too much coupling between the antenna and the first tuned circuit, either capacitive or inductive, will result in less induced current flowing through the tuned circuit than when the optimum value of coupling is used. If the antenna circuit is *resonant* to the frequency of the radio signal, and if the circuit L-C_2 in figure 2 (or L_2-C in figure 1) is tuned to this same frequency, very loose coupling is necessary in order to obtain both a high current in the coil and a high impedance across the tuned circuit.

The current which flows around and through the tuned circuit is limited only by the resistance of the circuit when the coil and condenser are tuned to resonance. The reactance of the coil is neutralized by the reactance of the condenser, so that relatively greater current may flow in the circuit L_2-C than in the coil L_1. The voltage developed at resonance across the coil or condenser is equal to the product of this current and the reactance of *either* the coil or condenser.

Since resonance increases the radio-frequency current (the reactance of the coil remaining the same) the voltage applied across the grid circuit of the vacuum tube is much greater at resonant frequency. Signals of other frequencies will not have this resonant tuned circuit effect, with the result that the voltage of those signals across the coil applied to the grid of the vacuum tube will be very minute. Additional tuned circuits in the radio receiver further discriminate against these undesired signals of other frequencies.

• Efficiency of Resonant Circuits

The efficiency of a tuned circuit can be defined as its "Q". This is a mathematical expression of the ratio of the reactance to the resistance of the coil in the tuned circuit. A high-"Q" will result in better selectivity and greater radio-frequency voltage across the grid of the vacuum tube. Low-"Q" coils are sometimes desirable where a relatively wide band of radio-frequencies must be passed through the radio-frequency amplifier, such as in modern types of high-fidelity broadcast receivers. Short-wave receivers are designed with circuits having as high a "Q" as possible in comparison to the cost involved in such designs.

The "Q" of a coil or tuned circuit is given in the following formulas:

$$(1)\ \text{"Q"} = \frac{2\pi fL}{R}$$

$$(2)\ \text{"Q"} = \frac{1}{2\pi fCR}$$

where f is the frequency,
L is the inductance of the coil,
C is the capacity across the tuned circuit,
R is the equivalent resistance in series with the tuned circuit.

Either of these expressions will provide the correct "Q", since at resonance $X_c = X_L$ and hence $2\pi fL = \dfrac{1}{2\pi fC}$.

The value of R depends upon the relative amount of coupling between the antenna and tuned circuit, or between the plate circuit of a vacuum tube and the succeeding tuned circuit; in either case, the effect is to increase the total resistance R when the coupling is increased. The resistance of the tuning condenser is relatively much lower than that of the coil, or inductance, so that special care should be exercised in designing this coil. Whenever possible, the shape of the coil should be such that its length is made equal to its diameter; this will provide a high "Q". The diameter of the wire and the spacing between turns also has a definite influence on the "Q".

At radio frequencies, most of the resistance of the inductance coil is due to "*skin effect.*" This effect increases with the frequency, and becomes significant at high frequencies because the current then is not equally distributed throughout the conductor. Instead it tends to travel only on the outermost surface of the wire. For this reason, the radio-frequency resistance may be a great many times higher than the resistance which the wire would offer to direct current.

Spaced winding, i.e., an air space between turns on the coil, reduces the *distributed capacity* between turns and also increases the "Q". Dielectric losses in the insulating material and coil forms also have an important effect on the efficiency of the coil. The proximity of other objects, such as *metal shields* or chassis, appreciably reduces the "Q" of the coil, unless the distance between the coil and the shielding is at least equal to the diameter of the coil from its sides, and twice this distance from the ends of the coil. The wire with which the coil is wound is a compromise between several factors, such as the size of the wire, its cost, allowable physical size of the coil, distributed capacity between turns, and skin effect.

The variable tuning condensers in radio receivers are designed to have as low a minimum capacity as possible, in comparison with the capacity when the plates are fully enmeshed. The maximum capacity of the tuning condenser varies from 10 micromicrofarads up to approximately 370 micromicrofarads in the various types of radio-receivers; still larger values are used in some long-wave receivers. *All-wave* radio receivers, which cover short-wave as well as broadcast wavelengths, generally use rather large tuning condensers, thereby crowding the tuning on the short wavelengths. Very small tuning condensers are desirable for short-wave receivers so that tuning of the receiver to the desired station is made more easy and the "Q" of the high frequency resonant circuits is kept high.

Band-Spread Tuning

Short-wave signals are difficult to tune when the receiver has large tuning condensers, unless some method is used to slow down the rotation of the condenser with respect to the tuning band, either mechanically or electrically. This process is known as *band-spreading*. Most short-wave stations of a particular type operate in relatively narrow bands in the short-wave spectrum and these narrow bands should be spread out by the tuning device of the receiver.

Mechanical band-spreading often consists of a two-speed dial arrangement attached to a large tuning condenser. One control on the dial operates the tuning condenser at a very slow speed, and sometimes this control is geared to an additional pointer in order to facilitate tuning-in the short-wave bands. There is a practical limit to the amount of mechanical reduction in the drive of a vernier dial before back-lash develops, which makes tuning difficult.

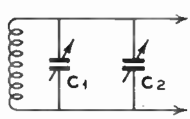


FIG. 3

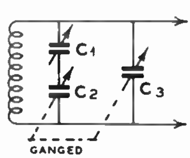


FIG. 4

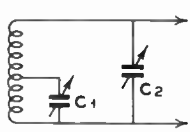


FIG. 5

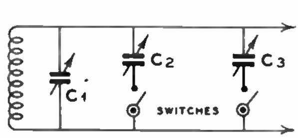


FIG. 6

ELECTRICAL BAND-SPREADING

Electrical band-spreading is accomplished in a number of ways, as shown in figures 3, 4, 5 and 6. The principle is to connect an additional tuning condenser of very small capacity across the larger tuning condenser so that equal rotations of the two condensers will cover vastly different portions of the short-wave band. The large condenser is for rough tuning or band setting, the small condenser for fine, or *vernier* tuning. A typical system of this type is shown in figure 3, in which the large tuning condenser C_1 may have a maximum capacity of any value from 100 $\mu\mu$fd. to 370 $\mu\mu$fd. The small vernier tuning condenser C_2 may have any value from 10 $\mu\mu$fd. to 50 $\mu\mu$fd., depending upon the particular design of the receiver. In some circuits the small condenser C_2 is made semi-variable by means of a screwdriver adjustment, in which case it is used only for the purpose of *aligning* several tuned circuits for single-tuning-dial-control.

The circuit in figure 4 is similar in action to that in figure 3 and has certain advantages, except from the standpoint of cost. Condenser C_3 is the usual large tuning condenser and two additional smaller tuning condensers, C_1 and C_2, are connected in series and across the large condenser C_3. If C_2 and C_3 are mechanically ganged together, the relative amount of band-spread tuning of C_1 can be made the same over the complete range of C_3. If condenser C_2 in figure 3 has a fairly high capacity, such as 350 $\mu\mu$fd., the band which can be covered by C_1 will only be a fraction as wide at the higher capacity values of C_2 as compared with its lower values. Figure 4 overcomes this disadvantage.

The band-spread method in figure 5 is often used when condensers C_1 and C_2 both have a maximum capacity of say 100 $\mu\mu$fd. Band-spreading is accomplished by means of C_1, which is connected across a small portion of the tuned circuit. The advantage of this method is that the location of the tap on the coil can be changed for the various coils which cover the different bands, with the result that fairly constant band-spread is accomplished in each coil range. The disadvantage lies in the effect produced by connecting C_1 across a portion of the coil in the r.f. circuit of a super-heterodyne receiver; the effect is to cause *image interference* to be more pronounced in this type of circuit, and makes necessary the use of additional tuned circuits.

Figure 6 illustrates another method of equalizing the degree of band-spread over a wide range of frequencies. C_1 is the large 350 $\mu\mu$fd. tuning condenser; two band-spread condensers C_2 and C_3, of 50 $\mu\mu$fd. and 15 $\mu\mu$fd. respectively, are switched across the large tuning condenser for band-spreading the short-wave bands. The 50 $\mu\mu$fd. condenser is suitable for band-spread tuning in the range from 75 to 200 meters, and the smaller condenser is suitable from 10 to 75 meters. The disadvantage of this circuit lies in the switching arrangement, which may require relatively long connecting leads; the minimum capacity of the circuit also would be rather high.

• Tuned R. F. Circuits

The foregoing discussion was devoted solely to tuned circuits. A radio-frequency amplifier tube can be connected between these tuned circuits in order to increase the *sensitivity* of the receiver. The amplification derived from the vacuum tube depends upon the type of circuit in which it is used, and if the plate load impedance can be made very high the gain may be as much as 200 or 300 times that of the signal impressed across the grid circuit. Normal values of gain in the broadcast band are in the vicinity of 100 times. A gain of 30 per r.f. stage is considered excellent for short-wave receivers which have a range of from 30 to 100 meters. Radio-frequency amplifiers for the very short wavelengths, such as from 5 to 20 meters, seldom provide a gain of more than 10 times because of the difficulty in obtaining high load impedances and the shunt effect of input capacities of most screen-grid tubes.

A simple r.f. amplifier and regenerative detector circuit is shown in figure 7.

The two L-C circuits are tuned to the same frequency throughout the tuning range of each set of coils. This requires that the coils L_2 and L_5 have equal values of induc-

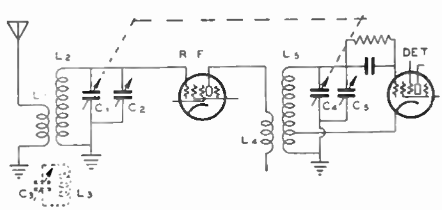


Figure 7—R. F. Amplifier and Regenerative Detector Circuit

tance, as well as equal values of shunt capacity at each point on the tuning dial. The coils can be closely matched by winding the same number of turns of wire on similar coil forms, with the same exact length of winding space for each coil. Condensers C_2 and C_3 are generally called "*padder condensers*," or "*band-setting condensers*," depending upon their maximum capacity. In certain receiver designs the ganged condensers C_1 and C_4 are used for tuning over the desired range, and C_2 and C_3 are small mica or air-dielectric trimmer condensers aligning the two tuned circuits at the high-frequency end of the tuning range. The miscellaneous circuit capacities are not the same for a detector and r.f. amplifier, so that some additional capacities such as padder condensers are needed to align the receiver properly. A resonant antenna will unbalance the r.f. stage unless L_1 is loosely coupled to L_2. Coil L_3 and condenser C_3 are closely coupled to L_2, and are sometimes used to simulate the effect of both L_1 and the output capacity of the screen-grid r.f. tube.

● Autodyne Detector

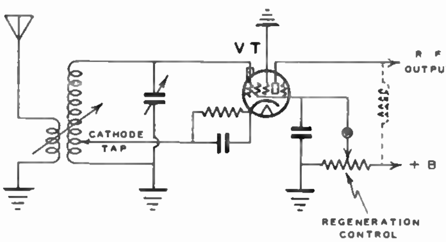
Nearly all "tuned-radio-frequency" receivers have a regenerative *autodyne detector*, similar to the one shown in figure 7. In some cases the r.f. amplifier is omitted, and the antenna is then coupled to the tuned circuit of the detector. More than one stage of r.f. amplification can be used ahead of the detector in some circuits. *Regeneration* can be obtained in a number of ways, such as with a "tickler" in the plate or screen-grid circuits of the detector, or by means of a *tap* in the tuned grid circuit, to which the cathode of the detector tube is connected. In the latter case, the screen-grid must be bypassed to the chassis ground connection; the screen-grid voltage is then varied to control the regeneration to the point of oscillation.

Regeneration is introduced by feeding back a small portion of the amplified r.f. voltage in the plate or screen circuit of the detector tube; this r.f. energy is fed back into the tuned grid circuit so that it will aid the impressed signal. If the amount of feed-back is sufficiently high, the tube will break into oscillation; heterodyne reception may then be used for receiving c.w. telegraph signals. As shown in figure 7, the "*tickler*" portion consists of that part of the coil L_3 which is between the ground and cathode connections. A better name for "*tickler*" is "*feed-back*" *coil*.

The purpose of the detector is to convert the radio-frequency signal into an intelligible audio-frequency signal which can be detected by the human ear. Audio-frequency amplifiers increase the audio-frequency energy to any desired output for headphone or loudspeaker reception.

● Regenerative R. F. Amplifiers

Radio-frequency amplifiers for wavelengths down to 30 meters can be made to operate more efficiently in a *non-regenerative* condition. Amplification and selectivity are ample over this range. For higher frequencies, on the other hand, (wavelengths below 30 meters), *controlled regeneration* in the r.f. amplifier is often very desirable for the purpose of increasing the gain and selectivity. The input impedance of the grid circuit of a radio-frequency amplifier consists of a very high capacitive reactance which becomes part of the tuning capacity for longer wavelengths. However, in very short wave receivers the input reactance of a screen-grid tube may drop to very low values, such as a few thousand ohms. The input impedance then drops to such a low value that very little amplification can be secured from the complete r.f. amplifier stage.



REGENERATIVE R. F. AMPLIFIER

Figure 8

A small amount of r.f. feed-back can be introduced to compensate for this tube loss. Regeneration can be carried to the point of actually creating the effect of negative resistance in the tuned circuit, and thereby balancing the resistance introduced in series with the tuned circuit of the relatively low parallel tube resistance. Excessive regeneration will result in too much negative resistance, which will cause the r.f. amplifier to oscillate. Operation should always be below the point of self-oscillation. A minor disadvantage of the regenerative r.f. amplifier is the need for an additional regeneration control, and the difficulty of aligning this circuit with the following tuned r.f. stages. Resonant effects of antenna systems usually must be taken into account; a variable antenna coupling device can be used for balancing out this effect. Another disadvantage is the increase in hiss, or internal noise, in the radio receiver. These disadvantages are more than offset by the ability to receive weak signals which would otherwise not be audible in the average receiver on very short waves.

● Circuit Capacities

Several capacities are involved in every tuned circuit. These are the tuning condenser capacity, tube capacity, trimmer condenser capacity, coil distributed capacity, and miscellaneous capacities due to wiring and placement of parts. These capacities all combine to increase the apparent capacity of the tuning condenser, thereby limiting the obtainable minimum capacity at the high-frequency tuning portion of the circuit. A high minimum capacity reduces the ratio of maximum-to-minimum tuning capacity, which results in a narrower tuning range for a tuning condenser of a given size. High minimum capacity is also objectionable in very-short-wave reception because the average ratio of capacity to inductance becomes too high for efficient reception.

In multi-stage tuned circuits, trimmer condensers are necessary in order to align the circuits properly for single-dial control. The trimmer condensers are adjusted at the high-frequency end of the band under test. Slight variations of inductance are often compensated for by slightly bending the end plate on the rotor of each section of the main tuning condenser. Sometimes this plate is slotted in order that it can be more easily bent in or out. The so-called secondaries of the tuned coils are often made to have the same value of inductance by matching them on some form of coil or inductance-matching bridge before the coils are placed into the receiver.

● Types of Receivers

Numerous kinds of radio receivers are used for short-wave reception:

(1) *Regenerative Detector,*

(2) *Regenerative Detector and Audio Amplifier,*

(3) *T.R.F. Receiver,*

(4) *Superregenerative Receiver,*

(5) *Superheterodyne Receiver.*

A *regenerative detector* consists of any triode or screen-grid tube in conjunction with a single tuned circuit, and some means for obtaining regeneration, as mentioned in previous discussions.

The addition of an audio amplifier to a regenerative detector increases the strength of the signal and also the sensitivity, the latter, however, only to the extent that the signal may be more easily heard; an audio amplifier ordinarily will not increase the selectivity nor the sensitivity to weak signals. Audio amplifiers are coupled to the output of a detector by means of resistance coupling, impedance coupling, or transformer coupling.

T.R.F. receivers have one or more stages of radio-frequency amplification ahead of the detector and audio amplifier. These receivers are more sensitive to weak signals and have somewhat better selectivity than the two previously mentioned types.

The *superregenerative receiver* is similar in action to a regenerative receiver, except that the regeneration is carried to a far greater extent by permitting the tube to break into oscillation. Then by means of an additional low-frequency oscillation, the detector is made to break in and out of signal-frequency oscillation at a frequency depending upon the low-frequency oscillation. Superregeneration is used on very short wavelengths, such as in the micro-wave and ultra-high-frequency regions.

The *superheterodyne receiver* consists of a radio-frequency circuit (or circuits) tuned to the frequency of the desired signal, and also an additional amplifier which is generally tuned permanently to some low frequency, such as 465 kilocycles. The incoming radio-frequency signal is converted into the new *intermediate frequency* by means of a *high-frequency oscillator* and *first detector* or *mixer tube* circuit. The additional amplifier, consisting of one or more intermediate frequency stages can be made very selective, with the result that this type of receiver is much more selective than any of the previously mentioned types.

The *superheterodyne receiver* requires a *second detector* and an audio amplifier to convert the intermediate signal into an audio signal, just as in the case of the simple regenerative detector receiver.

● Receiver Vacuum Tubes

There are dozens of different types of tubes for use in radio receivers. Many similar tubes are made in different forms, such as metal tubes, glass tubes with standard bases, glass tubes with octal bases similar to those used on metal tubes, glass tubes encased in metal shells and fitted with octal bases, and tubes with similar characteristics but differing in their heater or filament voltage and current ratings. Some tubes are designed for dry-battery filament supply, others for automobile service, and another group for operation from an a.c. source.

In general, there are certain distinct classes of tubes for particular purposes. Screen-grid tubes were primarily designed for radio-frequency amplifiers, yet they are often employed for regenerative detectors, mixers and high-gain voltage audio amplifiers. General-purpose triode tubes are designed for oscillators, detectors and audio amplifiers. Power-triodes, tetrodes and pentodes are designed for obtaining as much power output as possible in the output audio amplifier stage of a radio receiver. Diodes are designed for power supply rectifiers, radio detectors, automatic volume control circuits and noise-suppression circuits. In addition to these general types of tubes there are a great many others designed for some particular service, such as oscillator-mixer operation in a superheterodyne receiver.

All vacuum tubes require a source of power for the filament and other electrodes. Various components in a radio receiver are for the purpose of supplying direct current energy to the electrodes of the tubes, such as the plate and screen circuits. In nearly all circuits the control-grid of the vacuum tube is biased negatively with respect to the cathode, for proper amplifier action. This bias is obtained in several ways, such as from a self-biasing resistor in series with the cathode, fixed bias from the power supply, or grid-leak bias for some oscillators and detectors.

Various bypass and coupling condensers are found in different portions of the circuits throughout a radio receiver. Bypass condensers provide a low impedance for r.f. or audio frequencies around such components as resistors and choke coils. Coupling condensers provide a means of connection between plate and grid circuits in which the d.c. voltage components are of widely different values. The coupling condenser offers an infinite impedance to the d.c. voltages, and a relatively low impedance to the r.f. or a.f. voltages.

Screen-grid tubes have a higher plate impedance than triodes and therefore require a much higher value of plate-load-impedance in order to obtain the greatest possible amount of amplification in the audio or radio circuits. Screen-grid tubes are normally used in all r.f. and i.f. amplifiers because the control grid is electrostatically screened from the plate circuit. Lack of this screening would cause self-oscillation in the amplifier; when triodes are used in amplifiers the grid-to-plate capacities must be neutralized. The r.f. amplification from a triode amplifier in a radio receiver is so much less than can be obtained from a screen-grid tube amplifier that triodes are no longer used for this purpose.

Reference should be made to the chapter on *Vacuum Tubes* for data on all types of tubes. Practical applications of various types are shown in the receivers described in the succeeding chapter of this *Handbook.*

● Automatic Volume Control

An elementary circuit of an automatic volume control system is shown in figure 9. A diode tube is used as a rectifier of the carrier signal. The radio (i.f.) frequency circuit to the diode is completed through the small condenser C_1, which is too low in value to bypass audio frequencies. The carrier signal is detected or rectified, and the resulting current flows through the diode circuit and the resistance R_1. This rectified

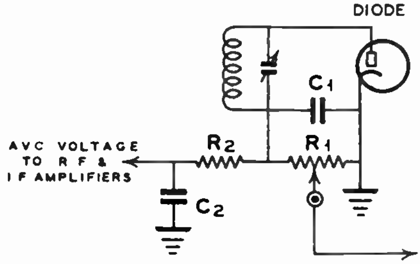


Figure 9—Typical A.V.C. Circuit Using Diode

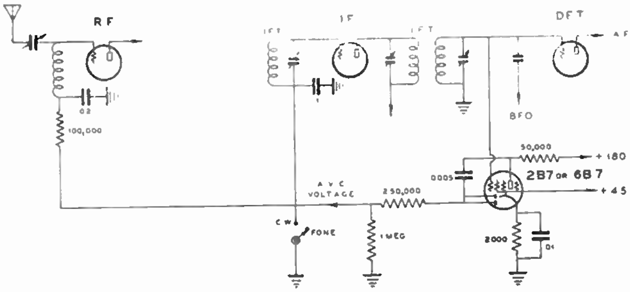


Figure 10—Automatic volume control is a distinct advantage when the receiver is used for phone reception. It automatically compensates for signal fading. Briefly, the carrier signal strength causes a control voltage to vary in proportion to the actual carrier intensity.

current develops a voltage across R_1, which is more negative at the ungrounded end.

A simple R-C (resistance-capacity) filter in the form of R_2-C_2 may be connected to the diode circuit in order to utilize the d.c. voltage for automatic volume control purposes. This filter removes the audio frequencies and also acts as a decoupling filter. The negative voltage developed across R_1 and C_2 has a value directly proportional to the incoming carrier signal. This voltage is used to bias the control-grids of some of the r.f. and i.f. amplifier stages. An increased negative bias will reduce the amplification of the radio receiver, so that a strong carrier, such as from a local broadcast station, furnishes approximately the same audio-frequency output signal as would be obtained from a distant broadcast station. Automatic volume control has the further advantage of maintaining the audio signal at a fairly constant level, even though the signal from a distant station may be fading or varying in amplitude.

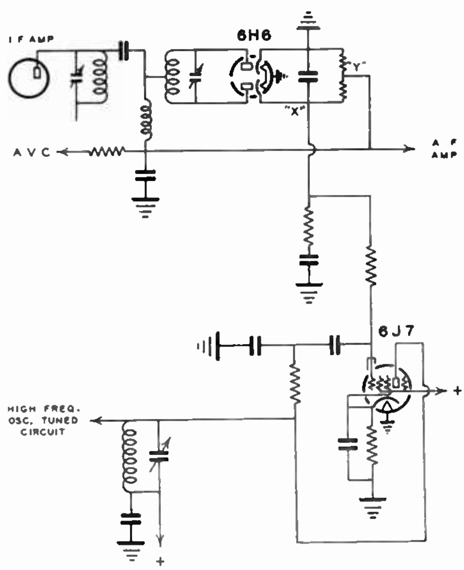
A great many different kinds of tubes are used for automatic volume control, but nearly all of these tubes operate on the principle of a diode rectifier.

Figure 10 shows a typical automatic volume control circuit which can be applied to almost any superheterodyne receiver.

Automatic Frequency Control

Many new receivers are equipped with automatic tuning dial mechanisms which require an addition to the electrical portion of the receiver in order to tune the circuits *exactly* to the carrier of the desired station. This is accomplished by *automatic frequency control,* which is an electrical device for varying the frequency of the oscillator from 5 to 15 kc. either side of the mechanically-controlled circuit. Mechanically-operated dials which tune to a fixed number of broadcast stations can neither be accurately set nor maintained in service on the exact frequency of each station. Automatic frequency control compensates for this defect, and thus there is no distortion due to mistuning.

The high frequency r.f. and detector stages are not automatically tuned; they must therefore have a very broad tuning characteristic, preferably of the band-pass type. The automatic frequency control circuit consists of two parts, one of which discriminates between a too-high or too-low dial setting and thereby translates this effect into control voltages which are negative when



AUTOMATIC FREQUENCY CONTROL

Figure 11

the dial is detuned in one direction, and positive when detuned in the opposite direction. The second portion of the circuit is to correct the high-frequency oscillator. This is accomplished by means of the 6J7 tube, as shown in figure 11.

A 6H6 can be used as an automatic volume control, detector and automatic frequency control tube, as indicated in figure 11. The principle of operation is, briefly, based upon a phase difference when the applied frequency from the i.f. amplifier is too low or too high. Both capacitive and inductive coupling are used into the 6H6 tube; a phase difference results in the point "X" in the cathode of the 6H6 tube having a positive or negative voltage which is impressed on the grid of the 6J7 "corrector tube." Audio and a.v.c. voltages can be obtained from point "Y", if desired.

The 6J7 tube acts as a variable impedance having the characteristics of an inductance or capacity, depending upon the bias on the grid of the tube. This tube is connected across the oscillator tuned circuit and thereby automatically tunes the oscillator circuit to a point which will heterodyne the incoming carrier signal into the exact frequency to which the i.f. amplifier is tuned. When this occurs, the phase relations in the 6H6 circuit are such that no further bias change is applied to the 6J7 tube.

Automatic frequency control has the disadvantage that the amount of correction varies with the wavelength of the incoming signal. This might result in an oscillator frequency change of as much as 100 kc. in the short-wave bands on an all-wave receiver incorporating a.f.c., so that a strong shortwave signal will detune the receiver from the desired station unless its own signal is very strong. For this reason provision is made for switching out the a.f.c. circuit when tuning the short wave bands.

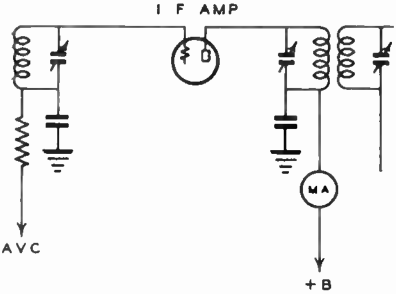


Figure 12—Circuit for Using Meter as Tuning Indicator.

• Tuning Indicators

Visual means for determining whether or not the receiver is properly tuned, as well as an indication of the relative signal strength, are both provided by means of *tuning indicators* of the meter or vacuum tube types. Direct current milliammeters can be connected in the plate return circuit of an r.f. amplifier in such a manner that the change in plate current, due to the a.v.c. voltage which is supplied to that tube, will indicate proper tuning or *resonance*. Sometimes these d.c. meters are built in such a manner as to produce a shadow of varying width. Vacuum tube tuning indicators are designed so that an electron-ray "eye" changes its relative size when the input circuit of the tube is connected across part of the d.c. component of the automatic volume control circuit.

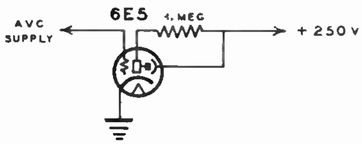


Figure 13—Electron Ray "Tuning Eye" Indicator.

• Beat-Frequency Oscillators

Beat-frequency oscillators, usually called "*b.f.o.*" in superheterodyne receivers, are a necessary adjunct for reception of c.w. telegraph signals on superheterodynes. The oscillator is coupled into the second detector circuit and supplies a weak signal of nearly the same frequency as that of the desired signal from the output of the i.f. amplifier. If the i.f. amplifier is tuned to 465 kc., for example, the b.f.o. is tuned to approximately 464 or 466 kc. in order to produce a 1,000 cycle beat-note in the output of the second detector of the superheterodyne. The carrier signal would otherwise be inaudible. The b.f.o. is not used for voice reception, except as an aid in tuning a weak carrier to zero beat, or in searching for weak stations.

The b.f.o. input to the second detector need only be sufficient to give a good beatnote on an average signal. Too much coupling into the second detector will give an excessively high hiss level, and masking of weak signals by the high noise background will result. This oscillator should be well shielded to prevent harmonics of the circuit from radiating into the front end of the radio receiver, thereby producing undesired whistles in various portions of the short wave band. The b.f.o. circuit should have as high a C-to-L ratio as possible in order to obtain an output of good stability.

• Crystal Filters

The selectivity of an intermediate-frequency amplifier can be greatly increased for c.w. reception by means of a quartz crystal filter. This results in a better signal-to-noise ratio, and is a very satisfactory means for obtaining a high degree of selectivity in the i.f. amplifier. The quartz crystal is placed in the i.f. amplifier circuit in such a way that it acts as a very sharply resonant filter which will only pass an extremely narrow band of frequencies. A typical crystal filter circuit is shown in figure 14.

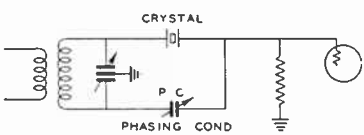


Figure 14—Typical Crystal Filter Circuit.

The crystal functions as a series-resonant circuit having a very high "Q." The capacity across the crystal holder is neutralized by means of the phasing condenser and center-tapped tuning condenser or center-tapped input coil. The phasing condenser can also be made to change the selectivity characteristic of the filter circuit, and therefore this control always should be located on the front panel of the radio receiver.

The circuit in figure 15 will illustrate the principle of operation of a quartz crystal filter.

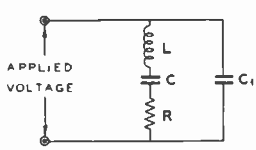


Figure 15—Equivalent Circuit of a Quartz Crystal.

The quartz crystal may be compared to the equivalent electrical circuit shown, where C_1 is the capacity across the quartz plate when not vibrating, R is the resistance equivalent to the frictional effects of the vibrating crystal, L the inductance corresponding to the inertia, and C the capacity corresponding to the elasticity. On one side of resonance the circuit has capacitive reactance, due to the elastic forces which control the crystal vibrations, while on the other side of resonance the reactance is inductive because of the effects of inertia. The crystal vibrates freely at resonance, its amplitude being limited by the frictional effects at resonance. L and C are equal and opposite in reactance, the impedance is very low, and the resonant frequency is the same as the mechanical vibration mode.

A typical 451 kc. quartz crystal has an equivalent inductance of 3.5 henrys and a series capacity of less than 0.1 $\mu\mu$fd. The effective "Q" may run as high as 10,000, which results in an extremely sharp resonant curve, not obtainable with ordinary condensers and coils. At frequencies slightly off resonance, the series impedance is extremely high due to the minute series capacity C and enormous inductance L.

By placing the phasing condenser C_1 in the circuit so that the voltage across it is out of phase with that across the crystal, the parallel resonance can be shifted above or below the series crystal resonance. Thus the phasing condenser can be adjusted so that the parallel resonance causes a sharp dip in the response curve at some desired point, such as 2 kc. from the desired signal peak. This effect can be utilized to eliminate completely the unwanted sideband 1 kc. away from zero-beat for c.w. reception. The b.f.o. then provides a true single signal effect, i.e., a single beat frequency note. This effectively increases the number of c.w. channels that can be used in any short-wave band. The series resonant effect of the crystal passes the desired signal through the i.f. amplifier for further amplification.

Other typical quartz crystal filter circuits are shown in figures 16, 17 and 18.

The ideal response curve for an i.f. amplifier in either a phone or c.w. receiver would be *flat topped* and *straight sided.* The "pass band" would be somewhat wider for phone, however, than for c.w. An ideal c.w. curve would have a 300 or 400 cycle flat top, while for phone the flat top for good intelligibility and maximum freedom from QRM would be 3000 or 4000 cycles wide. The phone *fidelity* would be impaired with this degree of

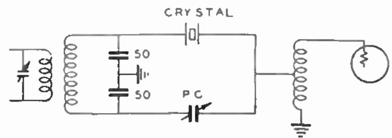


Figure 16

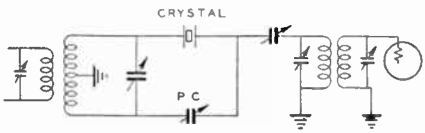


Figure 17

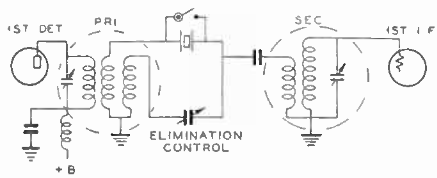


Figure 18

selectivity because of the chopping off of the higher frequency sidebands, but the intelligibility would still be quite good in spite of the narrow pass-band. The narrow pass band has the advantage of allowing one to discriminate between two stations quite close together in frequency without "slop-over" interference.

By *straight sided* is meant that the response drops very rapidly to an extremely low value either side of the pass band. For freedom from interference from strong local stations, the response should drop at least 120 db; otherwise the local may come through as bad interference even though not in the actual "pass band." The high degree of attenuation is necessary because of the tremendous difference between the signal strength of a nearby station as compared to a distant one.

Series crystal circuits, as commonly used in single signal superheterodynes, give a very narrow response width at 465 kc., and while the response is a little narrower than optimum for c.w., it is entirely satisfactory for c.w. work. However, a 465 kc. series crystal filter has a response much too narrow for intelligible phone reception.

The main disadvantage of the series crystal filter is the presence of a wide "skirt" in the response curve; in other words, the response curve resembles a volcano. Thus it does not meet the "straight sided" requirement of an ideal filter.

• Wide Band Crystal Filters

For radiophone reception, a higher frequency filter crystal and i.f. amplifier may be used to give a wider response curve. By using 1550 kc. instead of 465 kc., the filter will have a much wider pass band, wide enough to pass intelligible phone signals yet still sharp enough to be useful for c.w. reception.

The same effect is sometimes procured by using several quartz filter crystals in the 465 kc. vicinity in a suitable network. This gives a wider pass band the same as does a 1550 kc. crystal filter and at the same time has the additional advantage of steeper sides, or more rapid attenuation.

Another type of wide band filter is the *Transfilter*, an electro-mechanical device that is piezo electric in action yet cannot be compared to a quartz crystal filter. Small, piezo electric Rochelle salt crystal "driver" elements actuate a small, steel "resonating rod." The device has higher mechanical damping than a quartz crystal resonator, and therefore is not so sharp.

By the incorporation of impedance matching networks or tuned circuits in the filter circuit, it is possible to modify the shape of the response curve. This gives a control over the selectivity, and enables one to vary the band width from approximately 3 kc. up to 10 kc., making the device highly useful for amateur phone work.

Inasmuch as the "Transfilter" is commercially available as a complete resonator unit, detailed constructional data will not be given here. A word of warning is in order, however, to those designing receivers in which a Transfilter is to be used. The receiver should be so laid out mechanically and the filter unit placed so that it will not become heated from other components. Temperatures above 130 degrees F. will damage the small Rochelle salt crystal plates.

• Noise Suppression

The problem of noise suppression confronts the listener who is located in such places where interference from power lines, electrical appliances and automobile ignition systems is troublesome. This noise is often of such intensity as to swamp out signals from desired stations.

There are three principal methods for reducing this noise:

(1) A.c. line filters at the source of interference, if the noise is created by an electrical appliance.
(2) Noise-balancing circuits, for the reduction of power-leak interference.
(3) Noise-limiting circuits, for the reduction of interference caused by automobile ignition systems.

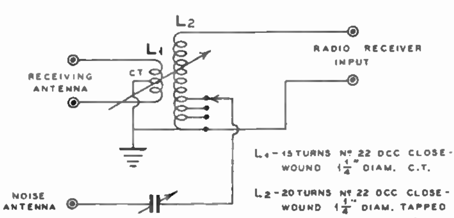
• Line Filters

Household appliances, such as electric mixers, heating pads, vacuum sweepers, refrigerators, oil-burners, sewing machines, doorbells, etc., create an interference of an intermittent nature. The insertion of a line filter near the source of interference often will effect a complete cure. Filters for small appliances can consist of a 0.1 ufd. condenser connected across the 110 volt a.c. line. Two condensers in series across the line, with the mid-point connected to ground, can be used in conjunction with ultra-violet-ray machines, refrigerators, oil-burner furnaces, and other more stubborn offenders. In severe cases of interference, additional filters in the form of heavy-duty r.f. choke coils must be connected in series with the 110 volt a.c. line on both sides of the line.

• Jones Noise-Balancing System

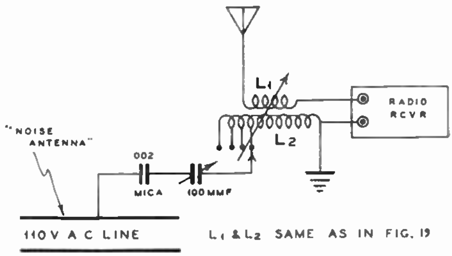
A very troublesome form of interference which has heretofore been incurable, except by elimination directly at the source, is that which is carried along the power lines. This form of interference is of such a continuous nature, or buzz, that none of the noise-limiting circuits has proved of value in reducing the noise. Noise-limiters are effective only on popping types of noise, such as automobile ignition.

Power-line noise interference can be greatly reduced by the installation of a noise-balancing circuit ahead of the receiver, as shown in figures 19 and 20. The noise-



NOISE BALANCING COUPLER CIRCUIT

Figure 19



NOISE BALANCING COUPLER CIRCUIT

Figure 20

balancing circuit adds the noise components from a separate noise antenna in such a manner that this noise antenna will buck the noise picked up by the regular receiving antenna. The noise antenna can consist of a connection to one side of the a.c. line, in some cases, while at other times an additional wire, 20 to 50 feet in length, can be run parallel to the a.c. house supply line. The noise antenna should pick up as much noise as possible in comparison with the amount of signal pick-up. The regular receiving antenna should be a good-sized outdoor antenna, so that the signal-to-noise ratio will be as high as possible. When the noise components are balanced-out in the circuit ahead of the receiver, the signals will not be appreciably attenuated.

Noise-balancing is not a simple process; it requires a bit of experimentation in order to obtain good results. When proper adjustments have been made, it is possible to reduce the power-leak noise from 3 to 5 "R" points without reducing the signal strength more than one "R" point, and in some cases there will be no reduction in signal strength whatsoever. This means that fairly weak signals can be received through terrific power-leak interference. Hash-type interference from electrical appliances can be reduced to a very low value by means of the same circuits.

The Noise Balancer, figures 19 and 20, must have variable coupling between the two coils in order to obtain a balancing-out effect. Different noise antennas generally are needed for different amateur bands.

The noise at one part of the short-wave spectrum occasionally will be of a different phase than the same type of noise in the next short-wave band. This requires a reversal of the connecting leads to the coil L_1 from the antenna feeders. If a single-wire feeder or an ordinary antenna and ground are used for receiving, one connection to the coil L_1 (figure 19) is unused. The position of the tap on coil L_2 depends upon the amount of noise which is picked up by the noise antenna. In adjusting the coupler, one antenna is disconnected while the other is being adjusted, and vice versa, until the noise level as heard in the receiver is approximately the same with either antenna. Incorrect connection to coil L_1 will increase the noise as heard in the radio receiver, and the correct connection will reduce the noise. Careful tuning of the variable condenser and proper coupling between the two coils will result in either a complete elimination of the noise or its reduction to a low value.

The connecting leads to the radio receiver should be fairly short. The coil turns given in the circuit diagram for this noise-balancing coupler are for short-wave operation over the range of from 10 to 80 meters. More coil turns are needed for longer wavelengths.

• Noise-Limiting Circuits

Numerous noise-limiting circuits have become popular in the past year. These circuits are beneficial in overcoming automobile ignition interference. They operate on the principle that each individual noise-pulse is of very short duration, yet of extremely high amplitude. The popping or clicking type of noise from electrical ignition systems may produce a signal ten to twenty times as great as the incoming radio signal.

If the duration of the noise peak is sufficiently short, the receiver can be made inoperative during the noise peak without the human ear detecting the total loss of signal. Some noise-limiters, or eliminators, actually "*punch a hole*" in the signal, while others merely *limit* the maximum peak signal which reaches the headphones or loudspeaker.

The noise peak is of such short duration that it would not be objectionable, except for the fact that it produces an overloading effect in the receiver which increases its time constant. A sharp voltage peak will give a "kick" to the diaphragm of the headphones or speaker, and the momentum or inertia keeps the diaphragm in motion until the damping of the diaphragm stops it. This movement produces a popping sound which may completely obliterate the desired signal. If the noise peak can be limited to an amplitude equal to that of the desired signal, the resulting interference is practically negligible, except in extreme cases.

• Copper-Oxide-Rectifier Noise Limiter

Figure 25 shows a new circuit which is automatic in its action and very effective for reducing ignition interference in the output of the radio receiver. It consists of a small copper-oxide rectifier, of the type used for a.c. voltmeter replacement purposes. The rectifier is operated as a non-linear resistor by connecting the positive and minus leads together for one terminal, and the two a.c. leads together for the other terminal. With no a.c. impressed, the impedance is nearly 1,000 ohms. When the a.c. voltage across the oxide resistor is between one and two volts, the resistor value drops to less than 100 ohms; this unit therefore can be used as a short-circuiting device across the low-level audio section of the radio receiver.

The impedance of the oxide-rectifier is rather low for connection directly across the plate circuit of an audio amplifier and it should be connected therefore across a center-tapped choke, as shown in figure 21, or across the primary of a step-up transformer, as shown in figure 22.

The incoming signal will be slightly attenuated and noise impulses of a high amplitude will be "leveled-off" to an amplitude little higher than that of the desired incoming signal. This type of noise-limiter also will limit the volume of a code or 'phone signal, unless additional audio amplifiers are added to the receiver, as shown in figure 22.

• Neon-Bulb Noise-Limiter

A 2-watt neon bulb can be connected across the primary of a loud-speaker output transformer to provide noise limiting, but

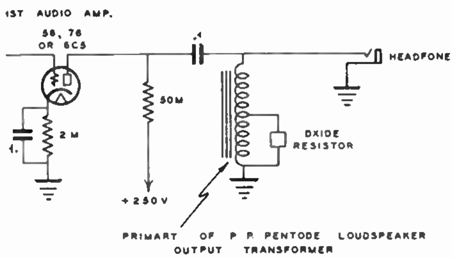


Figure 21—Automatic Noise Limiter Circuit.

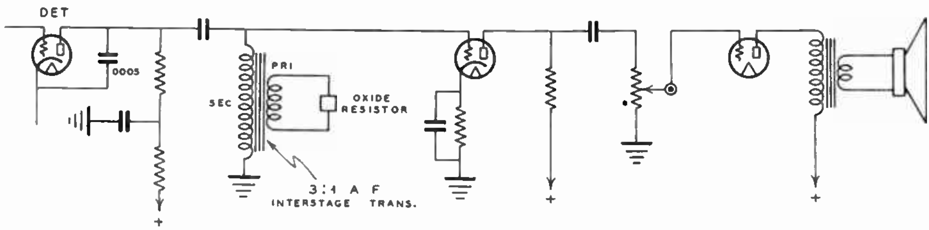


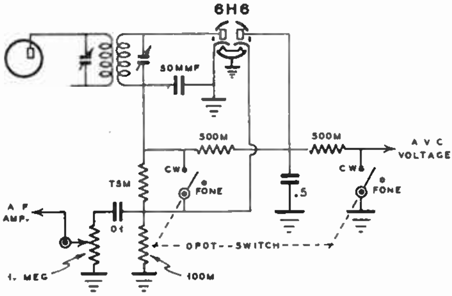
Figure 22—Oxide Rectifier Noise Silencer Circuit for Loud Speaker.

the resistor must first be removed from the base of the neon bulb. By setting the audio volume control to a certain critical point, the neon bulb will flash-over on noise pulses and tend to act as a noise-limiter. The bulb must not be shunted with condensers in the output circuit; condensers will charge and discharge, and produce a loud popping sound. The neon bulb is not as satisfactory for noise-limiting purposes as the copper-oxide rectifier. A high-level audio system is required for operation of the bulb-limiter, since the latter requires from 60 to 100 volts potential in order to flash-over and cause the bulb to act as a low resistance across the output.

● Noise-Silencers for Connection Into I. F. Amplifier Circuits

Several noise-silencing or limiting circuits have been developed for connection into the i.f. or detector portions of a superheterodyne receiver. Tests conducted with a great many of these circuits have indicated that the one shown in figure 23 is among the most practical and desirable for use in amateur communications receivers. The noise-silencing action is entirely automatic and does not require readjustment for each incoming signal.

A double-diode, such as a 6H6, or two separate tubes are necessary for second detector and noise-suppression tubes. One diode acts as a second detector and a.v.c. tube, the other being connected across it as a noise-suppression tube. The principle of operation is as follows: The incoming carrier signal will build up a certain value of a.v.c. voltage across the 75,000 and 100,000 ohm resistors in the detector diode. The plate of the noise diode is connected across these two resistors, as well as the cathode of the noise diode, as shown in figure 23. The plate of the noise diode will remain at the average potential developed by the a.v.c. voltage due to the carrier signal. The time constant of the ½-megohm resistor and ½-μfd. condenser in the noise diode plate circuit will not follow the short pulse period of a noise signal. This noise pulse will act upon the cathode of the noise diode, due to the very short time constant in that circuit. The noise peak causes the cathode to be more negative than the plate, so that the noise diode conducts current and drops to a very low impedance value. This effectively short-circuits the audio-frequency output for the duration of the noise pulse. Thus it can be seen that this noise silencer will operate very effectively on noise pulses of short-time duration, such as ignition noise, without destroying the intelligibility of the desired signal. However, in the case of a power-leak which produces a more or less constant noise voltage, the signal would be blocked out for so great a time that it would be unintelligible.



AUTOMATIC NOISE SILENCER, DETECTOR & AVC SYSTEM

Figure 23

The noise-silencer shown in figure 23 can be used for either 'phone or c.w. reception, but is most effective for the latter. The noise diode for 'phone reception must be set so that it will not operate for noise pulses of an amplitude less than twice that of the incoming carrier signal; for c.w. the device can be made to operate for any noise pulse of greater intensity than the c.w. carrier. The changeover from 'phone to c.w. is accomplished by short-circuiting the 75,000 ohm resistor. This operation can be accomplished by means of a single-pole-single-throw switch, or, if desired, by a double-pole-single-throw switch, in which case the automatic volume control can simultaneously be cut off for c.w. reception.

• Receiver Adjustments

Satisfactory results can only be obtained from a radio receiver when it is properly aligned and adjusted. The most practical technique for making these adjustments is given in the following discussion:

The simplest type of regenerative receiver requires little adjustment other than those necessary to insure correct tuning and smooth regeneration over some desired range. Receivers of the tuned radio-frequency type and superheterodynes require precise alignment to obtain the highest possible degree of selectivity and sensitivity.

• Test Instruments

Only a very small number of instruments are necessary to check and align any multi-tube receiver, the most important of these testing units being a modulated oscillator and a d.c. and a.c. voltmeter. The meters are essential in checking the voltage applied at each circuit point from the power supply. NOTE: If the a.c. voltmeter is of the oxide-rectifier type, it can be used, in addition, as an output meter when connected across the receiver output when tuning to a modulated signal. If the signal is a steady tone, such as from a test oscillator, the output meter will indicate the value of the detected signal. In this manner line-up adjustments may be visually noted on the meter rather than by increases or decreases of sound intensity as detected by ear.

Receiver Alignment

• Tuned R. F. Receivers

The alignment procedure in a multi-stage r.f. receiver is exactly the same as aligning a single stage. If the detector is regenerative, each preceding stage is successively aligned while keeping the detector circuit tuned to the test signal, the latter being a station signal or one locally generated by a test oscillator loosely coupled to the antenna lead. During these adjustments the r. f. amplifier gain control is adjusted for maximum sensitivity, assuming that the r.f. amplifier is stable and does not oscillate. Oscillation is indicative of improper bypassing or shielding. Often a sensitive receiver can be roughly aligned by tuning for maximum noise pick-up, such as parasitic oscillations originating from static or electrical machinery.

• Superheterodynes

A superheterodyne presents an involved alignment procedure since it is necessary to align both the oscillator and first detector as well as the intermediate frequency amplifier. In this case, the latter should be aligned first.

METHOD: A calibrated modulated oscillator is set to the frequency of the i.f. amplifier; this is usually between 175 and 500 kc. A lead from the oscillator is connected to the grid of the last i.f. stage, and C_5 and C_6 of figure 24 varied until maximum signal strength is obtained in the output of the 2nd detector or audio amplifier. The adjustment can be simplified if the receiver has a.v.c., the tuning meter being used to indicate the maximum signal strength. Since the coupling inductances L_5 and L_6 are generally fixed, the only possible adjustment will be by varying the trimmer condensers.

After C_5 and C_6 are properly set, the oscillator power is decreased, then coupled to the grid of the first i.f. amplifier tube. C_3 and C_4 may then be adjusted for maximum signal strength. The r.f. input to the receiver must be kept at an optimum value to insure signal readability. The procedure is repeated to align C_1 and C_2, providing the receiver has two i.f. stages.

Sometimes it is necessary to disconnect the first detector grid lead from the coil, grounding it through a 1000 or 5000 ohm grid leak, and the test oscillator coupled through a small capacity to the grid. The oscillator should preferably have some form of attenuator; however, the coupling may be varied by moving the oscillator lead further away from the tube grid into which it is coupled. The first detector acts as an ampli-

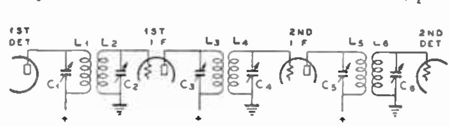


Figure 24—I. F. Amplifier.

fier. After the i.f. is aligned, the first detector grid lead is connected back to its r.f. coil.

The technique of lining-up the first detector and r.f. stages, if any, is precisely the same as that described in aligning a tuned r.f. receiver. However, the line-up with the r.f. oscillator is slightly modified. METHOD: The h.f. oscillator is used to provide a signal in the first detector which will beat with the desired signal to form a new signal at the frequency to which the i.f. amplifier is tuned. If this is 450 kc., the h.f. oscillator should tune to 450 kc. higher frequency than that of the first detector and r.f. stage. Figure 25 illustrates this circuit.

In general, coil L_2 must have less inductance than L_1, and C_4 must have less tuning range than C_1. These requirements necessitate that L_2 have less turns than L_1 and less capacity in C_4 than in C_1. If C_1 and C_4 are of the same capacity and are coupled in tandem, a fixed or variable condenser C_3 is placed in series with C_4 to reduce its maximum capacity. C_2 and C_5 may be either trimmer or band-setting condensers. C_3 is required at longer wavelengths where the ratio of the oscillator to detector frequency is not approaching unity. For example: at 14,000 kc. with the oscillator at 14,450 kc., no series condenser is necessary, but one

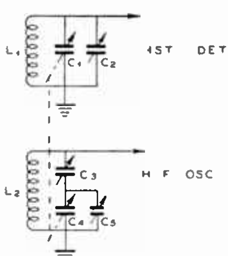


Figure 25—Front-End of Superheterodyne.

would be required at frequencies of 2,000 kc. and 2,450 kc. if the tuning condensers C_1 and C_4 were very large.

• Alignment Procedure

Actual alignment of the front end of a "superhet," such as shown in figure 25, follows: The *test* oscillator is set at the highest frequency which can be tuned in with a given set of coils. This may require a little manipulation, but if the tuning range is known or can be estimated, an approximate frequency setting of the test oscillator can be made.

The test signal intensity is increased in value until it is heard or can be measured at the output of the receiver. C_5 is then adjusted to bring the dial reading to the desired point for a given frequency, providing the dial is calibrated. C_2 is then adjusted for maximum sensitivity. Next, the tuning dial is rotated through to nearly full capacity setting of C_1 and C_4, of figure 25, and the test oscillator set for this lower frequency. These circuits can be aligned by moving the tuning dial while adjusting "padding" condenser C_3 with a screwdriver or by plate bending of C_1.

A middle dial setting can be checked by means of a third setting of the test oscillator and plate bending of C_1. Sometimes L_2 has to have considerably less turns than L_1 and a few turns added or subtracted to allow the h.f. oscillator to tune through the whole range at precisely 450 kc. higher in frequency than the detector and r.f. stages.

• Multi-Band Receivers

Individual coils in multi-band receivers with coil switching arrangements must have small

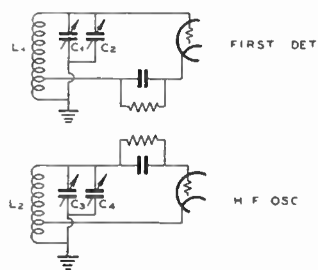


Figure 26—Another Type of Front-End.

trimmer condensers shunted across the inductive circuits, as shown in figure 27. This allows fairly accurate alignment in each band by following the procedure previously

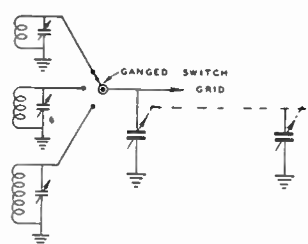


Figure 27—Tuned Circuits for Coil Switching

outlined. In assembling a superheterodyne, the labor of checking is rather long and tedious since each coil must have *exactly* the correct number of turns because bending the main tuning condenser plates would unbalance or misalign all other coils. Unfortunately in receivers incorporating coil switching arrangements, it is impossible to obtain *accurate* circuit alignment on all coils. Many commercially built receivers use two stages of r.f. ahead of the first detector, tuned rather broadly in order to overcome this defect and obtain better signal-to-noise and image ratios.

If either the r.f. stage or first detector is regenerative, it must track exactly with the h.f. oscillator. This type of circuit is shown in figure 26 where C_1 and C_3 are approximately 25 μμfd. ganged tuning condensers on the main tuning dial, and C_2 and C_4 are band setting condensers of 100 to 140 μμfd. In this instance C_2 can be used as a panel-operated trimmer condenser to hold the circuits exactly in line at high degrees of regeneration. The series padding condenser C_3 of figure 25 is not required in this class of receiver due to the very narrow band tuning-range of C_1 and C_3. The coil turns on L_1 and L_2 can be adjusted so that at random settings of C_2 and C_4 they will give practically perfect alignment. Varying the coil turns and spacing between turns will insure good tracking throughout all the amateur bands with the possible exception of the 160 meter band. This form of receiver invariably uses plug-in coils which first must be adjusted properly, the turns then being cemented in place with celluloidal cement.

Crystal Filter Alignment

In lining up the i.f. amplifier for use with a crystal filter, it is customary to employ the crystal itself as an oscillator. The circuit shown in figure 28 should be used. A

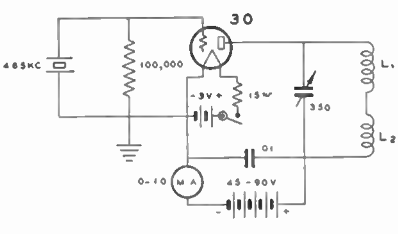


Figure 28—Rough Alignment of Crystal Filter.

winding from an i.f. transformer can be used for the plate inductance. If none is handy, a b.f.o. coil can be used. In either case, it is necessary to disconnect the trimmer across the winding.

For lining-up purposes, a type 30 tube with 2 volts a.c. on the filament will suffice; the a.c. modulates the signal and simplifies the adjusting procedure. Plate voltage (180 volts) can be secured from a tap on the receiver voltage divider or procured from one or two "B" batteries. A milliammeter inserted in the plate circuit will indicate oscillation, the plate current dipping as the condenser tunes the inductance to the resonant frequency of the crystal. The oscillator is then used as a "line up" oscillator as already described earlier in this chapter.

Exact i.f. alignment should be made with the crystal *in the circuit*, after the preliminary adjustment is made, because the crystal frequency is not *exactly* the same in a resonator as in an oscillator.

In adjusting the crystal filter, the phasing condenser and input tuning condenser should be adjusted simultaneously for maximum signal response, then a slight readjustment of the phasing condenser will allow elimination of the other sideband.

Notes

In lining up a receiver which has automatic volume control (a.v.c.) it is considered good practice to keep the test-oscillator signal near the threshold sensitivity at all times to give the effect of a very weak signal relative to the audio amplifier output with the audio gain control on maximum setting.

In checking over a receiver certain troubles are often difficult to locate. By making voltage or continuity tests, blown-out condensers, or burned-out resistors, coils or transformers may usually be located. Oscillators are usually checked by means of a d.c. voltmeter connected from ground to screen or plate-return circuits. Short-circuiting the tuning condenser plates usually should produce a change in voltmeter reading. A vacuum-tube voltmeter is also very handy for the purpose of measuring the correct amount of oscillator r.f. voltage supplied to the first detector circuit. The proper value of the r.f. voltage is approximately one volt less than the fixed grid bias on the first detector when the voltage is introduced into either the grid or the cathode circuit.

Incorrect voltages, poor resistors or leaky bypass or blocking condensers will ruin the audio tone of the receiver. Defective tubes can be checked in a tube tester. Loudspeaker rattle is not always a defect in the voice coil or spider support, or metallic filings in its air-gap; more often the distortion is caused by overloading the audio amplifier. An i.f. amplifier can also impair splendid tone due to a defective tube or overloading of the final i.f. tube. In some circuits the last i.f. tube will overload on strong carrier signals. Diode detectors provide best fidelity when operated at fairly high input levels, which means that there must be ample voltage swing delivered by the last i.f. tube.

Chapter 7

Radio Receiver Construction

A RECEIVER of modest cost, incorporating a dual-triode tube which serves the combined purpose of a detector and audio amplifier, is shown in figure 1. This receiver operates from dry-cells for the filament supply, and from either a power pack or B-batteries for the plate supply. The type-19 dual-triode tube enables this receiver to give performance comparable with that of any other dry-cell operated receiver in which two separate tubes are used for detection and audio amplification.

The receiver is of the regenerative type, regeneration being controlled by means of a midget variable condenser of 140 $\mu\mu$fd. capacity. Band-spread tuning is accomplished by means of a 15 $\mu\mu$fd. midget variable condenser in shunt with the main "tank" condenser of either 50 or 100 $\mu\mu$fd. Satisfactory operation can be secured from a single 45-volt B battery, but performance is improved if the B-supply is increased to 90 volts.

Pictorial and schematic wiring diagrams and front and rear view illustrations of the receiver show clearly how the parts are mounted and wired. The receiver baseboard should be of oak or other hardwood, 9 in. x 11 in. x ¾ in. Small wood cleats are screwed to the underside of the board at each end so as to elevate the board slightly above the operating table and thereby conceal many of the connecting wires.

The front panel is of no. 10 or 12 gauge aluminum, 7 in. x 9 in. A slow-motion vernier dial is a distinct aid in tuning. An on-off toggle snap switch is provided for the purpose of disconnecting the battery supply from the receiver when not in use.

The insulated antenna lead-in is capacity coupled to the receiver by twisting a few turns of it around the protruding wire hook which is attached to the antenna binding post at the rear of the receiver baseboard. The number of twists in the lead-in wire can be varied in order to overcome antenna dead-spot effects; three or four twists will suffice for ordinary purposes.

The receiver is capable of covering all of the amateur and intermediate short-wave bands from 20 to 160 meters by winding a set of four separate coils on standard 1½ in. diameter 4-prong plug-in coil forms. Complete coil data and specifications are given on pages 134 and 135.

The only major precaution in building this receiver is to guard against incorrect wiring of the 6-prong socket which holds the type 19 tube. Careful adherence to the pictorial wiring diagram will safeguard the builder against error.

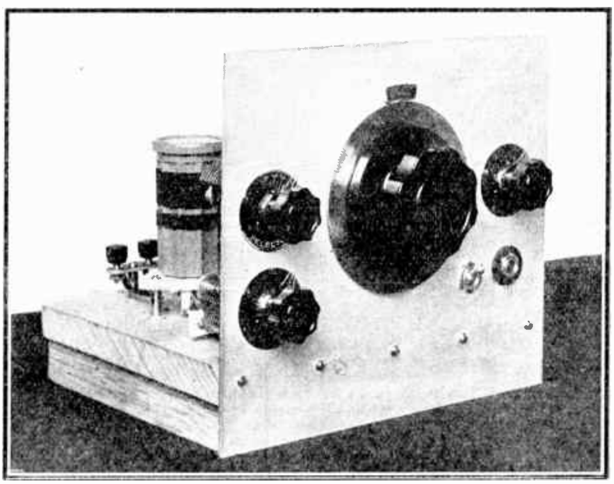


Figure 1—Dual Triode Regenerative Receiver, wood baseboard model described in detail in the text. Components should preferably be mounted as shown here and in figure 2.

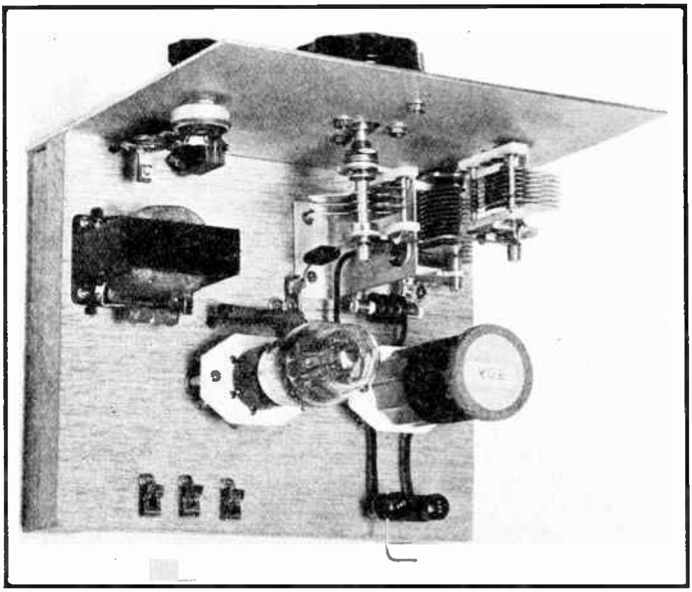
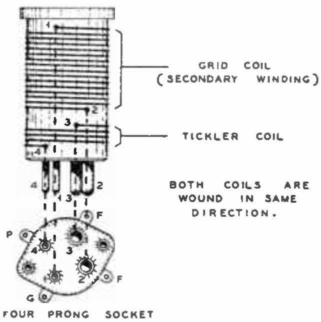


Figure 2—Rear View of the Dual Triode Receiver, Showing Layout of Parts.



COIL DATA

The upper coil is the grid (secondary) coil. Start the winding at point 1, make the connection to prong 1. The bottom of the grid coil (2) connects to prong 2. The top of the tickler coil (3) connects to prong 3; the bottom of the tickler (4) connects to prong 4. Mark the coil prongs and the coil socket contacts to correspond with these numbers. See the pictorial layout to show how the connections are made to the coil socket. Make certain that Connection No. 1 goes to the stators of both tuning condensers, and also to one side of the .0001 μfd. grid condenser. Likewise, take care to see that Connection No. 4 goes to the plate of the detector portion (P2) of the type 19 tube. If these connections are not properly made, the receiver will not function. The antenna lead-in wire can be looped around the No. 1 connecting lead.

COIL WINDING DATA

The secondary coil and the tickler coil are both wound in the same direction.

20-METER COIL: Secondary winding—7 turns of No. 22 DSC wire, space-wound to cover a winding space of 1-in.

Tickler Winding—5 turns of No. 22 DSC wire, close-wound, and spaced about ⅛-in. from the secondary winding.

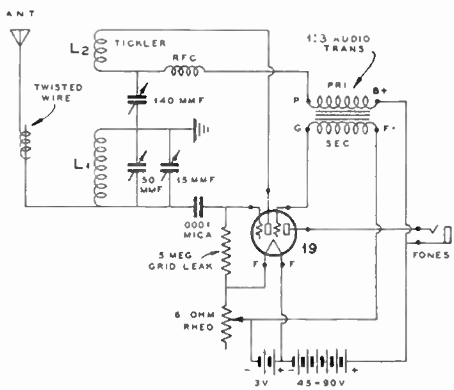


Figure 3—Schematic circuit diagram of the one-tube receiver. L1 is the secondary, or grid coil. L2 is the "tickler," or regeneration coil.

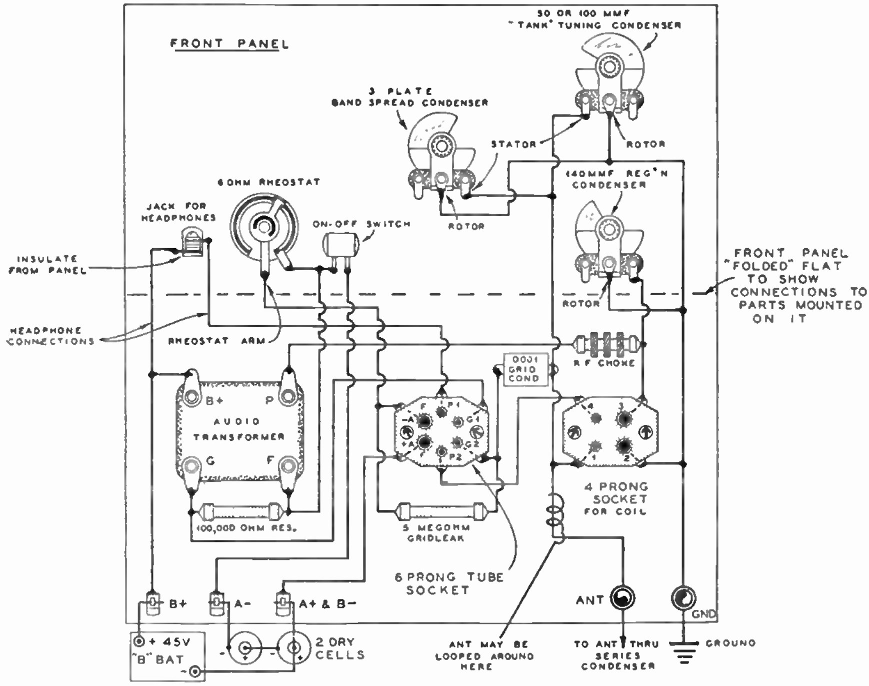


Figure 4—Pictorial Wiring Plan for Type-19 Twin-Triode Regenerative Receiver.

40-METER COIL: Secondary Winding—14 turns of No. 22 DSC wire, space-wound to cover a winding space of 1-in.

Tickler Winding—11 turns of No. 22 DSC wire, close-wound, and spaced ⅛-in. from secondary winding.

80-METER COIL: Secondary Winding—27 turns of No. 22 DSC wire, close-wound.

Tickler Winding—11 turns of No. 22 DSC wire, close-wound, and spaced ⅛-in. from secondary winding.

160-METER COIL: Secondary Winding—60 turns of No. 22 DSC wire, close-wound.

Tickler Winding—17 turns of No. 32 Enameled wire, close-wound, and spaced ⅛-inch from secondary winding.

COIL FORM LEGEND

TERMINAL No. 1 connects to one side of the .0001 μfd. mica fixed condenser and to the stator of the 100 $\mu\mu$fd. (or 50 $\mu\mu$fd.) condenser, as well as to the stator of the 3-plate midget variable tuning condenser. Likewise, the insulated antenna lead-in wire is twisted around the lead which connects to Terminal No. 1.

TERMINAL No. 2 connects to the rotors of all three variable condensers, and at the point where the three are connected together another lead is run to the "ground" terminal of the receiver.

TERMINAL No. 3 connects to the stator of the 140 $\mu\mu$fd. variable condenser which is used for regeneration, and the same terminal also connects to one end of the 2.5 mh. r.f. choke.

TERMINAL No. 4 connects to the P2 terminal on the type '19 tube.

Standard Regenerative "Gainer" Receiver

An a.c. operated receiver which also can be used with dry-cells, and which gives greater sensitivity and more volume than the single tube receiver previously described, is the two-tube standard regenerative *"Gainer"*. This receiver will operate with glass or metal tubes. Glass tubes are used in the model described in detail because they are lower in cost than metal tubes, and because their use makes the receiver easier to build, due to the simpler socket connections. If metal tubes are to be used, the only change will be in the tube sockets and the grounding of the metal tube shells to the common ground lead. Metal tube socket connections shown in the chapter on *Receiver Tubes*. A metal tube version is pictured in figure 8.

The circuit consists of a regenerative detector having excellent sensitivity, and an

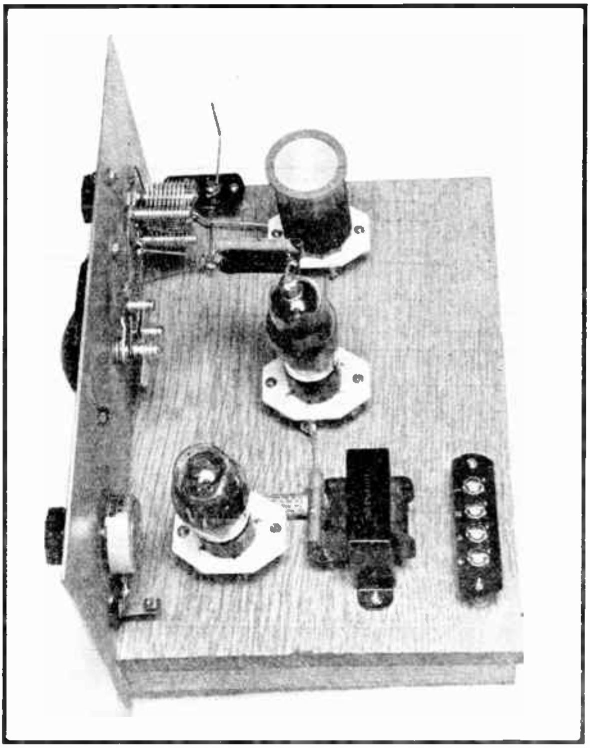


Figure 5—Looking Into the Receiver. The Various Parts Should be Mounted Exactly as Shown.

For the sake of simplicity, the circuit diagram is shown in both schematic and pictorial form, so that those building their first receiver will have no difficulty in following the wiring diagram.

The circuit consists of a regenerative screen-grid detector which is impedance-coupled into a triode audio amplifier stage. The antenna is coupled to the grid circuit of the detector by twisting from one to five turns of insulated hookup wire around the grid connection to the tuned circuit. The amount of coupling depends upon the length of antenna; it should not have too many twists of wire or else the detector stage will not oscillate. Regeneration is obtained by means of a cathode tap in the tuned grid circuit. Standard plug-in coils are used to cover the various amateur bands, as shown in the coil-winding table.

Grid-leak detection gives maximum sensitivity and smooth control of regeneration, which is adjusted by varying the screen-grid voltage applied to the 6C6 tube. The screen-grid lead has an additional resistance filter in the circuit to prevent noise from being introduced into the detector circuit when varying the screen-

impedance-coupled audio amplifier stage which gives sufficient volume for headphone reception. Loud-speaker operation of the receiver would require an additional audio amplifier stage.

The main tuning control drives a small band-spread tuning condenser. A band-setting variable condenser is controlled from the front panel by means of a knob and pointer and small dial. The third front-panel control is for adjustment of regeneration, which is accomplished by varying the screen-grid voltage of the detector tube. The band-setting condenser is adjusted to the desired band, and the actual tuning is done with the band-spread condenser which is connected to the vernier tuning dial.

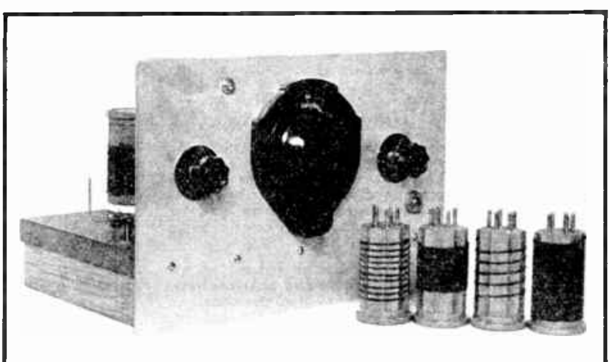
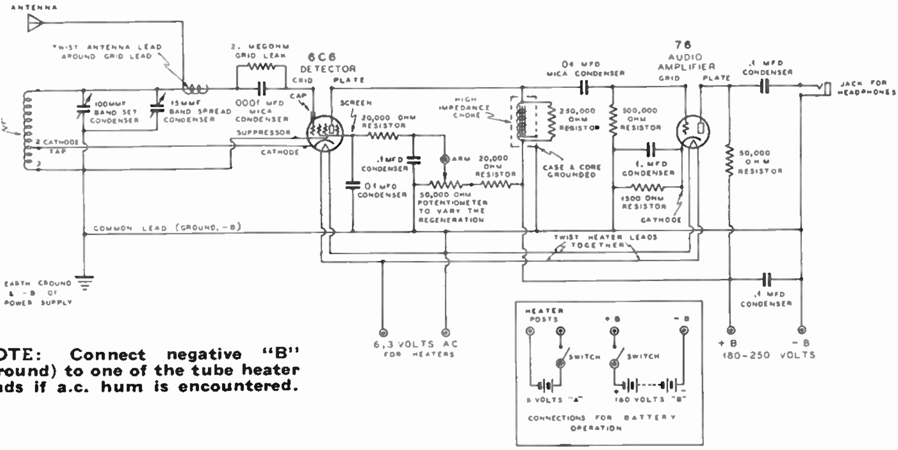


Figure 6—Front View of Receiver. Coils for All-Band Operation are to the Right.



NOTE: Connect negative "B" (ground) to one of the tube heater leads if a.c. hum is encountered.

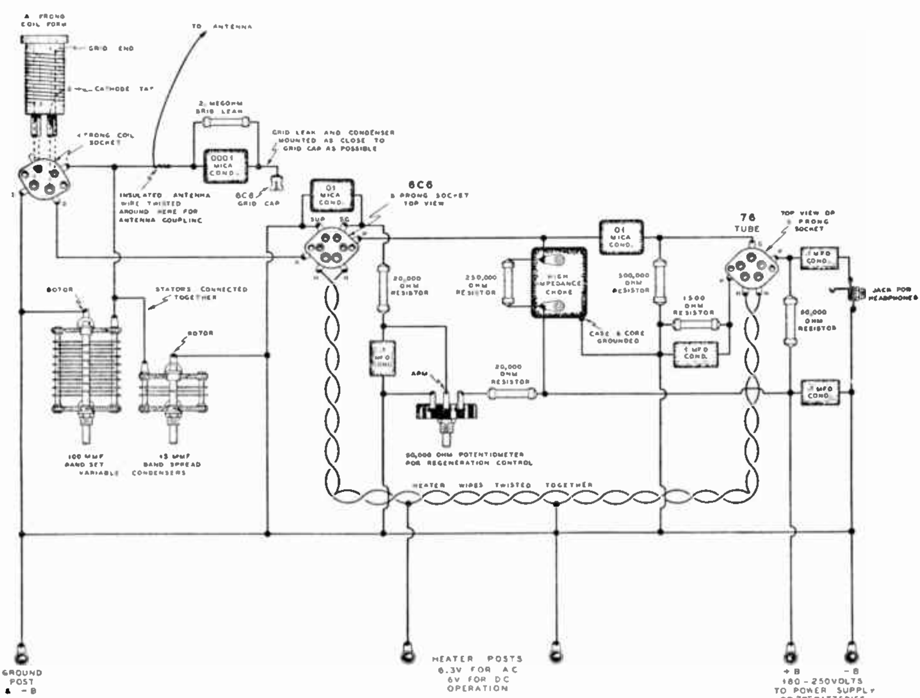


Figure 7—Schematic and Pictorial Circuit Diagrams of the Standard "Gainer" Regenerative Receiver.

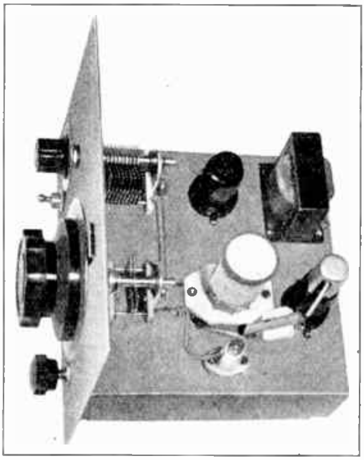


Figure 8—Metal tube version of the receiver. The circuit is the same, though the mechanical layout is slightly different. It is built on a metal chassis instead of a wood baseboard.

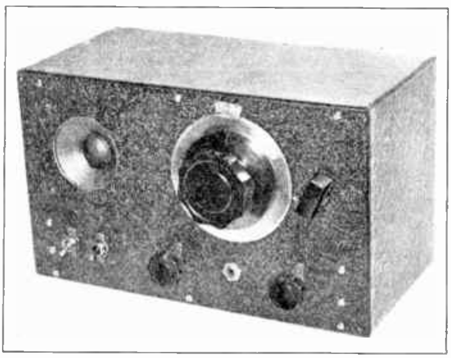


Figure 9—Another modification of the simple regenerative receiver. A miniature loudspeaker and conventional pentode power audio stage have been added. A 7 x 12 x 7 in. metal cabinet houses the complete receiver.

grid potentiometer. Impedance coupling allows full plate voltage to be applied to the plate of the screen-grid tube, and results in louder signals than would be secured with ordinary resistance coupling. The type-76 audio amplifier is conventional, with a resistor and condenser in the plate circuit to remove the d.c. plate potential from the headphones.

The high impedance choke in the detector plate circuit should be one designed to carry approximately 5 milliamperes of plate current, with an inductance of between 100 and 500 henrys. A 250,000 ohm resistor connected across this choke will prevent *"fringe-howl"* when the detector tube is used near the "edge" of oscillation.

The detector grid-leak and grid condenser should be mounted as close as possible to the grid cap of the 6C6 detector tube to prevent hum pickup. The 0.1 μfd. condenser which is connected across the positive and negative terminals of the "B" supply *in the receiver* prevents what is known as *"tunable hum"* in some of the short-wave bands when the receiver is operated from an a.c. source of supply.

• Construction

The receiver is built on an oak baseboard, 11 in. x 8 in. x ¾ in. with cleats at either end secured to the bottom of the board to provide space for mounting small resistors and bypass condensers under the board. The front panel is of no. 12 gauge aluminum, 8 in. x 12 in. The metal front panel prevents the effect of *"body capacity,"* which would cause difficulty in tuning the receiver if a bakelite panel were used. The metal panel is connected to the common ground connection of the receiver. The various parts should be mounted as shown in the photograph.

The following parts are mounted under the board: 1-μfd. bypass condenser for the cathode of the 76 tube; 0.1-μfd. condenser across positive and negative terminals of the B-supply; 0.1-μfd. condenser in the headphone circuit; 0.1-μfd. screen-bypass condenser; 1500 ohm cathode resistor for the 76 tube; 20,000 ohm screen-grid resistor; 20,000 ohm resistor in the potentiometer circuit; 50,000 ohm resistor in the type 76 tube plate circuit. These parts are mounted under the baseboard in order to improve the appearance of the receiver and to conceal much of the wiring.

All coils are wound on standard four-prong coil forms. The coil table gives the correct number of turns of wire for each of the required coils.

The receiver uses an a.c. power supply which should consist of three filter chokes and three or four 8-μfd. filter condensers in order to provide a source of very pure d.c. plate supply. Such a power supply is described in the chapter devoted to *Power Supply Systems*.

• Operation

Before putting the receiver into operation, the wiring should be carefully checked. The power supply is then connected to the receiver, the tubes permitted to warm-up, and the regeneration control advanced to the point where a "hiss" is heard in the headphones. In this condition c.w. telegraph signals can

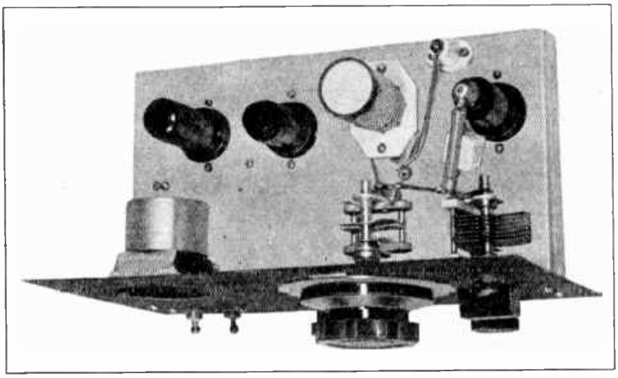


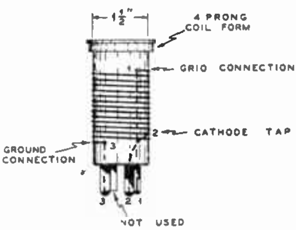
Figure 10—Interior of the receiver illustrated in figure 9. The permanent magnet, dynamic loudspeaker at the extreme left gives ample volume for enjoyable room reception of both code and voice signals.

be received; just below this "hiss" point is the correct setting for reception of weak voice signals. The *band-setting* condenser is set near minimum capacity for locating the various amateur bands, and the *band-spread* condenser is then tuned to receive the desired signals. If no signals are heard, the difficulty usually can be traced to one or more of the following causes:

(1) *Defective grid condenser.*
(2) *Defective grid resistor.*
(3) *Defective tube or tubes.*
(4) *Defective regeneration condenser.*
(5) *Defective high impedance choke.*
(6) *Open circuit in coil or socket connections.*
(7) *Short-circuited bypass condenser.*
(8) *Antenna not connected to receiver.*
(9) *Incorrect wiring.*
(10) *Socket prong broken or bent out of position.*
(11) *Cathode tap not soldered to coil winding.*
(12) *Short-circuited tuning condenser.*
(13) *Excessive antenna coupling.*

Winding the Coils

Five tuning coils are needed to cover the amateur bands—160, 80, 40, 20, and 10 meters. These coils are wound on standard Hammarlund 4-prong 1½-inch diameter coil forms.



Each coil has three connections: top, bottom, and cathode-tap. These connections are made to three of the coil prongs; the wires must be soldered into the prongs.

Coil-Winding Table for Standard Regenerative "GAINER" Receiver

160-225 METERS: Wind 70 turns of No. 24 DSC wire on a 1½-in. dia. form. Connect cathode tap 1½ turns up from ground end.

70-110 METERS: Wind 36 turns of No. 22 DSC wire on a 1½-in. dia. form. Connect cathode tap 1½ turns up from ground end.

32-60 METERS: Wind 21 turns of No. 22 DSC wire on a 1½-in. dia. form and space-wind the wire over a winding space of 1¾-in. Connect cathode tap ½ turn up from ground end.

19-30 METERS: Wind 11 turns of No. 22 DSC wire on a 1½-in. dia. form and space-wind the wire over a winding space of 1¾-in. Connect cathode tap ½ turn up from ground end. The location of the cathode tap is quite critical on the 19-30 meter coil, and a slight amount of experimenting must sometimes be done in order to find the point where smooth oscillation control is obtained.

10-25 METERS: Wind 5 turns of No. 16 DSC wire on a 1½-in. dia. form and space-wind the wire over a winding space of 1½-in. Connect cathode tap 1/3rd turn up from ground end. Experiment with cathode tap connecting point until best control of regeneration is secured.

NOTE: This receiver will not cover the broadcast band unless a 350 μμfd. variable condenser is connected in parallel with the 100 μμfd. band-setting condenser. A coil which will cover the broadcast band can be made with a 2-inch winding length of No. 28 or 30 DSC or Enameled wire on a 1½-in. dia. form. Connect cathode tap 2½ turns up from ground end.

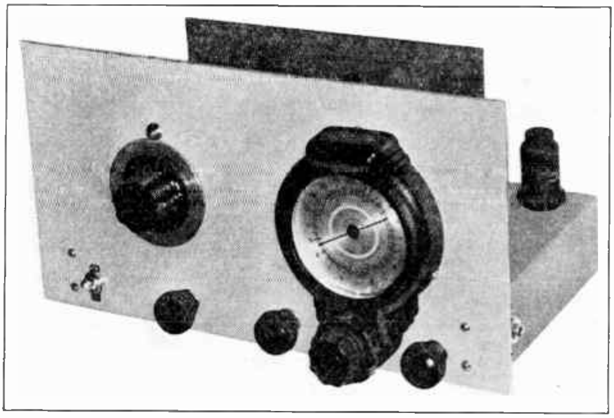


Figure 11—Front view of the t.r.f. amateur receiver. A precision type, slow-speed illuminated tuning dial drives the band-spread condenser. Regeneration, volume, and sensitivity controls are arranged along the lower portion of the panel.

For the benefit of those who want to build an exact replica of the model shown and use duplicate parts, the following list is given:

PARTS LIST

2 Hammarlund 5-prong Isolantite Sockets.
1 Hammarlund 6-prong Isolantite Socket.
5 Hammarlund 5-prong 1½" dia. Coil Forms.
1 50,000 Ohm Centralab Potentiometer.
1 Hammarlund 3-plate Midget "Star" Variable Condenser.
1 Hammarlund 100-μμfd. (.0001 μfd.) "Star" Variable Condenser.
1 Open-circuit Jack for Headphones.
1 4-terminal Connector Strip for connecting batteries or power supply to the receiver.
1 2-terminal Ant-Gnd Terminal Strip.
1 High Impedance Choke, 200 henrys inductance or higher.
1 250,000 ohm Resistor, 1 watt.
2 20,000 ohm Resistors, 1 watt.
1 1500 ohm Resistor, 1 watt.
1 500,000 ohm Resistor, 1 watt.
1 50,000 ohm Resistor, 1 watt.
1 1-μfd. Tubular Paper Condenser, Cornell-Dubilier, 400 volt rating.
2 .01-μfd. Tubular Paper Condensers, Cornell-Dubilier, 600 volt rating.
3 0.1-μfd. Tubular Paper Condensers, Cornell-Dubilier, 600 volt rating.
1 .0001 μfd. MICA Fixed Condenser (Grid Condenser for 6C6).
1 2 megohm Grid-Leak.
6 Small tie-connector strips.
1 Roll, 25 ft., Push-back hookup wire.
1 Small reel rosin-core solder.
10 6/32x2-inch round-head brass machine screws for sockets and terminal strip mountings.
1 Doz. round-head brass wood screws, ½-in. long.
1 3-foot length No. 14 bus-bar wire.
1 ¼-lb. spool No. 22 DSC wire for coils.
1 Spool, approx. 300 ft., No. 24 DSC wire for 160 meter coil.

Continuous-Coverage T.R.F. Receiver

This receiver is similar in design to the *Standard Regenerative "Gainer,"* except for the addition of a tuned r.f. stage and the use of metal tubes throughout. The coils are designed to give complete coverage on all wavelengths from 9 to 200 meters, rather than merely covering the amateur bands. The tuned r.f. stage increases the sensitivity to weak signals and prevents cross-talk from nearby powerful broadcast stations, which sometimes ride-in on the short-wave bands on the more simple types of regenerative receivers.

The r.f. amplifier has a sensitivity control which consists of a variable resistor in the cathode circuit. This is essential for proper operation of the receiver in locations where interference from powerful nearby stations is troublesome. The receiver is designed for simplicity in construction by using two midget two-gang tuning condensers, separated by a heavy aluminum shield partition. This type of construction gives fairly-good isolation between the two tuned circuits. Each coil socket has its grid and ground leads connected to the

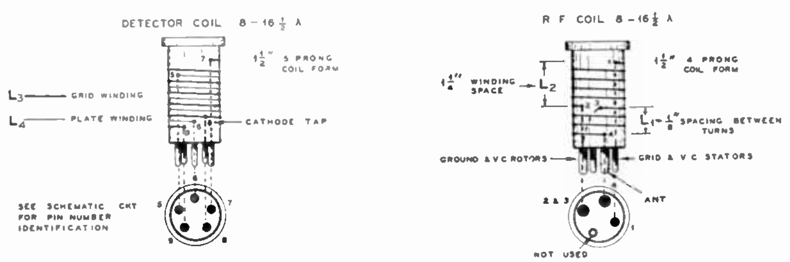


Figure 12—8 to 16½-Meter Coil Construction for Continuous Coverage T.R.F. Receiver.

Continuous Coverage T. R. F. Receiver Coil Table

All Coils Wound on 1½" Diameter Forms.

Approx. Range in Meters	Ant. Coil L1	Secondary Coil L2	Primary Coil L3	Secondary Coil L4	Cathode Tap on L4
8 to 16	3 turns, spaced ⅛-in. from ground end end of L2.	3½ turns no. 20 d.s.c. ¾-in. long.	2½ turns no. 24 d.s.c. interwound with L4. + B at bottom.	3½ turns no. 20 d.s.c. ¾-in. long.	Tap at 1/3 turn on bottom turn.
15½ to 32	5 turns ⅛-in. from L2.	7 turns no. 24 d.s.c. 1½-in. long.	3 turns no. 24 d.s.c. interwound with L4.	7 turns no. 24 d.s.c. 1½-in. long.	Tap at ½ turn on bottom turn.
29 to 62	8 turns, ⅛-in. from L2.	16 turns no. 24 d.s.c. 1½-in. long.	6 turns no. 24 d.s.c. interwound with L4.	16 turns no. 24 d.s.c. 1½-in. long.	Tap at ¾ turn on bottom turn.
59 to 107	10 turns, ⅛-in. from L2.	31 turns no. 24 d.s.c. 1½-in. long.	8 turns no. 34 d.s.c. interwound with L4 at ground end.	31 turns no. 24 d.s.c. 1½-in. long.	Tap at 1 turn up from bottom.
97 to 215	12 turns, ⅛-in. from L2.	54 turns no. 24 d.s.c. 1½-in. long.	12 turns no. 34 d.s.c. wound over bottom end of L4 over celluloid layer of insulation.	54 turns no. 24 d.s.c. 1½-in. long.	Tap at 1¼ turns up from bottom.

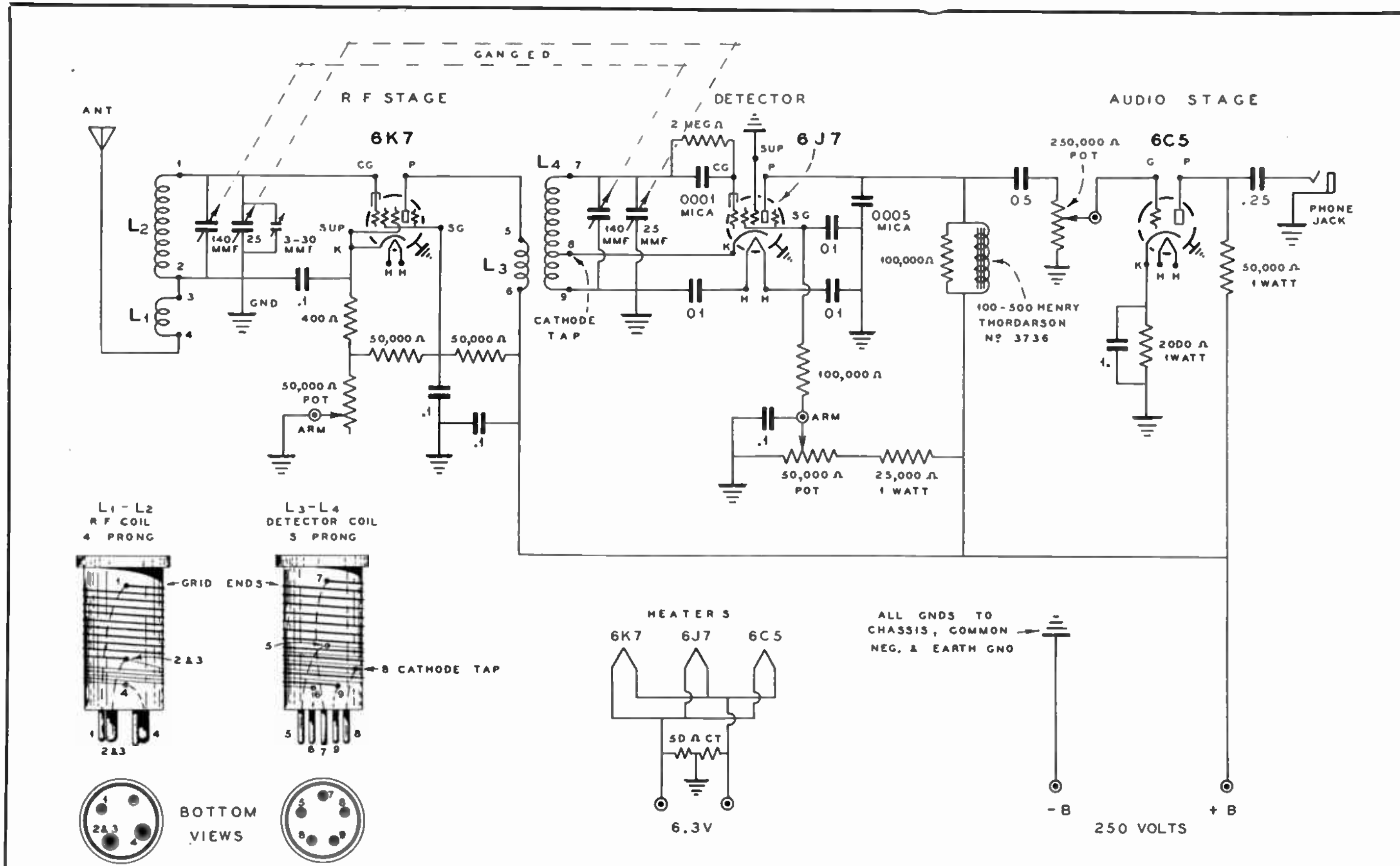


Figure 13—General Wiring Diagram and Coil Construction.

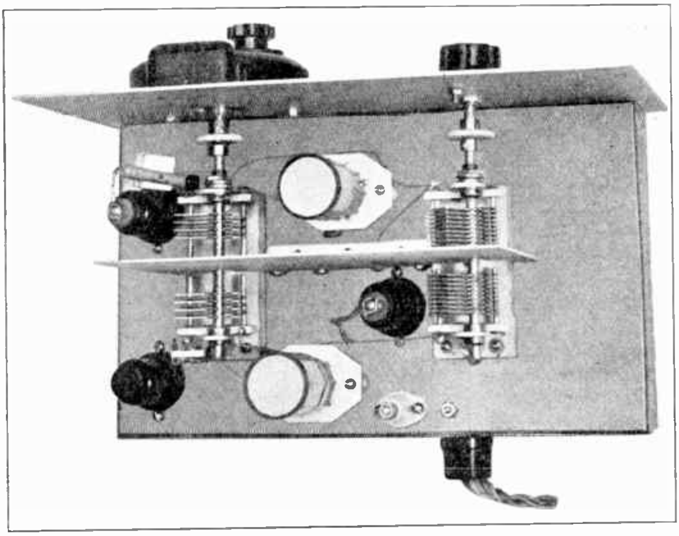


Figure 14—Interior view of the t.r.f. amateur type receiver. The receiver should preferably be housed in a metal container in order to reduce hum pickup.

stators and rotors of its particular band-setting and band-spread tuning condenser sections. Insulated couplings between the tuning dials and variable condenser shafts prevent the introduction of noise when tuning-in the short-wave bands.

The r.f. and detector tuned circuits are made to "*track*" by winding the secondaries of each pair of coils in a similar manner. The coil turns are then slightly pushed together, or spaced more widely, when the circuits are lined-up with the receiver under test. The r.f. tuned circuit has an additional 3-to-30 μμfd. trimmer condenser to compensate for the additional circuit capacities in the detector grid circuit. This condenser can be adjusted to a compromise value for all coils without much loss in exact tuning, if the coils are carefully wound and spaced before the turns are cemented in place.

From one-third to one-half the total number of plates in a 35 μμfd. per section variable condenser must be removed to give best band-spread tuning. The number of plates to be removed will depend upon the operator's particular desire for a particular amount of band-spread. 12 to 15 μμfds. per section gives very good band-spread for the high-frequency bands, but will not cover the 80 and 160 meter amateur bands without resetting the band-setting condensers. If the receiver is to be used primarily for the longer wavelengths, such as for the 160 meter band, a capacity of approximately 25 μμfds. per section in the band-spread condenser will be more satisfactory.

Bypass condensers and resistors should be connected directly to the coil and tube socket terminals. All bypass connections to ground should be made as short as possible, directly to the chassis which serves as a common ground connection. The chassis should be made of zinc or lead coated steel in order that the leads may be soldered to any point on the chassis. The tuning condenser rotor should also be connected to the chassis, and each rotor section connected to its proper coil socket. No. 10 or 12 gauge aluminum is suitable for the shield partition and front panel. The partition should extend upward as high as the front panel in order to provide an effective baffle between the two coils. The chassis is 9 in. x 12 in. x 2½ in. The metal front panel is 13 in. x 9 in.

1938 "Ultra Gainer" Receiver

The "*Ultra-Gainer*" receiver described in previous editions of this *Handbook* has been still further improved and modernized by the addition of a noise-balancing input circuit, a better noise suppressor in the output circuit, a quartz-crystal filter in the i.f. amplifier, and a simplified tuning control. These improvements make this new model more effective than ever as a communications receiver.

• Technical Features

The input circuit is designed to use a *noise-bucking antenna* in conjunction with the regular receiving antenna for balancing-out power-leak noises. This balancing circuit consists of a 140 μμfd. variable condenser, a 3-to-30 μμfd. semi-adjustable condenser, and a separate antenna primary. The latter also is semi-adjustable in that the turns can be moved toward or away from the secondary winding, or the number of turns can be changed, in order to balance the circuit with the particular antenna in use. As shown in the circuit diagram, a single long wire antenna can be connected to the antenna coupling condensers, the noise antenna being connected to the primary coil. Another combination would be a doublet receiving antenna connected to the primary coil, and the noise antenna to the antenna condensers. The purpose of the noise antenna is to pick up as much of the interfering power-leak type of noise as possible, in comparison to the actual desired signal pick-up. The regular receiving antenna should be designed to pick up as much signal as possible; the noise component which it also picks up must be balanced-out by that introduced from the noise antenna. The proper connection of the noise antenna and ground to the antenna coil will depend upon the particular out-of-phase balancing necessary for the particular amateur band and type of power-leak, so that these two connections may have to be reversed.

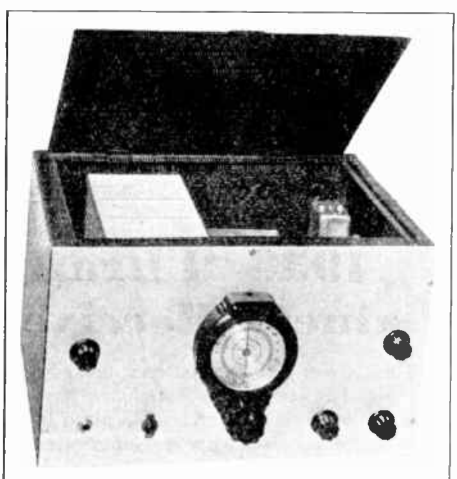


Figure 15—The 1938 "Ultra Gainer" receiver, showing fully enclosed coil shield compartment and front panel layout.

The noise antenna may consist of a 20 to 50 foot length of wire, run outwardly towards the power lines, or telephone circuits, from which the interference emanates. This antenna should not be more than 10 or 20 feet above ground, so that it will be relatively inefficient in picking up signals but highly efficient in picking up noise. The signals will be balanced-out *with* the noise unless the regular receiving antenna is much higher than the noise antenna, and resonant to the signal.

Another very effective noise antenna for many locations is a connection back to one side of the 110-volt a.c. line through a .002 μfd. mica condenser. Careful balancing of the two antennas will often permit weak signal reception in locations where the power buzz is so loud as to render normal reception impossible. The problem of noise balancing is not simple, because the length of ground lead, type of receiver, location of antennas and values of antenna coil turns and condenser capacities are factors which must be taken into consideration. Sometimes the ground connection to a water pipe will introduce a power buzz of such a phase that it cannot be balanced-out by means of the circuit shown. One or more ground rods, driven into the earth to a depth of approximately three feet, will often serve as an effective noise-free ground connection.

The r.f. amplifier tuning condenser in this new receiver has been ganged with the detector and oscillator tuning condensers to simplify the tuning. The ratio of L to C is made as high as possible so as to obtain high gain on 10 and 20 meters. This model was primarily designed for 10, 20 and 40 meter operation; however, it can be used to cover nearly all of the 80 meter band, even with its small two-plate tuning condensers. Ganging the r.f. stage makes it difficult to utilize regeneration in the r.f. amplifier, and the r.f. gain is therefore increased by using a 6J7 sharp cut-off screen-grid tube, rather than a 6K7 variable μ r.f. amplifier tube.

The 6J7 is operated with low bias, high screen voltage, and high plate current in order to obtain very high operating mutual conductance. This results in greater r.f. gain than can be obtained from a 6K7. The ratio of signal-to-noise is much higher with this design, and tends to offset the lack of controlled regeneration present in last year's *"Ultra Gainer."* This r.f. amplifier is operated at maximum gain at all times in order to have a very high signal-to-noise ratio. The plate current is at least twice normal value for a 6J7 tube, which will probably shorten

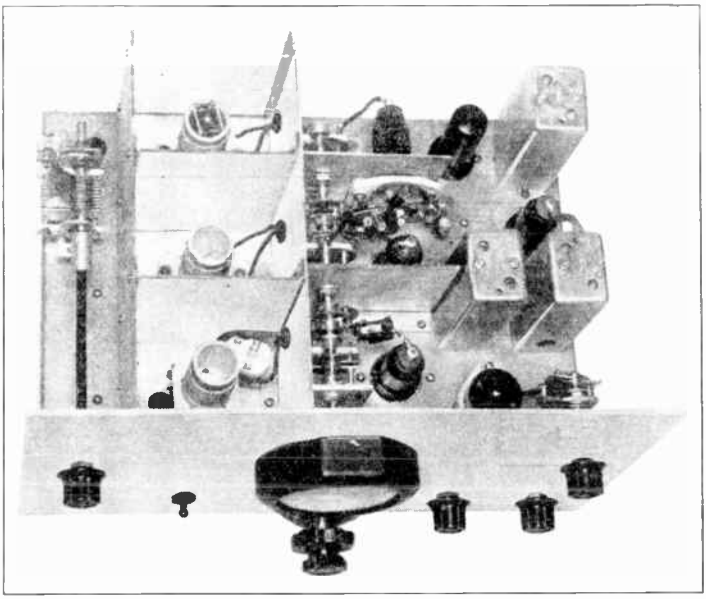


Figure 16—Illustrating assembly of the new "Ultra Gainer," showing antenna noise suppressor, shielded coil compartment (cover removed to show coils) and ganged condenser arrangement.

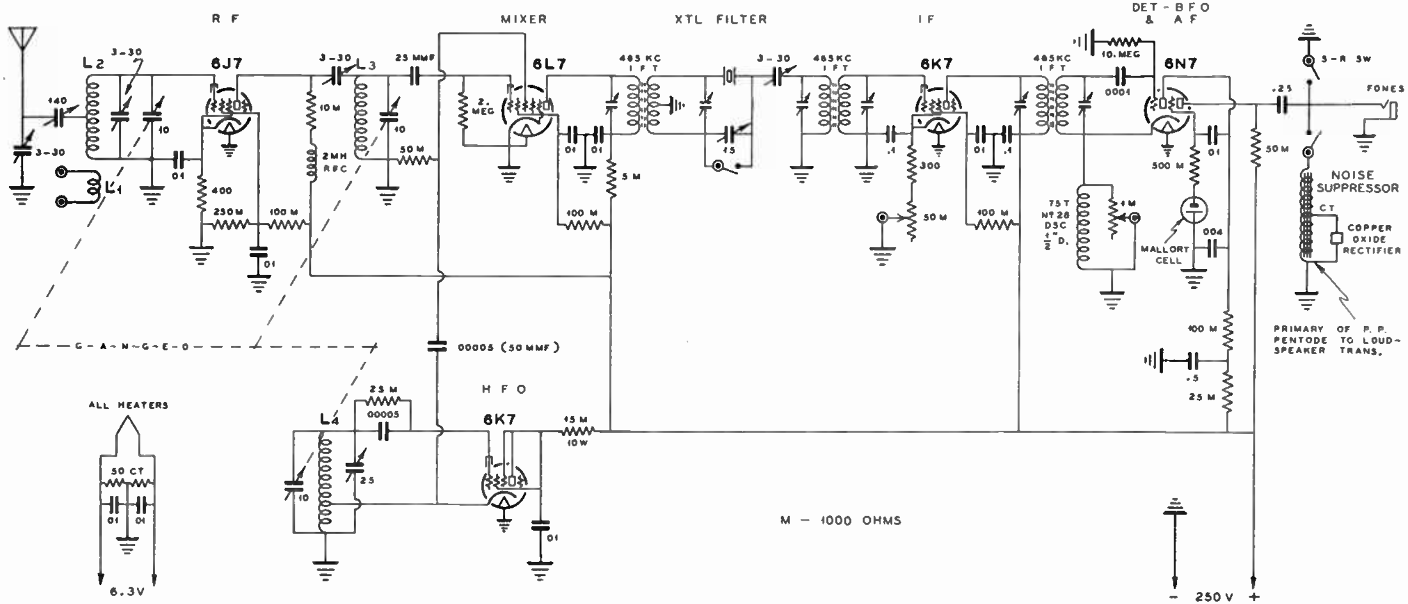
the life of the tube to some extent; in spite of this, the 6J7 should be capable of satisfactory operation for at least 800 hours, so that this factor is of no importance when compared with the advantages secured when operating the tube in the manner prescribed. The only serious disadvantage of using a 6J7 with low grid bias is a tendency for cross-talk if the receiver is operated in the vicinity of a powerful broadcast transmitter.

The r.f. amplifier is capacitively-coupled to the 6L7 first detector. A 10,000 ohm resistor in series with a 2 mh. r.f. choke provides an effective r.f. impedance for all amateur bands. The semi-variable r.f. coupling condenser serves a dual purpose, in that it can also be used to line-up the detector tuned circuit.. Low bias on the 6J7 tube is obtained by using a 400 ohm resistor, rather than the usual 1500 ohm value recommended for this type of tube. A small mica trimmer condenser is connected across each individual r.f. plug-in coil in order to insure proper tracking for each amateur band.

A 6K7 tube is connected as a triode for the h.f. oscillator so as to obtain sufficient r.f voltage for driving the injection-grid in the 6L7 first detector tube. Insufficient injection voltage results in a high hiss level, especially in the 10 and 20 meter bands. The 6K7 plate circuit is connected to the power supply through a voltage-dropping resistor and the cathode is connected to a tap on the coil to obtain oscillation. The injection-grid of the 6L7 connects to the cathode and the detuning effect on the oscillator circuit will therefore be minimized. The circuit, as shown, provides sufficient r.f. voltage without connection to the grid-end of the oscillator tuned circuit.

A great many first detector circuits and tubes were tried in this receiver in order to determine a most satisfactory type for weak signal reception. The arrangement with grid-leak detection apparently is somewhat better than bias-detection for very weak signal input, as checked with a standard signal generator. Space-charge detectors, 6A8 bias and grid-leak detectors, and 6J7 detectors were all tried and found to be lacking in sensitivity to weak signals as compared to a properly operated 6L7.

The small capacity of the grid condenser in the first detector circuit is necessary for satisfactory detector action at 465 kc. Even at best grid-leak detection is very poor for 465 kc. because the 6L7 must act as an i.f. amplifier with a relatively low impedance in the grid circuit at that frequency. This is more than offset by the increased detection efficiency procured when detection or mixing action takes place in the grid rather than in the plate circuit. The screen-grid voltage



JONES' 1938 ULTRA-GAINER

Figure 17—General wiring schematic. If the layout of parts shown in figure 16 is followed closely, there is no need to worry about short leads, as the important leads will then all be short.

must be somewhat less with grid-leak than with bias-detection.

A 465 kc. crystal filter is incorporated in the i.f. amplifier for the purpose of improving the selectivity for c.w. reception. The volume control for the receiver is located in the cathode circuit of the i.f. amplifier.

The second detector circuit utilizes a 6N7 twin-triode connected as an audio amplifier and regenerative second detector. This regenerative detector provides a beat-oscillator action for c.w. reception and also has a lower hiss-to-signal ratio than when a separate b.f.o. circuit is used. Regeneration is obtained by means of a 75-turn cathode coil, ½ in. diameter, jumble-wound with no. 28 d.s.c. wire. Regeneration and oscillation are controlled by means of a variable 1,000 ohm resistance in shunt to the cathode coil. Grid-leak detection provides good sensitivity and very smooth regeneration in the detector circuit. Iron-core air-tuned i.f. transformers give good selectivity and high i.f. amplifier gain.

The audio output circuit is designed for headphone operation, and a special noise-suppression circuit is incorporated for minimizing automobile ignition interference. An ordinary copper-oxid rectifier, such as those sold for replacement purposes in oxide-rectifier a.c. voltmeters, is connected across part of the output circuit, as indicated in the circuit diagram. The copper-oxide rectifier has its plus and minus leads connected together for one terminal, and the two a.c. leads connected together for the remaining terminal to make it operate as a non-linear resistance. Its impedance is too low to connect across the headphones; thus it should be connected across only one-half of the primary of a push-pull-pentode-to-loud-speaker output transformer. The noise suppressor operates as follows:

All very loud signals, such as noise peaks, overload the copper-oxide rectifier so that the latter acts as a short-circuit across the output for the duration of the noise peak. This effectively reduces the noise peaks to a level equal to that of the desired signal, even though these peaks may be ten or twenty times as strong as the original signal. This noise-suppressor is entirely automatic. It is very simple and economical, and quite effective in operation.

If loudspeaker reception is desired, a 3-to-1 audio transformer should be used to couple the output into a 6F6 pentode audio amplifier.

• Construction

The receiver is built on a zinc-coated metal chassis, 10 in. x 14 in. x 2½ in. The front panel is 15 in. x 8 in., of no. 8 aluminum. The tuning coil sockets are mounted on 1⅛ in. bushings in order to raise the coils well above the chassis. An aluminum box with two partitions is built around the coils to pro-

Coils for 1938 "Ultra-Gainer Receiver"

Band (Meters)	Oscillator Coil	Detector Coil	R. F. Coil
10	5 turns, no. 22 d.s.c. 1-in. long, 1⅛-in. diameter, tapped at 1½ turns.	5 turns, no. 22 d.s.c. 1-in. long, 1⅛-in. diameter.	5 turns, no. 22 d.s.c. 1-in. long, 1⅛-in. diameter, tapped at ¾-turn.
20	13 turns, no. 22 d.s.c. 1-in. long, 1⅛-in. diameter, tapped at 2 turns.	13 turns, no. 22 d.s.c. ⅞-in. long, 1⅛-in. diameter.	13 turns, no. 22 d.s.c. ⅞-in. long, 1⅛-in. diameter, tapped at one turn.
40	26 turns, no. 22 d.s.c. 1-in. long, 1⅛-in. diameter, tapped at 4 turns.	27 turns, no. 22 d.s.c. 1-in. long, 1⅛-in. diameter.	27 turns, no. 22 d.s.c. 1-in. long, 1⅛-in. diameter, tapped at 2 turns.
80	52 turns, no. 22 d.s.c. 1⅝-in. long, 1¼-in. diameter, tapped at 7 turns.	60 turns, no. 22 d.s.c. 1¾-in. long, 1¼-in. diameter.	60 turns, no. 22 d.s.c. 1¾-in. long, 1¼-in. diameter, tapped at 4 turns.

vide good shielding between stages. This aluminum catacomb is made 5 inches high and about 4 inches wide, with each partition about 3¼ inches wide. This provides wide spacing around the small isolantite plug-in coil forms, with the result that r.f. losses in the shielding are negligible.

The oscillator air-tuning padder condenser is soldered across the oscillator coil socket, which is in the front section of the receiver. The detector coil is in the center section, the r.f. coil in the rear. The ganged tuning condenser is made by mounting three *Hammarlund* midget variable condensers on three separate aluminum vertical partitions. The mounting holes are made large enough so that the condensers can be lined-up accurately before the single-mounting nut is tightened. Flexible couplings are used between sections, and to the vernier tuning dial, in order to give smooth action in spite of the many fixed bearing surfaces in the ganged condenser. Excessive friction in the tuning of the ganged condenser will cause backlash in the drive of the tuning dial for c.w. reception, because of the extremely high vernier action of the particular dial shown in the photograph of the complete receiver.

The r.f. amplifier tube is mounted in a horizontal position so as to secure very short grid and plate leads. The tube socket is mounted on one of the vertical aluminum partitions near the tuning condenser.

• Lining-Up the Receiver

An all-wave test oscillator is required for aligning this receiver. The i.f. transformers should first be aligned to the frequency of the quartz crystal, as described in the *Receiver Theory chapter*. The second detector should go into oscillation smoothly as the 1,000-ohm variable resistance is rotated. The i.f. tuning into the second detector should be adjusted so that the latter will give single-signal reception in conjunction with the crystal filter and phasing condenser in the crystal circuit.

If insufficient cathode turns are used, the second detector cannot be made to oscillate; too many turns will cause a detuning effect when adjusting the i.f. transformers, and smooth control of regeneration cannot be secured.

The h.f. circuit alignment is rather difficult, unless the signal generator is accurately calibrated. The oscillator padder condenser should be set so that the oscillator will track with the first detector circuit over one of the coil ranges, preferably the 10-meter band. The r.f. coupling condenser should be adjusted to approximately two-thirds its maximum capacity. The r.f. padding condenser can be adjusted for maximum sensitivity with the particular antennas used for each band. It will be found that coils made as shown in the coil table, with some slight re-spacing of the coil turns before they are cemented into position, will make the tracking very accurate over the narrow amateur bands. The tuning condensers have a low maximum capacity, so that the amateur bands are spread over a large portion of the tuning dial. The additional time involved in originally lining up the coils and condenser in the h.f. circuits is well repaid because the band-setting condensers then need not be readjusted and tuning can be accomplished with the single-dial.

• Coil Data

The 10, 20 and 40 meter coils are wound on small Isolantite coil forms, 1⅛-in. diameter. The 75 meter coils, which cover a range of from 4.0 to 3.5 megacycles, are wound on ribbed bakelite forms, 1¼-in. diameter. The coil chart appears on page 147.

De Luxe Communications Receiver

Those who have the ability and the facilities for building a de luxe communications receiver will find many features of interest in this ten-tube superheterodyne. It incorporates a very high gain r.f. amplifier, antenna noise-balancing circuit, crystal filter, a very effective noise-silencing circuit, and reverse-feed-back audio amplification. It has an "*R*" meter for denoting carrier signal strength, a precision single-tuning control, built-in power supply, cast aluminum chassis, and shielded plug-in coils which can be mechanically ganged together by means of bakelite strips and handles for quick coil change when desired.

• Technical Features

The circuit begins with an antenna noise balancer which is built into the receiver, with the exception of the 140-$\mu\mu$fd. variable condenser, which is connected in series with the noise antenna. Reference should be made to

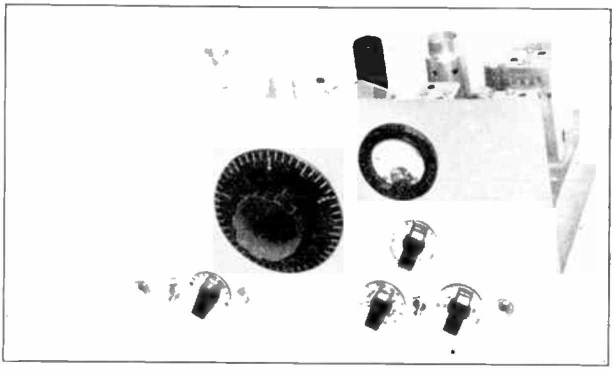


Figure 18—Front View of the De Luxe Communications Receiver.

the description of the *1938 "Ultra Gainer" Receiver* for a more complete description of this noise-balancing circuit.

The r.f. amplifier has a sharp cut-off screen-grid tube, operated with low bias and high screen voltage and plate current to obtain maximum signal-to-noise ratio in the front-end of the receiver. A standard 6L7 first detector has its injection-grid connected to the cathode of a 6K7 power type triode oscillator. The position of the cathode tap on the oscillator coil was selected so that proper injection voltage is provided for each amateur band. Under these conditions, the 6L7 first detector is very efficient for weak signal detection or mixing action.

A 465-kc. quartz crystal filter is built into the circuit between the first detector and first i.f. amplier. Two stages of i.f. amplification make possible very high selectivity and ample gain to work into a diode second detector. The latter provides a.v.c voltage for 'phone reception, second detector action, and is part of the noise-suppression circuit for elimination of automobile ignition interference. A 6R7 serves as a second detector diode and for the first stage of audio amplification. This tube drives a 6L6 pentode audio amplifier which has reverse-feedback in the audio stage in order to reduce the hum level and instability of the 6L6.

A separate b.f.o. circuit is incorporated for c.w. reception. For 'phone reception an *"R"* meter is connected in the first detector plate circuit in a *Wheatstone-Bridge* arrangement. This meter indicates the relative signal strength, since the plate current of the 6L7 varies in accordance with the a.v.c. voltage; the letter depends upon the strength of the incoming carrier signal. A 1,000 ohm variable resistor gives a convenient zero-setting adjustment for the *"R"* meter scale. For c.w. reception the a.v.c. voltage is short-circuited to ground, and the *"R"* meter indication is meaningless in this condition.

A separate type 1-v diode tube is incorporated in the noise-silencing circuit of the type developed by *Dickert*. This circuit is very effective for reducing automobile ignition noise and is entirely automatic in action. It will follow a slowly fading signal, and can be used for either 'phone or c.w. Its effectiveness can be greatly increased for c.w. reception by short-circuiting one of the resistors in the 1-v tube circuit. This connection tends to operate on the modulated side-bands of a 'phone signal, so that for good quality phone reception the switch should be in the "open" position. The additional diode acts as a short-circuit across the audio amplifier for sharp peaks of noise which have an amplitude greater than that of the incoming signal. The time constants of the 1-v circuit are chosen so that the diode acts as a very high impedance shunt across the audio circuit except during the very short time interval of a high noise pulse. The plate circuit of the 1-v tube has a large time constant, and thus its potential remains at the average value determined by the rectified incoming carrier signal. The cathode bias of this tube has a short time constant and is connected into the a.v.c. circuit so that its instantaneous value depends upon the peak signal which is present, such as that of the noise pulse. This causes the 1-v diode to act as a short-circuit to the audio amplifier and its instantaneous bias is more negative than the plate potential. However, the plate potential is a function of the a.v.c. voltage; it therefore is entirely

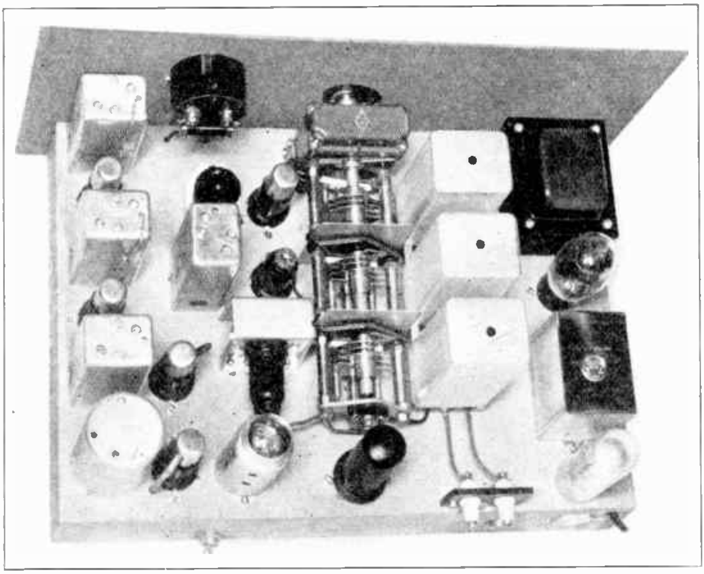


Figure 19—Layout of Parts, Showing Individually Shielded Plug-In Coils.

automatic and needs no readjustment for different signals when tuning the receiver.

The audio volume control is connected in the grid circuit of the 6R7 audio triode tube. The jack for headphone reception is located in the plate circuit of the 6R7, and when the headphones are plugged-in, the loudspeaker is disconnected from the circuit. The 6L6 gives additional amplification for loudspeaker reception. The reverse-feedback circuit consists of a 0.1 μfd. condenser in series with a 50,000 ohm resistor connected from the plate of the 6L6 tube to the return grid circuit of the audio transformer. A 5,000 ohm resistor from this point to ground provides the out-of-phase voltage in the grid circuit.

• Construction

The receiver is built on a cast aluminum chassis, 12 in. x 17 in. x 2½ in. The front panel is 8¾ in. x 19 in. x ¼ in. *Dural,* for standard relay-rack mounting. This very heavy construction insures good rigidity for elimination of detuning effects caused by touching the front panel, or when making tuning adjustments. A standard three-gang tuning condenser and vernier dial assembly is mounted in the center of the chassis, with the tubes on one side and the individually-shielded plug-in coils on the other. The oscillator tube and tuned circuit is nearest the front panel, while the r.f. circuit and horizontally-mounted r.f. amplifier tube are toward the rear of the chassis. The power supply is mounted on one end, with one of the two filter chokes mounted below the chassis. An external permanent-magnet dynamic speaker is needed for loudspeaker reception. The first i.f. transformer is mounted near the first detector, and directly in front of it (near the "*R*" meter) is the quartz crystal, which connects in turn to the i.f. transformer nearest the front panel. The b.f.o. coil is at the far rear of the chassis and an external vernier adjustment for the b.f.o. frequency is controlled from the front panel by means of a long bakelite extension shaft to a 25 μμfd. midget variable condenser under the chassis directly below the b.f.o. transformer.

The shielded coil assembly plugs into three individual isolantite sockets which are mounted on two ¼-in. square brass rods, raised approximately 1-inch above the chassis by means of brass bushings. The 3-to-30 μμfd. trimmer condensers are mounted on top of the individual coil forms and the condensers are adjusted by means of a bakelite-rod through the ¼-in. holes which are drilled into the top of each coil shield can. Individual trimmer condensers for each coil make possible an accurate alignment for each amateur band.

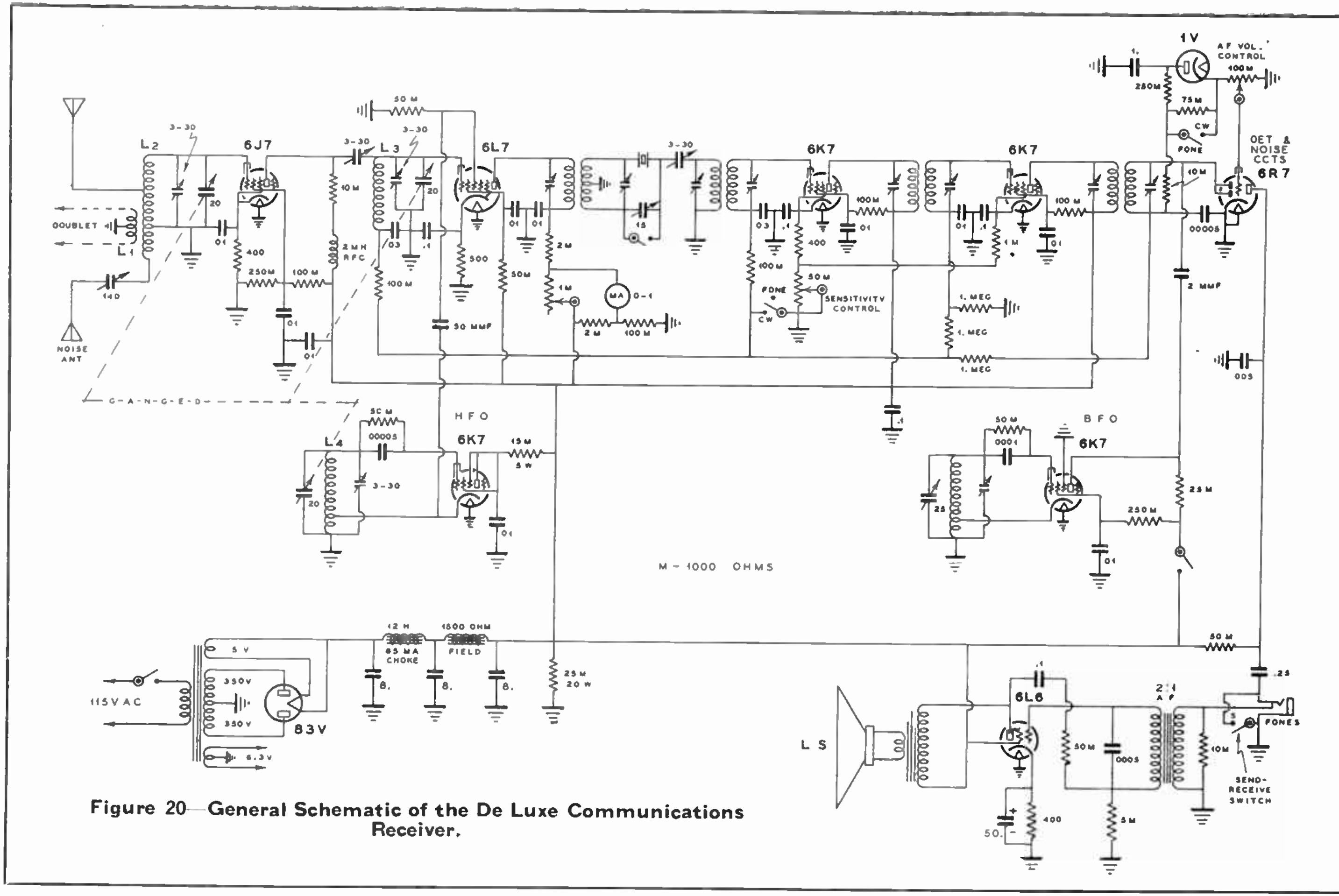


Figure 20—General Schematic of the De Luxe Communications Receiver.

Coil Table For De Luxe Communications Receiver

Band (Meters)	Antenna Coils	Detector and R. F. Coils	Oscillator Coils
10	2 turns each.	5 turns, No. 22 d.c.c., 1-in. long.	5 turns, No. 22 d.c.c., 1-in. long, tapped at 1 turn.
20	3 turns each.	12 turns, No. 22 d.c.c., 1-in. long.	12 turns, No. 22 d.c.c., 1-in. long, tapped at 2 turns.
40	6 turns each.	23 turns, No. 22 d.c.c., close-wound.	22 turns, No. 22 d.c.c., close-wound, tapped at 3½ turns.
80	10 turns each.	50 turns, No. 24 d.s.c., close-wound.	44 turns, No. 24 d.s.c., close-wound, tapped at 6 turns.
160	12 turns each.	108 turns, No 28 Enam., close-wound.	85 turns, No 28 Enam., close-wound, tapped at 9 turns.

The coils are wound on 1⅛-in. diameter forms, which have a rectangular moulded base with prongs for plugging the units into the sockets. The coil table appears above.

● Adjustments

The lining-up adjustments of this receiver are the same as those described earlier in this chapter for the *1938 Ultra Gainer Receiver*.

Improved Regenerative Pre-Selector

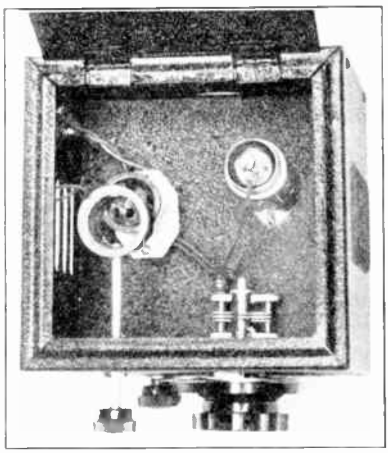


Figure 21—Regenerative Pre-Selector with Noise Balancing Antenna Circuit and Variable Antenna Coupling.

Many signals which are inaudible in most receivers can be heard by the addition of a regenerative pre-selector. A good r.f. amplifier ahead of any superheterodyne receiver will increase the signal-to-noise ratio and reduce image interference to a negligible quantity. A single-tube pre-selector with regeneration can be made equivalent to a two-tube pre-selector without regeneration, and the slight additional load on the receiver power pack, with only one extra tube, usually will not overload the power transformer. This eliminates the need of an additional power pack for the pre-selector.

In the pre-selector here illustrated, either a 2.5 volt type 57 or 6.3 volt 6C6 tube can be used, depending upon the type of tubes employed in the radio receiver proper. The circuit of this pre-selector has a built-in balanced noise-suppressing circuit for the elimination of power-leak noise. The r.f. amplifier is regenerative, due to the cathode being tapped into the tuned grid circuit. The degree of regeneration is controlled by means of a potentiometer which varies the screen-grid voltage. The plate circuit can be connected into any kind of receiver input circuit without much loss in efficiency, since any im-

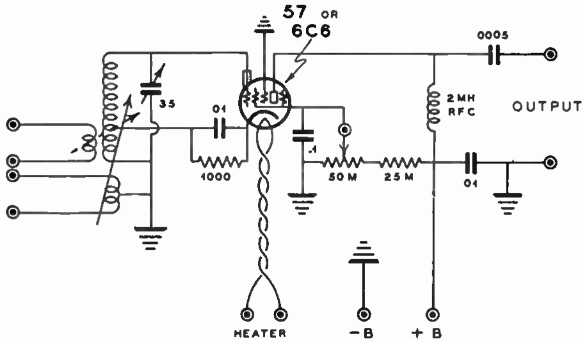


Figure 22—Wiring Diagram of the Regenerative Preselector.

pedance mismatch loss can be offset by regenerative gain in the r.f. amplifier.

The noise-balancing circuits were designed so that the regular receiving antenna and ground, or doublet antenna, can be connected to either of the primary windings, the noise antenna to the other. The noise-balancing antenna should be designed to pick up as much of the interfering noise as possible, while the receiving antenna should be mounted as high as is practicable to pick up a good ratio of signal-to-noise. The noise antenna should consist of a short wire near the ground, and parallel to the power line, or sometimes a connection can be made satisfactorily to one side of the 110-volt a.c. house-lighting circuit through a .002 μfd. mica condenser. The other side of the primary coil should be connected to ground in some cases, as determined by test. One antenna coil is made continuously adjustable by mounting it on a ¼-inch brass rod which slides through a telephone-jack in the front panel. This antenna coil consists of 12 turns of no. 24 d.s.c. wire, center-tapped, wound on the top portion of a 1½-in. diameter coil form, this portion being sawed from a conventional coil form. Flexible leads connect from the two ends of the winding to the antenna terminal strip. The center-tap connects to the brass rod, fastened to the coil form by means of a 6/32 machine screw which threads into the end of the brass rod. Coupling is varied by plunger-action from the knob control on the front panel.

The remaining primary is wound on each plug-in coil form at the top of the coil, near the grounded end of the secondary winding. The number of turns for the antenna winding, and the spacing of the secondary, are subject to experiment when balancing-out the power-leak noise. In quiet locations where there is no power-leak interference, the noise antenna and the additional semi-fixed coupling primary are not required. The adjustable primary should be built into the pre-selector for the purpose of obtaining ease of regeneration control for different types of antennas and various strengths of incoming signals.

A vernier tuning dial drives the 35 μμfd. midget tuning condenser.

The pre-selector is built into a metal cabinet, 7 in. high, 7½ in. long and 7 in. deep; the chassis is 1¾ in. deep. The tube must be shielded so as to prevent feedback between grid and plate circuit. The plate coupling lead should be made as short as possible to the antenna terminals of the radio receiver proper.

Coil Table For Regenerative Pre-Selector

All Coils Wound on 1¼ in. Diameter 5-Prong Forms.

Band Meters	Coil
10.....	**5 turns, No. 20 d.s.c., 1-in. long, tapped at 1/3rd turn.**
20.....	**12 turns, No. 20 d.s.c., 1-in. long, tapped at 1/3rd turn.**
40.....	**23 turns, No. 20 d.s.c., 1-in. long, tapped at ½ turn.**
80.....	**42 turns, No. 20 d.s.c., 1½-in long, tapped at ¾ turn.**
160.....	**80 turns, No. 30 Enam., close-wound, tapped at 1 turn.**

Receiver Notes

(Coil data, frequency-versus-dial-setting log, dates new tubes or batteries were installed, etc.)

Chapter 8

Radio Receiver Tube Characteristics

Receiver Tube Characteristics

TYPE	NAME	BASE	SOCKET CONNECTIONS	DIMENSIONS MAXIMUM OVERALL LENGTH x DIAMETER	CATHODE TYPE ■	RATING: FILAMENT OR HEATER VOLTS	FILAMENT OR HEATER AMPERES	PLATE MAX. VOLTS	SCREEN MAX. VOLTS
00-A	DETECTOR TRIODE	MEDIUM 4-PIN Bayonet	4D	4 11/16" x 1 13/16"	D-C FILAMENT	5.0	0.25	45	—
01-A	DETECTOR★ AMPLIFIER	MEDIUM 4-PIN Bayonet	4D	4 11/16" x 1 13/16"	D-C FILAMENT	5.0	0.25	135	—
1A4	SUPER-CONTROL R-F AMPLIFIER PENTODE	SMALL 4-PIN	4M	4 17/32" x 1 9/16"	D-C FILAMENT	2.0	0.06	180	67.5
1A6	PENTAGRID CONVERTER ¤	SMALL 6-PIN	6L	4 17/32" x 1 9/16"	D-C FILAMENT	2.0	0.06	180	67.5
1B4	R-F AMPLIFIER PENTODE	SMALL 4-PIN	4M	4 17/32" x 1 9/16"	D-C FILAMENT	2.0	0.06	180	67.5
1B5/25S	DUPLEX-DIODE TRIODE	SMALL 6-PIN	6M	4 1/4" x 1 9/16"	D-C FILAMENT	2.0	0.06	135	—
1C6	PENTAGRID CONVERTER ¤	SMALL 6-PIN	6L	4 17/32" x 1 9/16"	D-C FILAMENT	2.0	0.12	180	67.5
1F4	POWER AMPLIFIER PENTODE	MEDIUM 5-PIN	5K	4 11/16" x 1 13/16"	D-C FILAMENT	2.0	0.12	135	135
1F6	DUPLEX-DIODE PENTODE	SMALL 6-PIN	6W	4 17/32" x 1 9/16"	D-C FILAMENT	2.0	0.06	180	67.5
1-V	HALF-WAVE RECTIFIER	SMALL 4-PIN	4G	4 1/4" x 1 9/16"	HEATER	6.3	0.3	—	—
2A3	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN	4D	5 3/8" x 2 1/16"	FILAMENT	2.5	2.5	250 300	— —
2A5	POWER AMPLIFIER PENTODE	MEDIUM 6-PIN	6B	4 11/16" x 1 13/16"	HEATER	2.5	1.75	—	—
2A6	DUPLEX-DIODE HIGH-MU TRIODE	SMALL 6-PIN	6G	4 17/32" x 1 9/16"	HEATER	2.5	0.8	250	—
2A7	PENTAGRID CONVERTER ¤	SMALL 7-PIN	7C	4 17/32" x 1 9/16"	HEATER	2.5	0.8	250	100
2B7	DUPLEX-DIODE PENTODE	SMALL 7-PIN	7D	4 17/32" x 1 9/16"	HEATER	2.5	0.8	250	125
5W4	FULL-WAVE RECTIFIER	SMALL OCTAL 5-PIN	5T	3 1/4" x 1 5/16"	FILAMENT	5.0	1.5	—	—
5Z3	FULL-WAVE RECTIFIER	MEDIUM 4-PIN	4C	5 3/8" x 2 1/16"	FILAMENT	5.0	3.0	—	—
5Z4	FULL-WAVE RECTIFIER	SMALL OCTAL 5-PIN	5L	3 1/4" x 1 5/16"	HEATER	5.0	2.0	—	—
6A4/LA	POWER AMPLIFIER PENTODE	MEDIUM 5-PIN	5B	4 11/16" x 1 13/16"	FILAMENT	6.3	0.3	180	180
6A6	TWIN-TRIODE AMPLIFIER	MEDIUM 7-PIN #	7B	4 11/16" x 1 13/16"	HEATER	6.3	0.8	300	—
6A7	PENTAGRID CONVERTER ¤	SMALL 7-PIN	7C	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	100
6A8	PENTAGRID CONVERTER ¤	SMALL OCTAL 8-PIN	8A	3 1/8" x 1 5/16"	HEATER	6.3	0.3	250	100
6B7	DUPLEX-DIODE PENTODE	SMALL 7-PIN	7D	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	125
6B8	DUPLEX-DIODE PENTODE	SMALL OCTAL 8-PIN	8E	3 1/8" x 1 5/16"	HEATER	6.3	0.3	250	125
6C5	DETECTOR★ AMPLIFIER TRIODE	SMALL OCTAL 6-PIN	6Q	2 5/8" x 1 5/16"	HEATER	6.3	0.3	250	—
6C6	TRIPLE-GRID DETECTOR AMPLIFIER	SMALL 6-PIN	6F	4 15/16" x 1 9/16"	HEATER	6.3	0.3	250	100

Receiver Tube Characteristics

USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID BIAS ■ VOLTS	SCREEN SUPPLY VOLTS	SCREEN CURRENT MA.	PLATE CURRENT MA.	A-C PLATE RESISTANCE OHMS	TRANSCONDUCTANCE (GRID-PLATE) µMHOS	AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
GRID-LEAK DETECTOR	45	Grid Return to (−) Filament			1.5	30000	666	20	——	——	00-A
CLASS A AMPLIFIER	90 135	− 4.5 − 9.0	——	——	2.5 3.0	11000 10000	725 800	8.0 8.0	——	——	01-A
CLASS A AMPLIFIER	90 180	{− 3.0 min.}	67.5 67.5	0.9 0.8	2.2 2.3	600000 1000000	720 750	425 750	——	——	1A4
CONVERTER	135 180	{− 3.0 min.}	67.5 67.5	2.5 2.4	1.2 1.3	400000 500000	Anode-Grid (#2): 180◆ max. volts, 2.3 ma. Oscillator-Grid (#1) Resistor●. Conversion Conductance, 300 micromhos.				1A6
CLASS A AMPLIFIER	90 180	− 3.0 − 3.0	67.5 67.5	0.7 0.6	1.6 1.7	1000000 1500000	600 650	550 1000	——	——	1B4
CLASS A AMPLIFIER	135	− 3.0	——	——	0.8	35000	575	20	——	——	1B5/25S
CONVERTER	135 180	{− 3.0 min.}	67.5 67.5	2.0 2.0	1.3 1.5	550000 750000	Anode-Grid (#2): 180◆ max. volts, 3.3 ma. Oscillator-Grid (#1) Resistor●. Conversion Conductance, 325 micromhos.				1C6
CLASS A AMPLIFIER	135	− 4.5	135	2.6	8.0	200000	1700	340	16000	0.34	1F4
PENTODE UNIT AS R-F AMPLIFIER	180	− 1.5	67.5	0.6	2.0	1000000	650	650	——	——	1F6
PENTODE UNIT AS A-F AMPLIFIER	135✖	− 2.0	Screen Supply, 135 volts applied through 0.8-megohm resistor. Grid Resistor,●● 1.0 megohm. Voltage Gain, 46.								1F6
Maximum A-C Plate Voltage....350 Volts, RMS Maximum D-C Output Current....50 Milliamperes											1-v
CLASS A AMPLIFIER	250	−45.0	——	——	60.0	800	5250	4.2	2500	3.5	2A3
PUSH-PULL CLASS AB_1 AMPLIFIER	300 300	Self-bias, 780 ohms −62 volts, fixed bias			80.0 80.0	——	——	——	5000 3000	10.0† 15.0†	2A3
AMPLIFIER	For other ratings and characteristics, refer to Type 42.										2A5
TRIODE UNIT AS AMPLIFIER	For other characteristics, refer to Type 75.										2A6
CONVERTER	For other characteristics, refer to Type 6A7.										2A7
AMPLIFIER	For other characteristics, refer to Type 6B7.										2B7
Maximum A-C Voltage per Plate....350 Volts, RMS Maximum D-C Output Current....110 Milliamperes											5W4
Maximum A-C Voltage per Plate....500 Volts, RMS Maximum D-C Output Current....250 Milliamperes											5Z3
Maximum A-C Voltage per Plate....400 Volts, RMS Maximum D-C Output Current....125 Milliamperes											5Z4
CLASS A AMPLIFIER	100 180	− 6.5 −12.0	100 180	1.6 3.9	9.0 22.0	83250 45500	1200 2200	100 100	11000 8000	0.31 1.40	6A4/LA
AMPLIFIER	For other characteristics, refer to Type 6N7.										6A6
CONVERTER	100 250	{− 3.0 min.}	50 100	2.5 2.2	1.3 3.5	600000 360000	Anode-Grid (#2): 250◆ max. volts, 4.0 ma. Oscillator-Grid (#1) Resistor●. Conversion Conductance, 520 micromhos.				6A7
CONVERTER	100 250	{− 3.0 min.}	50 100	1.5 3.2	1.2 3.3	600000 360000	Anode-Grid (#2): 250◆ max. volts, 4.0 ma. Oscillator-Grid (#1) Resistor●. Conversion Conductance, 500 micromhos.				6A8
PENTODE UNIT AS R-F AMPLIFIER	100 250	− 3.0 − 3.0	100 125	1.7 2.3	5.8 9.0	300000 650000	950 1125	285 730	——	——	6B7
PENTODE UNIT AS A-F AMPLIFIER	90✖ 300✖	Self-bias, 3500 ohms. Screen Resistor = 1.1 meg. Self-bias, 1600 ohms. Screen Resistor = 1.2 meg.					Grid Resistor,●● 0.5 megohm.	{Gain per stage = 55 Gain per stage = 79			6B7
PENTODE UNIT AS R-F AMPLIFIER	250	− 3.0	125	2.3	10.0	600000	1325	800	——	——	6B8
PENTODE UNIT AS A-F AMPLIFIER	90✖ 300✖	Self-bias, 3500 ohms. Screen Resistor = 1.1 meg. Self-bias, 1600 ohms. Screen Resistor = 1.2 meg.					Grid Resistor,●● 0.5 megohm.	{Gain per stage = 55 Gain per stage = 79			6B8
CLASS A AMPLIFIER	250 250♥	− 8.0 − 5.0	——	——	8.0 1.0	10000 Gain per stage = 14	2000	20	——	——	6C5
BIAS DETECTOR	250	{−17.0 approx.}	——	——	Plate current to be adjusted to 0.2 milliampere with no signal.						6C5
AMPLIFIER DETECTOR	For other characteristics, refer to Type 6J7.										6C6

Receiver Tube Characteristics

TYPE	NAME	BASE	SOCKET CONNECTIONS	DIMENSIONS MAXIMUM OVERALL LENGTH X DIAMETER	CATHODE TYPE ■	RATING FILAMENT OR HEATER VOLTS	AMPERES	PLATE MAX. VOLTS	SCREEN MAX. VOLTS
6D6	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	SMALL 6-PIN	6F	4 13/16" x 1 9/16"	HEATER	6.3	0.3	250	100
6E5	ELECTRON-RAY TUBE	SMALL 6-PIN	6R	4 1/4" x 1 9/16"	HEATER	6.3	0.3	250†	—
6F5	HIGH-MU TRIODE	SMALL OCTAL 5-PIN	5M	3 1/8" x 1 5/16"	HEATER	6.3	0.3	250	—
6F6	POWER AMPLIFIER PENTODE	SMALL OCTAL 7-PIN	7S	3 1/4" x 1 5/16"	HEATER	6.3	0.7	315	315
								250	—
								375	250
								350	—
6F7	TRIODE-PENTODE	SMALL 7-PIN	7E	4 17/32" x 1 9/16"	HEATER	6.3	0.3	100	—
								250	100
								250	100
6G5	ELECTRON-RAY TUBE	SMALL 6-PIN	6R	4 1/4" x 1 9/16"	HEATER	6.3	0.3	250†	—
6H6	TWIN DIODE	SMALL OCTAL 7-PIN	7Q	1 5/8" x 1 5/16"	HEATER	6.3	0.3	—	—
6J7	TRIPLE-GRID DETECTOR AMPLIFIER	SMALL OCTAL 7-PIN	7R	3 1/8" x 1 5/16"	HEATER	6.3	0.3	250	125
6K7	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	SMALL OCTAL 7-PIN	7R	3 1/8" x 1 5/16"	HEATER	6.3	0.3	250	125
6L6	BEAM POWER AMPLIFIER	SMALL OCTAL 7-PIN	7AC	4 5/16" x 1 5/8"	HEATER	6.3	0.9	375	250
								375	250
								400	300
								400	300
6L7	PENTAGRID MIXER & AMPLIFIER	SMALL OCTAL 7-PIN	7T	3 1/8" x 1 5/16"	HEATER	6.3	0.3	250	150
								250	100
6N7	TWIN-TRIODE AMPLIFIER	SMALL OCTAL 8-PIN	8B	3 1/4" x 1 5/16"	HEATER	6.3	0.8	300	—
6Q7	DUPLEX-DIODE HIGH-MU TRIODE	SMALL OCTAL 7-PIN	7V	3 1/8" x 1 5/16"	HEATER	6.3	0.3	250	—
6R7	DUPLEX-DIODE TRIODE	SMALL OCTAL 7-PIN	7V	3 1/8" x 1 5/16"	HEATER	6.3	0.3	250	—
6X5	FULL-WAVE RECTIFIER	SMALL OCTAL 6-PIN	6S	3 1/4" x 1 5/16"	HEATER	6.3	0.6	—	—
10	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN Bayonet	4D	5 5/8" x 2 3/16"	FILAMENT	7.5	1.25	425	—

Receiver Tube Characteristics

USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID BIAS ■ VOLTS	SCREEN SUPPLY VOLTS	SCREEN CURRENT MA.	PLATE CURRENT MA.	A-C PLATE RESISTANCE OHMS	TRANSCONDUCTANCE (GRID-PLATE) μMHOS	AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
SCREEN-GRID R-F AMPLIFIER	100 250	− 3.0 min.	100 100	2.2 2.0	8.0 8.2	250000 800000	1500 1600	375 1280	——	——	6D6
MIXER IN SUPERHETERODYNE	100 250	−10.0 −10.0	100 100	——	——	Oscillator Peak Volts = 7.0					6D6
VISUAL INDICATOR	Plate & Target Supply = 100 volts. Triode Plate Resistor = 0.5 meg. Target Current = 4.5 ma. Grid Bias, −3.3 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.19 ma.										6E5
	Plate & Target Supply = 250 volts. Triode Plate Resistor = 1.0 meg. Target Current = 4.5 ma. Grid Bias, −8.0 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.24 ma.										6E5
CLASS A AMPLIFIER	250 250✖	− 2.0 − 0.3	——	——	0.9 0.4	66000 Grid Resistor, 0.25 meg.** Gain per stage = 52	1500	100	——	——	6F5
PENTODE CLASS A AMPLIFIER	250 315	−16.5 −22.0	250 315	6.5 8.0	34.0 42.0	80000 75000	2500 2650	200 200	7000 7000	3.0 5.0	6F6
TRIODE□ CLASS A AMPLIFIER	250	−20.0	——	——	31.0	2600	2700	7	4000	0.85	6F6
PENTODE PUSH-PULL CLASS AB_2 AMPLIFIER	375 375	Self-bias −26.0	250 250	8.0 5.0	54.0 34.0	Self-Bias Resistor, 340 ohms ——	——	——	10000 10000	19.0† 19.0†	6F6
TRIODE PUSH-PULL□ CLASS AB_2 AMPLIFIER	350 350	Self-bias −38.0	——	——	50.0 45.0	Self-Bias Resistor, 730 ohms ——	——	——	10000 6000	14.0† 18.0†	6F6
TRIODE UNIT AS CLASS A AMPLIFIER	100	− 3.0	——	——	3.5	16000	500	8	——	——	6F7
PENTODE UNIT AS CLASS A AMPLIFIER	100 250	− 3.0 min.	100 100	1.6 1.5	6.3 6.5	290000 850000	1050 1100	300 900	——	——	6F7
PENTODE UNIT AS MIXER	250	−10.0	100	0.6	2.8	Oscillator Peak Volts = 7.0. Conversion Conductance = 300 micromhos.					6F7
VISUAL INDICATOR	Plate & Target Supply = 100 volts. Triode Plate Resistor = 0.5 meg. Target Current = 4.5 ma. Grid Bias, −8 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.19 ma.										6G5
	Plate & Target Supply = 250 volts. Triode Plate Resistor = 1.0 meg. Target Current = 4.5 ma. Grid Bias, −22 volts; Shadow Angle, 0°. Bias, 0 volts; Angle, 90°; Plate Current, 0.24 ma.										6G5
TWIN-DIODE DETECTOR RECTIFIER	Maximum A-C Voltage per Plate..........100 Volts, RMS Maximum D-C Output Current.......... 4 Milliamperes										6H6
SCREEN-GRID R-F AMPLIFIER	100 250	− 3.0 − 3.0	100 100	0.5 0.5	2.0 2.0	1000000 1.5 +§	1185 1225	1185 1500+	——	——	6J7
SCREEN-GRID A-F AMPLIFIER	90✖ 300✖	Self-bias, 2600 ohms. Screen Resistor = 1.2 meg. Self-bias, 1200 ohms. Screen Resistor = 1.2 meg.					Grid Resistor,** 0.5 megohm.	Gain per stage = 85 Gain per stage = 140			6J7
BIAS DETECTOR	250	− 4.3	100	Cathode current 0.43 ma.		——	Plate Resistor, 500000 ohms. Grid Resistor,** 250000 ohms.				6J7
SCREEN-GRID R-F AMPLIFIER	90 250	− 3.0 min.	90 125	1.3 2.6	5.4 10.5	315000 600000	1275 1650	400 990	——	——	6K7
MIXER IN SUPERHETERODYNE	250	−10.0	100	——	——	Oscillator Peak Volts = 7.0					6K7
SINGLE-TUBE CLASS A_1 AMPLIFIER	250 250	−14.0 Self-bias	250 250	5.0 5.4	72.0 75.0	—— Self-Bias Resistor, 170 ohms.	——	——	2500 2500	6.5 6.5	6L6
PUSH-PULL CLASS A_1 AMPLIFIER	250 250	−16.0 Self-bias	250 250	10.0 10.0	120.0 120.0	—— Self-Bias Resistor, 125 ohms.	——	——	5000 5000	14.5† 13.8†	6L6
PUSH-PULL CLASS AB_1 AMPLIFIER	400 400	−25.0 Self-bias	300 300	6.0 7.0	102.0 112.0	—— Self-Bias Resistor, 200 ohms.	——	——	6600 6600	34.0† 32.0†	6L6
PUSH-PULL CLASS AB_2 AMPLIFIER	400 400	−20.0 −25.0	250 300	4.0 6.0	88.0 102.0	——	——	——	6000 3800	40.0† 60.0†	6L6
MIXER IN SUPERHETERODYNE	250	− 3.0	100	6.2	2.4	Oscillator-Grid (#3) Bias, −10 volts. Grid #3 Peak Swing, 12 volts min. Conversion Conductance, 350 micromhos.					6L7
CLASS A AMPLIFIER	250	− 3.0 min.◖	100	5.5	5.3	800000	1100	880	——	——	6L7
CLASS A AMPLIFIER (As Driver)○	250 294	− 5.0 − 6.0	——	——	6.0 7.0	11300 11000	3100 3200	35 35	20000 or more	exceeds 0.4	6N7
CLASS B AMPLIFIER	250 300	0 0	——	——	Power Output is for one tube at stated plate-to-plate load.				8000 10000	8.0 10.0	6N7
TRIODE UNIT AS CLASS A AMPLIFIER	100 250	− 1.5 − 3.0	——	——	0.35 1.1	87500 58000	800 1200	70 70	——	——	6Q7
	100○○ 250■	− 1.1 − 2.0	——	——	0.25 0.5	Grid Resistor, ** 0.5 megohm		Gain per stage = 35 Gain per stage = 43			6Q7
TRIODE UNIT AS CLASS A AMPLIFIER	250 250♥	− 9.0 − 6.0	——	——	9.5 1.3	8500 Grid Resistor, ** 0.5 meg. Gain per stage = 12	1900	16	10000	0.28	6R7
	Maximum A-C Voltage per Plate..........350 Volts, RMS Maximum D-C Output Current.......... 75 Milliamperes										6X5
CLASS A AMPLIFIER	350 425	−32.0 −40.0	——	——	16.0 18.0	5150 5000	1550 1600	8.0 8.0	11000 10200	0.9 1.6	10

Receiver Tube Characteristics

TYPE	NAME	BASE	SOCKET CONNEC-TIONS	DIMENSIONS MAXIMUM OVERALL LENGTH X DIAMETER	CATHODE TYPE ■	RATING			
						FILAMENT OR HEATER		PLATE	SCREEN
						VOLTS	AMPERES	MAX. VOLTS	MAX. VOLTS
11 12	DETECTOR★ AMPLIFIER TRIODE	WD 4-PIN MEDIUM 4-PIN Bayonet	4F 4D	$4\frac{1}{8}$" x $1\frac{3}{16}$" $4\frac{11}{16}$" x $1\frac{7}{16}$"	D-C FILAMENT	1.1	0.25	135	—
12Z3	HALF-WAVE RECTIFIER	SMALL 4-PIN	4G	$4\frac{1}{4}$" x $1\frac{9}{16}$"	HEATER	12.6	0.3	—	—
15	R-F AMPLIFIER PENTODE	SMALL 5-PIN	5F	$4\frac{17}{32}$" x $1\frac{9}{16}$"	HEATER	2.0	0.22	135	67.5
19	TWIN-TRIODE AMPLIFIER	SMALL 6-PIN	6C	$4\frac{1}{4}$" x $1\frac{9}{16}$"	D-C FILAMENT	2.0	0.26	135	—
20	POWER AMPLIFIER TRIODE	SMALL 4-PIN	4D	$4\frac{1}{8}$" x $1\frac{3}{16}$"	D-C FILAMENT	3.3	0.132	135	—
22	R-F AMPLIFIER TETRODE	MEDIUM 4-PIN	4K	$5\frac{1}{32}$" x $1\frac{13}{16}$"	D-C FILAMENT	3.3	0.132	135	67.5
24-A	R-F AMPLIFIER TETRODE	MEDIUM 5-PIN	5E	$5\frac{1}{32}$" x $1\frac{13}{16}$"	HEATER	2.5	1.75	275	90
25A6	POWER AMPLIFIER PENTODE	SMALL OCTAL 7-PIN	7S	$3\frac{1}{4}$" x $1\frac{5}{16}$"	HEATER	25.0	0.3	180	135
25Z5	RECTIFIER-DOUBLER	SMALL 6-PIN	6E	$4\frac{1}{4}$" x $1\frac{9}{16}$"	HEATER	25.0	0.3	—	—
25Z6	RECTIFIER-DOUBLER	SMALL OCTAL 7-PIN	7Q	$3\frac{1}{4}$" x $1\frac{5}{16}$"	HEATER	25.0	0.3	—	—
26	AMPLIFIER TRIODE	MEDIUM 4-PIN	4D	$4\frac{11}{16}$" x $1\frac{13}{16}$"	FILAMENT	1.5	1.05	180	—
27	DETECTOR★ AMPLIFIER TRIODE	MEDIUM 5-PIN	5A	$4\frac{1}{4}$" x $1\frac{9}{16}$"	HEATER	2.5	1.75	275	—
30	DETECTOR★ AMPLIFIER TRIODE	SMALL 4-PIN	4D	$4\frac{1}{4}$" x $1\frac{9}{16}$"	D-C FILAMENT	2.0	0.06	180	—
31	POWER AMPLIFIER TRIODE	SMALL 4-PIN	4D	$4\frac{1}{4}$" x $1\frac{9}{16}$"	D-C FILAMENT	2.0	0.13	180	—
32	R-F AMPLIFIER TETRODE	MEDIUM 4-PIN	4K	$5\frac{1}{32}$" x $1\frac{13}{16}$"	D-C FILAMENT	2.0	0.06	180	67.5
33	POWER AMPLIFIER PENTODE	MEDIUM 5-PIN	5K	$4\frac{11}{16}$" x $1\frac{13}{16}$"	D-C FILAMENT	2.0	0.26	180	180
34	SUPER-CONTROL R-F AMPLIFIER PENTODE	MEDIUM 4-PIN	4M	$5\frac{1}{32}$" x $1\frac{13}{16}$"	D-C FILAMENT	2.0	0.06	180	67.5
35	SUPER-CONTROL R-F AMPLIFIER TETRODE	MEDIUM 5-PIN	5E	$5\frac{1}{32}$" x $1\frac{13}{16}$"	HEATER	2.5	1.75	275	90
36	R-F AMPLIFIER TETRODE	SMALL 5-PIN	5E	$4\frac{17}{32}$" x $1\frac{9}{16}$"	HEATER	6.3	0.3	250	90
37	DETECTOR★ AMPLIFIER TRIODE	SMALL 5-PIN	5A	$4\frac{1}{4}$" x $1\frac{9}{16}$"	HEATER	6.3	0.3	250	—
38	POWER AMPLIFIER PENTODE	SMALL 5-PIN	5F	$4\frac{17}{32}$" x $1\frac{9}{16}$"	HEATER	6.3	0.3	250	250
39/44	SUPER-CONTROL R-F AMPLIFIER PENTODE	SMALL 5-PIN	5F	$4\frac{17}{32}$" x $1\frac{9}{16}$"	HEATER	6.3	0.3	250	90
40	VOLTAGE AMPLIFIER TRIODE	MEDIUM 4-PIN Bayonet	4D	$4\frac{11}{16}$" x $1\frac{13}{16}$"	D-C FILAMENT	5.0	0.25	180	—
41	POWER AMPLIFIER PENTODE	SMALL 6-PIN	6B	$4\frac{1}{4}$" x $1\frac{9}{16}$"	HEATER	6.3	0.4	250	250

Receiver Tube Characteristics

USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID BIAS ■ VOLTS	SCREEN SUPPLY VOLTS	SCREEN CURRENT MA.	PLATE CURRENT MA.	A-C PLATE RESISTANCE OHMS	TRANSCONDUCTANCE (GRID-PLATE) μMHOS	AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
CLASS A AMPLIFIER	90 135	− 4.5 −10.5	—	—	2.5 3.0	15500 15000	425 440	6.6 6.6	—	—	11 12
Maximum A-C Plate Voltage ....250 Volts, RMS Maximum D-C Output Current .... 60 Milliamperes											1Z3
CLASS A AMPLIFIER	67.5 135	− 1.5 − 1.5	67.5 67.5	0.3 0.3	1.85 1.85	630000 800000	710 750	450 600	—	—	15
CLASS B AMPLIFIER	135 135	0 − 3.0	—	—	Power Output is for one tube at stated plate-to-plate load.				10000 10000	2.1 1.9	19
CLASS A AMPLIFIER	90 135	−16.5 −22.5	—	—	3.0 6.5	8000 6300	415 525	3.3 3.3	9600 6500	0.045 0.110	20
SCREEN-GRID R-F AMPLIFIER	135 135	− 1.5 − 1.5	45 67.5	0.6* 1.3*	1.7 3.7	725000 325000	375 500	270 160	—	—	22
SCREEN-GRID R-F AMPLIFIER	180 250	− 3.0 − 3.0	90 90	1.7* 1.7*	4.0 4.0	400000 600000	1000 1050	400 630	—	—	24-A
BIAS DETECTOR	250●	−5.0 approx.	20 to 45	—	Plate current to be adjusted to 0.1 milliampere with no signal.						24-A
CLASS A AMPLIFIER	95 180	−15.0 −20.0	95 135	4.0 7.5	20.0 38.0	45000 40000	2000 2500	90 100	4500 5000	0.9 2.75	25A6
VOLTAGE DOUBLER	Maximum A-C Voltage per Plate .... 125 Volts, RMS Maximum D-C Output Current .... 100 Milliamperes										25Z5
HALF-WAVE RECTIFIER	Maximum A-C Voltage per Plate ¶ ....250 Volts, RMS Maximum D-C Output Current per Plate .... 85 Milliamperes										25Z5
VOLTAGE DOUBLER	Maximum A-C Voltage per Plate .... 125 Volts, RMS Maximum D-C Output Current .... 85 Milliamperes										25Z6
HALF-WAVE RECTIFIER	Maximum A-C Voltage per Plate ¶ .... 250 Volts, RMS Maximum D-C Output Current per Plate .... 85 Milliamperes										25Z6
CLASS A AMPLIFIER	90 180	− 7.0 −14.5	—	—	2.9 6.2	8900 7300	935 1150	8.3 8.3	—	—	26
CLASS A AMPLIFIER	135 250	− 9.0 −21.0	—	—	4.5 5.2	9000 9250	1000 975	9.0 9.0	—	—	27
BIAS DETECTOR	250	−30.0 approx.	—	—	Plate current to be adjusted to 0.2 milliampere with no signal.						27
CLASS A AMPLIFIER	90 135 180	− 4.5 − 9.0 −13.5	—	—	2.5 3.0 3.1	11000 10300 10300	850 900 900	9.3 9.3 9.3	—	—	30
CLASS B AMPLIFIER	157.5	−15.0	—	—	1.0	—	—	—	8000	2.1†	30
CLASS A AMPLIFIER	135 180	−22.5 −30.0	—	—	8.0 12.3	4100 3600	925 1050	3.8 3.8	7000 5700	0.185 0.375	31
SCREEN-GRID R-F AMPLIFIER	135 180	− 3.0 − 3.0	67.5 67.5	0.4* 0.4*	1.7 1.7	950000 1200000	640 650	610 780	—	—	32
BIAS DETECTOR	180♥	− 6.0 approx.	67.5	—	Plate current to be adjusted to 0.2 milliampere with no signal.						32
CLASS A AMPLIFIER	180	−18.0	180	5.0	22.0	55000	1700	90	6000	1.4	33
SCREEN-GRID R-F AMPLIFIER	135 180	− 3.0 min.	67.5 67.5	1.0 1.0	2.8 2.8	600000 1000000	600 620	360 620	—	—	34
SCREEN-GRID R-F AMPLIFIER	180 250	− 3.0 min.	90 90	2.5* 2.5*	6.3 6.5	300000 400000	1020 1050	305 420	—	—	35
SCREEN-GRID R-F AMPLIFIER	100 250	− 1.5 − 3.0	55 90	— 1.7*	1.8 3.2	550000 550000	850 1080	470 595	—	—	36
BIAS DETECTOR	100● 250●	− 5.0 − 8.0	55 90	—	Grid-bias values are approximate. Plate current to be adjusted to 0.1 milliampere with no signal.						36
CLASS A AMPLIFIER	90 250	− 6.0 −18.0	—	—	2.5 7.5	11500 8400	800 1100	9.2 9.2	—	—	37
BIAS DETECTOR	90 250	−10.0 −28.0	—	—	Grid-bias values are approximate. Plate current to be adjusted to 0.2 milliampere with no signal.						37
CLASS A AMPLIFIER	100 250	− 9.0 −25.0	100 250	1.2 3.8	7.0 22.0	140000 100000	875 1200	120 120	15000 10000	0.27 2.50	38
SCREEN-GRID R-F AMPLIFIER	90 250	− 3.0 min.	90 90	1.6 1.4	5.6 5.8	375000 1000000	960 1050	360 1050	—	—	39/44
CLASS A AMPLIFIER	135✖ 180✖	− 1.5 − 3.0	—	—	0.2 0.2	150000 150000	200 200	30 30	—	—	40
CLASS A AMPLIFIER	100 250	− 7.0 −18.0	100 250	1.6 5.5	9.0 32.0	103500 68000	1450 2200	150 150	12000 7600	0.33 3.40	41

Receiver Tube Characteristics

TYPE	NAME	BASE	SOCKET CONNECTIONS	DIMENSIONS MAXIMUM OVERALL LENGTH X DIAMETER	CATHODE TYPE ■	RATING: FILAMENT OR HEATER VOLTS	RATING: FILAMENT OR HEATER AMPERES	RATING: PLATE MAX. VOLTS	RATING: SCREEN MAX. VOLTS
42	POWER AMPLIFIER PENTODE	MEDIUM 6-PIN	6B	$4\frac{11}{16}$" x $1\frac{13}{16}$"	HEATER	6.3	0.7	315 315 375 350	315 — 250 —
43	POWER AMPLIFIER PENTODE	MEDIUM 6-PIN	6B	$4\frac{11}{16}$" x $1\frac{13}{16}$"	HEATER	25.0	0.3	180	135
45	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN	4D	$4\frac{11}{16}$" x $1\frac{13}{16}$"	FILAMENT	2.5	1.5	275	—
46	DUAL-GRID POWER AMPLIFIER	MEDIUM 5-PIN	5C	$5\frac{5}{8}$" x $2\frac{3}{16}$"	FILAMENT	2.5	1.75	250 400	— —
47	POWER AMPLIFIER PENTODE	MEDIUM 5-PIN	5B	$5\frac{7}{8}$" x $2\frac{1}{16}$"	FILAMENT	2.5	1.75	250	250
48	POWER AMPLIFIER TETRODE	MEDIUM 6-PIN	6A	$5\frac{3}{8}$" x $2\frac{1}{16}$"	D-C HEATER	30.0	0.4	125	100
49	DUAL-GRID POWER AMPLIFIER	MEDIUM 5-PIN	5C	$4\frac{11}{16}$" x $1\frac{13}{16}$"	D-C FILAMENT	2.0	0.12	135 180	— —
50	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN Bayonet	4D	$6\frac{1}{4}$" x $2\frac{7}{16}$"	FILAMENT	7.5	1.25	450	—
53	TWIN-TRIODE AMPLIFIER	MEDIUM 7-PIN#	7B	$4\frac{11}{16}$" x $1\frac{13}{16}$"	HEATER	2.5	2.0	300	—
55	DUPLEX-DIODE TRIODE	SMALL 6-PIN	6G	$4\frac{17}{32}$" x $1\frac{9}{16}$"	HEATER	2.5	1.0	250	—
56	SUPER-TRIODE AMPLIFIER DETECTOR★	SMALL 5-PIN	5A	$4\frac{1}{4}$" x $1\frac{9}{16}$"	HEATER	2.5	1.0	250	—
57	TRIPLE-GRID DETECTOR AMPLIFIER	SMALL 6-PIN	6F	$4\frac{15}{16}$" x $1\frac{9}{16}$"	HEATER	2.5	1.0	250	100
58	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	SMALL 6-PIN	6F	$4\frac{15}{16}$" x $1\frac{9}{16}$"	HEATER	2.5	1.0	250	100
59	TRIPLE-GRID POWER AMPLIFIER	MEDIUM 7-PIN#	7A	$5\frac{3}{8}$" x $2\frac{1}{16}$"	HEATER	2.5	2.0	250 250 400	— 250 —
71-A	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN Bayonet	4D	$4\frac{11}{16}$" x $1\frac{13}{16}$"	FILAMENT	5.0	0.25	180	—
75	DUPLEX-DIODE HIGH-MU TRIODE	SMALL 6-PIN	6G	$4\frac{17}{32}$" x $1\frac{9}{16}$"	HEATER	6.3	0.3	250	—
76	SUPER-TRIODE AMPLIFIER DETECTOR★	SMALL 5-PIN	5A	$4\frac{1}{4}$" x $1\frac{9}{16}$"	HEATER	6.3	0.3	250	—
77	TRIPLE-GRID DETECTOR AMPLIFIER	SMALL 6-PIN	6F	$4\frac{17}{32}$" x $1\frac{9}{16}$"	HEATER	6.3	0.3	250	100
78	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	SMALL 6-PIN	6F	$4\frac{17}{32}$" x $1\frac{9}{16}$"	HEATER	6.3	0.3	250	125

Receiver Tube Characteristics

USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID BIAS ■ VOLTS	SCREEN SUPPLY VOLTS	SCREEN CURRENT MA.	PLATE CURRENT MA.	A-C PLATE RESISTANCE OHMS	TRANSCONDUCTANCE (GRID-PLATE) µMHOS	AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
PENTODE CLASS A AMPLIFIER	250 315	−16.5 −22.0	250 315	6.5 8.0	34.0 42.0	80000 100000	2350 2600	190 260	7000 7000	3.0 5.0	42
TRIODE □ CLASS A AMPLIFIER	250	−20.0	——	——	31.0	2700	2300	6.2	3000	0.65	42
PENTODE PUSH-PULL CLASS AB_2 AMPLIFIER	375 375	Self-bias −26.0	250 250	8.0 5.0	54.0 34.0	Self-Bias Resistor, 340 ohms ——	 ——	 ——	10000 10000	19.0† 19.0†	42
TRIODE PUSH-PULL □ CLASS AB_2 AMPLIFIER	350 350	Self-bias, 730 ohms −38.0 volts, fixed bias			50.0 45.0	——	——	——	10000 6000	14.0† 18.0†	42
CLASS A AMPLIFIER	95 180	−15.0 −20.0	95 135	4.0 7.5	20.0 38.0	45000 40000	2000 2500	90 100	4500 5000	0.90 2.75	43
CLASS A AMPLIFIER	180 275	−31.5 −56.0	——	——	31.0 36.0	1650 1700	2125 2050	3.5 3.5	2700 4600	0.82 2.00	45
CLASS AB_2 AMPLIFIER	275 275	Self-bias, 775 ohms −68.0 volts, fixed bias			72.0 28.0	——	——	——	5060 3200	12.0† 18.0†	45
CLASS A AMPLIFIER □	250	−33.0	——	——	22.0	2380	2350	5.6	6400	1.25	46
CLASS B AMPLIFIER ♦	300 400	0 0	——	——	8.0 12.0	——	——	——	5200 5800	16.0† 20.0†	46
CLASS A AMPLIFIER	250	−16.5	250	6.0	31.0	60000	2500	150	7000	2.7	47
TETRODE CLASS A AMPLIFIER	96 125	−19.0 −20.0	96 100	9.0 9.5	52.0 56.0	—— ——	3800 3900	—— ——	1500 1500	2.0 2.5	48
TETRODE PUSH-PULL CLASS A AMPLIFIER	125	−20.0	100	——	100.0	——	——	——	3000	5.0†	48
CLASS A AMPLIFIER □	135	−20.0	——	——	6.0	4175	1125	4.7	11000	0.17	49
CLASS B AMPLIFIER ♦	180	0	——	——	4.0	——	——	——	12000	3.5†	49
CLASS A AMPLIFIER	300 400 450	−54.0 −70.0 −84.0	——	——	35.0 55.0 55.0	2000 1800 1800	1900 2100 2100	3.8 3.8 3.8	4600 3670 4350	1.6 3.4 4.6	50
AMPLIFIER	For other characteristics, refer to Type 6N7.										53
TRIODE UNIT AS AMPLIFIER	For other characteristics, refer to Type 85.										55
AMPLIFIER DETECTOR	For other characteristics, refer to Type 76.										56
AMPLIFIER DETECTOR	For other characteristics, refer to Type 6J7.										57
AMPLIFIER MIXER	For other characteristics, refer to Type 6D6.										58
TRIODE • CLASS A AMPLIFIER	250	−28.0	——	——	26.0	2300	2600	6.0	5000	1.25	59
PENTODE •• CLASS A AMPLIFIER	250	−18.0	250	9.0	35.0	40000	2500	100	6000	3.0	59
TRIODE ♦ CLASS B AMPLIFIER	300 400	0 0	——	——	20.0 26.0	——	——	——	4600 6000	15.0† 20.0†	59
CLASS A AMPLIFIER	90 180	−19.0 −43.0	——	——	10.0 20.0	2170 1750	1400 1700	3.0 3.0	3000 4800	0.125 0.790	71-A
TRIODE UNIT AS CLASS A AMPLIFIER	250 ✖	−1.35	——	——	0.4	——	——	Gain per stage = 50-60			75
CLASS A AMPLIFIER	100 250 250 ♥	−5.0 −13.5 −9.0	——	——	2.5 5.0 1.0	12000 9500 ——	1150 1450 ——	13.8 13.8 ——	——	——	76
BIAS DETECTOR	250	−20.0 approx.	——	——	Plate current to be adjusted to 0.2 milliampere with no signal.						76
SCREEN-GRID R-F AMPLIFIER	100 250	−1.5 −3.0	60 100	0.4 0.5	1.7 2.3	650000 1500000	1100 1250	715 1500	——	——	77
BIAS DETECTOR	250	−1.95	50	Cathode current 0.65 ma.		——	Plate Resistor, 250000 ohms. Grid Resistor,** 250000 ohms.				77
AMPLIFIER MIXER	For other characteristics, refer to Type 6K7.										78

Receiver Tube Characteristics

TYPE	NAME	BASE	SOCKET CONNEC-TIONS	DIMENSIONS MAXIMUM OVERALL	CATHODE TYPE ■	RATING			
				LENGTH X DIAMETER		FILAMENT OR HEATER		PLATE	SCREEN
						VOLTS	AMPERES	MAX. VOLTS	MAX. VOLTS
79	TWIN-TRIODE AMPLIFIER	SMALL 6-PIN	6H	$4\frac{17}{32}''$ x $1\frac{9}{16}''$	HEATER	6.3	0.6	250	—
80	FULL-WAVE RECTIFIER	MEDIUM 4-PIN	4C	$4\frac{11}{16}''$ x $1\frac{13}{16}''$	FILAMENT	5.0	2.0	—	—
81	HALF-WAVE RECTIFIER	MEDIUM 4-PIN Bayonet	4B	$6\frac{1}{4}''$ x $2\frac{7}{16}''$	FILAMENT	7.5	1.25	—	—
82	FULL-WAVE ▶ RECTIFIER	MEDIUM 4-PIN	4C	$4\frac{11}{16}''$ x $1\frac{13}{16}''$	FILAMENT	2.5	3.0	—	—
83	FULL-WAVE ▶ RECTIFIER	MEDIUM 4-PIN	4C	$5\frac{3}{8}''$ x $2\frac{1}{16}''$	FILAMENT	5.0	3.0	—	—
83-v	FULL-WAVE RECTIFIER	MEDIUM 4-PIN	4L	$4\frac{11}{16}''$ x $1\frac{13}{16}''$	HEATER	5.0	2.0	—	—
84/6Z4	FULL-WAVE RECTIFIER	SMALL 5-PIN	5D	$4\frac{1}{4}''$ x $1\frac{9}{16}''$	HEATER	6.3	0.5	—	—
85	DUPLEX-DIODE TRIODE	SMALL 6-PIN	6G	$4\frac{17}{32}''$ x $1\frac{9}{16}''$	HEATER	6.3	0.3	250	—
89	TRIPLE-GRID POWER AMPLIFIER	SMALL 6-PIN	6F	$4\frac{17}{32}''$ x $1\frac{9}{16}''$	HEATER	6.3	0.4	250 250 250	— 250 —
V-99 X-99	DETECTOR★ AMPLIFIER TRIODE	SMALL 4-NUB SMALL 4-PIN	4E 4D	$3\frac{1}{2}''$ x $1\frac{1}{16}''$ $4''$ x $1\frac{3}{16}''$	D-C FILAMENT	3.3	0.063	90	—
112-A	DETECTOR★ AMPLIFIER TRIODE	MEDIUM 4-PIN Bayonet	4D	$4\frac{11}{16}''$ x $1\frac{13}{16}''$	D-C FILAMENT	5.0	0.25	180	—
874	VOLTAGE REGULATOR	MEDIUM 4-PIN Bayonet	4S	$5\frac{5}{8}''$ x $2\frac{3}{16}''$	—	—	—	—	—
876	CURRENT REGULATOR	MOGUL SCREW	--	$8''$ x $2\frac{1}{16}''$	FILAMENT	—	—	—	—
886	CURRENT REGULATOR	MOGUL SCREW	—	$8''$ x $2\frac{1}{16}''$	FILAMENT	—	—	—	—

★For Grid-leak Detection—plate volts 45, grid return to + filament or to cathode.

■Either A. C. or D. C. may be used on filament or heater, except as specifically noted. For use of D.C. on A-C filament types, decrease stated grid volts by ½ (approx.) of filament voltage.

ᵛSupply voltage applied through 20000-ohm voltage-dropping resistor.

▶Mercury-Vapor Type.

••Grid #1 is control grid. Grid #2 is screen. Grid #3 tied to cathode.

•Grid #1 is control grid. Grids #2 and #3 tied to plate.

✦Grids #1 and #2 connected together. Grid #3 tied to plate.

◘Grids #3 and #5 are screen. Grid #4 is signal-input control grid.

▲Grids #2 and #4 are screen. Grid #1 is signal-input control grid.

✢Triode Plate-Supply Voltage and Max. Target Voltage; Min. Target Voltage = 90 volts.

°Both grids connected together; likewise, both plates.

†Power output is for two tubes at stated plate-to-plate load.

Receiver Tube Characteristics

USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID BIAS ▣ VOLTS	SCREEN SUPPLY VOLTS	SCREEN CURRENT MA.	PLATE CURRENT MA.	A-C PLATE RESISTANCE OHMS	TRANSCONDUCTANCE (GRID-PLATE) μMHOS	AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
CLASS B AMPLIFIER	180 250	0 0	——	——	Power Output is for one tube at stated plate-to-plate load.				7000 14000	5.5 8.0	79
A-C Voltage per Plate (Volts RMS) 350 400 550 D-C Output Current (Maximum MA.) 125 110 135					The 550-volt rating applies to filter circuits having an input choke of at least 20 henries.						80
Maximum A-C Plate Voltage ... 700 Volts, RMS Maximum D-C Output Current ... 85 Milliamperes											81
Maximum A-C Voltage per Plate 500 Volts, RMS Maximum D-C Output Current 125 Milliamperes					Maximum Peak Inverse Voltage ... 1400 Volts Maximum Peak Plate Current ... 400 Milliamperes						82
Maximum A-C Voltage per Plate 500 Volts, RMS Maximum D-C Output Current 250 Milliamperes					Maximum Peak Inverse Voltage ... 1400 Volts Maximum Peak Plate Current ... 800 Milliamperes						83
Maximum A-C Voltage per Plate ... 400 Volts, RMS Maximum D-C Output Current ... 200 Milliamperes											83-v
Maximum A-C Voltage per Plate ... 350 Volts, RMS Maximum D-C Output Current ... 60 Milliamperes											84/6Z4
TRIODE UNIT AS CLASS A AMPLIFIER	135 250	−10.5 −20.0	——	——	3.7 8.0	11000 7500	750 1100	8.3 8.3	25000 20000	0.075 0.350	85
AS TRIODE ¶ CLASS A AMPLIFIER	160 250	−20.0 −31.0	——	——	17.0 32.0	3300 2600	1425 1800	4.7 4.7	7000 5500	0.30 0.90	
AS PENTODE •• CLASS A AMPLIFIER	100 250	−10.0 −25.0	100 250	1.6 5.5	9.5 32.0	104000 7000	1200 1800	125 125	10700 6750	0.33 3.40	89
AS TRIODE ♦ CLASS B AMPLIFIER	180	0	——	——	6.0	——	——	——	13600 9400	2.50† 3.50†	
CLASS A AMPLIFIER	90	− 4.5	——	——	2.5	15500	425	6.6	——	——	V-99 X-99
CLASS A AMPLIFIER	90 180	− 4.5 −13.5	——	——	5.0 7.7	5400 4700	1575 1800	8.5 8.5	——	——	112-A
Minimum D-C Starting Supply Voltage 125 Volts D-C Operating Voltage ... 90 Volts					D-C Operating Current ... 10-50 Ma. Maximum Current (Continuous) ... 50 Ma.						874
Voltage Range ... 40 to 60 Volts					Operating Current ... 1.7 Amperes						876
Voltage Range ... 40 to 60 Volts					Operating Current ... 2.05 Amperes						886

● Applied through plate resistor of 250000 ohms or 500-henry choke shunted by 0.25-megohm resistor.
♥ Applied through plate resistor of 100000 ohms.
⌘ Applied through plate resistor of 250000 ohms.
❧ 50000 ohms.
▰ Requires different socket from small 7-pin.
□ Grid #2 tied to plate. ♦ Grids #1 and #2 tied together. ** For grid of following tube.
† Plate voltages greater than 125 volts RMS require 100-ohm series-plate resistor.
°° Applied through plate resistor of 150000 ohms.
◖ For signal-input control-grid (#1); control-grid #3 bias, −3 volts.
▣ Applied through 200000-ohm plate resistor.
*Maximum.
§ Megohms.

Note 1: Types with octal bases have *Miniature Metal Cap;* all others have *Small Metal Cap.*

Note 2: Subscript 1 on class of amplifier service (as AB_1) indicates that grid current does not flow during any part of input cycle.
Subscript 2 on class of amplifier service (as AB_2) indicates that grid current flows during some part of the input cycle.

Receiver Tube Characteristics

INDEX OF TYPES BY USE AND BY CATHODE VOLTAGE

Tubes of All-Metal construction are shown in BOLD FACE

CATHODE VOLTS	RECTIFIERS	VOLTAGE AMPLIFIERS *Including Duplex-Diode Types*	POWER AMPLIFIERS
1.1	—	11, 12	—
1.5	—	26	—
2.0	—	1A4, 1A6, 1B4, 1B5/25S, 1F6, 15, 30, 32, 34	1F4, 19, 31, 33, 49
2.5	82	2A6, 2B7, 24-A, 27, 35, 55, 56, 57, 58	2A3, 2A5, 45, 46, 47, 53, 59
3.3	—	22, 99	20
5.0	**5W4**, 5Z3, **5Z4**, 80, 83, 83-v	01-A, 40, 112-A	71-A, 112-A
6.3	**6H6, 6X5**, 1-v, 84/6Z4	6B7, **6B8, 6C5**, 6C6, 6D6, **6F5**, 6F7, **6J7, 6K7, 6L7, 6Q7, 6R7**, 36, 37, 39/44, 75, 76, 77, 78, 85	6A4, 6A6, **6F6, 6L6, 6N7**, 38, 41, 42, 79, 89
7.5	81	—	10, 50
12.6	12Z3	—	—
25.0	25Z5, **25Z6**	—	**25A6**, 43
30.0	—	—	48

CATHODE VOLTS	CONVERTERS IN SUPERHETERODYNES	DETECTORS	MIXER TUBES IN SUPERHETERODYNES	INDICATORS (Visual)
1.1	—	11, 12	—	—
1.5	—	—	—	—
2.0	1A6, 1C6	1A6, 1B5 25S, 1F6, 30, 32	1A6, 1C6, 34	—
2.5	2A7	2A6, 2B7, 24-A, 27, 55, 56, 57	2A7, 35, 58	—
3.3	—	99	—	—
5.0	—	00-A, 01-A, 40, 112-A	—	—
6.3	6A7, **6A8**	6B7, **6B8, 6C5**, 6C6, 6F7, **6J7, 6H6, 6Q7, 6R7**, 36, 37, 75, 76, 77, 85	6A7, **6A8**, 6D6, **6K7, 6L7**, 39/44, 78	6E5, 6G5
7.5	—	—	—	—
12.6	—	—	—	—
25.0	—	—	—	—
30.0	—	—	—	—

* * * * * *

RCA-25B6-G:

Characteristics:

Heater Voltage	25.0 a-c or d-c	Volts
Heater Current	0.3	Ampere
Plate Voltage	95	Volts
Screen Voltage	95	Volts
Grid Voltage	-15	Volts
Plate Current	45	Milliamperes
Screen Current	4	Milliamperes
Plate Resistance	Subject to considerable variation	
Transconductance	4000	Micromhos
Load Resistance	2000	Ohms
Power Output (10% Distortion)	1.75	Watts

* * * * * *

KEY TO TERMINAL DESIGNATIONS OF SOCKETS

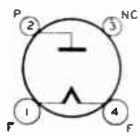
Alphabetical subscripts D, P, and T indicate, respectively, diode unit, pentode unit, and triode unit in multi-unit types.

Numerical subscripts are used (1) in multi-grid types to indicate relative position of grids to cathode or filament, and (2) in multi-unit types to differentiate between two identical electrodes which would otherwise have the same designation.

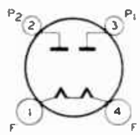
BP = **Bayonet Pin** **H** = **Heater** **P** = **Plate**
F = **Filament** **K** = **Cathode** P_{BF} = **Beam-Forming Plates**
G = **Grid** **NC** = **No Connection** **TA** = **Target**

Receiver Tubes

SOCKET CONNECTIONS
BOTTOM VIEWS



4B



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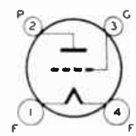

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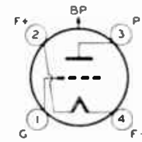

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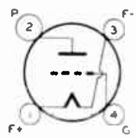

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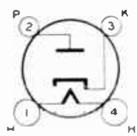

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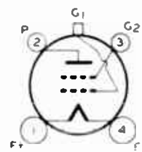

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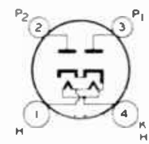

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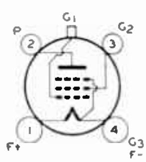

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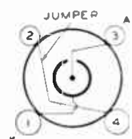

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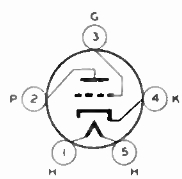

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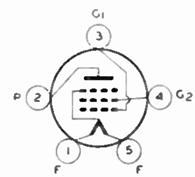

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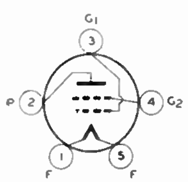

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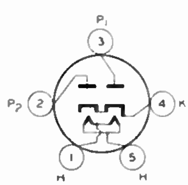

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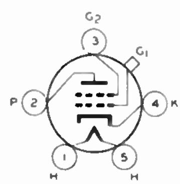

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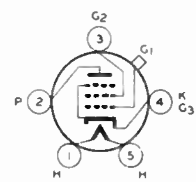

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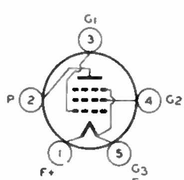

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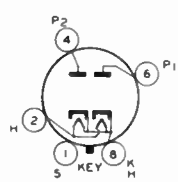

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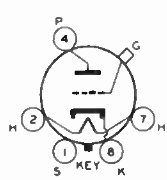

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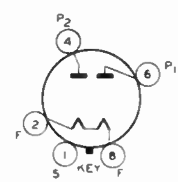
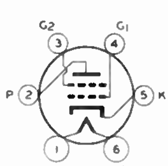


5T



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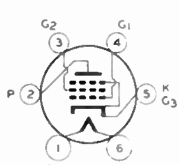

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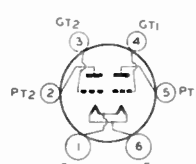

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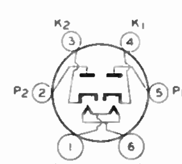
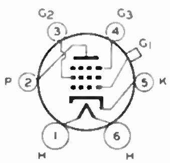


6E

Receiver Tubes

SOCKET CONNECTIONS
BOTTOM VIEWS



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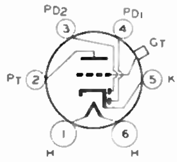

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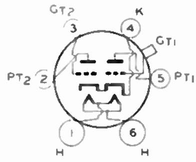

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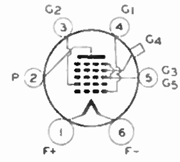

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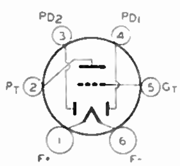

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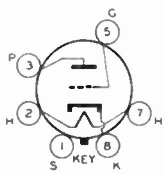

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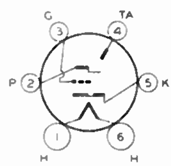

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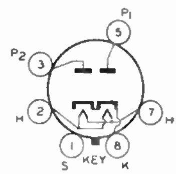
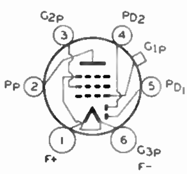


6S



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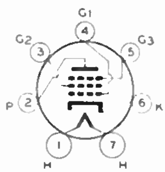

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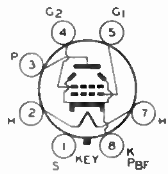

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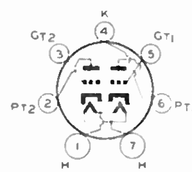

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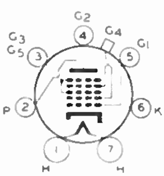

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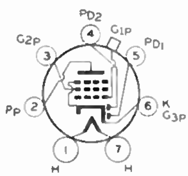
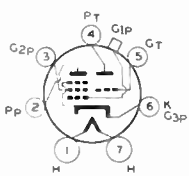


7D



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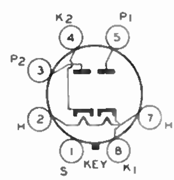

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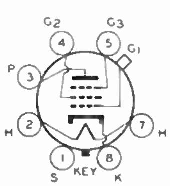

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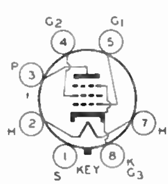

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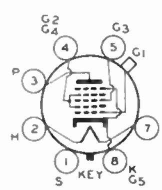
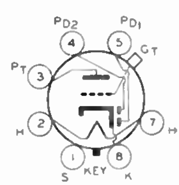
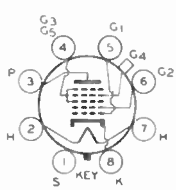


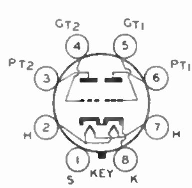
7T



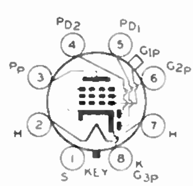
7V



8A



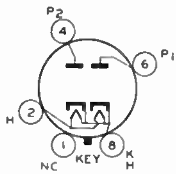
8B



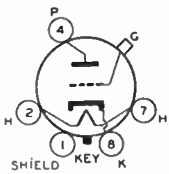
8E

Receiver Tubes

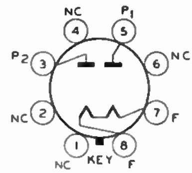
SOCKET CONNECTIONS FOR G-TYPES
BOTTOM VIEWS



G-5L



G-5M



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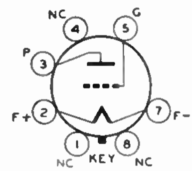
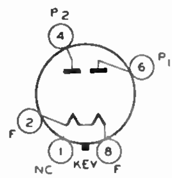
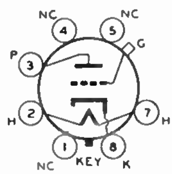


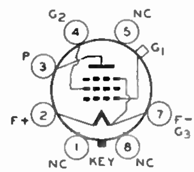
G-5S



G-5T



G-5U



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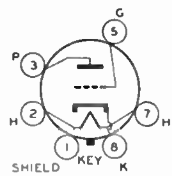
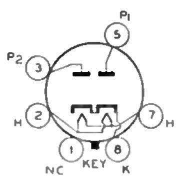
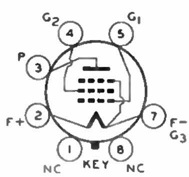


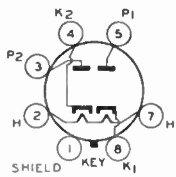
G-6Q



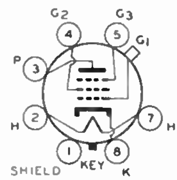
G-6S



G-6X



G-7Q



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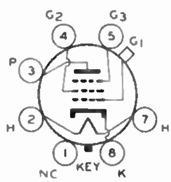
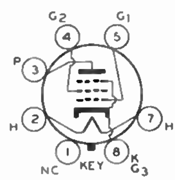
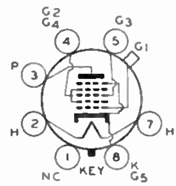


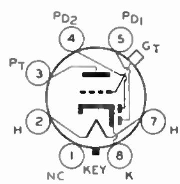
G-7R(6K7-G)



G-7S



G-7T



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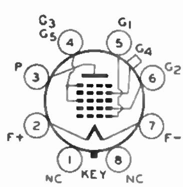
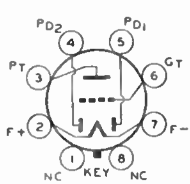
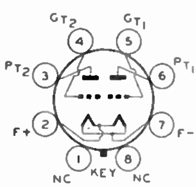


G-7Z



G-7AA



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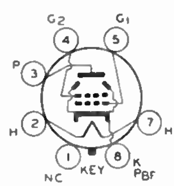

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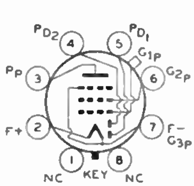

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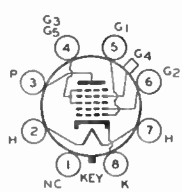

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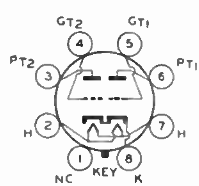
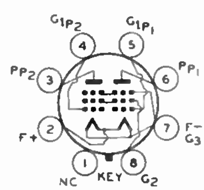


G-8B



G-8C

G-Type Radio Tubes

(Octal-Base, Glass-Bulb Types)

In addition to the types of tubes shown on the preceding pages, the following octal-base, glass-bulb types are also available. These types are identified by the letter "G" following the type number. For each of these types, the corresponding glass or metal types are indicated below, together with socket connections and overall dimensions. Characteristics data for the G-types, except for some differences in capacity values, are the same as those for the corresponding types.

G-Series Type	Corresponding Glass Type	Corresponding Metal Type	Socket Connections	Max. Overall Dimensions Length x Diam.
1C7-G	1C6	—	G-7Z	$4\frac{15}{32}$" x $1\frac{9}{16}$"
1D5-G	1A4	—	G-5Y	$4\frac{15}{32}$" x $1\frac{9}{16}$"
1D7-G	1A6	—	G-7Z	$4\frac{15}{32}$" x $1\frac{9}{16}$"
1E5-G	1B4	—	G-5Y	$4\frac{15}{32}$" x $1\frac{9}{16}$"
1E7-G	§	—	G-8C	$4\frac{1}{8}$" x $1\frac{9}{16}$"
1F5-G	1F4	—	G-6X	$4\frac{5}{8}$" x $1\frac{13}{16}$"
1F7-G	1F6	—	G-7AD	$4\frac{15}{32}$" x $1\frac{9}{16}$"
1H4-G	30	—	G-5S	$4\frac{1}{8}$" x $1\frac{9}{16}$"
1H6-G	1B5/25S	—	G-7AA	$4\frac{1}{8}$" x $1\frac{9}{16}$"
1J6-G	19*	—	G-7AB	$4\frac{1}{8}$" x $1\frac{9}{16}$"
5U4-G	5Z3	—	G-5T	$5\frac{5}{16}$" x $2\frac{1}{16}$"
5V4-G	83-v	—	G-5L	$4\frac{5}{8}$" x $1\frac{13}{16}$"
5X4-G	5Z3	—	G-5Q	$5\frac{5}{16}$" x $2\frac{1}{16}$"
5Y3-G	80	—	G-5T	$4\frac{5}{8}$" x $1\frac{13}{16}$"
5Y4-G	80	—	G-5Q	$4\frac{5}{8}$" x $1\frac{13}{16}$"
6A8-G	—	6A8	G-8A	$4\frac{15}{32}$" x $1\frac{9}{16}$"
6C5-G	—	6C5	G-6Q	$4\frac{1}{8}$" x $1\frac{9}{16}$"
6F5-G	—	6F5	G-5M	$4\frac{15}{32}$" x $1\frac{9}{16}$"
6F6-G	—	6F6	G-7S	$4\frac{5}{8}$" x $1\frac{13}{16}$"
6H6-G	—	6H6	G-7Q	$4\frac{1}{8}$" x $1\frac{9}{16}$"
6J5-G	—	6J5	G-6Q	$4\frac{3}{16}$" x $1\frac{9}{16}$"
6J7-G	—	6J7	G-7R (6J7-G)	$4\frac{15}{16}$" x $1\frac{9}{16}$"
6K5-G	See data below		G-5U	$4\frac{15}{32}$" x $1\frac{9}{16}$"
6K6-G	41	—	G-7S	$4\frac{1}{8}$" x $1\frac{9}{16}$"
6K7-G	—	6K7	G-7R (6K7-G)	$4\frac{15}{32}$" x $1\frac{9}{16}$"
6L6-G	—	6L6	G-7AC	$5\frac{5}{16}$" x $2\frac{1}{16}$"
6L7-G	—	6L7	G-7T	$4\frac{15}{32}$" x $1\frac{9}{16}$"
6N7-G	—	6N7	G-8B	$4\frac{5}{8}$" x $1\frac{13}{16}$"
6Q7-G	—	6Q7	G-7V	$4\frac{15}{32}$" x $1\frac{9}{16}$"
6R7-G	—	6R7	G-7V	$4\frac{15}{32}$" x $1\frac{9}{16}$"
6T7-G	—	6Q7	G-7V	$4\frac{15}{32}$" x $1\frac{9}{16}$"
6V7-G	85	—	G-7V	$4\frac{1}{2}$" x $1\frac{9}{16}$"
6W5-G	—	84	G-6S	$4\frac{1}{8}$" x $1\frac{9}{16}$"
6X5-G	—	6X5	G-6S	$4\frac{1}{8}$" x $1\frac{9}{16}$"
6Y7-G	79	—	G-8B	$4\frac{1}{2}$" x $1\frac{9}{16}$"
25A6-G	—	25AG	G-7S	$4\frac{5}{8}$" x $1\frac{13}{16}$"
25B6-G	—	—	G-7S	$4\frac{5}{8}$" x $1\frac{13}{16}$"
25Z6-G	—	25Z6	G-7Q	$4\frac{1}{8}$" x $1\frac{9}{16}$"

*Except that filament current is 0.24 ampere. §Two 1F4's in the same bulb.

NOTE: Certain G-types have an internal shield which is brought out to Pin No. 1. Socket connections for such types designate Pin No. 1 as SHIELD. For G-types without SHIELD connections. Pin No. 1 is marked NC. Other symbols on socket diagrams are explained in the KEY TO TERMINAL DESIGNATIONS OF SOCKET CONNECTIONS on page 166.

RCA-6K5-G: Similar to triode section of 6Q7.

Characteristics:

Heater Voltage	6.3	6.3 a-c or d-c	Volts
Heater Current	0.3	0.3	Ampere
Plate Voltage	100	250	Volts
Grid Voltage	—1.5	—3	Volts
Amplification Factor	70	70 approx.	
Plate Resistance	78000	50000 approx.	Ohms
Transconductance	900	1400	Micromhos
Plate Current	0.35	1.1	Milliamperes

Chapter 9

Transmitting Tubes

SOME OF THE necessary information for determining the operating conditions of transmitter vacuum tubes is not generally found in technical bulletins which are supplied by tube manufacturers. For this reason it was necessary to compute this data in "*RADIO's*" laboratory; the findings are in the pages which follow.

The typical operating conditions for class-B audio amplifiers or modulators, and for r.f. amplifier service, are included. From this data the reader can tell at a glance what type of driver stage is needed, what the power supply requirements must be, the approximate output that can be expected, and how the tube constants vary under certain operating conditions.

The ratings in the *Tube Tables* are for *safe values* of plate voltage and current. Amateurs who operate their transmitters at higher than normal tube ratings, without exceeding the actual plate dissipation ratings of the tubes, should remember that this condition of operation sometimes can be tolerated for *c.w. telegraphy only,* and with consequent increase in the required grid driving power, so that the tube can be operated over a lesser angle of plate current flow during each r.f. cycle. The d.c. grid current never should exceed the maximum rated value, yet the grid bias voltage may be increased to such an extent that from two to four times as much grid driving power is applied to the grid (or grids) of the tube (or tubes) in the final amplifier stage. This practice results in greater *plate efficiency* (within limits), but with a sacrifice in *power gain.*

In extreme cases, 200 watts of grid-driving power would be required to obtain 600 watts of antenna power from the final r.f. amplifier stage. Thus it can be seen that the foregoing does not represent economy in design; for this reason the *Tube Tables* in this *chapter* are, in general, based on a power gain of approximately 10, with plate efficiencies of from 66 per cent to 75 per cent. Radiation of harmonics will not be so troublesome when the class-C amplifier operates in this range of efficiencies, particularly when the C-to-L ratio of the tank circuit is chosen correctly.

The values of *grid driving power* shown in the *Tables* are those actually used by the grid of the tube. The power loss in the C-bias supply or grid-leak should be added to these values. Circuit losses should be given consideration when designing buffer or amplifier stages for all-band operation. The tuned circuit losses are appreciably higher in the 10- and 20-meter bands than for operation at 80- or 160-meters. These circuit losses cannot be given in a tube table; only the grid bias loss and grid-driving power can be listed. The driving stage should be capable of supplying some excess of power to compensate for circuit losses.

• Crystal Oscillator Circuit Tubes

The most satisfactory tube for operation in a crystal oscillator circuit of an amateur transmitter is the 6L6 beam power pentode or its glass equivalent with octal base, the 6L6G. These tubes also are available with isolantite sockets, enabling slightly higher plate voltages to be used without breakdown in the tube base. Next in order are the types 6A6 and 53, identical in characteristics except for heater voltage and current. Other suitable tubes for crystal oscillators are the types 41, 42, 2A5, 59, 47, 56, 76, 6F6, 6C5, 6F5, 6N7, 30, 19, and 10.

• Frequency Doubler Tubes

The 6L6 or 6L6G again takes its place at the top of the list for most satisfactory frequency doubler service. And too, the 6A6 and 53 are next in order, followed by the 46. It is obviously assumed that these tubes are for operation in medium power stages only. A tube for frequency doubler service should have a high amplification constant; pentode 2A5, 42 or 59 types are, therefore, used occasionally. Outputs of from 2 to 15 watts can be realized from these receiver type pentodes.

Greater output from frequency doublers is secured with larger tubes, such as the 35T, 841, and 756. These tubes will deliver from 15 to 50 watts of output when driven by a 6A6 or 6L6-6L6G crystal oscillator. They have a further advantage in that they can be easily neutralized when operated as buffers. The output from a frequency doubler is almost as high as that from a buffer stage if the grid bias in the former is at least six times cut-off and if nearly normal d.c. grid current flows.

• R. F. Amplifier Tubes

The more popular inexpensive tubes for moderate-power, c.w. amateur service are the types 10 and T-20, the latter having its plate lead brought through the top of the glass envelope. When two or three of these tubes are driven by a crystal exciter, the output will be more than 100 watts.

Many of the new carbon plate tubes are easy to drive to high outputs. This is particularly true of some of the *Taylor* and *Amperex* types, such as the T-55, HF-100, and T-200. On the other hand, the interelectrode capacities of tantalum plate tubes are lower than in those tubes which have carbon plates; thus, they are more efficient for operation at the higher frequencies and at higher plate voltages. *Both types can be made to operate with equal effectiveness in the most commonly used amateur bands.*

Tantalum plate tubes are gas-free and can be operated at plate potentials as high as 4,000 or 5,000 volts for one kw. input to a single tube; however, a more powerful driver is needed than for two carbon plate tubes operated at lower plate voltage with the same power input.

• The Tube Tables

With the exception of small receiver-type tubes, all tubes for transmitter, modulator and audio application are listed in the Tables in the order of their rated plate dissipation. Frequency range, interelectrode capacities, grid driving power, power output, and average operating conditions are given. The capacity of the neutralizing condenser should be made to equal the grid-to-plate capacity of the tube. Power output and grid-driving power requirements are given for average conditions where Class-C amplifiers operate at an angle between 120° and 140°. The Class-C plate efficiency will be between 66 percent and 75 percent under these conditions. Greater output and higher efficiency sometimes can be secured when more grid drive is available. The amplification factor (μ) determines the value of d.c. grid bias needed for the particular type of amplifier circuit in which the tube operates.

• Receiver-Type Tubes for Crystal Oscillators and Low-Power Buffer-Doubler Service

RK-15

RAYTHEON 4-pin base tube, similar to 46, and designed for Class B audio amplifier or r.f. doubling. Control grid at top of tube.

Characteristics:

Max. DC Plate Voltage	400 volts
Max. DC Plate Current	50 ma.
Max. Plate Dissipation	10 watts

•

RK-16

RAYTHEON Triode 5-pin base, similar to 59 when triode-connected. For use as Class B driver stage. Characteristics same as RK-15.

•

RK-17

RAYTHEON Pentode, 5-pin base. Designed primarily for crystal oscillators in standard pentode circuits. Control grid at top of tube. Characteristics same as RK-15.

•

RK-34

RAYTHEON Twin-Triode Power Amplifier. Designed primarily for U.H.F. amplifier or oscillator service. May be used efficiently up to 240 mc., providing the plate dissipation is not allowed to exceed 10 watts.

Note: A fixed bias of —15 volts is desirable in case of failure of RF-excitation.

Unusual Feature: Two plate leads are brought through the top of the tube envelope, thus reducing interelectrode capacities for U.H.F. service.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.8 amps.
Amplification Factor	13
Grid-to-Plate Capacity	2.7 μμfd.
Input Capacity	4.2 μμfd.
Output Capacity	2.1 μμfd.
Max. Plate Dissipation	10 watts
Max. D.C. Plate Voltage	300 volts
Max. D.C. Plate Current	80 ma
Max. D.C. Grid Current	25 ma.

Class A Amplifier (Sections in Parallel):

D.C. Plate Voltage	300 volts
D.C. Grid Voltage	—16 volts
Plate Resistance	2950 ohms.
Mutual Conductance	4400 micromhos.
Plate Current	25 ma.
Load Resistance	5000 ohms.
Power Output	0.8 watts

Class B Amplifier:

D.C. Plate Voltage	180	300 volts
D.C. Grid Voltage	—6	—15 volts
Static Plate Current	15	15 ma.
Load Resistance	6000	10,000 ohms.
Power Output	7.2	12 watts
Peak A.F. Input (grid-to-grid)	100	100 volts

R-F Service—Class C Amplifier:

D.C. Plate Voltage	300 volts
D.C. Grid Voltage	—45 volts
D.C. Plate Current	75 ma.
D.C. Grid Current	15 ma.
Grid Driving Power	1.8 watts
Grid Bias Loss	0.67 watts
Power Input	14 watts
Approx. A.C. Load Impedance	1600 ohms

•

19

Twin triode class B audio amplifier for portable radio receivers. Class B Modulator in portable U.H.F. transmitters and transceivers. U.H.F oscillator in push-pull circuits. Occasionally used as crystal oscillator or r.f. amplifier in portable transmitters.

Characteristics:

Filament Voltage (D.C.)			2.0 volts
Filament Current			0.26 amps.

As Class B Power Amplifier:

Plate Voltage	135 max. volts
Dynamic Peak Plate Current (per plate)	50 max. ma.

Typical Operation:

Filament Voltage			2.0 volts
Plate Voltage	135	135	135 volts
Grid Voltage	—6	—3	0 volts
Static Plate Current	1	4	10 ma.
Load Resistance (plate-to-plate)	10000	10000	10000 ohms
Average Power Input	95	130	170 ap. mw.
Nominal Power Output	1.6	1.9	2.1 watts

2A3-6A3

Triode Power Amplifier. Normally used in push-pull in radio receivers and as a P.P. driver stage for Class B modulators which have outputs of from 100 to 300 watts. The low plate resistance load with fixed grid bias makes these tubes desirable as Class B stage drivers. Sometimes operated as a Class C r.f. amplifier in radio transmitters, in which case the maximum plate voltage is 400 volts. The 6A3 is similar to the 2A3, except for its heater, which is rated at 6.3 volts and one ampere.

Note: As a Class C r.f. amlifier, approx. 15% more output can be obtained than from a 45 tube. Not recommended for Class C service above 7 mc.

Characteristics, Class A Amplifier:

Filament Voltage	2.5 volts
Filament Current	2.5 amps.
Grid to Plate Capacitance	13 μμfd.
Input Capacitance	9 μμfd.
Output Capacitance	4 μμfd.
Plate Voltage	250 max. volts
Grid Voltage	—45 volts
Plate Current	60 ma.
Plate Resistance	800 ohms
Amplification Factor	4.2
Mutual Conductance	5250 micromhos
Load Resistance	2500 ohms
Self Bias Resistor	750 ohms
Power Output	3.5 watts

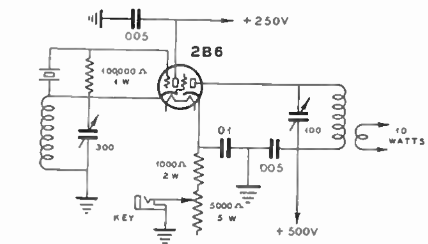
Push-Pull Class AB Amplifier (2 tubes):

	Fixed Bias	Self Bias
Plate Voltage	300	300 max. volts
Grid Voltage	—62	... volts
Self Bias Resistor	...	750 ohms
Plate Current (per tube)	40	40
Load Resistance (Plate to Plate)	3000	5000 ohms
Harmonic Distortion	2.5	5%
Power Output	15	10 watts

2B6

Power Amplifier for radio receivers. More often used as a crystal oscillator-amplifier or doubler in radio transmitters.

Unusual Characteristics: Two triodes in one envelope. The power amplifier grid is direct-coupled to the driver cathode, and the driver plate connects directly to plus B.



2B6 "LES-TET" CRYSTAL OSCILLATOR-DOUBLER
WHEN SECOND TRIODE IS USED AS AN R F AMPLIFIER IT MUST BE NEUTRALIZED

Characteristics, Class A Amplifier:

Heater Voltage	2.5 volts
Heater Current	2.25 amps.
Plate Supply	250 volts
Grid Bias	—24 volts
Plate Current	40 ma.
Plate Resistance	5150 ohms
Mutual Conductance	3500 micromhos
Amplification Factor	18
Load Resistance	5000 ohms
Power Output	4 watts
Base	med. 7 pin

30

Triode Detector. Audio Amplifier and Oscillator for battery-operated radio receivers. Also used in 5 meter transceivers. Sometimes used as crystal oscillator or amplifier, in portable transmitters.

Characteristics:

Filament Voltage (D.C.)	2.0 volts
Filament Current	.06 amps.
Grid to Plate Capacitance	6.0 μμfd.
Input Capacitance	3.0 μμfd.
Output Capacitance	2.1 μμfd.
Base	small 4 pin

RK-42

RAYTHEON TRIODE for Portable Sets. Similar to Type 30, except for filament.

Filament Voltage	1.5 volts
Filament Current	60 ma.

RK-43

RAYTHEON High Mu Twin-Triode for Class B service. Each Triode is somewhat similar to RK-42, except for higher MU.

Filament Voltage	1.5 volts
Filament Current	120 ma.

42-6F6-2A5

Pentode Power Amplifier for radio receivers. 2.5 volt equivalent of glass 42 tube is 2A5, with filament current of 1.7 amp.

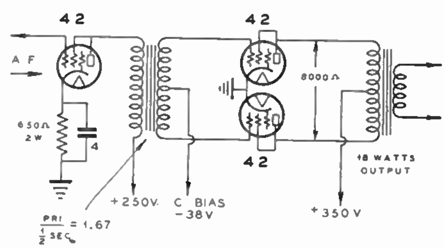
(1) Single or push-pull audio amplifier for radio receivers (pentode).

(2) Crystal oscillators in transmitters.

(3) Frequency doublers in transmitters.

(4) Triode driver stage or Class AB push-pull power amplifier.

(See 6L6 applications for other uses.)



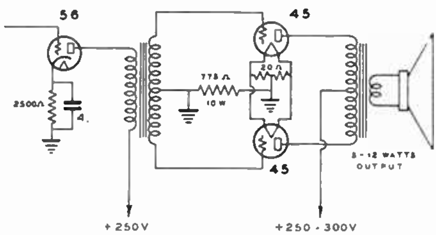
CLASS AB TRIODE AUDIO AMPLIFIER

Characteristics, Pentode Amplifier, Class A:

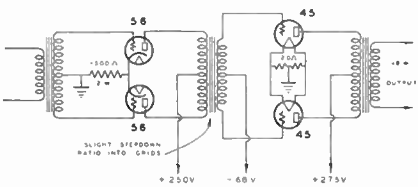
Heater Voltage (42, 6F6)	6.3 volts
Heater Current	0.7 amp.
Plate Voltage	250 volts
Screen Voltage	250 volts
Grid Voltage	—16.5 volts
Plate Current	34 ma.
Screen Current	6.5 ma.
Plate Resistance	100,000 ohms
Amplification Factor	220
Mutual Conductance	2200 micromhos
Load Resistance	7000 ohms
Power Output (7% distortion)	3.0 watts

45

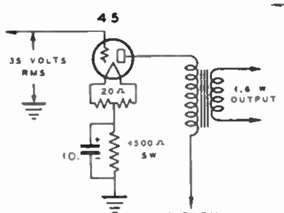
Equivalent to Metal Tube 6D5. Triode Power Tube for push-pull Class A or AB service. The output in Class AB is sufficient to drive Class B modulators of 100 to 200 watts output. Also useful as a low power R-F buffer tube in transmitters.



Low Distortion Audio Amplifier for Radio Receivers



Push-Pull Class AB Amplifier for Class B Driver or P. A. Service



AUDIO AMPLIFIER,— OR MODULATOR FOR GRID MODULATED TUBES

Characteristics for Class A Amplification:

Filament Voltage	2.5 volts
Filament Current	1.5 amps.
Plate Voltage	250 volts
Grid Voltage	—50 volts
Plate Current	34 ma.
Plate Resistance	1610 ohms.
Amplification Factor	3.5
Mutual Conductance	2175 micromhos.
Load Resistance	3900 ohms.
Power Output	1.6 watts
Grid-to-plate Capacitance	7 μμfd.
Input Capacitance	4 μμfd.
Output Capacitance	3 μμfd.

Class AB Push-Pull Amplifier:

	Fixed Bias	Self Bias
Plate Voltage	275	275 volts
Grid Voltage	—68	...
Zero Signal Plate Current (per tube)	35	36 ma.
Max. Signal Plate Current (per tube)	69	45 ma.
Load Resistance (plate to plate)	3200	5060 ohms
Self Bias Resistor	..	775 ohms
Total Harmonic Distortion	5	5%
Power Output	18	12 watts

Class C R-F Amplifier:

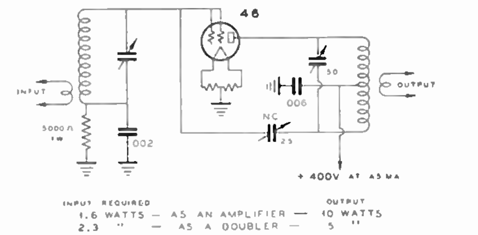
Plate Voltage	400 volts
Plate Current	50 ma.
Peak Plate Current (AC)	90 ma.
Grid Bias Voltage	—200 volts
Grid Bias Current	4 ma.
Plate Power Input	20 watts
Grid Power Input	1.0 watts
Grid-Bias Power Loss	0.8 watt
Power Output	15 watts
Efficiency	75%
Plate load impedance	3700 ohms

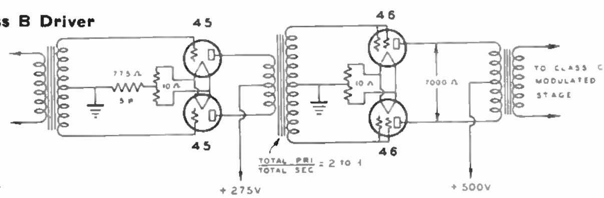
●

46

Class B Amplifier for radio receivers and public address systems. More often used in modulator systems for small radiophone transmitters. Frequently serves as a doubler in RF circuits of radio transmitter.

Note: Audio peak outputs of 40 watts for speech can be secured if a 500 volt plate supply is available, although this exceeds the manufacturers' ratings of 400 volts plate supply.





CLASS B MODULATOR FOR PHONE TRANSMITTER
AVERAGE POWER OUTPUT 20 WATTS - PEAK OUTPUT 40 WATTS

Characteristics:

Filament Voltage	2.5 volts
Filament Current	1.75 amps.

As Class A Amplifier (grid adjacent to plate tied to it):

Plate Voltage	250 volts
Grid Voltage	—33 volts
Plate Current	22 ma.
Plate Resistance	2380 ohms
Amplification Factor	5.6
Mutual Conductance	2350 micromhos
Load Resistance	6400 ohms
Power Output	1.25 watts

As Class B Amplifier (grids tied together):

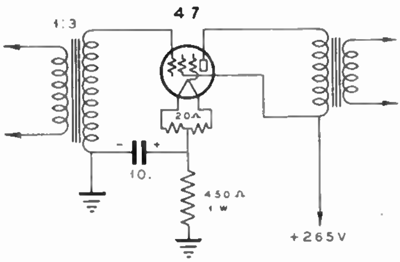
Plate Voltage	300	400 volts
Grid Voltage	0	0 volts
Zero Signal Plate Current (per tube)	4	6 ma.
Load Resistance (plate to plate)	5200	5800 ohms
Power Output	16	20 watts
Grid Driving Power	950	650 milliwatts

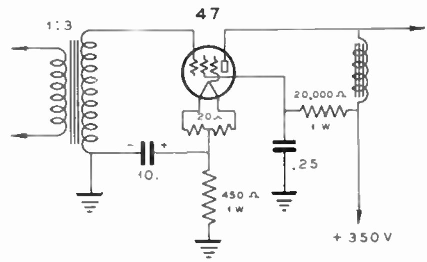
●

47

Audio power amplifier for radio receivers or modulator service in small AC operated 5-meter transmitters. Crystal oscillator in radio transmitters.

Note: This tube has been replaced for most services by tubes with a separate cathode and heater.





AUDIO AMPLIFIERS OR MODULATORS

Characteristics:

Filament Voltage	2.5 volts
Filament Current	1.75 amps.
Plate Voltage	250 volts
Screen Voltage	250 volts
Grid Voltage	—16.5 volts
Plate Current	31 ma.
Screen Current	6 ma.
Amplification Factor	150
Plate Resistance	60,000 ohms
Mutual Conductance	2500 micromhos
Power Output	2.7 watts
Load Resistance	7000 ohms
Plate to Grid Capacitance	1.2 μμfd.
Input Capacitance	8.6 μμfd.
Output Capacitance	13 μμfd.

RCA-1609

Battery type Pentode incorporating low microphonic design for speech amplifier application. 5-prong base.

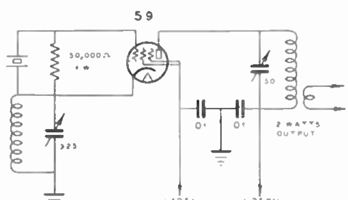
Filament Voltage	1.1 volts
Filament Current	0.25 amps.
Maximum D.C. Plate Voltage	135 volts
Maximum D.C. Screen Voltage	67.5 volts

RCA-1610

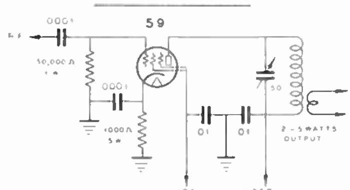
Pentode crystal oscillator tube having characteristics and tube base identical to that of type 47.

59

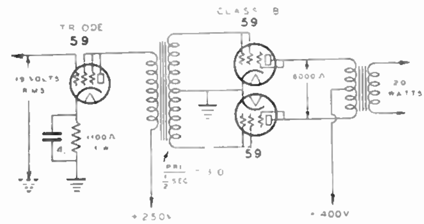
Triple Grid Pentode Amplifier. Class A Audio amplifier. Triode Class A driver for Class B stage of 59 tubes. Crystal oscillator and frequency-doubler in radio transmitters.



TRITET CRYSTAL OSCILLATOR - DOUBLER



REGENERATIVE FREQUENCY DOUBLER (CATHODE CONDENSER TYPE)



Characteristics:

Heater Voltage	2.5 volts
Heater Current	2.0 amps.

Class A Amplifier	Triode	Pentode
Plate Voltage	250	250 volts
Screen Voltage	...	250 volts
Grid Voltage (No. 1)	—28	—18 volts
Plate Current	26	35 ma.
Screen Current	...	9 ma.
Amplification Factor	6	100
Plate Resistance	2300	40,000 ohms
Mutual Conductance	2600	2500 micromhos
Load Resistance	5000	6000 ohms
Self-Bias Resistor	1080	410 ohms
Power Output	1.25	3 watts
Grid No. 2	tied to plate	Screen
Grid No. 3	tied to plate	Tied to cathode

Class B Amplifier:	Triode Connected	
Plate Voltage	300	400 volts
Avg. Plate Dissipation	10	10 watts max.
Grids No. 1 and 2 tied together. Grid No. 3 tied to plate.		
Zero Signal Plate Current (per tube)	10	13 ma.
Max. Signal Plate Current	...	200 ma.
Load Resistance (plate to plate)	4600	6000 ohms
Power Output (2 tubes)	15	20 watts

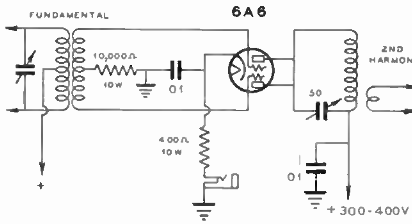
6A6-53

Equivalent Metal Tube—6N7. Type 53 is identical in characteristics, except for its heater, which is rated at 2.5 volts at 2 amps. Twin Triode Power Tube designed for Class B audio amplifiers in radio receivers. Also very useful as crystal oscillator and frequency doubler in transmitters, for frequencies up to 30 mc. Often used in 5 meter transmitters and receivers as oscillators and detectors.

Precautionary Measures: 300 volt plate supply is maximum as a Class B audio amplifier. As an RF oscillator or doubler, the plate potential must not exceed 400 volts if cathode bias is used, and not over 300 for grid-leak bias. For RF purposes the DC plate current per plate should not exceed 35 ma. and excessive grid excitation should be avoided.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.8 amp.
Plate Dissipation	10 watts



6A6 Push-Push RF Frequency Doubler

As Class A Amplifiers (Triodes in Parallel):

Plate Voltage	250	300 volts
Plate Current	6	7 ma.
Grid Voltage	—5	—6 volts
Amplification Factor	35	35
Plate Resistance	11300	11000 ohms
Mutual Conductance	3100	3200 micromhos.

As Class B Amplifier (Triodes in Push-Pull):

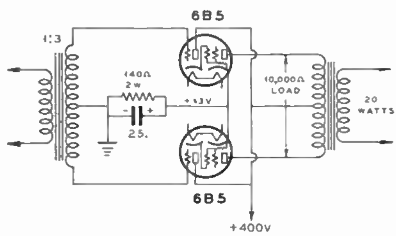
Plate Voltage	250	300 volts
Grid Voltage	0	0 volts
Zero Signal Plate Current (per plate)	14	17.5 ma.
Maximum Plate Current	125	125 ma.
Load Resistance (plate-to-plate)	8000	10000 ohms
Power output (with 350 milliwatt input to grids)	8	10 watts

●

6B5

Equivalent Tubes—6N6G, 6N6. Glass Tube Special Power Amplifier. Designed for power amplifier use in the output stage of a radio receiver. Can be used in push-pull for outputs as high as 20 watts in small power amplifiers or modulators. Due to the gain within the double triode tube, the input grid does not need to be driven beyond Class A, and a 76 tube will drive a pair of 6B5 tubes to 20 watts output.

Unusual Characteristics: An internal grid of the power output triode is direct-coupled to an internal cathode. No external connections are necessary, and the small triode drives the large triode in Class AB.



6B5 MODULATOR OR DRIVER STAGE

Characteristics, Single Tube Class A Amplifier:

Heater Voltage	6.3 volts
Heater Current	0.8 amps.
Plate Supply	300 volts
Input Plate Current	6 ma.
Output Plate Current	45 ma.
Plate Resistance	24100 ohms
Load Resistance	7000 ohms
Power Output	4 watts
Amplification Factor	58
Mutual Conductance	2400 micromhos.
Grid Bias Voltage	0
Base	medium, 7 pin

●

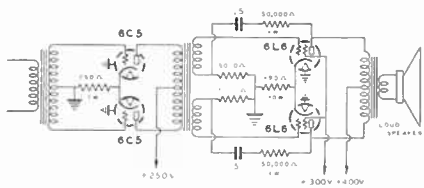
6L6-6L6G

Purpose: Designed primarily for push-pull ampifier in radio receivers but also widely used in crystal oscillator and RF amplifiers for radio transmitters.

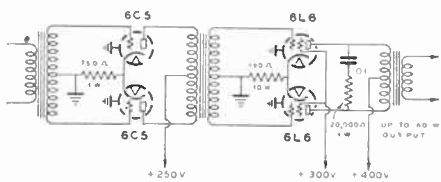
Unusual Characteristic: Has two beam-forming plates internally connected to the cathode. Has no physical suppressor grid. The beam action suppresses secondary emission and results in a more ideal pentode operation.

Precautionary Measures: Good air ventilation is desirable because the tube shell becomes very hot under normal operation. In push-pull circuits, balanced tubes are necessary, as well as balanced transformers if second harmonic elimination is desired.

Audio Amplifier Application: If not over 34 watts of audio output is required, a single 6C5 audio amplifier or power detector will drive a pair of 6L6 tubes in push-pull. A 1-to-2, or 1-to-3 step-up interstage transformer is suitable. For outputs of over 34 watts, push-pull 6C5 tubes are suitable for drivers, with a 1-to-½ ratio interstage transformer (primary to ½ secondary). The output transformer should be of large size in order to handle up to 60 watts of audio power without core saturation. May be used as a modulator for phone transmitters.

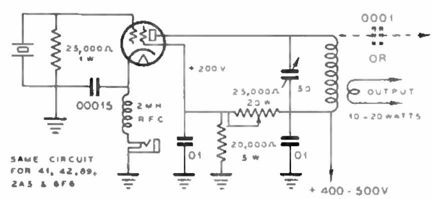


REVERSED FEEDBACK AUDIO AMPLIFIER FOR HIGH QUALITY RECEIVERS



PUSH-PULL AUDIO AMPLIFIER FOR RECEIVERS, PUBLIC ADDRESS OR MODULATOR SERVICE.

Feed-back Amplifier Application: Reverse feed-back operation in a receiver amplifier will damp out low-frequency loudspeaker resonance. The result is similar in action to a triode, but the DC efficiency of a pentode is retained without much sacrifice in power sensitivity. Part of the output is fed back to the grid circuits in reverse phase in order to produce the effect of lower plate impedance.



6L6 CRYSTAL OSCILLATOR WITH CATHODE REGENERATION

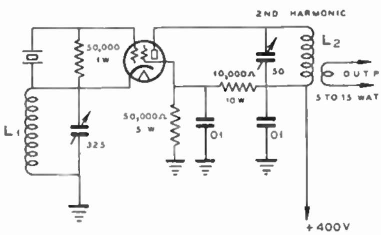
This Circuit Can Also Be Used with 41, 42, 2A5, 89 and 6F6 Tubes

Crystal Oscillator Application: The crystal RF current is very low due to the high power sensitivity of this tube. Outputs of from 5 to 15 watts can be obtained as a crystal oscillator without exceeding tube ratings.

Characteristics:

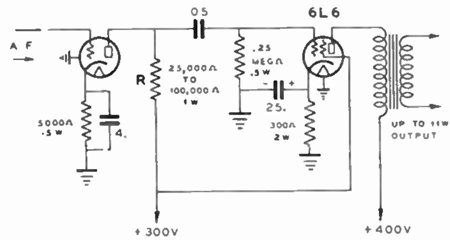
Heater Voltage	6.3 volts
Heater Current	0.9 amps.
Amplification Factor	135
Plate Resistance	22500 ohms
Mutual Conductance	6000 micromhos.

A. F. Operation Characteristics:	Single Tube		Push Pull Tubes		
Plate Voltage	250	375	250	400	400
Screen Voltage	250	250	250	300	300
Control Grid Voltage	—14	—17.5	—16	—25	—25
Zero Signal Plate Current	72	57	60	50	50
Full Signal Plate Current	79	67	70	76	114
Zero Signal Screen Current	5	2.5	5	2.5	2.5 per tube
Full Signal Screen Current	7.3	6	8	8.5	9.5
Signal-Peak Volts	14	17.5	16	25	42.5
Load in Ohms	2500	4000	5000	6600	3800 plate to plate
Power Output—Watts	6.5	11.5	14.5	34	60
Total Distortion	10.	14.5	2.	2.	2.
2nd Harmonic	9.7	11.5	...	...	...
3rd Harmonic	2.5	4.2	2.	2.	2.
Peak Grid Driving Power	...	...	...	0	400 milliwatts



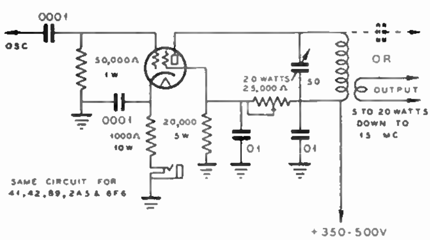
6L6 TRITET OR DOW CRYSTAL OSCILLATOR

The Same Circuit Is Also Suitable for 41, 42, 2A5 89 and 6F6 Tubes



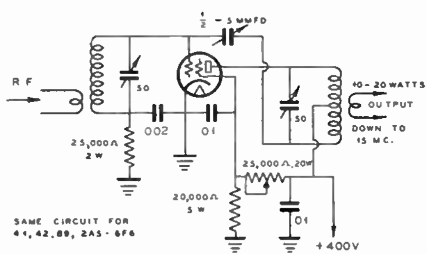
6L6 Audio Amplifier with 6F5 Driver. Low Values of "R" Tend to Generate Out-of-Phase 2nd Harmonic Which Cancels Distortion of 6L6 as Single-Tube Audio Amplifier

RF Applications: The 6L6 is suitable for a low power frequency doubler in transmitters. Due to high sensitivity and harmonic output, only a small amount of power is required to drive the grid as a doubler for outputs of 20 watts and more for frequencies as high as 15 mc.



6L6 REGENERATIVE R F DOUBLER

Circuit also Suitable for Other Tubes, Such as 41 42, 2A5, 89 and 6F6



6L6 NEUTRALIZED R F BUFFER OR DOUBLER

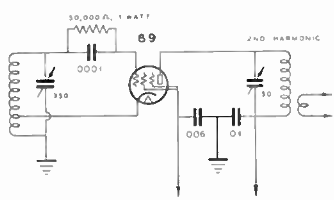
41, 42, 2A5, 89 or 6F6 Tubes Can Be Used in Same Circuit

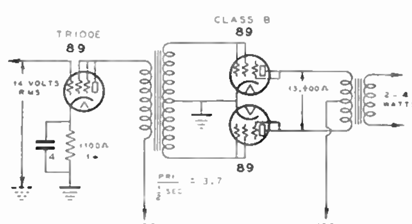
89

Triple Grid Power Amplifier. Designed for storage battery operation, such as in automobile radio receivers. Can be used with AC supply. Occasionally used as an electron-coupled or crystal oscillator in short-wave transmitters.

Note: The triple-grid construction makes operation possible as a Class A triode or pentode amplifier and as a Class B triode.

Not in general use. Not very desirable for operation at RF frequencies above 10 mc.





Characteristics:

Heater Voltage (A.C. or D.C.)	6.3 volts
Heater Current	0.4 amps.
Base	Small 6-pin

Class A Power Amplifier—Pentode Connection:
(Grid No. 3 tied to cathode).

Heater Voltage				6.3 volts
Plate Voltage	100	135	180	250 max. volts
Screen Voltage (Grid No. 2)	100	135	180	250 max. volts
Grid Voltage (Grid No. 1)	—10	—13.5	—18	—25 volts
Amplification Factor	125	125	125	125
Plate Resistance	104000	92500	80000	70000 ohms
Mutual Conductance	1200	1350	1550	1800 micromhos
Plate Current	9.5	14	20	32 milliamperes
Screen Current	1.6	2.2	3.0	5.5 milliamperes
Power Output*	0.33	0.75	1.5	3.4 watts
Load Resistance	10700	9200	8000	6750 ohms

*9% total harmonic distortion.

Class B Power Amplifier—Triode Connection:
(Grids No. 1 and No. 2 tied together; grid No. 3 tied to plate)

Plate Voltage	250 max. volts
Dynamic Peak Plate Current	90 max. milliamperes
Average Grid Dissipation (Grids No. 1 and No. 2 together)	0.35 max. watt

Class A Power Amplifier—Triode Connection:
(Grids No. 2 and No. 3 tied to plate).

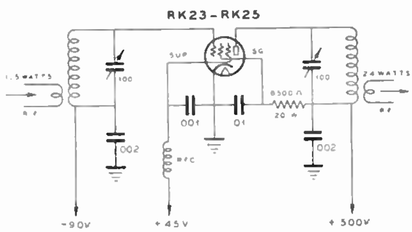
Heater Voltage			6.3 volts
Plate Voltage	160	180	250 max. volts
Grid Voltage (Grid No. 1)	—20	—22.5	—31 volts
Amplification Factor	4.7	4.7	4.7
Plate Resistance	3300	3000	2600 ohms
Mutual Conductance	1425	1550	1800 micromhos
Plate Current	17	20	32 milliamperes
Load Resistance	7000	6500	5500 ohms
Undistorted Power Output	0.3	0.4	0.9 watt

• Transmitting Type Tubes

RK-23-25

RAYTHEON R-F Amplifier, Frequency Doubler, Oscillator, Suppressor, Control Grid or Plate Modulated Amplifier. As a doubler, approx. 12 watts can be obtained. This tube has large 7-pin base. Plate at top of tube.

Frequency Range: 100% ratings up to 30 mc.



Typical Low Power Buffer Circuit for RK-23, RK-25

Characteristics:	RK-23	RK-25
Heater Voltage	2.5	6.3 volts
Heater Current	2.0	0.8 amps.
Grid-Plate Cap.		0.2 μμfd.
Input Capacity		10 μμfd.
Output Capacity		10 μμfd.
Max. Plate Dissipation		8 watts

R-F Service:

	Control Grid Modulation	Supp. Mod.	Class C Telegraphy	
D.C. Plate Voltage	500	500	500	500 v.
D.C. Screen Voltage	200	200	200	200 v.
D.C. Suppress. Voltg.	45	—45	0	45 v.
D.C. Grid Voltage	—125	—90	—90	—90 v.
Peak RF Grid Voltage	150	135	135	135 v.
Peak AF Grid Voltage	45	75	...	...
D.C. Plate Current	34	32	50	55 ma.
D.C. Screen Current	20	40	40	35 ma.
D.C. Grid Current	1.5	6	6	6 ma.
Grid Driving Power	1.3	.8	.8	.8 watts
Grid Bias Loss	.2	.5	.5	.5 watts
Pwr. Output (approx.)	6.5	5.5	18	24 watts
Screen Resistor	20,000	7500	7500	8500 ohms.

•

RK-44

Raytheon pentode, similar to RK-25, except for somewhat higher ratings. Designed for aircraft and mobile services.

Heater Voltage	12.6 volts
Heater Current	0.7 amps.
Maximum D.C. Plate Voltage	650 volts
Maximum D.C. Plate Current	80 ma.
Class-C Output	30 watts

•

RK-45

Raytheon pentode, identical to RK-25, except for heater, which operates at 12.6 volts and 0.45 amps. Designed for aircraft and mobile transmitters.

•

842

RCA Audio Frequency Amplifier and Modulator. Triode. Not as desirable as a type 2A3, which will provide more output at lower plate voltage.

Characteristics:	
Filament Voltage	7.5 volts
Filament Current	1.25 amps.
Grid-Plate Capacity	7 μμfd.
Grid-Filament Capacity	4 μμfd.
Plate-Filament Capacity	3 μμfd.
Amplification Factor	3
Max. Plate Dissipation	12 watts
Max. Plate Voltage	425 volts
Base	4-pin

Class A Audio Amplifier (1 Tube):		
Plate Voltage	350	425 volts
Grid Voltage	—72	—100 volts
Plate Current	34	28 ma.
Plate Resistance	2400	2500 ohms.
Mutual Conductance	1250	1200 micromhos.
Peak Grid AF Voltage	67	95 volts
Load Resistance	5000	8000 ohms.
Power Output	2.1	3.0 watts
Self-Bias Resistor	2120	3570 ohms.

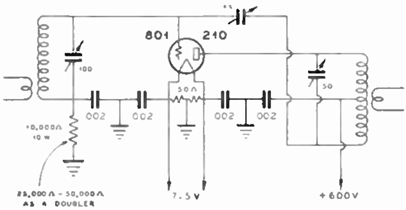
•

10

Triode. Class C Amplifier or Doubler. Class B Power Amplifier and Modulator for medium power transmitters. Crystal Oscillator in commercial transmitters (at 250 volts max. plate supply). Often operated at 750 to 900 volts plate supply and 75 ma. per tube in Class C Telegraphy, amateur service.

Frequency Range: Up to 15 mc. at normal ratings. May be operated on frequencies as high as 60 mc. at reduced plate voltage (400 volts) if tube is equipped with ceramic base, or if molded bakelite bases are cross-slotted with hacksaw cut.

Characteristics:		
Filament Voltage		7.5 volts
Filament Current		1.25 amps.
Plate Voltage	350	425 max. volts
Grid Voltage	—31	—39 max. volts
Plate Current	16	18 ma.
Plate Resistance	5150	5000 ohms.
Amplification Factor	8	8
Mutual Conductance	1550	1600 micromhos.
Load Resistance	11,000	10,200 ohms.
Self-Bias Resistance	1950	2150 ohms.
Power Output	0.9	1.6 watts
Plate-Grid Cap.		7 μμfd.
Input Capacitance		4 μμfd.
Output Capacitance		3 μμfd.
Base		Medium 4 pin



210 or 801 Buffer-Doubler Circuit with Split Plate Coil, Requiring Minimum Grid Drive Under Load

Class C Amplifier (Telegraphy):

D.C. Plate Voltage	400	500	600 v.
D.C. Plate Current	65	65	65 ma.
D.C. Grid Voltage	—100	—125	—150 v.
D.C. Grid Current	10	10	12 ma.
Approx. AC Load Imped.	3000	3800	4600 ohms.
Approx. Power Output	16	21	27 watts
R.F. Grid Excitation	2.7	3.0	3.8 watts
Grid Bias Loss	1.0	1.25	1.8 watts
Plate Loss	10	11.5	12 watts

Class B, A-F Amplifier:

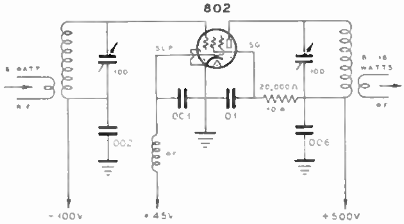
Plate Voltage	400	600 v.
Grid Bias	—50	—75 v.
Zero Sig. Plate Current (per tube)	4	4 ma.
Max. Sig. Plate Current (per tube)	65	65 ma.
Load Resistance (Plate to Plate)	6000	10,000 ohms.
Approx. Power Output (2 tubes)	27	45 watts

802

RCA Pentode. R-F Amplifier, Frequency Doubler, Oscillator; Suppressor, Grid or Plate Modulated Amplifier. Plate at top of tube.

Frequency Range: 100% up to 30 mc., 55% at 60 mc.

Note: The internal shield should connect to cathode at the socket, in all circuits.



802 Pentode Low Power Buffer Stage

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.8 amps.
Grid-to-Plate Capacity	0.15 μμfd.
Input Capacity	12 μμfd.
Output Capacity	8.5 μμfd.
Max. Plate Dissipation	10 watts
Max. Screen Dissipation	6 watts
Base	7 pin, large

R-F Service:

	Grid Modulation	Supp. Mod.	Class C Teleg.	
D.C. Plate Voltage	500	500	500	500 volts
D.C. Screen Voltage	200	200	200	200 volts
D.S. Suppress. Voltg.	0	—45	0	40 volts
D.C. Grid Voltage	—130	—90	—100	—100 volts
Peak RF Grid Voltg.	145	125	155	135 volts
Peak AF Grid Voltg.	50	65	...	...
D.C. Plate Current	25	22	45	45 ma.
D.C. Screen Current	8	28	22	12 ma.
D.C. Grid Current	1	4.5	6	2 ma.
Grid Driving Power	.8	.5	.9	.25 watts
Grid Bias Loss	.13	.4	.6	.2 watts
Pwr. Output (Approx.)	4	3.5	14	16 watts
Screen Resistor	37,500	10,700	13,700	20,000 ohms.

WE-307A

Western Electric Pentode. Oscillator, High-Frequency Amplifier and Doubler, Suppressor-Modulated Amplifier. Designed for portable H.F. and U.H.F. transmitters.

Frequency Range: 100% ratings up to approx. 60 mc.

Unusual Feature: Quick-heating filament instead of heater for intermittent use in automobile transmitters.

Characteristics:

Filament Voltage	5.5 volts
Filament Current	1.0 amps.
Grid-to-Plate Cap.	0.55 μμfd.
Input Cap.	15 μμfd.
Output Cap.	12 μμfd.
Max. Plate Dissipation	15 watts

R-F Service:

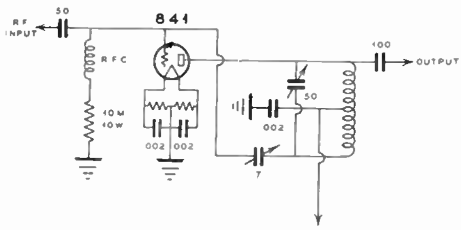
	Suppress. Mod.	Class C Teleg.
D.C. Plate Voltage	500	500 v.
D.C. Screen Voltage	200	200 v.
D.C. Suppress. Voltage	—50	0 v.
D.C. Grid Voltage	—35	—35 v.
Peak R-F Grid Voltage	50	50 v.
Peak A.F. Grid Voltage	50	0 v.
D.C. Plate Current	40	52 ma.
D.C. Screen Current	21	18 ma.
Power Output (Approx.)	6	17 watts
Screen Resistor	14,000	14,000 ohms.

841

RCA, Amperex, United. High-Mu ('10) Triode. Class B modulator. Class C RF amplifier or doubler. Oscillator. Resistance Coupled audio amplifier.

Frequency Range: 100% ratings up to 6 mc. New ceramic base types may be operated up to 30 mc. at full ratings, which are about 50% higher than the 450 volt type listed.

Note: Grid excitation varies under different operating conditions; thus the driver stage should be capable of supplying twice as much power as listed for grid drive and bias loss.



Neutralized Buffer or Doubler Stage

Characteristics:

Filament Voltage	7.5 volts
Filament Current	1.25 amps.
Amplification Factor	30
Grid to Plate Capacity	7 μμfd.
Grid to Filament Capacity	4 μμfd.
Plate to Filament Capacity	3 μμfd.
Maximum Plate Dissipation	15 watts
Maximum DC Plate Voltage	450 volts
Maximum DC Plate Current	60 ma.
Maximum DC Grid Current	20 ma.
Base	UX-4-pin

Class B Modulator or AF Amplifier:

DC Plate Voltage	350	425 volts
DC Grid Voltage	—5	—5 volts
Zero Sig. Plate Current (per tube)	3.5	6.5 ma.
Maximum Sig. Plate Current (per tube)	57	60 ma.
Load Resistance (plate to plate)	5200	7000 ohms.
Power Output	21	28 watts

R-F Service

	Class C Telephony	Class C Telegraphy		Doubler
DC Plate Voltage	350	450	600	450 volts
DC Grid Voltage	—36	—32	—74	—170 volts
DC Plate Current	50	50	50	28 ma.
DC Grid Current	18	12.5	12	8 ma.
Grid Driving Power (Approx.)	1.75	1.25	2.1	1.75 watts
Grid Bias Loss	.65	.4	.9	1.4 watts
Power Output (Approx.)	11.5	14	18.5	7.5 watts
Approx. A.C. Load Impedance	3500	4500	5400	8100 ohms
Mod. DC Load Resistance	7000	9000	12,000	.... ohms

843

RCA Triode. Oscillator, AF power amplifier and R.F. Amplifier of the heater-cathode type for 2.5 volt filament supply. Not in general use.

Frequency Range: 100% ratings up to 6 mc. 50% at 30 mc.

Note: Grid driving power requirements vary over wide limits.

Characteristics:

Heater Voltage	2.5 volts
Heater Current	2.5 amps.
Amplification Factor	7.7
Grid to Plate Capacity	6 μμfd.
Grid to Cathode Capacity	5 μμfd.
Plate to Cathode Capacity	5 μμfd.
Maximum D.C. Plate Voltage	450 volts
Maximum D.C. Plate Dissipation	15 watts
Maximum D.C. Plate Current	40 ma.
Maximum D.C. Grid Current	7.5 ma.
Base	UX-5 pin

Class A Audio Amplifier:

D.C. Plate Voltage	350	425 volts
D.C. Grid Voltage (Approx.)	—25	—35 volts
Peak Grid Swing (Approx.)	25	35 volts
D.C. Plate Current	25	25 ma.
Plate Resistance	4700	4800 ohms.
Mutual Conductance	1700	1600 micromhos.
Load Resistance	9500	12,000 ohms.
Power Output	0.95	1.6 watts

Class C Amplifier:

	Plate Mod. Telephony		Telegraphy	
D.C. Plate Voltage	250	350	350	450 volts
D.C. Grid Voltage	—100	—140	—100	—149 volts
D.C. Plate Current	30	30	30	30 ma.
D.C. Grid Current	7	7	5	5 ma.
Grid Driving Power	1.3	1.6	0.8	1.0 watts
Grid bias loss	0.7	1.0	0.8	1.5 watts
Power Input	7.5	10.5	10.5	13.5 watts
Power Output (Approx.)	4	6	6	8 watts

844

RCA Screen-grid R. F. Amplifier—doubler or buffer. Oscillator. Not in general use.

Characteristics:

(Heater-Cathode Type)

Heater Voltage	2.5 volts
Heater Current	3.25 amps.
Amplification Factor	75
Grid to Plate Capacity	0.15 μμfd.
Input Capacity	9.5 μμfd.
Output Capacity	7.5 μμfd.
Maximum Plate Dissipation	15 watts
Maximum Screen Dissipation	3 watts
Maximum D.C. Plate Voltage	500 volts
Maximum D.C. Plate Current	30 ma.
Maximum D.C. Grid Current	5 ma.
Base	UX 5-pin

R-F Service

	Class B Telephony	Plate Mod. Class C	Class C Telegraphy	
D.C. Plate Voltage	500	500	400	500 volts
D.C. Screen Voltage	180	150	175	175 volts
D.C. Grid Current	—40	—100	—125	—125 volts
D.C. Plate Current	20	20	25	25 ma.
Power Output	8	4	6	9 watts

865

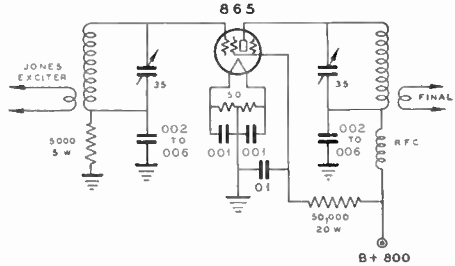
RCA Screen-Grid Tetrode. Buffer, amplifier, and frequency doublers. As a doubler about 5 to 10 watts may be obtained.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	2.0 amps.
Grid to Plate Capacity	0.10 μμfd.
Input Capacity	8.5 μμfd.
Output Capacity	8.5 μμfd.
Plate Voltage	500 volts
Screen Voltage	125 volts
Grid Voltage	0 volts
Amplification Factor	130
Plate Resistance	200,000 ohms.
Mutal Conductance	750 micromhos
Plate Current	21 ma.
Maximum Plate Dissipation	15 watts
Base	4-pin. Plate through top of envelope

Class C Operation:

D.C. Plate Voltage	500	750 volts
D.C. Plate Current	50	40 ma.
D.C. Screen Voltage	125	125 volts
D.C. Grid Voltage	—80	—80 volts
D.C. Grid Current	9	5 5 ma.
Grid Driving Power (Approx.)	2.0	1.0 watts
Grid Bias Power Loss	.7	.45 watts
Plate Power Input	25	30 watts
Power Output (Approx.)	10	16 watts



Single 865 Buffer or Doubler Circuit

T20

Taylor Tube Co. H.F. Triode. General purpose high μ; suitable for high-frequencies up to 56 Mc. Suitable for class B audio service, or as an r.f. frequency-doubler or r.f. amplifier. Isolantite-based tube with plate through top of envelope. 4-pin base. Molybdenum plate. Greater plate dissipation than type 10 or 841 triode.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	1.75 amps.
Amplification Factor	20
Grid-to-Plate Capacity	4 μμfd.
Maximum Plate Dissipation	20 watts
Maximum D.C. Plate Voltage	750 volts
Maximum D.C. Plate Current	75 ma.
Maximum D.C. Grid Current	25 ma.

Class B Modulator or A.F. Amplifier (2 Tubes)

D.C. Plate Voltage	800	600 volts
D.C. Grid Voltage	—40	—30 volts
Zero signal plate current (per tube)	10	10 ma.
Maximum signal plate current (per tube)	68	70 ma.
Load resistance (plate-to-plate)	12,000	8100 ohms
Power Output	70	50 watts

Class C Amplifier:

D.C. Plate Voltage	750 volts
D.C. Grid Voltage	—100 volts
D.C. Plate Current	75 ma.
D.C. Grid Current	20 ma.
Grid Driving Power (Approx.)	3 watts
Grid Bias Loss	2 watts
Power Output (Approx.)	42 watts

TZ-20

Taylor Tube Co. H.F. triode. Primarily designed for zero-bias class B audio use. Also suitable for all r.f. uses for which the T-20 is suitable. Operating conditions for r.f. use of the TZ-20 will be similar to those of the T 20; the grid bias, however, will be somewhat lower in each case. An improved doubler over the T-20. Isolantite base, metal plate, plate lead through top.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	1.75 amps.
Amplification Factor	62
Average Plate Resistance	26,700 ohms
Mutual Conductance	2320 µmhos

Class B Audio Amplifier or Modulator:

D.C. Plate Voltage	800	600 volts
Grid Bias Voltage	0	0 volts
Zero-signal Plate Current	20	14 ma.
Max.-signal Plate Current	69	70 ma.
Load Res., Plate-to Plate	12,000	8100 ohms
Power Output, Two Tubes	70	50 watts

Radio Frequency Amplifier Service:
See operating conditions for T-20.

●

801

RCA, Amperex, United 310. Triode. Class C. RF amplifier for phone or cw. Class B modulators. Frequency doubler.

Caution: The values given for grid driving power and power output vary with frequency and load circuit impedance. The driving stage should have, if possible, twice as much power output as needed for grid driving power and bias supply loss.

Note: As a doubler, regeneration can be obtained at the output frequency to improve the output efficiency without requiring as high grid bias and grid drive as listed in the table.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	1.25 amps.
Grid to Plate Capacity	6.0 µµfd.
Amplification Factor	8
Grid to Filament Capacity	4.5 µµfd.
Plate to Filament Capacity	1.5 µµfd.
Maximum Plate Dissipation	20 watts
Maximum D.C. Plate Voltage	600 volts
Maximum D.C. Plate Current	70 ma.
Maximum D.C. Grid Current	15 ma.
Base	UX-4 prong Isolantite

Class B Audio:

Plate Voltage	400	500	600	750 volts
Grid Voltage (Approx.)	—50	—60	—75	—90 volts
Zero Sig Plate Current (per tube)	4	5	4	6 ma.
Maximum Sig Plate Current (per tube)	65	65	65	65 ma.
Load Resistance (plate to plate)	6000	8000	10,000	12,000 ohms.
Power Output	27	36	45	60 watts

Class C Operation, Amplifier:

D.C. Plate Voltage	500	500	600	750 volts
D.C. Grid Bias	—190	—125	—150	—190 volts
D.C. Plate Current	55	65	65	65 ma.
D.C. Grid Current	15	10	15	15 ma.
Grid Driving Power (Approx.)	4.5	2.2	4	5.3 watts
Bias Supply Power Loss	2.9	1.2	2.25	2.9 watts
Power Output (Approx.)	18	16	25	35 watts
Approximate A.C. Load Resistance	4300	3600	4500	5500 ohms.
D.C. Modulator Load	9100	....	....	.... ohms.

Frequency Range	60	90	120	150 megacycles
Class C Telephony	480	360	310	260 volts
Class C Telegraphy	600	455	390	330 volts

Frequency Doubler	No Regeneration	With Regeneration
D.C. Plate Voltage	600	600 volts
D.C. Plate Current	75	75 ma.
D.C. Grid Voltage	—495	—250 volts
D.C. Grid Current	8	10 ma.
Grid Driving Power	4.75	3.5 watts
Grid Bias Supply Loss	4	2.5 watts
Power Output (Approx.)	25	25 watts
Plate Loss	20	20 watts

●

RCA-1608

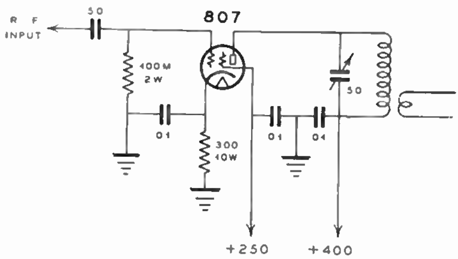
Coated filament triode, similar to RCA-801, but with a higher amplification constant.

Filament Voltage	2.5 volts
Filament Current	2.5 amps.
Amplification Factor	20
Maximum D.C. Plate Voltage	425 volts
Maximum D.C. Plate Current	95 ma.
Class-C R.F. Output	27 watts
Class-B Linear Output	10 watts
Class-B Audio (Two Tubes)	50 watts

●

807

R.C.A. Beam Power Pentode Transmitter Tube. R-F buffer or doubler for frequencies up to 60 mc. at full rated input. 50% ratings at 150 mc. Also useful as crystal oscillator with external capacity connected between grid and plate. Class AB audio amplifier with 60 watts output for two tubes (see 6L6 characteristics). If care is taken in placement of parts and if shield is placed around tube and if the input circuits are shielded from the output circuits, no neutralization will be required for R-F circuits.



Buffer or Doubler Circuit

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.9 amps.
Grid to Plate Capacity	0.2 µµfd.
Input Capacity	11.6 µµfd.
Output Capacity	5.6 µµfd.
Maximum Plate Dissipation	21 watts
Maximum D.C. Plate Voltage	600 volts

Plate lead at top of envelope.
Standard 5-pin Ceramic base.

R-F Amplifier:	C. W.	Phone
D.C. Plate Voltage	600	400 volts
D.C. Screen Voltage	250	250 volts
D.C. Grid Voltage	—50	—50 volts
Peak R-F Grid Voltage	80	80 volts
D.C. Plate Current	95	95 ma.
D.C. Screen Current	10	9 ma.
D.C Grid Current	3	2.5 ma.
Grid Driving Power (Approx)	0.22	0.18 watts
Power Output (Approx.)	37	25 watts

●

RK-39

Raytheon beam power tetrode, designed for frequency-doubler, amplifier, or crystal oscillator service. Frequency range: full voltage ratings up to 30 Mc. Maximum plate voltage at 60 Mc., 400 volts.

Characteristics:

Heater voltage	6.3 volts
Heater Current	0.9 amps.
Grid-to-Plate Capacity	0.15 µµfd.
Input Capacity	13 µµfd.
Output Capacity	10.5 µµfd.
Maximum Plate Dissipation	21 watts
Maximum Screen Dissipation	3.5 watts
Maximum D.C. Plate Voltage	500 volts
Maximum D.C. Screen Voltage	300 volts
Maximum D.C. Screen Current	20 ma.
Maximum D.C. Plate Current	100 ma.
Maximum D.C. Control Grid Current	5 ma.
Base	Standard 5 Pin (Isolantite.)

Plate Through Top of Envelope.

R.F. Service	Class B R.F.	Class C
D.C. Plate Voltage	500	500 volts
D.C. Plate Current	75	95 ma.
D.C. Screen Voltage	250	250 volts
D.C. Screen Current	3	12 ma.
D.C. Control Grid Current	0.3	3 ma.
Carrier Power Output	11	35 watts

RK-41

Raytheon Beam Power Pentode, identical with RK-39, except for heater which is 2.5 volts at 2.4 amps.

●

250

RCA Audio Amplifier in radio receivers or as a low power modulator for transmitters.

Note: Not over 10,000 ohms resistance can be placed in the grid circuit without endangering tube operation. These tubes have been supplemented by more modern tubes, such as the 2A3 and 6L6.

Characteristics:

Filament Voltage .... 7.5 volts
Filament Current .... 1.25 amp.
Grid to Plate Capacity .... 9 μμfd.
Grid to Filament Capacity .... 5 μμfd.
Plate to Filament Capacity .... 3 μμfd.
Maximum Plate Dissipation .... 25 watts
Maximum Plate Voltage .... 450 volts
Base .... 4 pin

Class A Audio Amplifier:

Plate Voltage	350	400	450 max.	volts
Grid Voltage	—63	—70	—84	volts
Plate Current	45	55	55	milliamperes
Plate Resistance ...	1900	1800	1800	ohms.
Amplification Factor	3.8	3.8	3.8	
Mutual Conductance	2000	2100	2100	micromhos.
Load Resistance ..	4100	3670	4350	ohms.
Undistorted Power Output	2.4	3.4	4.6	watts

●

WE-254B

Tetrode R. F. Amplifier. *Frequency Range:* 100% up to 15 mc. 66⅔% at 20 mc.

Characteristics:

Filament Voltage .... 7.5 volts
Filament Current .... 3.25 amps.
Plate to Grid Capacity .... 0.85 μμfd.
Input Capacity .... 11.2 μμfd.
Output Capacity .... 5.4 μμfd.
Amplification Factor 100
Maximum Plate Dissipation .... 25 watts
Maximum Screen Dissipation .... 4 watts
Maximum D.C. Plate Voltage .... 750 volts
Maximum D.C. Plate Current .... 75 ma.
Maximum D.C. Grid Current .... 25 ma.
Base .... 4 prong, plate through top of envelope

R-F Service

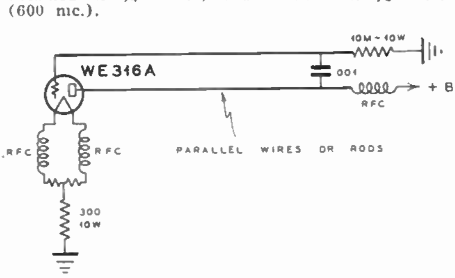
	Class B r. f.	Class C Telegraphy	
D.C. Plate Voltage	750	500	750 volts
D.C. Screen Voltage	150	150	150 volts
D.C. Grid Voltage	—70	—125	—125 volts
D.C. Plate Current	50	75	75 ma.
Approximate Power Output ..	12.5	25	37.5 watts

●

WE-316A

U.H.F. oscillator or amplifier especially designed for operation at frequencies above 100 megacycles. The upper limit of oscillation as a regenerative negative grid oscillator is 750 mc.

Note: Outputs of approximately 8 watts can be obtained at ¼ meter, and 4 watts at ½ meter (600 mc.).



U H F OSCILLATOR

Characteristics:

Filament Voltage .... 2 volts
Filament Current .... 3.65 amps.
Thermionic Emission .... 0.4 amp
Amplification Factor 6.5
Grid to Plate Capacity .... 1.6 μμfd.
Grid to Filament Capacity .... 1.2 μμfd.
Plate to Filament Capacity .... 0.8 μμfd.
Maximum Plate Dissipation .... 30 watts
Maximum D.C. Plate Voltage .... 450 volts
Maximum D.C. Plate Current .... 80 ma.
Maximum D.C. Grid Current .... 10 ma.
All leads extend directly out from tube elements.

●

800

RCA or Amperex Triode. Class B Modulator. Class C RF Amplifier. Frequency doubler. U.H.F. oscillator and amplifier.

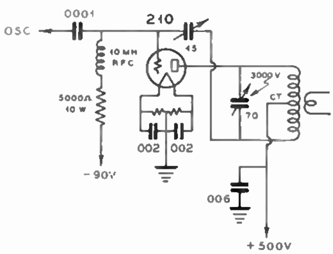
Frequency Range:	90	120	150	200 MC.
Class C plate Voltage (max.)	1125	1000	875	650 Teleg.
	900	800	700	500 Telep.

Caution: Maintain at least 7.5 volts at filament terminals of tubes.

Note: Grid driving power is a function of load impedance, frequency and type of neutralizing circuit. The driver stage should be capable of supplying approximately twice as much power output as required for the listed values of grid drive and grid bias loss.

Class B RF Telephony: Plate voltage of 1000, plate current of 42 ma., grid voltage—55, carrier power 14 watts.

Note: Regeneration at the output frequency in doubler operation will allow equivalent outputs without as high grid drive and grid bias.



DRIVER FOR PUSH-PULL CLASS C TYPE 800 TUBES

Characteristics:

Filament Voltage .... 7.5 volts
Filament Current .... 3.25 amps.
Amplification Factor 15
Maximum Plate Dissipation .... 35 watts
Grid to Plate Capacity .... 2.5 μμfd.
Grid to Filament Capacity .... 2.75 μμfd.
Plate to Filament Capacity .... 1.0 μμfd.
Maximum D.C. Plate Voltage .... 1250 volts
Maximum D.C. Plate Current .... 80 ma.
Maximum D.C. Grid Current .... 25 ma.
Base .... 4 pin
Plate and grid at top of envelope.

Class B Audio Amplifier:			
D.C. Plate Voltage	750	1000	1250 volts
D.C. Grid Voltage (Approx.)	—40	—55	—70 volts
Zero Sig. Plate Current (per tube)	13	14	15 ma.
Load Resistance (plate to plate)	6400	12.500	21.000 ohms.
D.C. Plate Input	80	80	80 watts
Power Output (2 tubes)	90	100	106 watts
Class C R.-F. Amplifier (Telegraphy):			
D.C. Plate Voltage	750	1000	1250 volts
D.C. Plate Current	70	70	70 ma.
D.C. Grid Voltage	—100	—135	—175 volts
D.C. Grid Current	15	15	15 ma.
Grid Driving Power	2.5	3.5	4.5 watts
Grid Bias Loss	1.5	2.0	2.6 watts
Approximate Power Output ..	35	50	65 watts
Power Input	52.5	70	87.5 watts
Approximate A.C. Load Impedance	5300	7100	9000 ohms.

R.-F. Frequency Doubler:

D.C. Plate Voltage .... 1000 volts
D.C. Plate Current .... 53.5 ma.
D.C. Grid Voltage .... —517 volts
D.C. Grid Current .... 6 ma.
Grid Driving Power .... 3.8 watts

Grid Bias Loss		3.1 watts
Approximate Power Output		36 watts
A.C. Load Impedance (Approx.)		10,100 ohms

Class C R.F. Amplifier (Telephony):

D.C. Plate Voltage	750	1000 volts (max.)
D.C. Plate Current	70	70
D.C. Grid Voltage	—150	—200 volts
D.C. Grid Current	18	18 ma.
Grid Driving Power (Approx.)	5	6 watts
Grid Bias Loss	2.7	3.6 watts
Power Output (Approx.)	35	50 watts
A.C. Load Resistance (Approx.)	5300	7100 ohms.
Modulator D.C. Load	10,700	14,300 ohms
Power Input	52.5	70 watts

●

RK-30

Raytheon H. F. Triode. Similar to 800 in all respects. See 800 data.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Maximum Plate Dissipation	35 watts
Amplification Factor	14
Grid—Plate Capacity	2.5 μμfd.
Grid—Filament Capacity	2.75 μμfd.
Plate—Filament Capacity	2.75 μμfd.
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	115 ma.
Maximum D.C. Grid Current	25 ma.
Base	UX 4 pin

Plate and grid at top of envelope.

●

RK-35

Raytheon U.H.F. Triode. General purpose triode with tantalum plate. Class B Audio, R.F. Amplifier or oscillator.

Frequency Range: 80% of full ratings at 56 mc., 60% at 112 mc.

Note: Grid driving power requirements vary over wide limits, depending upon plate load, circuit losses and type of circuit.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Amplification Factor	8
Grid to Plate Capacity	2.7 μμfd.
Grid to Filament Capacity	3.5 μμfd.
Plate to Filament Capacity	0.4 μμfd.
Maximum Plate Dissipation	35 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	100 ma.
Maximum D.C. Grid Current	20 ma.

Base......UX-4 pin. Plate at top, grid at side of envelope

R-F Service

	Class B r.f.	Grid Mod. r.f.	Class C
D.C. Plate Voltage	1000	1000	1000 volts
D.C. Grid Voltage	160	240	320 volts
D.C. Plate Current	52	50	96 ma.
D.C. Grid Current	..	..	15 ma.
Grid Driving Power	6	2.6	6.5 watts
Grid Bias Loss	..	..	5 watts
Power Input	52	50	96 watts
Power Output (Approx.)	17	16	70 watts

●

RK-37

Raytheon High-Mu Triode, Tantalum Plate. Oscillator or Amplifier for very high frequency operation. 100% ratings up to 30 MC. 80% ratings at 56 MC. 60% ratings at 112 MC.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Maximum Plate Dissipation	35 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	100 ma.
Maximum D.C. Grid Current	25 ma.
Grid to Plate Capacity	2.9 μμfd.
Grid to Filament Capacity	3.2 μμfd.
Plate to Filament Capacity	0.3 μμfd.

Standard UX-4 pin base.
Plate through top, grid through side of envelope.

R. F. Service

	Class B R.F.	Grid Mod. Telephony	Class C
D.C. Plate Voltage	1000	1000	1000 volts
D.C. Grid Voltage	—45	—52.5	—70 volts
D.C. Plate Current	50	50	95 ma.
D.C. Grid Current	....	....	20 ma.
Peak RF Grid Power	2.3	2.3	3.0 watts
Peak Audio Voltage	...	45	.. volts
Carrier Output Power	15	15	60 watts

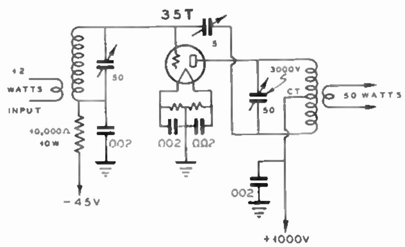
35-T

Eimac High-Mu Triode. Crystal oscillator for plate voltages up to 1200 volts. Class B modulator or AF amplifier. Class C buffer or doubler. Class C telephony. U.H.F. oscillators with quarter-wave line frequency control. U.H.F. r. f. amplifiers.

Frequency Range: 100% ratings up to 100 mc.

Note (1): For plate modulation, the values of grid bias should be increased at least 50%, and the grid drive will be approximately doubled.

Note (2): Values of grid bias and grid drive may be reduced with regenerative doubler circuits. The above values are for values of efficiencies between 58% and 68%. Lower grid bias and drive give lower efficiencies. With regeneration, the bias may be reduced to approximately ⅓ of the above values without loss of output. The bias should never be less than 3½ times cut-off bias when doubling.



REGENERATIVE FREQUENCY DOUBLER

Characteristics:

Filament Voltage	5 to 5¼ volts
Filament Current	4 amps
Amplication Factor (Average)	30
Maximum Normal Plate Dissipation	35 watts
Grid to Plate Capacity	1.9 μμfd.
Maximum D.C. Plate Voltage	1500 volts
Maximum D.C. Plate Current	150 ma.
Maximum D.C. Grid Current	25 ma.

Base: UX-4 pin. Plate at top of envelope.

Class B Audio Amplifier (2 tubes):

D.C. Plate Voltage	500	750	1000	1250	1500 volts
D.C. Grid Voltage	0	—10	—22.5	—40	—50 volts
Zero Signal D.C. Plate Current	65	50	40	20	16 ma.
Maximum Signal D.C. Plate Current	200	200	188	158	140 ma.
Load Resistance (Plate to Plate)	4000	7000	11000	17200	23600 ohms
Driving Power	6.5	8.5	7.5	5.5	4.5 watts
Output Power	50	90	120	130	140 watts

Class C r.f. Amplifier Telegraphy (Buffer Service)

D.C. Plate Voltage	400	750	1000	1500 volts
D.C. Grid Voltage	—20	—38	—50	—100 volts
D.C. Plate Current	90	90	90	90 ma.
D.C. Grid Current	15	18	20	20 ma.
Grid Driving Power (Approx.)	2	3.0	3.5	4.5 watts
Grid Bias Loss	.3	.7	1	2 watts
Power Input	36	67.5	90	135 watts
Power Output (Approx.)	20	47.5	62	101 watts
A.C. Load Resistance	1700	3500	5200	8400 ohms

Frequency Doubler (Without Regeneration):

D.C. Plate Voltage	750	1250	1500 volts
D.C. Grid Voltage	—445	—502	—530 volts
D.C. Plate Current	87	85	87 ma.
D.C. Grid Current	10	10	10 ma.
Grid Driving Power	5	6.5	6.8 watts
Grid Bias Loss	4.5	5	5.3 watts
Power Input	65	106	130 watts
Power Output	37.5	72	90 watts
A.C. Load Resistance	4000	7600	9500 ohms

Regenerative Frequency Doubler:

D.C. Plate Voltage	750	1000 volts
D.C. Grid Voltage	—90	—150 volts
D.C. Plate Current	100	80 ma.
D.C. Grid Current	20	20 ma.
Grid Driving Power	4.5	5.5 watts
Grid Bias Loss	1.8	3 watts
Power Input	75	80 watts
Power Output (Approx.)	40	50 watts

825

Taylor 40 watt Triode. Intermediate between 801 and 211 tubes. Class B audio amplifier operating in the Class AB region. Class B r.f. amplifier for telephony or telegraphy in high frequency transmitters.

Note: Grid drive requirements vary widely under various circuit conditions.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	2 amps.
Amplification Factor	8
Grid to Plate Capacity	7 μμfd.
Grid to Filament Capacity	3 μμfd.
Plate to Filament Capacity	2.7 μμfd.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	850 volts
Maximum D.C. Plate Current	110 ma.
Maximum D.C. Grid Current	25 ma.
Base	UX-4 pin

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	850 volts
D.C. Grid Voltage (Approx.)	—67.5 volts
Zero Signal D.C. Plate Current	50 ma.
Maximum Signal D.C. Plate Current	170 ma.
Load Impedance (Plate to Plate)	8000 ohms.
Power Output	80 watts

Class C R-F Amplifier:

	Plate Mod. Telephony	Telegraphy	
D.C. Plate Voltage	750	750	850 volts
D.C. Grid Voltage	—235	—180	—225 volts
D.C. Plate Current	80	100	100 ma.
D.C. Grid Current	20	15	15 ma.
Grid Driving Power (Approx.)	6	4.3	4.8 watts
Grid Bias Loss	4.7	2.7	3.4 watts
Power Input	60	75	85 watts
Power Output	40	45	55 watts

●

930

United Electronics Co. Triode. Amperex (830). Oscillator, modulator, r.f. amplifier, generally as a neutralized r.f. amplifier or buffer stage in high frequency transmitters.

Note: Intermediate between 211 and 210 or 801 in operation.

Frequency Range: 100% ratings up to 6 MC.

Characteristics:

Filament Voltage	10 volts
Filament Current	2 amps.
Amplification Factor	8
Grid to Plate Capacity	9.9 μμfd.
Grid to Filament Capacity	4.9 μμfd.
Plate to Filament Capacity	2.2 μμfd.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	750 volts
Maximum D.C. Plate Current	110 ma.
Maximum D.C. Grid Current	18 ma.
Base	UX 4 pin

R-F Service

	Class B Telephony	Class C Plate Mod. Telephony	Class C Telegraphy
D.C. Plate Voltage	750	600	750 max. v.
D.C. Grid Voltage	—95	—180	—180 volts
D.C. Plate Current	80	100	110 ma.
D.C. Grid Current	...	15	15 ma.
Grid Driving Power	...	5	5 watts
Grid Bias Loss	...	2.7	2.7 watts
Power Input	60	60	82.5 watts
Power Output	20	40	55 watts

●

WE-300A

Western Electric Class A audio amplifier or modulator, especially suitable for automobile transmitters.

Note: If fixed C bias is used, the plate current should be limited to not over 70 ma.

Characteristics:

Filament Voltage	5.0 volts a.c. or d.c.
Filament Current	1.2 amps.
Amplification Factor (Approx.)	3.8
Grid to Plate Capacity	15 μμfd.
Grid to Filament Capacity	9 μμfd.
Plate to Filament Capacity	4 3 μμfd.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	450 volts
Maximum D.C. Plate Current	100 ma.

Class A (Single Tube) Modulator:

D.C. Plate Voltage	200	250	350	450 volts
D.C. Grid Voltage	—39	—45	—71	—97 volts
D.C. Plate Current	40	80	80	80 ma.
Load Resistance	2500	1500	2200	3000 ohms.
Power Output	2.6	5.0	9.6	14.6 watts

Push Pull Operation (2 Tubes)

D.C. Plate Voltage	450 volts
D.C. Plate Current (Per Tube)	70 ma.
Mutual Conductance	5200 mhos.
Class-A Power Output	25 watts

●

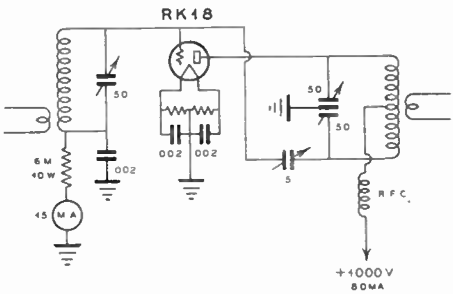
RK-18

Raytheon H. F. Triode, Class B modulator. Class C r. f. amplifier or oscillator. Buffer or doubler.

Note (1): Values of grid drive will vary with load resistance, circuit design, and losses; thus the driver stage should be capable of supplying approximately twice as much output as listed for grid drive and bias loss.

Note (2): The efficiency of a doubler at a lower value of grid bias than that listed may be improved by regeneration at the output frequency.

Frequency Range: 100% ratings up to 30 KC.



Neutralized Buffer Stage

Characteristics:

Filament Voltage	7.5 volts
Filament Current	3.0 amps.
Amplification Factor	18
Grid to Plate Capacity	4.8 μμfd.
Grid to Filament Capacity	4.6 μμfd.
Plate to Filament Capacity	2.9 μμfd.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	1000 volts
Maximum D.C. Plate Current	85 ma.
Maximum D.C Grid Current	25 ma.
Base	UX-4 pin. Plate at top of envelope

Class B Modulator or A.F. Amplifier:

D. C. Plate Voltage	750	1000 volts
D.C. Grid Voltage	—40	—50 volts
Peak A.F. Grid Voltage (per tube)	90	100 volts
Zero Signal D.C. Plate Current (per tube)	5	7 ma.
Maximum Signal D.C. Plate Current (per tube)	80	80 ma.
Load Resistance (Plate to Plate)	10,000	12,000 ohms
Power Output (2 Tubes)	65	100 watts

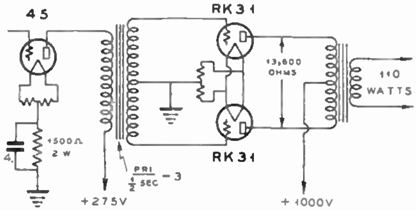
R-F Service

	Class C Telegraphy Final	Class C Telegraphy Buffer	Frequency Doubler
D.C. Plate Voltage	1000	1000	1000 volts
D.C. Grid Voltage	—122	—80	—425 volts
D.C. Plate Current	88	80	64 ma.
D.C. Grid Current	22	15	10 ma.
Grid Driving Power	6.0	2.7	5.3 watts
Grid Bias Loss	2.7	1.2	4.3 watts
Power Input	88	80	64 watts
Approximate Power Output	60	42	35 watts
Approximate A.C. Load Impedance	5300	5850	7000 ohms
Efficiency	68	52.5	55%

RK-31

Raytheon High Mu Triode. Primarily a Class B Audio Amplifier. May be used for R.F.

Note: R.F. grid excitation requirements vary widely, thus the driver stage should be designed with ample factor of safety for output needs.



CLASS B AUDIO AMPLIFIER OR MODULATOR

Characteristics:

Filament Voltage	7.5 volts
Filament Current	3.0 amps.
Amplification Factor Varies with Input	high mu.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	85 ma.
Base	UX-4 pin. Plate at top of envelope

Class B Modulator or AF Amplifier:

D.C. Plate Voltage	1000	1250 volts (max.)
D.C. Grid Voltage	0	0 volts
Grid Driving Power (2 tubes)	900	900 milliwatts
Zero Signal D.C. Plate Current (per tube)	12	15 ma.
Maximum Signal D.C. Plate Current (per tube)	80	80 ma.
Load Resistance (Plate to Plate)	13,600	17000 ohms
Power Output (2 tubes)	110	140 watts

R-F Service

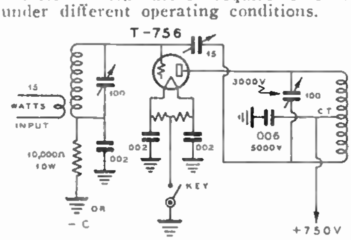
	Class C Telegraphy	Frequency Doubler
D.C. Plate Voltage	1250	1000 volts
D.C. Grid Voltage	—90	—300 volts
D.C. Plate Current	85	85 ma.
D.C. Grid Current	25	15 ma.
Grid Driving Power	5.25	6 watts
Grid Bias Loss	2.25	4.5 watts
Power Input	106	85 watts
Approximate Power Output	76	52 watts
Approximate A.C. Load Impedance	7250	5400 ohms

●

756

Taylor Triode for Doubler and Class C operation. Class B audio amplifier.

Note: Grid drive requirements vary widely under different operating conditions.



R F DOUBLER OR NEUTRALIZED BUFFER

Characteristics:

Filament Voltage	7.5 volts
Filament Current	2 amps.
Amplification Factor	25
Grid to Plate Capacity	8 μμfd.
Grid to Filament Capacity	3.5 μμfd.
Plate to Filament Capacity	2.7 μμfd.
Maximum D.C. Plate Voltage	850 volts
Maximum D.C. Plate Voltage	850 watts
Maximum D.C. Plate Current	110 ma.
Maximum D.C. Grid Current	20 ma.
Base	UX-4 pin. Isolantite.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	850 volts
D.C. Grid Voltage	—30 volts
Zero Signal Plate Current	20 ma.
Maximum Signal Plate Current	225 ma.
Load Impedance (Plate to Plate)	6750 ohms.
Power Output	100 watts

Class C R.F. Amplifier:

	Plate Mod. Telephony	Telegraphy	
D.C. Plate Voltage	750	750	850 volts
D.C. Grid Voltage	—80	—75	—85 volts
D.C. Plate Current	90	110	110 ma.
D. C. Grid Current	20	16	16 ma.
Grid Driving Power (Approx.)	5	3.5	3.7 watts
Grid Bias Loss	1.6	1.2	1.4 watts
Power Input	67.5	82.5	93.5 watts
Power Output	40	50	60 watts

●

804

RCA Pentode R. F. Amplifier. Frequency doubler. Oscillator. Suppressor, grid or plate modulated amplifier.

Caution: Do not apply screen voltage without simultaneous application of plate voltage.

Frequency Range: 100% ratings at 15 mc. 75% at 35 mc. and 50% at 80 mc. Special attention should be given to shielding and by-passing at high frequencies.

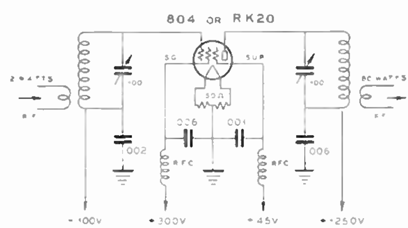
Characteristics:

Filament Voltage	7.5 volts
Filament Current	3.0 amps.
Grid to Plate Capacity	0.01 μμfd.
Input Capacity	16 μμfd.
Output Capacity	14.5 μμfd.
Maximum Plate Dissipation	40 watts
Maximum Screen Dissipation	15 watts
Mutual Conductance	3250 micromhos.

UX-5 pin base plate at top of envelope.

R-F Service

	Class B Telephony	Suppressor Mod. Telephony		Pentode Class C Telegraphy	Tetrode Class C Telegraphy
D.C. Plate Voltage	1250	1000	1250	1250	1250 volts
D.C. Screen Voltage	300	300	300	300	180 volts
D.C. Suppressor voltage	45	—35	—50	45	180 volts
D.C. Grid Bias	—20	—100	—100	—100	—100 volts
Peak R.F. Grid Volts	27	140	140	150	160 volts
Peak A.F. Grid Volts	..	60	70	..	... volts
D.C. Plate Current	45	45	48	92	92 ma.
D. C. Screen Current	11	33.5	35.5	27	23 ma.
D.C. Grid Current	1	5.5	7	7	8 ma.
Grid Driving Power	.25	.7	.85	.9	1.2 watts
Grid Bias Loss	..	.6	.7	.7	.8 watts
Power Output (Approx.)	16	16	21	80	80 watts
Screen Resistor	86,000	21.000	27.000	35.000	..... ohms.



Conventional Screen-Grid Buffer or Final Amplifier

●

RK-20

Raytheon RF Amplifier. Frequency Doubler. Oscillator. Suppressor, Grid - or - Plate - modulated Amplifier.

Caution: Do not apply screen voltage without simultaneous application of plate voltage.

Frequency Range: 100% ratings up to 20 MC. The RK 20 has lower input and output capacitances than the 804, and may therefore be used more effectively at higher frequencies, such as 30 mc.

Characteristics:

Filament Voltage ....7.5 volts
Grid Current ....3.0 amps.
Grid to Plate Capacity....0.12 μμfd.
Input Capacity ....11 μμfd.
Output Capacity ....10 μμfd.
Maximum Plate Dissipation....40 watts
Maximum Screen Dissipation ....15 watts
Base ....UX 5 pin
Isolantite. Plate at top of envelope.

R-F SERVICE

	Class B Telephony	Suppressor Modulation	Class C Telegraphy	
D.C. Plate Voltage..	1250	1250	1250	1250 volts
D.C. Screen Voltage..	300	300	300	300 volts
D.C. Suppressor Voltage	0	—45	0	—45 volts
D.C. Grid Bias ...	—30	—100	—100	—100 volts
Peak R.F. Grid Volts	70	175	175	175 volts
Peak A.F. Grid Volts	..	75	...	... volts
D.C. Plate Current...	43	43	80	92 ma.
D.C. Screen Current..	15	36	37	32 ma.
D.C. Grid Current...	..	5	5	5 ma.
Grid Driving Power..	.5	.9	.9	.9 watts
Grid Bias Loss	..	.5	.5	.5 watts
Power Output (Approx.)	16	18	64	80 watts
Screen Resistor	60,000	25,000	26,000	29,000 ohms.

●

RK-46

Raytheon pentode, similar to RK 20, except for filament and envelope, which are heavier in construction. Filament is rated at 12.6 volts at 2.5 amps. Designed for mobile and aircraft transmitters.

●

RK-47

Raytheon beam-power tetrode, designed for r.f. amplifier-doubler service. Somewhat similar to RK 20, except for special grid structure; slightly higher plate efficiency than in similar types of pentode tubes.

Characteristics:

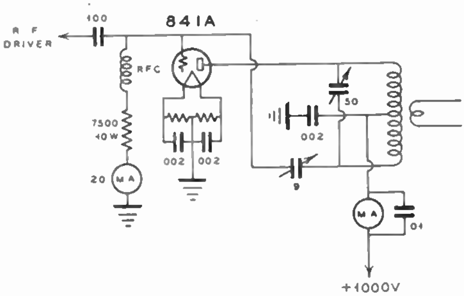
Filament Voltage ....10 volts
Filament Current ....3.25 amps.
Maximum D.C. Plate Voltage ....1250 volts
Maximum D.C. Screen Voltage ....300 volts
Maximum Plate Dissipation ....50 watts
Maximum Screen Dissipation ....15 watts
Maximum D.C. Grid Current ....10 ma.
Grid-to-Plate Capacity ....0.12 μμfd.
Input Capacity ....13 μμfd.
Output Capacity ....10 μμfd.
Base....Standard UX- 5-prong
Plate through top of envelope.

●

841A

Taylor H. F. Triode. Doubler or buffer stage in high power transmitters. R.F. Amplifier down to 7½ meters.

Note: Grid driving power requirements vary over wide limits under operating conditions.



Neutralized Buffer

Characteristics:

Filament Voltage ....10 volts
Filament Current ....2 amps.
Amplification Constant 14.6
Grid to Plate Capacity....9 μμfd.
Grid to Filament Capacity....3.5 μμfd.
Plate to Filament Capacity....2.5 μμfd.
Maximum Plate Dissipation....50 watts
Maximum D.C. Plate Voltage....1250 volts
Maximum D.C. Plate Current....150 ma.
Maximum D.C. Grid Current....30 ma.
Base ....UX 4 pin

Class C R-F Amplifier:

D.C. Plate Voltage....1000 volts
D.C. Grid Voltage.... —180 volts
D.C. Plate Current....150 ma.
D.C. Grid Current....20 ma.
Grid Driving Power....7 watts
Grid Bias Loss....3.6 watts
Power Input ....150 watts
Power Output ....100 watts

●

304B

Western Electric U.H.F. oscillator or amplifier up to 300 mc.

Frequency	Class C Telegraphy Plate Volts	Oscillator Plate Volts
100 mc.	1250	1000
200 mc.	1000	800
300 mc.	750	600

Characteristics:

Filament Voltage ....7.5 volts
Filament Current ....3.25 amps.
Amplification Factor 11
Grid to Plate Capacity....2.5 μμfd.
Grid to Filament Capacity....2.0 μμfd.
Plate to Filament Capacity....0.7 μμfd.
Maximum Plate Dissipation....50 watts
Maximum D.C. Plate Voltage....1250 volts
Maximum D.C. Plate Current....100 ma.
Maximum D.C. Grid Current....25 ma.
Base ....UX 4 pin
Plate and Grid at Top of Envelope

Class B Audio Amplifier (2 tubes):

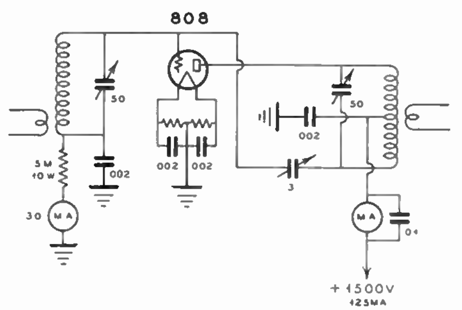
D.C. Plate Voltage.......	750	1000	1250 volts
D.C. Grid Voltage.......	—55	—85	—110 volts
Max. Sig. D.C Plate Cur.	200	200	200 ma.
Zero Sig. D.C. Plate Cur..	40	40	40 ma.
Load Res. (Plate to Plate)	7000	10,000	14,000 ohms
Power Output	85	110	140 watts
Driver Power	10	10	10 watts

Class C Service:—See 834.

●

808

RCA Tantalum Plate Triode. High-Frequency Oscillator and Amplifier. 100% ratings up to 30 MC. 50% ratings at 130 MC.



Neutralized Buffer or C. W. Amplifier

Characteristics:

Filament Voltage ....7.5 volts
Filament Current ....4 amps.
Amplification Factor 47
Grid to Plate Capacity....3 μμfd.
Grid to Filament Capacity....5 μμfd.
Plate to Filament Capacity....0.2 μμfd.
Standard UX-4 pin base.
Plate through top, grid through side of envelope.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	1250	1500 volts
D.C. Grid Voltage	—15	—25 volts
Zero Signal D.C. Plate Current	40	30 ma.
Maximum Signal D.C. Plate Current	230	190 ma.
Load Resistance (plate-to-plate)	12700	18300 ohms
Grid Driving Power	7.8	4.8 watts
Power Output, Approximate	190	185 watts

Class C RF Amplifier:

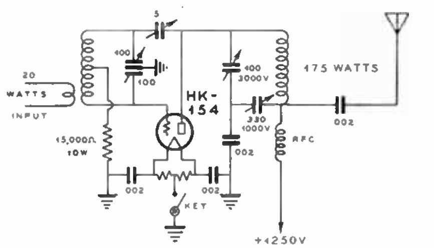
	Plate Mod. Telephony	Class C Telegraphy	
D.C. Plate Voltage	1250	1250	1500 volts
D.C. Grid Voltage	—225	—150	—200 volts
D.C. Plate Current	100	135	125 ma.
D.C. Grid Current	32	30	30 ma.
Grid Driving Power	10.5	8	9.5 watts
Grid Bias Loss	7	4.5	6 watts
Power Output (Approximate)	105	120	140 watts

●

HK-154

Heintz & Kaufman. General purpose U.H.F. and H.F. triode. Tantalum plate and grid.

Note: Grid drive requirements vary widely under different operating conditions.



GRID NEUTRALIZED FINAL AMPLIFIER

Characteristics:

Filament Voltage	5.0 volts
Filament Current	6.5 amps.
Amplification Factor	6.7
Grid to Plate Capacity	5 μμfd.
Maximum Plate Dissipation	50 watts
Maximum D.C. Plate Voltage	1500 volts
Maximum D.C. Plate Current	175 ma.
Maximum D.C. Grid Current	30 ma.
Base	UX-4 pin.

Grid and Plate Leads Through Opposite Sides of Envelope.

A-F Amplifier (2 tubes):

D.C. Plate Voltage	750	1000	1500 volts
Power Output	150	200	250 watts
Grid Driving Power (Approx.)	10	10	10 watts

R-F Service

	Class B R-F		Class C R-F		
D.C. Plate Voltage	750	1500	750	1000	1500 volts
D.C. Plate Current	80	56	175	175	175 ma.
D.C. Grid Voltage	—112	—225	—275	—350	—500 volts
D.C. Grid Current	...	...	20	20	20 ma.
Approx. Grid Driving Power	...	...	6	10	13 watts
Grid Bias Loss	...	...	5.5	7	10 watts
Approx. Power Output	18	28	85	125	200 watts

●

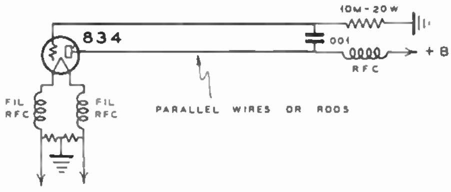
834

RCA U.H.F. amplifier and oscillator. *Frequency Range:* Up to 350 megacycles.

Rated input at 100 mc.—100%
Rated input at 350 mc.— 50%

Note (1): Grid driving power varies with type of circuit used, load impedance, and frequency range (dielectric and circuit losses increase with frequency). Driver should be capable of twice as much output as listed for grid drive and bias loss, as a factor of safety in design.

Note (2): Regeneration in the frequency doubler will allow lower values of grid bias and grid drive for same output power



U H F OSCILLATOR

Characteristics:

Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Amplification Factor	10.5
Grid to Plate Capacity	2.6 μμfd.
Grid to Filament Capacity	2.2 μμfd.
Plate to Filament Capacity	0.6 μμfd.
Maximum Plate Dissipation	50 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	100 ma.
Maximum D.C. Grid Current	20 ma.
Base	UX 4 pin

Plate and Grid Through Top of Tube Envelope.

R-F Amplifier

	Class C Telegraphy Amplifier	Class C Telegraphy Doubler	Class C Telephony	Class B Telephony
D.C. Plate Voltage	1250	1000	1000	1000 volts
D.C. Plate Current	95	78	90	50 ma.
D.C. Grid Current	15	10	17.5	0.5 ma.
D.C. Grid Voltage	—193	—684	—310	—90 volts
Grid Driving Power	4.8	8.4	7.5	3 watts
Grid Bias Loss	2.9	6.8	5.5	... watts
Power Input	119	78	90	50 watts
Approx. Power Output	89	45	60	16 watts
Approx. AC Load Imped.	6500	6600	5500	... ohms
Max. DC Load Imped.	...	...	11,100	... ohms

●

RK-32

Raytheon U.H.F. Triode. Similar to 834 in all respects. See 834 data.

Characteristics:

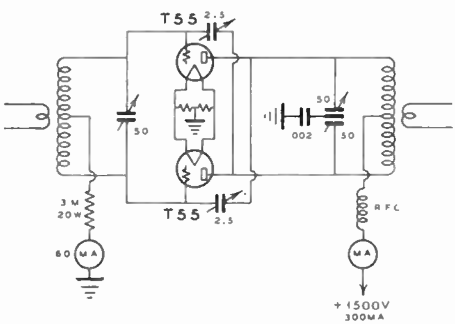
Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Amplification Factor	11
Grid to Plate Capacity	3.0 μμfd.
Grid to Filament Capacity	2.0 μμfd.
Plate to Filament Capacity	1.0 μμfd.
Maximum Plate Dissipation	50 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	100 ma.
Maximum D.C. Grid Current	20 ma.
Base	UX 4 pin

Plate and Grid at Top of Envelope.

●

T-55

Taylor Class C r.f. Amplifier. U.H.F. oscillator down to 2 meters wavelength.



P.P. R.F. Amplifier

Characteristics:

Filament Voltage	7.5 volts
Filament Current	2.75 amps.
Amplification Factor	20
Grid to Plate Capacity	3.75 μμfd.
Grid to Filament Capacity	4.0 μμfd.
Plate to Filament Capacity	1.5 μμfd.
Maximum Plate Dissipation	55 watts
Maximum D.C. Plate Voltage	1500 volts
Maximum D.C. Plate Current	150 ma.
Maximum D.C. Grid Current	40 ma.
Base	UX-4 pin.

Plate at Top of Envelope.

Class C R-F Amplifier:

D.C. Plate Voltage	1500 volts
D.C. Grid Voltage	—180
D.C. Plate Current	150 ma.
D.C. Grid Current	30 ma.
Grid Driving Power	10 watts
Grid Bias Loss	5.5 watts
Power Input	225 watts
Power Output	170 watts

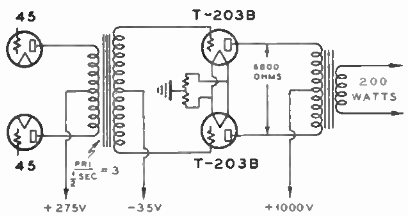
Class B Audio Amplifier (Two Tubes):

D.C. Plate Voltage	1000 volts	1500 volts
D.C. Grid Voltage (Approx.)	—45 volts	—67.5 volts
Zero D.C. Signal Plate Current	40 ma.	40 ma.
Load Resistance, Plate to Plate	10,000 ohms	12,000 ohms
Audio Output (2 tubes)	125 watts	175 watts

203-B

Taylor High-mu Triode. Redesigned primarily for class B audio amplifiers.

Driver: 2A3s in push-pull with $\frac{\text{Primary}}{\frac{1}{2}\text{ sec.}} = 1.6$ ratio input transformer.



ECONOMICAL CLASS B MODULATOR

Characteristics:

Filament Voltage	10 volts
Filament Current	3.85 amps.
Amplification Factor	25
Maximum Plate Dissipation	55 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	150 ma. (in R-F circuits)
Grid to Plate Capacity	14 μμfd.
Grid to Filament Capacity	6 μμfd.
Plate to Filament Capacity	5 μμfd.
Base	Standard 4 pin. 50 watt

Class B Audio Amplifier (2 Tubes):

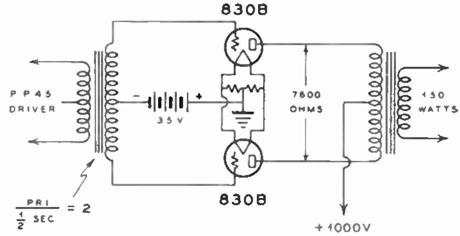
D.C. Plate Voltage	1000	1250 volts
D.C. Grid Voltage (approx.)	—35	—45 volts
Zero Signal D.C. Plate Current (per tube)	20	20 ma.
Maximum Signal D.C. Plate Current (2 tubes)	330	350 ma.
Load Impedance (Plate to Plate)	6800	7900 ohms
Power Output	200	300 watts
Driving Power	10	12 watts

830B

RCA 830-B. United Electronics Co. 930-B. Class B modulator for outputs up to 175 watts. May be driven by a push-pull 45 or 2A3 driver stage. Also used for RF.

R.F. Frequency range: 100% ratings up to 15 mc. 75% at 30 mc. 50% at 60 mc.

Note: R. F. Grid driving power requirements vary with load impedance, circuit design and circuit losses with increase of frequency. The driver stage should be capable of supplying twice as much power output as listed for grid drive and grid bias loss.



Characteristics:

Filament Voltage	10 volts
Filament Current	2 amps.
Amplification Factor	25
Maximum Plate Dissipation	60 watts
Grid to Plate Capacity	11 μμfd.
Grid to Filament Capacity	5 μμfd.
Plate Filament Capacity	1.8 μμfd.
Max. D.C. Plate Voltage	1000 volts
Maximum D.C. Grid Current	60 ma.
Maximum D.C. Plate Current	150 ma.
Base	UX 4 pin

Plate at top of envelope.

Class B Modulator or A-F Amplifier:

D.C. Plate Voltage	800	1000 volts
D.C. Grid Voltage	—27	—35 volts
Peak Grid to Grid A-F Volts	250	270 volts
Zero Sig. D.C. Plate Current (2 tubes)	20	20 ma.
Maximum Sig. D.C. Plate Current (2 tubes)	280	280 ma.
Eff. Load Resistance (Plate to Plate)	6000	7600 ohms
Grid Driving Power	5	6 watts
Maximum Sig. Power Output	110	150 watts

R-F SERVICE

	Class B R-F	Class C Telephony	Class C Telegraphy		Frequency Doubler
D.C. Plate Voltage	1000	800	600	1000	1000 volts
D. C. Plate Current	85	95	140	140	75 ma.
D.C. Grid Bias	—35	—150	—95	—110	—435 volts
D.C. Grid Current	6	20	30	30	15 ma.
Grid Driving Power (Approx.)	6*	5	6	7	8.5 watts
Grid Bias Loss	2	3	2.8	3.3	6.5 watts
Power Input	85	76	84	140	75 watts
Power Output (Approx.)	26	50	45	90	45 watts
Mod. D.C. Load Resist.	...	8400	...	...	... ohms
Approximate A.C. Load Impedance	...	4200	2150	3600	... ohms

*At Peak.

WE-305A

Western Electric R.F. amplifier, oscillator or harmonic generator at ultra-high frequencies.

Frequency Range: 100% ratings up to 50 mc. 50% plate voltage rating at 100 mc.

Note: Plate, screen, and filament center-tap leads come out through rods at top of tube to enable short leads at very high frequencies. Cooling lugs of copper are needed for operation at frequencies above 50 mc.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.1 amps.
Plate to Grid Capacity	0.14 μμfd.
Input Capacity	10.5 μμfd.
Output Capacity	5.4 μμfd.
Maximum Plate Dissipation	60 watts
Maximum Screen Dissipation	6 watts
Maximum D.C. Plate Voltage	1000 volts
Maximum D.C. Screen Voltage	200 volts
Maximum D.C. Plate Current	125 ma.
Maximum D.C. Grid Current	40 ma.

R-F Service

	Class B R-F	Class C R-F		
D.C. Plate Voltage	1000	1000	750	500 volts
D.C. Grid Voltage	—135	—250	—175	—200 volts
D.C. Screen Voltage	200	200	200	200 volts
D.C. Plate Current	90	125	125	125 ma.
Approx. Power Output	30	85	65	42 watts

203-Z

Taylor zero-bias audio amplifier. Designed for class B audio amplifiers or modulators with zero grid-bias. Can be operated as r.f. amplifier below 15 Mc.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.85 amps.
Mutual Conductance	5900 mhos
Amplification Factor	85
Maximum D.C. Plate Voltage	1250 volts
Maximum Plate Dissipation	65 watts
Base	Standard 4-pin 50-watt

Plate through top of envelope.

Class-B Modulator (2 Tubes):

D.C. Plate Voltage	900	1000	1100	1250 volts
D.C. Grid Bias	zero	zero	zero	zero volts
Zero Signal D.C. Plate Current (per tube)	30	35	40	45 ma.
Max. Signal D.C. Plate Current (2 Tubes)	350	300	350	350 ma.
Load Impedance, Plate-to-Plate	5400	6900	6700	7900 ohms
Audio Power Output	200	200	260	300 watts
Approx. Grid Driving Power	7	7	7	7 watts

WE-282A

Western Electric Tetrode. Screen-grid r.f. amplifier or frequency doubler.

Frequency Range: 100% ratings up to 30 mc. 50% ratings at 60 mc.

Characteristics:

Filament Voltage	10 volts
Filament Current	3 amps.
Amplification Factor	100
Plate to Grid Capacity	0.2 μμfd.
Input Capacity	12.2 μμfd.
Output Capacity	6.8 μμfd.
Maximum Plate Dissipation	70 watts
Maximum D.C. Plate Voltage	1000 volts
Maximum D.C. Plate Current	100 ma.
Maximum D.C. Grid Current	50 ma.
Maximum Screen-Grid Dissipation	5 watts
Base	Standard 4 pin 50 watt

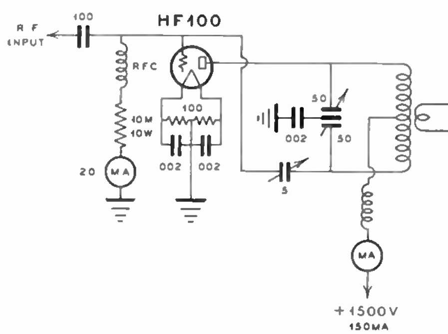
R-F Service

	Class B R-F	Class C Telegraphy	
D.C. Plate Voltage	1000	750	1000 volts
D.C. Grid Voltage	—90	—150	—150 volts
D.C. Screen Grid Voltage	150	150	150 volts
D.C. Plate Current	100	100	100 ma.
Plate Power Input	100	75	100 watts
Approximate Power Output	33	50	67 watts

HF-100

Amperex Triode. H.F. and U.H.F. amplifier or oscillator down to 2 meters in wavelength.

Note: Similar to 830-B, except for lower inter-electrode capacities and ability to operate efficiently in U.H.F. applications.



Neutralized R. F. Amplifier or Doubler

Characteristics:

Filament Voltage	10 to 10.5 volts
Filament Current	2 amp.
Amplification Factor	23
Grid to Plate Capacity	4.5 μμfd.
Grid to Filament Capacity	3.5 μμfd.
Plate to Filament Capacity	1.4 μμfd
Maximum Plate Dissipation	75 watts
Maximum D.C. Plate Voltage	1500 volts
Maximum D.C. Plate Current	150 ma.
Maximum DC. Grid Current	30 ma.
Base	Standard 4 prong base (UX)

Plate Out Top. Grid Out Side of Envelope. Carbon plate.

Class C R-F Service:

	30 mc. or Lower	120 mc.
D.C. Plate Voltage	1500	1000 volts
D.C. Grid Voltage	—200	—110 volts
D.C. Plate Current	150	120 ma.
D.C. Grid Current	20	20 ma.
Grid Drive (Approx.)	7	6 watts
Grid Bias Loss	4	2.2 watts
Power Output (Approx.)	170	70 watts
Maximum Plate Dissipation	75	50 watts

50T

Eimac general purpose H.F. and U.H.F. triode. Tantalum plate and grid. The low inter-electrode capacitances and small physical size make this tube very effective for ultra-high frequency amplification.

Frequency Range: 100% ratings up to 80 mc.

Note: Values of grid excitation vary considerably with load impedance, circuit design, and losses at higher frequencies; thus the driver should be designed to furnish approximately twice as much output as listed for grid drive and bias loss.

Characteristics:

Filament Voltage	5 to 5.25 volts
Filament Current	6 amps.
Amplification Factor (Avg.)	11
Grid to Plate Capacity	2 μμfd.
Grid to Filament Capacity	2 μμfd.
Plate to Filament Capacity	0.4 μμfd.
Maximum Plate Dissipation	75 watts
Maximum Plate Voltage	3000 volts
Maximum Plate Current	125 ma.
Maximum Grid Current	30 ma.
Base	UX-4 pin.

Plate at top, grid at side of envelope.

Class B Audio Amplifier (2 tubes):

DC plate voltage	1000	1500	2000	2500	3000 volts
D.C. Grid Voltage (Approx.)	—80	—135	—180	—225	—275 volts
Zero Sig. D.C. Plate Current (Approx.)	20	20	20	20	20 ma.
Max. Sig. D.C. Plate Current	250	230	200	180	160 ma.
Load Resistance (Plate to Plate)	5000	12,000	20,000	30,000	45,000 ohms
Driving Power	7	7	7	7	7 watts
Output Power	106	200	250	300	350 watts

R-F Service

	Plate Mod. Telephony		Class C Telegraphy			Frequency Doubler
D.C. Plate Voltage	1500	2500	1000	2000	3000	2000 volts
D.C. Grid Voltage	—350	—600	—200	—400	—600	—810 volts
D.C. Plate Current	100	100	125	125	125	100 ma.
D.C. Grid Current	25	25	25	25	25	15 ma.
Grid Driving Power (Ap.)	12.5	19	9	14	19	14 watts
Grid Bias Loss	9	15	5	10	15	12 watts
Power Input	150	250	125	250	375	200 watts
Power Output (Approx.)	105	185	90	197	300	132 watts
A.C. Load Resistance	8000	13,000	4000	8500	13,000	18,000 ohms
Mod D.C. Load	15,000	25,000	...	...	...	... ohms

ZB120

Amperex. Zero bias Triode. Especially designed for class B audio amplification. Can be used as linear r.f. power amplifier. Is capable of delivering up to 150 watts in class C r.f. service. Its high amplification factor makes it an efficient frequency doubler.

Characteristics:

Filament Voltage	10 volts
Filament Current	2 amps.
Amplification Factor	90
Maximum Plate Dissipation	74 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum A.F. Power Output (2 tubes)	300 watts
Transconductance at 100 Ma. Plate Current	5000 µmhos
Base	Standard 50-watt. Plate: Carbon

WE-242A

Western Electric Triode. R.F. Amplifier or oscillator. Audio amplifier in modulators.

Frequency Range: 100% up to 6 mc. 50% of plate voltage ratings at 30 mc.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	12.5
Grid to Plate Capacity	13.0 µµfd.
Grid to Filament Capacity	6.5 µµfd.
Plate to Filament Capacity	4.0 µµfd.
Maximum Plate Dissipation	85 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	150 ma.
Maximum D.C. Grid Current	50 ma.
Base	4 pin. 50 watt

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	1000	1250 volts
D.C. Grid Voltage	—55	—80 volts
Maximum Signal D.C. Plate Current	300	300 ma.
Zero Signal D.C. Plate Current	60	60 ma.
Load Resistance (plate to plate)	6000	8000 ohms.
Power Output	165	200 watts
Driver Power	25	25 watts

R-F Service

	Class B R-F	Class C Telephony	Class C Telegraphy
D.C. Plate Voltage	1250	1000	1250 volts (max.)
D.C. Grid Voltage	—90	—175	—200 volts
D.C. Plate Current	106	150	150 ma.
D.C. Grid Current	...	30	30 ma.
Grid Driving Power	...	10	11 watts
Grid Bias Loss	...	5	6 watts
Power Input	132.5	150	187.5 watts
Power Output	44	100	125 watts

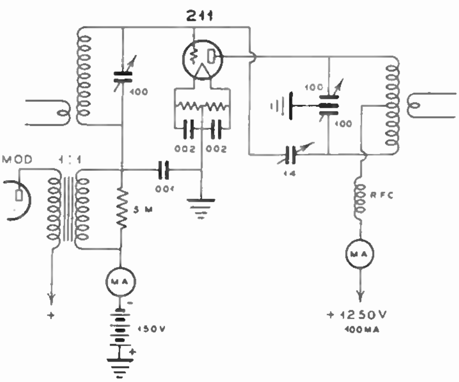
211

Class B modulator. Class B and C r.f. amplifier for telephony or telegraphy. Occasionally used as a frequency doubler.

Frequency Range: Full ratings up to 6 megacycles. 50% ratings at 30 mc.

Note (1): Grid driving requirements vary with load impedance, frequency of operation (due to losses), and type of circuit; thus the driver stage should be capable of supplying twice as much power output as listed for grid drive and bias loss.

Note (2): The W. E. 242A is similar in characteristics and operation to the 211. The 211D is similar to the 211 but it also has slightly lower inter-electrode capacities.



Grid-Modulated R. F. Amplifier

Characteristics:

Filament Voltage	10.0 volts
Filament Current	3.25 amps.
Amplification Factor	12
Grid-Plate Capacity	14.5 µµfd.
Grid-Filament Capacity	6 µµfd.
Plate-Filament Capacity	5.5 µµfd.
Maximum Plate Dissipation	100 watts
Base	4 pin, 50 watt

Class B Modulator (A-F):

D.C. Plate Voltage	1000	1250 volts
Zero Signal Plate Current (per tube)	10	10 ma.
Zero Grid Bias	—77	—100 volts
Maximum Signal Plate Current (per tube)	160	160 ma.
Load Resistance (plate to plate)	6900	9000 ohms.
Power Output (2 tubes)	200	260 watts

R-F Amplifier Service:

	Class B Telephony	Class C Telephony	Class C Telegraphy	Doubler
D.C. Plate Voltage	1250	1000	1250	1250 volts
D.C. Plate Current	106	150	165	145 ma.
D.C. Grid Bias	—100	—260	—215	—712 volt
D.C. Grid Current	Approx. zero	35	20	30 ma.
Grid Driving Power (Approx.)	...	14	7.3	26 watts
Grid Bias Loss	...	9	4.3	21 watts
Power Input	133	150	208	180 watts
Approx. Power Output	42.5	100	150	120 watts
Approx. A.C. Load Impedance	...	3300	3800	4870 ohms.
Modulator D.C. Load Resistance	...	6666	...	.... ohms.

WE-284D

Western Electric Triode for audio frequency applications.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Maximum Plate Voltage	1250 volts
Mutual Conductance	2500 mhos
D.C. Plate Current	175 ma.
Class-A Output, 2 Tubes	50 watts
Class-B Output, 2 Tubes	165 watts

203A

Class B audio service and as an RF Amplifier.

Frequency Range: 100% ratings up to 6 mc. 50% at 30 mc.

Note: The grid drive requirements vary with load impedance, circuit design, and high frequency circuit losses; thus the driver should be able to deliver twice as much power as listed for grid drive and bias loss.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	25
Maximum Plate Dissipation	100 watts
Grid-Plate Capacity	14.5 µµfd.
Grid-Filament Capacity	6.5 µµfd.
Plate-Filament Capacity	5.5 µµfd.
Base	4 pin, 50 watt

Class B Modulator or A-F Amplifier (2 Tubes):

D.C. Plate Voltage	1000	1250 volts
D.C. Grid Bias	—35	—45 volts
Zero Signal D.C. Plate Current (per tube)	13	13 ma.
Maximum Signal D.C. Plate Current (per tube)	160	160 ma.
Load Resistance (plate to plate)	6900	9000 ohms.
Power Output	200	260 watts

R-F Service

	Class B R-F	Class C Telephony	Class C Telegraphy	Frequency Doubler
D.C. Plate Voltage	1250	1000	1250	1000 volts
D.C. Plate Current	106	150	160	126 ma.
D.C. Grid Bias	—45	—135	—130	—495 volts
D.C. Grid Current	...	50	25	20 ma.
Grid Driving Power (Approx.)	...	7	7	13 watts
Grid Bias Loss	...	6.8	3.3	5 watts
Power Input	133	150	200	126 watts
Approx. Power Output	42.5	90	125	80 watts
Approx. A.C. Load Impedance	...	3300	3900	4200 ohms.
Modulator D.C. Load Resistance	...	6666	...	.... ohms.

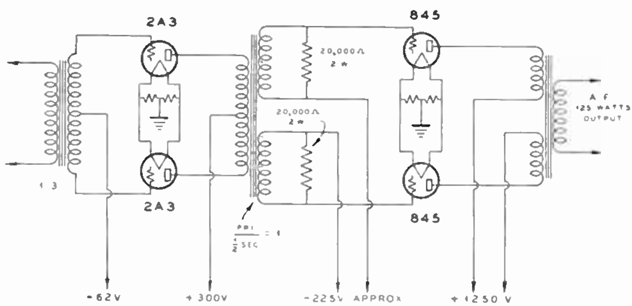
838

Most used as Class B modulator due to its zero bias characteristic.

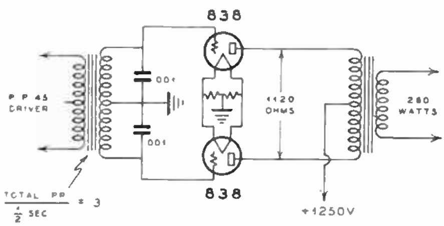
R.F. Frequency Range: 100% ratings up to 30 mc. 65% at 60 mc. 50% at 90 mc.

Note (1): Push-pull 2A3 tubes in Class A will serve as a driver for Class B 838 tubes. The Class B input transformer should have a turns ratio of $\frac{\text{Prim.}}{\frac{1}{2}\text{ sec.}} = 3.2$ if fixed bias is used on the 2A3s. A little greater ratio of stepdown is desirable if the 2A3 drivers are self biased.

Note (2): For R.F. the driver should have approx. twice as much output as listed in the table in order to compensate for variations of load impedance, circuit design and range of frequency of operation.



125-Watt Output Modulator with 845's in Push-Pull with Provision for Balancing Plate Current



CLASS B MODULATOR

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	varies with amplitude of signal
Maximum Plate Dissipation	100 watts
Grid-Plate Capacity	8 μμfd.
Grid-Filament Capacity	6.5 μμfd.
Plate-Filament Capacity	5 μμfd.
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	175 ma.
Maximum D.C. Grid Current	70 ma.
Base	4 pin, 50 watt

Class B Modulator:

D.C. Plate Voltage	1000	1250 volts
D.C. Grid Voltage	0	0 volts
Approx. Peak A-F Grid Input Voltage	90	90 volts
Zero Signal D.C. Plate Current (per tube)	53	74 ma.
Maximum Signal D.C. Plate Current (per tube)	160	160 ma.
Load Resistance (plate to plate)	7600	11200 ohms.
Maximum Power Output (2 tubes)	200	260 watts
Peak Driving Power (Approx.)	5	5 watts

R·F Service

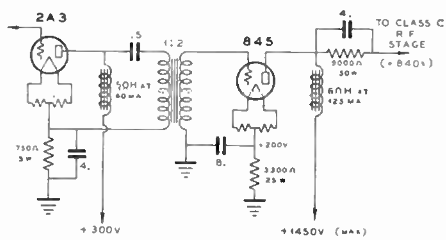
	Class B R·F	Class C Tel-ephony	Class C Teleg-raphy	Frequency Doubler
D.C. Plate Voltage	1250	1000	1250	1000 volts
D.C. Plate Current	106	150	155	157 ma.
D.C. Grid Bias	0	—135	—90	—465 volts
D.C. Grid Current	60*	60	30	20 ma.
Grid Driving power (Approx.)	10*	17.5	6	12.3 watts
Grid Bias Loss	...	8	2.7	9.3 watts
Power Input	133	150	195	157 watts
Approx. Power Output	42.5	100	140	100 watts
Approx. A.C. Load Impedance	...	3300	4070	5360 ohms.
Modulator D.C. Load Resistance	...	6666	...	... ohms.

*(At Peak).

●

845

Triode. Class A or AB audio amplifier in public address systems or as modulator in radio transmitters. Seldom used in R.F. amplifiers.



Single 845 Modulator for 50-Watt Radiophone

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor (average)	5
Grid to Plate Capacity	13.5 μμfd.
Grid to Filament Capacity	6.0 μμfd.
Plate to Filament Capacity	6.5 μμfd.
Maximum Plate Loss	100 watts
Maximum Plate Voltage	1250 volts
Maximum Plate Current	175 ma.
Base	4 pin, 50 watt

Class A Audio Amplifier (1 Tube):

D.C. Plate Voltage	750	1000	1250 volts
D.C. Grid Voltage	—98	—155	—209 volts
D.C. Plate Current	95	65	52 ma.
Peak Grid A-F Voltage	93	150	204 volts
Load Resistance	3400	9000	16000 ohms
Power Output	15	21	24 watts

Class AB Audio Amplifier (2 Tubes):

D.C. Plate Voltage	1250 volts
D.C. Grid Voltage	—225 volts
Zero Signal D.C. Plate Current	45 ma.
Power Output	125 watts
Load Impedance, Plate-to-Plate	12,000 ohms.

●

852

Triode. RCA, Amperex, United. U.H.F. Oscillator. H.F. Amplifier or Class B modulator.

Frequency Range: 100% ratings up to 30 mc. 80% at 60 mc. 50% at 120 mc. and 40% at 150 mc. (2 meters).

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	12
Grid to Plate Capacity	2.6 μμfd.
Grid to Filament Capacity	1.9 μμfd.
Plate to Filament Capacity	1.0 μμfd.
Maximum plate Dissipation	100 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D.C. Plate Current	150 ma.
Maximum D.C Grid Current	40 ma.
Base	Small 4 pin. UX

Grid at top, plate through side of envelope.

Class B Modulator or R-F Amplifier:

D.C. Plate Voltage	2000	3000 volts
D.C. Grid Voltage	—155	—250 volts
Zero Signal Plate Current (per tube)	11	7 ma.
Maximum Signal Plate Current (per tube)	90	80 ma.
Load Resistance (plate to plate)	22000	36000 ohms.
Power Output	220	360 watts

R-F Service

	Class B Telephony	Plate Modulation Telephony	Class C Telegraphy	
D.C. Plate Voltage	3000	2000*	3000	3500 volts
D.C. Grid Voltage	—250	—500	—600	—950 volts
D.C. Plate Current	43	67	85	100 ma.
D.C. Grid Current	...	30	25	35 ma.
Grid Driving Power (Approx.)	...	23	20	44 watts
Grid Bias Loss	...	15	15	33 watts
Power Output (Approx.)	40	75	180	270 watts
Power Input	129	134	255	350 watts
Approx. A.C. Load Impedance	...	15000	17000	15000 ohms.
Modulator D.C. Load Resistance	...	30000	...	... ohms.

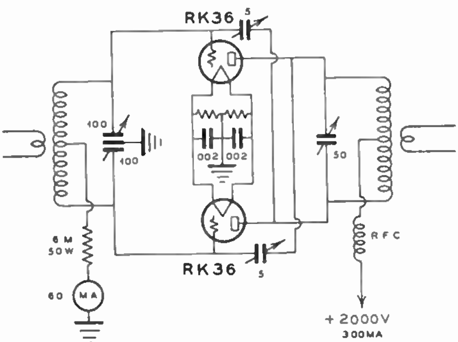
*(Max.)

RK-36

Raytheon R.F. amplifier or oscillator for H.F. and U.H.F. applications.

Frequency Range: 100% ratings up to 56 mc.

Note: Grid drive may vary widely under different operating conditions.



Grid-Neutralized P. P. Amplifier

Characteristics:

Filament Voltage	5.0 volts
Filament Current	8.0 amps.
Amplification Factor	11
Grid to Plate Capacity	5 μμfd.
Grid to Filament Capacity	4.5 μμfd.
Plate to Filament Capacity	1.0 μμfd.
Maximum Plate Dissipation	100 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	165 ma.
Maximum D.C. Grid Current	35 ma.

4 prong med. base. Plate out top and grid out side of envelope. Tantalum plate.

R-F Service

	Class B	Grid Mod.	Class C
D.C. Plate Voltage	2000	2000	2000 volts
D.C. Grid Voltage	—180	—270	—360 volts
D.C. Plate Current	75	72	150 ma.
D.C. Grid Current	...	...	30 ma.
Grid Driving Power (Approx.)	10*	3.5*	15 watts
Grid Bias Loss	...	...	5.4 watts
Power Output (Approx.)	50	42	200 watts

*(Peak).

RK-38

Raytheon High-Mu Triode. Tantalum Plate. Designed for Class B Audio Amplifier, RF Amplifier or Oscillator Service. 100% ratings up to 56 MC.

Characteristics:

Filament Voltage	5.0 volts
Filament Current	8 amps.
Grid to Plate Capacity	4.5 μμfd.
Grid to Filament Capacity	3.9 μμfd.
Plate to Filament Capacity	1.0 μμfd.
Maximum Plate Dissipation	100 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	165 ma.
Maximum D.C. Grid Current	40 ma.

Standard 4 pin-UX base. Plate through top, grid through side of envelope.

RF Service

	Class B RF	Grid Mod. Telephony	Class C
D.C. Plate Voltage	2000	2000	2000 volts
D.C. Grid Voltage	—100	—150	—200 volts
D.C. Plate Current	75	80	150 ma.
D.C. Grid Current	....	....	30 ma.
Peak RF Grid Power	7	4	11.5 watts
Peak Audio Voltage	....	100	... volts
Carrier Power Output	55	60	225 watts

100TL

Eimac UHF Triode with medium amplification constant. Designed primarily for diathermy service and as replacement for original Eimac 50T.

Characteristics:

Filament Voltage	5 to 5.1 volts
Filament Current	6.5 amps.
Grid-to-Plate Capacity	2.3 μμfd.
Grid-to-Filament Capacity	2.0 μμfd.
Plate-to-Filament Capacity	0.4 μμfd.
Normal Plate Dissipation	100 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	225 ma.
Maximum D.C. Grid Current	35 ma.
Amplification Factor	12
Base	Standard UX 4-pin

Plate through top, grid through side of envelope.

Class C R.F. Amplifier:

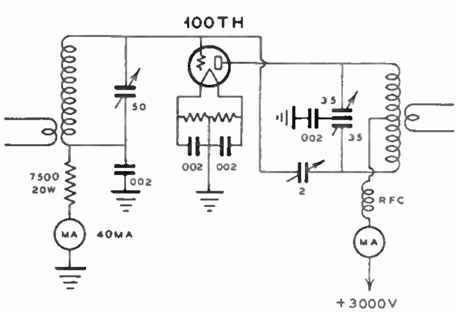
D.C. Plate Voltage	1000	2000	3000 volts
D.C. Plate Current	200	150	135 ma.
D.C. Grid Current	30	30	30 ma.
D.C. Grid Bias	—200	—400	—600 volts
Approximate Power Output	120	225	300 watts
Approx. Grid Driving Power	7.5	13.5	21 watts
Grid Bias Loss	6	12	18 watts

Class B Audio Amplifier:

D.C. Plate Voltage	1000	2000	3000 volts
Load Impedance, Plate-to-Plate	5200	16,000	30,000 ohms
Power Output, 2 Tubes	170	350	465 watts

100TH

Eimac. High-mu U.H.F. Triode. Especially suitable for class C r.f. amplification and class B audio service.



R. F. Amplifier

Characteristics:

Filament Voltage	5 to 5.1 volts
Filament Current	6.5 amps.
Amplification Factor	30
Grid-to-Plate Capacity	2 μμfd.
Grid-to-Filament Capacity	2.2 μμfd.

Plate-to-Filament Capacity	0.3 μμfd.
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	225 ma.
Maximum D.C. Grid Current	50 ma.
Normal Plate Dissipation	100 watts
Base	Standard UX 4-pin, Isolantite

Plate through top, grid through side of envelope.

Class C R.F. Amplifier:

D.C. Plate Voltage	1000	2000	3000 volts
D.C. Plate Current	200	150	135 ma.
D.C. Grid current	45	45	45 ma.
D.C. grid bias	—70	—140	—210 volts
Approximate grid driving power	4.5	8	10 watts
Grid bias loss	3.2	6.3	9.5 watts
Approximate power output	120	225	300 watts

Class B Audio Amplifier:

D.C. plate voltage	1000	2000	3000 volts
Load impedance, plate-to plate	5200	16000	30000 ohms
Power output, 2 tubes	210	380	500 watts

●

211C

The 211C tubes of various manufacturers (Amperex, Taylor, United) are similar to 211 tubes in operation, except for lower grid to plate capacitance. They are somewhat more effective at the higher frequencies down towards the U.H.F. region. *See 211 tube data.*

Note: The W.E. 261A and WE 276A are somewhat similar to the 211C in characteristics and operation.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Maximum Plate Dissipation	100 to 120 watts
Maximum D.C. Plate Voltage	1350 volts
Maximum D.C. Plate Current	180 ma.
Maximum D.C. Grid Current	50 ma.
Grid to Plate Capacity	7 to 9 μμfd.
Grid to Filament Capacity	5.5 μμfd.
Plate to Filament Capacity	5 μμfd.
Base	standard 4 pin 50 watt

●

850

RCA screen-grid r.f. amplifier of the 100 watt type.

Frequency Range: 100% ratings up to 13 mc. 50% at 30 mc.

Note: Grid drive varies widely under various load impedances.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	550
Grid to Plate Capacity	0.25 μμfd.
Input Capacity	17 μμfd.
Output Capacity	25 μμfd.
Maximum Plate Dissipation	100 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	175 ma.
Maximum D.C. Grid Current	40 ma.
Maximum Screen Dissipation	10 watts

R-F Service

	Class B Telephony	Class C Telegraphy		
D.C. Plate Voltage	1250	750	1000	1250 volts
D.C. Screen Voltage	175	175	175	175 volts
D.C. Grid Voltage	—13	—150	—150	—150 volts
D.C. Plate Current	110	160	160	160 ma.
D.C. Grid Current	...	35	35	35 ma.
Grid Driving Power (Approx.)	...	10	10	10 watts
Grid Bias Loss	...	5	5	5 watts
Plate Power Input	137.5	120	160	200 watts
Power Output	40	55	100	130 watts
Screen Series Resistor	...	15000	25000	40000 ohms.

●

860

Screen-Grid Tetrode. (RCA). R.F. Amplifier for high frequencies.

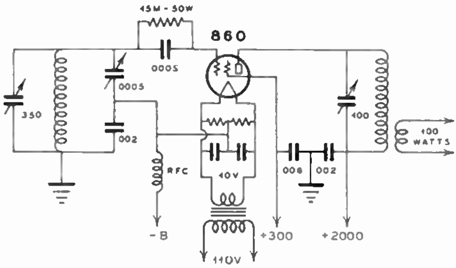
Frequency Range: 100% ratings up to 30 mc. 80% at 40 mc.

Note (1): When plate modulated, the screen should be modulated simultaneously.

A small r.f. by-pass condenser from screen to filament, and a series 100,000 ohm resistor to the r.f. plate return, will allow simultaneous screen and plate modulation.

Note (2): The grid excitation will vary with load impedance and circuit losses, thus the driver should have an available output of approximately twice that listed for grid drive and bias loss.

Caution: Do not turn off filament without first removing plate voltage. Do not apply screen voltage without plate voltage.



ELECTRON COUPLED COLPITTS OSCILLATOR

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	200
Grid-Plate Capacity	.08 μμfd.
Input Capacity	7.75 μμfd.
Output Capacity	7.5 μμfd.
Maximum Plate Dissipation	100 watts
Maximum Screen Dissipation	10 watt
Base	4 pin

R-F Service

	Class B Telephony	Plate Mod. Class C Telephony	Class C Telegraphy	
D.C. Plate Voltage	3000	2000*	2000	3000 volts
D.C. Screen Voltage	300	300	300	300 volts
D.C. Grid Voltage	—50	—225	—150	—150 volts
D.C. Plate Current	43	67	90	85 ma.
D.C. Grid Current	...	30	15	15 ma.
Grid Driving Power	...	15	7	7 watts
Grid Bias Loss	...	6.7	2.25	2.25 watts
Power Output (Ap.)	40	75	100	165 watts

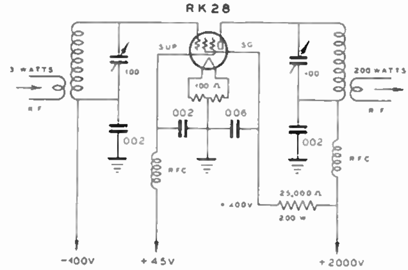
*Maximum.

●

RK-28

Raytheon screen-grid tube for Suppressor Modulated telephony. Buffer or final amplifier in radio transmitters. Since it is a screen grid tube, no neutralization is needed. May be used as a crystal oscillator or doubler at reduced inputs and outputs of approx. 60%.

Precaution: Input and output circuits should be shielded and all circuits carefully by-passed for r.f. Screen voltage should only be applied when plate voltage is connected.



RK-28 C-W Radio-Frequency Amplifier

Frequency Range: 100% ratings up to 20 mc. The RK-28 has a lower output capacitance than the 803, so can be operated more effectively at higher frequencies, such as 14 and 30 mc.

Note: Combined plate and screen modulation may be applied for a carrier output of 100 watts with a maximum plate supply of 1500 volts. With 400 volts DC on screen, 300 volts peak AF on it, and 1500 peak volts on the plate will provide 100% modulation.

Characteristics:
Filament Voltage ....10 volts
Filament Current ....5 amps.
Grid to Plate Capacity............0.02 μμfd.
Input Capacity ....15.5 μμfd.
Output Capacity ....5.5 μμfd.
Maximum Plate Dissipation ....100 watts
Maximum Screen Dissipation ....35 watts
Base ....5 pin, 50 watt. Plate at top of envelope

R-F Service

	Class B Telephony	Suppressor Modulation Telephony	Class C Telegraphy	
D.C. Plate Voltage ..	2000	2000	2000	2000 volts
D.C. Screen Voltage..	400	400	400	400 volts
D.C. Suppressor Voltage	0	—50	0	45 volts
D.C. Grid Bias Voltage	—38	—100	—100	—100 volts
Peak R-F Grid Voltage	90	180	180	180 volts
Peak A-F Grid Voltage	...	90	...	... volts
D.C. Plate Current....	75	80	120	140 ma.
D.C. Screen Current..	30	85	75	60 ma.
D.C. Grid Current	...	11	10	10 ma.
Grid Driving Power..	.9	2.7	1.8	1.8 watts
Grid Bias Loss........	...	1.1	1.0	1.0 watts
Power Output (Approx.)	50	60	160	200 watts
Screen Resistor	55000	20000	21000	26000 ohms.

●

RK-48

Raytheon beam-power tetrode, designed for r.f. amplifier service. Requires very low grid excitation. Somewhat similar to RK-28, but without suppressor grid. Easier to drive than RK-28 for slightly higher power output.

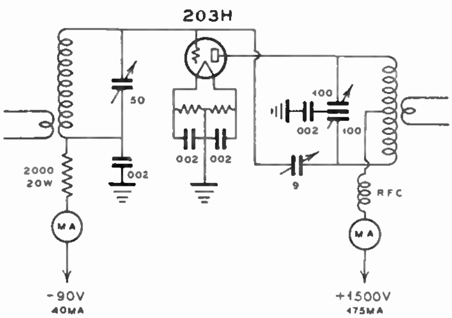
Characteristics:
Filament Voltage ....10 volts
Filament Current ....5 amps.
Maximum D.C. Plate Voltage ....2000 volts
Maximum D.C. Screen Voltage ....400 volts
Maximum Plate Dissipation ....100 watts
Maximum Screen Dissipation ....35 watts
Maximum D.C. Grid Current ....25 ma.
Average Required D.C. Grid Current............
............10 ma. for normal output
Base............5-prong 50-watt
Plate through top of envelope.

●

203H

Amperex R.F. Amplifier or Oscillator, especially at high frequencies.

Note (1): The grid r.f. excitation requirements vary with efficiency, plate load and circuit design; thus the driver must be designed to allow for these factors



Neutralized R. F. Amplifier

Note (2): The plate lead is through the top of the tube; thus it will stand higher plate voltages and operate more efficiently at high frequencies than a regular type 203-A.

Characteristics:
Filament Voltage ....10 volts
Filament Current ....3.25 amps.
Grid to Plate Capacity............9 μμfd.
Grid to Filament Capacity ....6 μμfd.
Plate to Filament Capacity............1.8 μμfd.
Maximum Plate Dissipation............120 watts
Maximum Plate Voltage............1500 volts
Maximum Plate Current............180 ma.
Maximum Grid Current............50 ma.
Amplification Factor 25
Base ....standard 50 watt

Class C Amplifier

	At 60 mc.	Less Than 20 mc.
D.C. Plate Voltage..................	1200	1500 volts
D.C. Grid Voltage..................	—150	—180 volts
D.C. Plate Current..................	175	175 ma.
D.C. Grid Current..................	40	40 ma.
Grid Driving Power..................	14	17 watts
Grid Bias Loss..................	6	7.3 watts
Power Input	210	263 watts
Power Output (Approx.)............	100	180 watts

●

211H

Amperex R.F. amplifier for radio transmitters.

Note (1): The grid input and plate output powers will vary greatly with different values of load impedance and frequency. The values listed are typical operating conditions.

Note (2): At high frequencies, circuit and dielectric losses increase and thus the grid driver should have available approximately twice as much output as shown in the table below for grid drive and bias supply power loss.

Note (3): This tube has the plate lead out through the top of the envelope and thus it will operate more efficiently at higher frequencies than a standard type 211 tube.

Characteristics:
Filament Voltage ....10 volts
Filament Current ....3.25 amps.
Grid to Plate Capacity ....8.0 μμfd.
Grid to Filament Capacity ....5.5 μμfd.
Plate to Filament Capacity............2.0 μμfd.
Amplification factor 12
Mutual Conductance at 100 ma. I_b............4000 micromhos
Maximum Allowable Plate Dissipation............120 watts
Base ....standard 4 pin 50 watt

Class C Amplifier

	Single Tube at 60 mc.	Less Than 20 mc.	Telegraphy
D.C. Plate Voltage.........	1200*	1500*	2000 volts
D.C. Plate Current........	175	175	180 ma.
D.C. Grid Bias............	—200	—300	—300
D.C. Grid Current........	30	30	50 ma.
Grid Driving Power (Ap.).	11	14	20 watts
Grid Bias Supply Loss....	6	9	15 watts
Power Output (Approx.)...	100	190	250 watts
Power Input	216	263	360 watts
Plate Loss	116	73	110 watts
Approx. A.C. Load Imped.	3500	4300	5500 ohms
Modulator D.C. Load......	6850	8500	11,100 ohms

*Maximum

●

T-125

Taylor carbon-tantalum plate high-frequency triode, suitable as replacement tube for type 203-A.

Characteristics:
Filament Voltage ....10 volts
Filament Current ....3.85 amps.
Mutual Conductance ....4400 mhos
Amplification Factor 25
Maximum Plate Dissipation ....125 watts
Maximum D.C. Plate Voltage ....2000 volts
Maximum D.C. Grid Current ....60 ma.
Maximum D.C. Plate Current ....200 ma.
Grid-to-Plate Capacity ....4.5 μμfd.
Base............Standard 4-pin 50-watt
Plate through top of envelope; grid through side.

Class-C R.F. Amplifier:

D.C. Plate Voltage	2000 volts
D.C. Plate Current	200 ma.
D.C. Grid Bias	—200 volts
D.C. Grid Current	50 ma.
Grid Driving Power (Approx.)	15 watts
Grid Bias Loss	10 watts
Approx. Power Output	300 watts

805

RCA High-mu type tube for Class B audio service. May also be used for r.f. service.

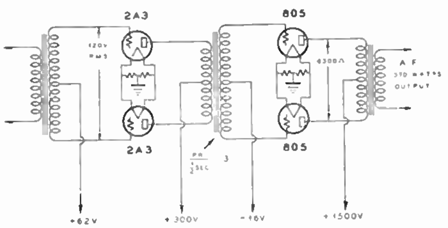
Note (1): Plate lead out top of tube reduces flash-over danger.

Frequency Range: 100% ratings up to 30 mc. 75% at 45 mc. and 50% at 85 mc.

Note (2): The Class B input transformer between push-pull 2A3s (fixed bias) and Class B 805 tubes should have a turns-ratio of

$$\frac{\text{primary}}{\tfrac{1}{2}\ \text{Sec.}} = 3.0$$

Note (3): The grid excitation and bias may vary widely for Class C operation. It is desirable that the driver be capable of supplying approximately twice as much output as listed for grid drive and bias loss.



805 High Power Class B Modulator and Driver

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor Varies with Input Signal.	
Grid to Plate Capacity	6.5 μμfd.
Grid to Filament Capacity	8.5 μμfd.
Plate to Filament Capacity	10.5 μμfd.
Maximum Plate Dissipation	125 watts
Maximum D.C. Plate Voltage	1500 volts
Maximum D.C. Plate Current	210 ma.
Maximum D.C. Grid Current	70 ma.
Base	standard 4 pin 50 watt

Plate at top of envelope.

Class B Modulator or A-F Amplifier:

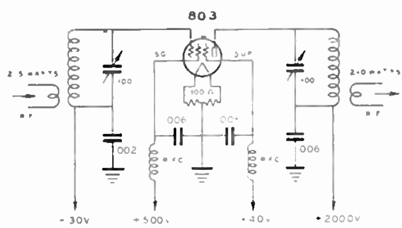
D.C. Plate Voltage	1250	1500 volts
D.C. Grid Bias	0	—16 volt
Peak A-F Grid to Grid Voltage	235	280 volts
Zero Signal D.C. Plate Current (per tube)	74	42 ma.
Max. Sig. D.C. Plate Current (per tube)	200	200 ma.
Load Resistance (Plate to Plate)	6700	8200 ohms
Maximum Signal Driving Power	6	7 watts
Maximum Signal Power Output	300	370 watts

R-F Service

	Class B Telephony	Plate Mod. Telephony	Class C Telegraphy	Frequency Doubler
D.C. Plate Voltage	1250	1250	1500	1250 volts
D.C. Grid Voltage	0	—160	—100	—400 volts
Peak R-F Grid Voltage	75	300	230	625 volts
D.C. Plate Current	135	160	200	135 ma.
D.C. Grid Current	15	60	40	25 ma.
Grid Driving Power (Approx.)	11	16	9.2	12.5 watts
Grid Bias Loss	...	9.6	4	10 watts
Power Input	169	200	300	169 watts
Approx. Power Output	55	140	215	85 watts
Ap. A-C Load Imped.	...	3900	3600	3800 ohms
Mod. D.C. Load Resist.	...	7800	...	...

803

RCA. Suppressor Modulated telephony. Buffer or final amplifier in radio transmitters. Since it is a screen grid tube, no neutralization is needed. May be used



Medium Power 803 Final Amplifier

as a crystal oscillator or doubler at approximately 60% output.

Frequency Range: 100% ratings up to 20 mc. High interelectrode capacities also tend to reduce output circuit efficiencies at higher frequencies such as 30 mc.

Precaution: Input and output circuits should be shielded and all circuits carefully by-passed for R.F. Screen voltage should not be applied unless plate voltage is connected.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Mutual Conductance at I_b=55	4000 micromhos
Grid to Plate Capacity	0.15 μμfd.
Input Capacity	15.5 μμfd.
Output Capacity	28.5 μμfd.
Maximum Plate Dissipation	125 watts
Maximum Screen Dissipation	30 watts
Base	5 pin 50 watt

Plate lead at top of envelope.

Operating Data Below

R-F Service

	Class B Telephony	Suppressor Mod. Telephony		Class C Telegraphy	
D.C. Plate Voltage	2000	1500	2000	1250	2000 volts
D.C. Screen Voltage	600	500	500	500	500 volts
D.C. Suppressor Voltage	40	—110	—135	40	40 volts
D.C. Grid Bias Voltage	—40	—50	—50	—30	—30 volts
Peak R-F Grid Voltage	55	120	120	150	150 volts
Peak A-F Grid Voltage	...	150	175	...	...
D.C. Plate Current	80	80	80	160	160 ma.
D.C. Screen Current	15	55	55	45	42 ma.
D.C. Grid Current	3	15	15	18	16 ma.
Grid Driving Power (Approx.)	1.5	1.6	1.6	1.8	1.6 watts
Grid Bias Loss	.1	.75	.75	.5	.5 watts
Power Output (Approx.)	53	40	53	130	210 watts
Screen Resistor	100.000	18,000	27,000	17.000	36.000 ohms

HD-203C
HD-211C

Taylor U.H.F. and H.F. oscillator for diathermy machines.

Characteristics:

Filament Voltage	10 volts
Filament Current	4 amps.
Amplification Factor	20 and 12
Grid to Plate Capacity	9 μμfd.
Plate to Filament Capacity	4 μμfd.
Maximum Plate Dissipation	150 watts
Maximum D.C. Plate Voltage	2000 volts
Maximum D.C. Plate Current	250 ma.
Maximum D.C. Grid Current	60 ma.
Base	Standard 4 pin 50 watt

Plate at top of envelope.

HD-203A

Taylor heavy duty 203A tube, intermediate between 204A and 203A. Class B audio amplifier or modulator. Class C r.f. amplifier.

Note: Grid driving power requirements vary over wide limits.

A. F. Driver. 2A3s in push-pull with fixed grid bias input transformer ratio of $\frac{\text{primary}}{\frac{1}{2}\text{ sec.}} = 1.6$.

Characteristics:

Filament Voltage	10 volts
Filament Current	4 amps.
Amplification Factor	25
Grid to Plate Capacity	12 μμfd.
Grid to Filament Capacity	7 μμfd.
Plate to Filament Capacity	5 μμfd.
Maximum Plate Dissipation	150 watts
Maximum D.C. Plate Voltage	2000 volts
Maximum D.C. Plate Current	250 ma.
Maximum D.C. Grid Current	60
Base	standard 4 pin 50 watt

Plate out top of envelope

Class B Audio Amplifier (2 tubes):

D.C. Plate Voltage	1500	1750 volts
D.C. Grid Voltage	—45	—67.5 volts
Load Resistance (Plate to Plate)	8000	9000 ohms
Static Plate Current (Per Tube)	18	18 ma.
Maximum D.C. Plate Current (2 Tubes)	425	425 ma.
Power Output	400	500 watts
Driver Power	18	18 watts

Class C R-F Amplifier:

D.C. Plate Voltage	1500	1750 volts
D.C. Grid Voltage	—150	—180 volts
D.C. Plate Current	250	250 ma.
D.C. Grid Current	50	50 ma.
Grid Driving Power	15	19 watts
Grid Bias Loss	7.5	9 watts
Power Input	375	433 watts
Power Output	250	300 watts

HF-200

Amperex general purpose high frequency triode. Suitable for U.H.F. oscillators.

Note: Grid excitation requirements vary greatly due to plate load, efficiency required, and circuit design.

Frequency Range: 100% ratings up to 45 mc.

Characteristics:

Filament Voltage	10 to 11 volts
Filament Current	3.4 amps
Amplification Factor	18
Grid to Plate Capacity	5.8 μμfd.
Grid to Filament Capacity	5.2 μμfd.
Plate to Filament Capacity	1.2 μμfd.
Maximum Plate Dissipation	150 watts
Maximum D.C. Plate Voltage	2000 volts
Maximum D.C. Plate Current	200 ma.
Maximum D.C. Grid Current	60 ma.
Base	standard 4 pin. 50 watt

Plate at top, grid at side of envelope.

Class C R-F Amplifier:

D.C. Plate Voltage	1500	2000 volt
D.C. Grid Voltage	—210	—300 volts
D.C. Plate Current	200	200 ma.
D.C. Grid Current	35	35 ma.
Grid Driving Power	13	19 watts
Grid Bias Loss	7.5	10 watts
Power Input	300	400 watts
Power Output	180	260 watts

806

RCA U.H.F. power triode for general use in either r.f. or audio service. Frequency range: 100% of rating up to 56 Mc.

Characteristics:

Filament voltage	5.0 volts
Filament current	10.0 amps.
Amplification factor	12.6
Grid-to-plate capacity	3.4 μμfd.
Grid-to-filament capacity	6.1 μμfd.
Plate-to-filament capacity	1.1 μμfd.
Maximum d.c. plate voltage	3000 volts
Maximum d.c. plate current	200 m.a.
Maximum d.c. grid current	50 m.a.
Normal plate dissipation	150 watts

Base: Standard 50-watt; grid through side, plate through top of envelope.

Class B Audio Amplifier (two tubes):

D.C. plate voltage	2000	3000 volts
D.C. grid voltage	—150	—210 volts
Zero signal plate current	20	20 m.a.
Max. signal plate current	390	330 m.a.
Load res. (plate to plate)	11500	21500 ohms
Max. signal driving power	14	10 watts
Power output	500	660 watts

Class C R.F. Amplifier:

Maximum d.c. plate voltage	3000 volts
Maximum d.c. plate current	200 m.a.
Maximum d.c. grid voltage	1000 volts
Maximum plate input	600 watts

HK-354

Heintz & Kaufman Triode. Tantalum plate and grid. Class B modulator. Class C r.f. amplifier. Maximum DC plate voltage for plate modulation is 3000-volts.

Note (1): The values of grid drive may be lowered for plate voltages less than 3500 without much sacrifice in plate efficiency. A 50% decrease of grid drive from the above values will drop the efficiency 10% to 15% which will not cause excessive plate dissipation if the load is reduced slightly with correspondingly less output and less plate current.

Note (2): May be used as a linear (Class B) r.f. amplifier as above and also with grid modulation under similar operating conditions, but with higher grid bias.

Note (3): With forced ventilation, the plate dissipation may be increased to as high as 250 watts.

Frequency Range: 100% ratings up to 15 mc. Reduced ratings at U.H.F. (above 30 mc).

Characteristics:

Filament Voltage	5.0 volts
Filament Current	10 amps
Amp. Factor (avg.)	14
Normal Plate Dissipation	150 watts
Grid to Plate Capacity	4 μμfd.
Grid to Filament Capacity	9 μμfd.
Plate to Filament Capacity	0.2 μμfd.
Maximum D.C. Plate Voltage	3500 volts
Maximum D.C. Plate Current	300 ma.
Maximum D.C. Grid Current	50 ma.

Plate Thru Top of Envelope Base..Standard 4-Pin 50 watt

Class B Modulator or A-F Amplifier (2 Tubes):

D.C. Plate Voltage	1000	2000	2500	3000 volts
D.C. Grid Voltage	—60	—150	—180	—225 volts
Zero Sig. D.C. Plate Current (2 Tubes)	20	20	20	20 ma.
Maximum Sig. D.C. Plate Current (2 Tubes)	160	320	345	330 ma.
Load Resistance (Plate to Plate)	15,000	15,000	18,000	25,000 ohms
Peak Driving Power	5.6	21	26	30 watts
Power Output	100	400	560	650 watts
Plate Loss	60	232	300	300 watts

Class C r.f. Amplifier:

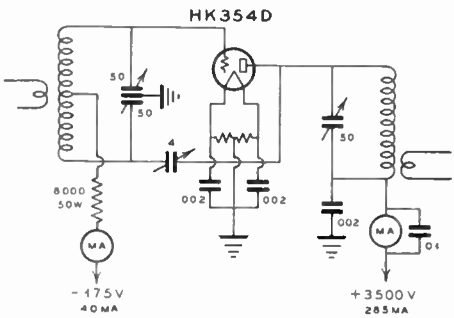
D.C. Plate Voltage	1500	2000	3000	3500	4000 volts
D.C. Grid Voltage	—428	—602	—960	—1180	—1300 volts
D.C. Plate Current	285	285	285	285	277 ma.
D.C. Grid Current	50	45	37	36	40 ma.
Grid Driving Power	30	35	45	53	65 watts
Grid Bias Loss	21	27	35	47	52 watts
Power Input	430	572	850	1000	1100 watts
Approximate Power Output	320	450	700	850	950 watts
Approximate A.C. Load Resistance	2340	3060	4690	5630	6750 ohms

Class B R-F Amplifier, Telephony:

D.C. Plate Voltages	1500	2000	2500	3000 volts
D.C. Grid Voltages	-105	—155	—188	—233 volts
D.C. Plate Current	65	84	88	82 ma.
Grid Driving Power	6	11	13	15 watts
Plate Loss	70	116	150	150 watts
Carrier Power Output	27.5	50	70	81 watts

HK-354C

Heintz & Kaufman Triode. Ultra-high-frequency amplifier, tantalum plate and grid. Suitable for use as class B modulator and class C amplifier. All characteristics are the same as those for HK-354, except for lower grid-to-filament capacity. The grid comes out through the side of the glass envelope, rather than though the base of the tube as in the HK-354, which makes the tube more suitable for high-frequency operation. Refer to HK-354 for characteristics and operating data.



HK-354D

Heintz & Kaufman Triode. Ultra-high-frequency amplifier, doubler and class B audio amplifier. Similar to HK-354C except for amplification constant.

Characteristics:

Filament voltage	5.0 volts
Filament current	10.0 amps.
Amplification constant	22
Normal plate dissipation	150 watts
Maximum d.c. plate voltage	4000 volts
Maximum d.c. plate current	300 m.a.
Maximum d.c. grid current	50 m.a.

Base: Standard 50 watt. Plate through top, grid through side of envelope.

Class C R.F. Amplifier:

D.C. plate voltage	1500	2000	2500	3000	3500 volts
D.C. grid voltage	236	—242	—317	—124	—490 volts
D.C. plate current	300	297	274	255	240 m.a.
D.C. grid current	50	50	50	50	50 m.a.
Grid driving power	24	26	30	35	38 watts
Grid-bias loss	12	12	16	21	25 watts
Approximate power output	316	415	535	614	690 watts

R.F. Doubler:

D.C. plate voltage	1000	1500	2000 volts
D.C. grid voltage	—361	—458	—619 volts
D.C. plate current	250	200	175 m.a.
D.C. grid current	58	50	50 m.a.
Grid driving power	32	36	44 watts
Grid-bias loss	16	22	32 watts
Approximate power output	100	150	200 watts

Class B Audio Amplifier (Two Tubes):

D.C. plate voltage	1500	2000	2500	3000 volts
D.C. grid voltage	—60	—87	—112	—135 volts
Zero signal d.c. plate current	50	50	50	50 m.a.
Maximum signal d.c. plate current	277	362	290	327 m.a.
Plate-to-plate load resistance	12000	20000	20000	21000 ohms
Power output	302	469	519	692 watts

Suggested Driver: Four type 2A5 or 42 tubes triode connected, with fixed bias and 350 volts plate supply.

HK-354E

Heintz & Kaufman triode for U.H.F. service. Tantalum plate and grid. Similar to HK-354 in physical size, but with grid out of side of envelope. Principal difference lies in amplification constant. Suitable for class C r.f. amplifiers, class B audio and r.f. frequency doubling.

Characteristics:

Filament voltage	5 volts
Filament current	10 amps.
Amplification constant	35
Maximum d.c. plate voltage	4000 volts
Maximum d.c. plate current	300 m.a.
Normal plate dissipation	150 watts

Base: Standard 50 watt. Plate through top, grid through side of envelope.

Class C R.F. Amplifier:

D.C. plate voltage	1500	2000	2500	3000	3500 volts
D.C. plate current	300	297	275	255	240 m.a.
D.C. grid bias	—287	—295	—392	—437	—448 volts
D.C. grid current	60	60	60	60	60 m.a.
Grid driving power	35	36	42	45	45 watts
Grid-bias loss	17	18	24	26	27 watts
Power output, approximate	315	445	525	615	690 watts

R.F. Doubler:

D.C. plate voltage	1000	1500	2000 volts
D.D. plate current	250	200	175 m.a.
D.C. grid bias	—238	—379	—471 volts
D.D. grid current	60	60	60 m.a.
Grid driving power	31	38	41 watts
Grid-bias loss	14	23	29 watts
Power output, approximate	100	150	200 watts

Class B. Audio Amplifier (Two Tubes):

D.C. plate voltage	1500	2000	2500	3000 volts
D.C. grid bias	—25	—37.5	—50	—67 volts
No signal d.m. plate current	50	50	50	50 m.a.
Maximum signal d.c. plate current	325	372	343	335 m.a.
Load resistance, plate-to-plate	10000	11000	16000	20000 ohms
Power output	320	470	600	700 watts

HK-354F

Heintz & Kaufman triode. Ultra-high-frequency. Class C r.f. frequency doubling and class B audio amplification. Similar to HK-354 in size.

Characteristics:

Filament voltage	5.0 volts
Filament current	10.0 amps.
Amplification factor	50
Normal plate dissipation	150 watts
Maximum d.c. plate voltage	4000 volts
Maximum d.c. plate current	300 m.a.
Maximum d.c. grid current	75 m.a.

Base: Standard 50 watt. Plate through top, grid through side of envelope.

Class C R.F. Amplifier:

D.C. plate voltage	1500	2000	2500	3000	3500 volts
D.C. grid voltage	—85	—135	—225	—312	—368 volts
D.C. plate current	300	295	260	255	250 m.a.
D.C. grid current	75	75	75	75	75 m.a.
Grid driving power	28	31	38	45	50 watts
Grid-bias loss	6.5	10	17	23.5	27.5 watts
Power output, approximate	300	435	500	615	720 watts

R.F. Doubler:

D.C. plate voltage	1000	1500	2000 volts
D.C. grid voltage	—243	— 395	—425 volts
D.C. plate current	250	200	175 m.a.
D.C. grid current	75	75	75 m.a.
Grid driving power	38	49	50 watts
Grid-bias loss	18	30	32 watts
Power output, approximate	100	150	200 watts

Class B Audio Amplifier (Two Tubes):

D.C. plate voltage	1500	2000	2500	3000 volts
D.C. grid voltage	—15	—22.5	—35	—45 watts
Zero signal plate current	50	50	50	50 m.a.
Maximum signal d.c. plate current	280	347	300	344 m.a.
Plate-to-plate load resistance	12000	12000	20000	20000 ohms
Power output	290	445	550	725 watts

H-K Heintz and Kaufman Gridless Gammatrons, Types HK55, HK155, HK255.

Characteristics:

	Type 55	Type 155	Type 255
Filament Voltage	6.0	5	14 volts
Filament Current	3	10	30 amps.
Normal Plate Dissipation	75	150	500 watts
Amplification Factor	3.5	2	3
Maximum D.C. Plate Current	150	300	1000 ma.
Maximum D.C. Plate Voltage	1250	3000	5000 volts
Plate Impedance	1200	1100	1000 ohms.

Unusual Features:

Control element is a gamma plate of tantalum.

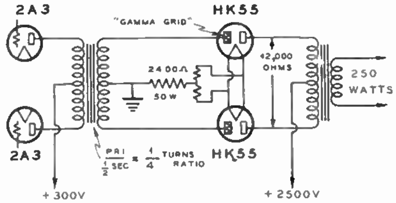
Filament is between regular plate and gamma plate.

Uses: Oscillators, audio and radio frequency amplifiers. Nearly complete plate current variation may be secured without driving the control (gamma plate) element positive.

Type 255. Inter-Electrode Capacity:

Gamma Plate to Power Plate	5 μμfd.
Filament to Gamma Plate	12 μμfd.
Filament to Power Plate	7 μμfd.

Type 255 Class A Audio Amplifier (Single Tube with no Grid (Gamma) Current):



HIGH OUTPUT CLASS A AUDIO AMPLIFIER

D.C. Plate Voltage	1500	2000	2500	3000 volts
D.C. Grid Voltage	—350	—570	—800	—1000 volts
D.C. Plate Current	.34	.25	.20	.17 amps.
Load Resistance	5000	6000	8000	20000 ohms
Output Power	60	125	175	180 watts
Efficiency	12	25	35	36%
Harmonic Distortion (Approx.)	5	5	5	5%

Type 255 Class B Audio Amplifier (2 Tubes, "Grids" Swing to Zero and Draw no Current):

D.C. Plate Voltage	2000	3000	5000	8000 volts
D.C. Grid Voltage	—800	—1200	—2100	—3300 volts
D.C. Plate Current	.60	.83	.90	.75 amps.
Power Output	450	1100	2500	4000 watts
Plate Efficiency	38	44	56	67%
Load Resistance (Plate to Plate)	4000	5000	10000	23000 ohms.
Plate Loss	750	1400	2000	2000 watts

Type 255 Class B R-F Amplifier (Single Tube, no "Grid" Current):

D.C. Plate Voltage	2000	3000	5000	8000 volts
D.C. Grid Voltage	—800	—1200	—2100	—3300 volts
D.C. Plate Current	120	155	142	97 ma.
Load Resistance	1500	2000	4500	12000 ohms.
Plate Loss	188	347	490	500 watts
Power Input	240	465	710	775 watts
Power Output	52	118	220	275 watts
Efficiency	21.5	25	31	36%

150T

Eimac medium power triode for general use, either in r.f. or audio circuits. More efficient at high frequencies than tubes with higher inter-electrode capacities (of equal power ratings).

Frequency Range: 100% ratings up to 60 mc.

Note (1): Values of grid r.f. excitation vary over wide limits depending upon efficiency desired, circuit losses at higher frequencies, plate load impedance and circuit design. The driver should be designed to provide considerably more output than shown by the table, if possible.

Note (2): For keyed telegraphy, the above ratings may be exceeded by 50%. Higher grid bias and grid drive are desirable if more output is wanted.

Characteristics:

Filament Voltage ....5 to 5.25 volts
Filament Current ....10 amps.
Amplification Factor 11
Grid to Plate Capacity....3.5 μμfd.
Grid to Filament Capacity....3.0 μμfd.
Plate to Filament Capacity....0.5 μμfd.
Normal Plate Dissipation ....150 watts
Normal Plate Voltage....3000 volts
Normal Plate Current ....200 ma.
Normal Grid Current ....50 ma.
Base....Standard 4 Pin 50 watt
Plate through top, grid through side of envelope.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	1000	2000	3000 volts
D.C. Grid Voltage	—75	—160	—230 volts
Zero Sig. D.C. Plate Current (Approximate)	20	20	20 ma.
Maximum Sig. D.C. Plate Current (Approximate)	400	400	365 ma.
Load Resistance (Plate to Plate)	4500	13,500	20,000 ohms
Driving Power	11	15	17 watts
Output Power	200	450	700 watts

Class C R-F Amplifier Telephony or Telegraphy:

D.C. Plate Voltage	1000	2000	3000 volts
D.C. Grid Voltage	—200	—400	—600 volts
D.C. Plate Current	200	200	200 ma.
D.C. Grid Current	35	35	35 ma.
Grid Driving Power	14	21	30 watts
Grid Bias Loss	7	14	21 watts
Power Input	200	400	600 watts
Power Output	150	300	450 watts
A.C. Load Resistance	2500	5000	8000 ohms.
Mod. D.C. Load	5000	10,000	15,000 ohms

T-155

Taylor general purpose triode, suitable for U.H.F. service down to 2 meters.

Characteristics:

Filament Voltage ....10 volts
Filament Current ....4 amps.
Amplification Factor 20
Grid to Plate Capacity ....3 μμfd.
Grid to Filament Capacity ....2.5 μμfd.
Plate to Filament Capacity....1 μμfd.
Maximum Plate Dissipation....155 watts
Maximum D.C. Plate Voltage....3000 volts
Maximum D.C. Plate Current....200 ma.
Maximum D.C. Grid Current....60 ma.
Base....Standard 4 Pin 50 watt
Plate through top, grid through side of envelope.

Class C R-F Amplifier:

D.C. Plate Voltage....2500 volts
D.C. Grid Voltage....250 volts
D.C. Plate Current....200 ma.
D.C. Grid Current....50 ma.
Grid Driving Power....22 watts
Grid Bias Loss....12.5 watts
Power Input ....500 watts
Power Output ....370 watts

WL461

Westinghouse ultra-high-frequency triode for medium and high power service. Special design of terminals for elements enables direct connection to elements, thus providing a very low inductance path to the tube electrodes. This construction, together with low interelectrode capacities, gives 5 megacycle performance at 50 megacycles and useful output up to 150 megacycles.

Characteristics:

Filament Voltage ....5.0 volts
Filament Current ....11.5 amps.
Amplification Constant 28
Maximum D.C. Plate Voltage ....2000 volts
Maximum A.C. Plate Voltage (RMS)....2500 volts
Maximum D.C. Plate Current ....250 ma.
Maximum Plate Dissipation ....160 watts
Dimensions....7½" long, 3¾" diameter
Tantalum plate, all leads out through base in special short leads for diathermy operation.
Approximate Power Output on 50 Mc....400 watts

F-108A

Federal Tel. Co. General purpose triode. Especially suitable for very high frequencies.

Note: Grid excitation requirements vary greatly, due to circuit design, plate load, and required efficiencies.

Frequency Range: 100% ratings up to 30 mc.

Characteristics:

Filament Voltage ....10 volts
Filament Current ....11 amps.
Amplification Factor 12
Grid to Plate Capacity ....7 μμfd.
Grid to Filament Capacity ....3 μμfd.
Plate to Filament Capacity....2 μμfd.
Maximum Plate Dissipation ....175 watts
Maximum D.C. Plate Voltage ....3000 volts
Maximum D.C. Plate Current ....200 ma.
Maximum D.C. Grid Current ....50 ma.

Class C R-F Amplifier:

D.C. Plate Voltage...	2000	3000 volts
D.C. Grid Voltage...	—400	—600 volts
D.C. Plate Current...	200	200 ma.
D.C. Grid Current (Approx.)	40	40 ma.
Grid Drive	26	34 watts
Grid Bias Loss	16	24 watts
Power Input	400	600 watts
Power Output	260	480 watts

HF-300

Amperex General purpose triode for high frequency and U.H.F. amplifiers or oscillators.

Note: Grid excitation requirements vary greatly due to circuit design, plate load, and required efficiency.

Frequency Range: 100% ratings up to 45 mc.

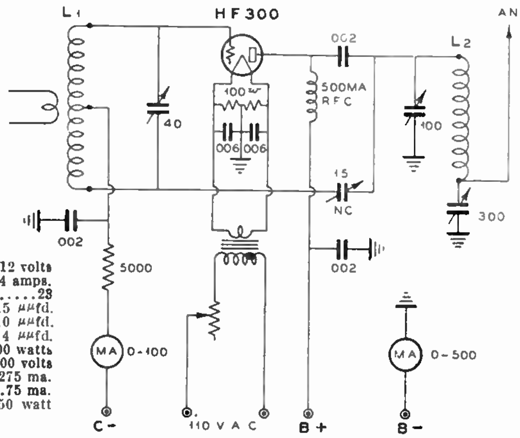
Characteristics:

Filament Voltage	11 to 12 volts
Filament Current	4 amps.
Amplification Factor	23
Grid to Plate Capacity	6.5 μμfd.
Grid to Filament Capacity	6.0 μμfd.
Plate to Filament Capacity	1.4 μμfd.
Maximum Plate Dissipation	200 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D. C. Plate Current	275 ma.
Maximum D.C. Grid Current	75 ma.
Base	standard 4 pin 50 watt

Plate through top, grid through side of envelope.

Class C R-F Amplifier

D.C. Plate Voltage	1500	2500 volts
D.C. Grid Voltage	—200	—300 volts
D.C. Plate Current	275	275 ma.
D.C. Grid Current	60	60 ma.
Grid Driving Power	27	33 watts
Grid Bias Loss	12	18 watts
Power Input	420	700 watts
Power Output	260	500 watts

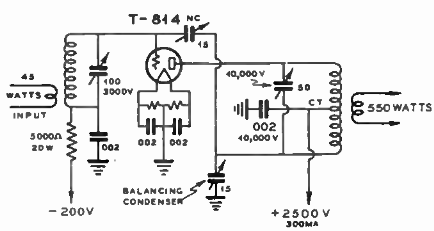


Grid-Neutralized Circuit for HF-300 Amplifier

814

Taylor H.F. Triode. Class C r.f. amplifier of high output with relatively low grid-driving requirements.

Frequency Range: 30 to 2 mc.



HIGH POWER FINAL AMPLIFIER

Characteristics:

Filament Voltage	10 volts
Filament Current	4 amps.
Amplification Factor	12
Grid to Plate Capacity	13 μμfd.
Grid to Filament Capacity	7μμfd.
Plate to Filament Capacity	5.5 μμfd.
Maximum Plate Dissipation	200 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D.C. Plate Current	300 ma.
Maximum D.C. Grid Current	75 ma.
Base	standard 4 pin 50 watt

Plate through top of envelope.

Class C R-F Amplifier:

D.C. Plate Voltage	2000 volts
D.C. Grid Voltage	—400 volts
D.C. Plate Current	300 ma.
D.C. Grid Current	45 ma.
Grid Driving Power	25 watts
Grid Bias Loss	18 watts
Power Input	600 watts
Power Output	400 watts

822

Taylor High-Mu Triode. Class B audio amplifier or modulator. May be used in Class C r.f. service.

A.F. Driver: Push-pull parallel 2A3 tubes with input transformer ratio of $\frac{\text{Primary}}{\frac{1}{2}\text{ sec.}} = 1.6$.

Characteristics:

Filament Voltage	10 volts
Filament Current	4 amps.
Amplification Constant	27
Grid to Plate Capacity	14 μμfd.
Grid to Filament Capacity	8 μμfd.
Plate to Filament Capacity	6 μμfd.
Maximum Plate Dissipation	200 watts
Maximum D.C. Plate Voltage	2000 volts
Maximum D.C. Plate Current	300 ma.
Maximum D.C. Grid Current	60 ma.
Base	standard 4 pin 50 watt

Plate through top of envelope.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	2000 volts
D.C. Grid Voltage (Approx.)	—75 volts
Zero Signal D.C. Plate Current	50 ma.
Maximum Signal D.C. Plate Current	450 ma.
Load Impedance (Plate to Plate)	9000 ohms
Power Output	500 watts
Driving Power	30 watts

Class C R-F Amplifier:

D.C. Plate Voltage	2000 volts
D.C. Grid Voltage	—220 volts
D.C. Plate Current	300 ma.
D.C. Grid Current	50 ma.
Grid Driving Power	20 watts
Grid Bias Loss	11 watts
Power Input	600 watts
Power Output	400 watts

T-200

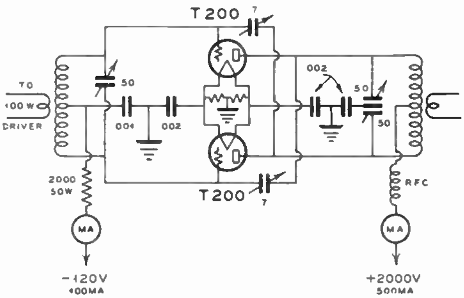
Taylor U.H.F. Triode, suitable for Oscillator or Amplifier service. Similar to HF-300.

Note: Grid driving requirements vary widely under different operating conditions.

Characteristics:

Filament Voltage	10 to 11 volts
Filament Current	4 amps.
Amplification Factor	16.6
Grid to Plate Capacity	7 μμfd.
Grid to Filament Capacity	5 μμfd.
Plate to Filament Capacity	3 μμfd.
Maximum Plate Dissipation	200 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	30 ma.
Base	standard 4 pin 50 watt

Plate at top, grid at side of envelope.



1 Kw. P.P. Amplifier

Class C R-F Amplifier:

D.C. Plate Voltage	2500 volts
D.C. Grid Voltage	—300 volts
D.C. Plate Current	300 ma.
D.C. Grid Current	50 ma.
Grid Driving Power (Approx.)	24 watts
Grid Bias Loss	15 watts
Power Input	750 watts
Power Output	560 watts

250TL

Eimac. U.H.F. Triode with medium amplification factor. Designed for diathermy service and for replacement of older type 150 T Eimac.

Characteristics:

Filament voltage	5 to 5.1 volts
Filament current	10.5 amps.
Amplification factor	13
Grid-to-plate capacity	3.5 μμfd.
Grid-to-filament capacity	3.0 μμfd.
Plate-to-filament capacity	0.5 μμfd.
Maximum d.c. plate voltage	3000 volts
Maximum d.c. plate current	350 m.a.
Maximum d.c. grid current	50 m.a.
Normal plate dissipation	250 watts

Base: Standard 50 watt. Plate through top, grid through side of envelope.

Class C R.F. Amplifier:

D.C. plate voltage	1000	2000	3000	volts
D.C. plate current	300	350	330	m.a.
D.C. grid current	45	45	45	m.a.
D.C. grid bias	—200	—400	—600	volts
Approximate grid driving power	11	22	33	watts
Grid bias loss	9	18	27	watts
Approximate power output	200	500	750	watts

Class B. Audio Amplifier:

D.C. plate voltage	1250	2000	3000	volts
Load impedance, plate-to-plate	3280	6000	12400	ohms
Power output, 2 tubes	540	900	1180	watts

250TH

Eimac. High-mu U.H.F. Triode. Designed primarily for r.f. amplification and class B audio service.

Characteristics.

Filament voltage	5 to 5.1 volts
Filament current	10.5 amps.
Amplification factor	32
Grid-to-plate capacity	3.3 μμfd.
Grid-to-filament capacity	3.5 μμfd.
Plate-to-filament capacity	0.3 μμfd.
Maximum d.c. plate voltage	3000 volts
Maximum d.c. plate current	350 m.a.
Maximum d.c. grid current	65 m.a.
Normal plate dissipation	250 watts

Base: Standard 50-watt. Grid through side, plate through top of envelope.

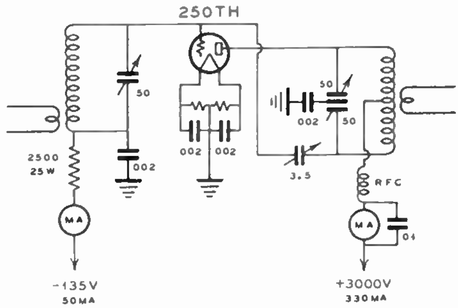
Class C R.F. Amplifier:

D.C. plate voltage	1000	2000	3000	volts
D.C. plate current	300	350	330	m.a.
D.C. grid current	55	55	55	m.a.
D.C. grid bias	—70	—140	—210	volts
Approximate grid driving power	8	16	25	watts
Grid bias loss	3.9	7.7	11.6	watts
Approximate power output	200	500	750	watts

Class B. Audio Amplifier:

D.C. plate voltage	1000	1500	3000	volts
Load impedance, plate-to-plate	2360	4200	1180	watts
Power output, 2 tubes	350	630	12400	ohms

Grid Bias: Zero for plate potentials up to 1400 volts.



1 Kw. R F Amplifier

WE-308B

Western Electric Triode, designed for modulators in radiotelephone transmitters.

Characteristics:

Filament Voltage	14 volts
Filament Current	6 amps.
D.C. Plate Current	300 ma.
Maximum Plate Voltage	2250 volts
Mutual Conductance	7500 mhos
Class-A Output, 2 Tubes	100 watts
Class-B Output, 2 Tubes	500 watts

204A

Triode (RCA-Amperex-United). Oscillator or amplifier for frequencies below 3000 KC.

Frequency Range: 100% ratings up to 3 mc. 50% at 15 mc.

Note: Grid excitation requirements vary with plate impedance, circuit design and circuit losses, so the driver stage should be able to supply approximately twice as much output as listed for grid drive and bias loss.

Characteristics:

Filament Voltage	11 volts
Filament Current	3.85 amps.
Amplification Factor	25
Grid to Plate Capacity	15 μμfd.
Grid to Filament Capacity	12.5 μμfd.
Plate to Filament Capacity	2.3 μμfd.
Maximum Plate Dissipation	250 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D.C. Plate Current	275 ma.
Maximum D.C. Grid Current	80 ma.
Base	standard 250 watt

Plate through top.

Class B Modulator or A-F Amplifier:

D.C. Plate Voltage	1500	2000 volts
D.C. Grid Bias (Approx.)	—40	—60 volts
Zero Signal Plate Current (Per Tube)	37	37 ma.
Max. Signal Plate Current (Per Tube)	250	250 ma.
Load Resistance (Plate to Plate)	7800	8800 ohms
Power Output (2 tubes)	400	600 watts

R-F Service

	Class B Telephony	Plate Mod. Telephony	Class C Telegraphy	
D.C. Plate Voltage	2000	1800	1500	2500 volts
D.C. Grid Bias	—70	—250	—150	—200 volts
D.C. Plate Current	160	250	250	250 ma.
D.C. Grid Current	...	70	50	50 ma.
Power Output (Approx.)	100	300	225	400 watts
Grid Driving Power	...	35	17	22 watts
Grid Bias Loss	...	17.5	7.5	10 watts
Power Input	140	450	375	625 watts

WE-212E

Western Electric general purpose triode for frequencies below 1500 KC. Normally used in audio circuits.

Frequency Range: 100% ratings up to 1.5 mc. 33% plate voltage ratings at 4.5 mc.

Characteristics:

Filament Voltage	14 volts
Filament Current	6 amps.
Amplification Factor	16
Grid to Plate Capacity	18.8 μμfd.
Grid to Filament Capacity	14.9 μμfd.
Plate to Filament Capacity	8.6 μμfd.
Maximum Plate Dissipation	275 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	75 ma.

Special W.E. base.

Class B Audio Amplifier (2 tubes):

DC. Plate Voltage	1500	2000 volts
D.C. Grid Voltage	—75	—105 volts
Maximum Signal D.C. Plate Current	600	600 ma.
Zero Signal D.C. Plate Current	80	100 ma.
Load Resistance (Plate to Plate)	5900	8000 ohms
Power Output	500	650 watts
Driver Power	50	50 watts

R-F Service

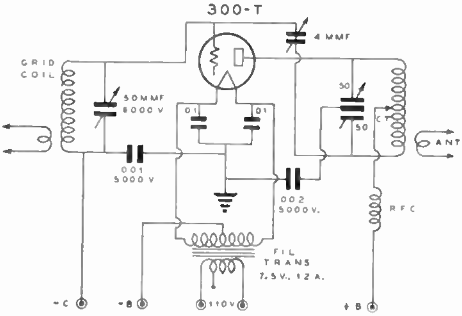
	Class B R-F	Class C Telephony	Class C Telegraphy
D.C. Plate Voltage	2000	1500	2000 volts
D.C. Grid Voltage	—120	—200	—250 volts
D.C. Plate Current	200	300	300 ma.
D.C. Grid Current	...	60	60 ma.
Grid Drive (Approx.)	...	21	25 watts
Grid Bias (Loss)	...	12	15 watts
Power Input	400	450	600 watts
Power Output	135	300	400 watts

300T

Eimac. General purpose "Low C" triode for audio and high frequency amplifiers.

Frequency Range: 100% ratings up to 40 mc.

Note: Values of grid r.f. excitation vary over wide limits so this should be taken into account when designing the driver stage.



1-K.W. AMPLIFIER

Characteristics:

Filament Voltage	7.5 volt
Filament Current	11.5 amps.
Normal Plate Dissipation	300 watts
Amplification Factor (Avg.)	16
Maximum Plate Current	350 ma.
Maximum Plate Voltage	3500 volts
Maximum Grid Current	75 ma.
Grid to Plate Capacity	4 μμfd.
Grid to Filament Capacity	4 μμfd.
Plate to Filament Capacity	0.6 μμfd.
Base	standard 4 pin 50 watt

Plate through top, grid through side of envelope.

Class B Audio Amplifier (2 tubes):

D.C. Plate Voltage	1000	2000	3000	3500 volts
D.C. Grid Voltage (Ap.)	—60	—135	—200	—240 volts
Zero Signal D.C. Plate Current (Approx.)	40	40	40	40 ma.
Max. Signal D.C. Plate Current	700	700	700	600 ma.
Load Resistance (Plate to Plate)	2800	8500	10,000	13,000 ohms
Driving Power	30	38	48	46 watts
Output Power	400	950	1500	1620 watts

Class C R-F Amplifier (1 tube) Telephony or Telegraphy:

D.C. Plate Voltage	2000	3000	3500 volts
D.C. Grid Voltage	—300	—500	—600 volts
D.C. Plate Current	300	300	300 ma.
D.C. Grid Current	40	50	60 ma.
Grid Driving Power (Approx.)	22	40	55 watts
Grid Bias Loss	12	25	36 watts
Power Input	600	900	1050 watts
Power Output	450	700	800 watts
AC Load Resistance	3400	5000	5800 ohms

HK-654

Heintz and Kaufman Triode for Class B, Modulator and high-frequency RF Service. Especially suitable for Class B RF and grid-modulated telephony. Tantalum plate and grid. 100% ratings up to 15 MC; reduced ratings above 30 MC.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	15 amps.
Amplification Factor	25
Normal Plate Dissipation	300 watts
Maximum D.C. Plate Voltage	5000 volts
Maximum D.C. Plate Current	450 ma.
Maximum D.C. Grid Current	100 ma.

Base: Standard 4-pin 50-watt. Plate through top, grid through side of envelope.

WE-270A

Western Electric general purpose triode for broadcast station operation in high frequency transmitters.

Frequency Range: 100% ratings up to 7.5 mc. 33% plate voltage ratings at upper limit of 22.5 mc.

Characteristics:

Filament Voltage	10 volts
Filament Current	9.75 amps.
Amplification Factor	16
Grid to Plate Capacity	21 μμfd.
Grid to Filament Capacity	18 μμfd.
Plate to Filament Capacity	2 μμfd.
Maximum Plate Dissipation	350 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	375 ma.
Maximum D.C. Grid Current	75 ma.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	2000	2500 volts
D.C. Grid Voltage	—105	—140 volts
Maximum Sig. D.C. Plate Current	750	750 ma.
Zero Sig. D.C. Plate Current	120	120 ma.
Load Resistance (Plate to Plate)	6000	8060 ohms
Power Output	850	1000 watts
Driver Power	75	75 watts

R-F Service

	Class B R-F	Class C Telephony	Class C Telegraphy
D.C. Plate Voltage	3000	2250	3000 volts (max.)
D.C. Grid Voltage	—180	—300	—375 volts
D.C. Plate Current	175	300	350 ma.
D.C. Grid Current	....	70	70 ma.
Grid Driver (Approx.)	....	32	37 watts
Grid Bias Loss	....	21	11 watts
Power Input	525	675	1050 watts
Power Output	175	450	700 watts

861

RCA Screen Grid RF. Amplifier for normal operation up to 20 megacycles.

Frequency Range: 100% ratings up to 20 mc. 75% at 30 mc.

Note (1): Grid driving power requirements vary over wide limits, depending upon load impedance and circuit losses.

Note (2): In modulated operation (plate type) the screen voltage should be modulated simultaneously with the plate voltage. Grid modulation characteristics are approx. similar to Class B r.f. operation, except for grid bias.

Characteristics:

Filament Voltage	11 volts
Filament Current	10 amps.
Amplification Factor	300
Grid to Plate Capacity	0.1 μμfd.
Input Capacity	11.5 μμfd.
Output Capacity	11 μμfd.
Maximum Plate Voltage	3500 volts
Maximum Plate Dissipation	400 watts
Maximum Screen Dissipation	35 watts
Maximum D.C. Plate Current	350 ma
Maximum D.C. Grid Current	75 ma.

R-F Service	Class B Telephony	Plate Mod. Class C Telephony		Class C Telegraphy	
D.C. Plate Voltage	3500	2000	3000 max.	2000	3500 volts
D.C. Screen Voltage	500	350	500	350	600 volts
D.C. Grid Voltage	—60	—200	—300	—150	—250 volts
D.C. Plate Current	145	265	200	300	275 ma.
D.C. Grid Current	...	70	50	60	30 ma.
Grid Driving Power	...	40	35	40	25 watts
Grid Bias Loss	...	14	15	9	7.5 watts
Plate Power Input	510	530	600	600	965 watts
Power Output	160	285	360	325	590 watts

831

RCA and Amperex Oscillator and r.f. amplifier for high frequency operation.

Frequency Range: 100% ratings up to 20 mc. 55% at 75 mc.

Note: Grid driving requirements vary greatly under different values of load impedance, neutralizing circuits and circuit losses which vary with frequency.

Characteristics:

Filament Voltage	11 volts
Filament Current	10 amp.
Amplification Factor	14.5
Grid to Plate Capacity	4.0 μμfd.
Grid to Filament Capacity	3.8 μμfd.
Plate to Filament Capacity	1.4 μμfd.
Maximum Plate Dissipation	400 watts
Maximum D.C. Plate Voltage	3500 volts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	75 ma.

R-F Service

	Class B Telephony	Class C Plate Mod. Telephony	Class C Telegraphy	
D.C. Plate Voltage	3500	3000*	2000	3500 volts
D.C. Grid Voltage	—220	—500	—200	—400 volts
D.C. Plate Current	145	200	300	275 ma.
D.C. Grid Current	...	60	45	40 ma.
Grid Driving Power	...	50	25	30 watts
Grid Bias Loss	...	30	9	16 watts
Power Input	510	600	600	965 watts
Power Output	160	375	400	600 watts

*(Max.)

849

Triode. RCA-Amperex-United. Especially suited for Class B modulators. May be used in Class C as well as Class B r.f. amplifiers.

Frequency Range: 100% ratings up to 3 mc. 50% at 15 mc.

Characteristics:

Filament Voltage	11 volts
Filament Current	5.0 amps.
Amplification Factor	19
Grid to Plate Capacity	33.5 μμfd.
Grid to Filament Capacity	17 μμfd.
Plate to Filament Capacity	3 μμfd.
Maximum Plate Dissipation	400 watts
Maximum Plate Dissipation (Telephony)	270 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	125 ma.
Base	250 watt

Plate through top of envelope.

Class B Modulator or A-F Amplifier:

D.C. Plate Voltage	2000	2500 volts
Grid Bias (Approximate)	—105	—130 volts
Zero Sig. Plate Current (Per Tube)	7	10 ma.
Maximum Sig. Plate Current (Per Tube)	325	275 ma.
Load Resistance (Plate to Plate)	7040	11,480 ohms
Power Output	870	920 watts

Class B—R-F Amplifier:

D.C. Plate Voltage	1500	2000 volts
D.C. Grid Bias	—70	—95 volts
D.C. Plate Current	340	265 ma.
Carrier Output	155	175 watts

Plate Modulated Class C. Amplifier:

D.C. Plate Voltage	1500	1800 volts
D.C. Grid Bias	—250	—300 volts
D.C. Plate Current	300	300 ma.
Power Output	300	390 watts

Class C Telegraphy:

D.C. Plate Voltage	1500	2000 volts
D.C. Grid Bias	—175	—200 volts
D.C. Plate Current	300	300 ma.
Power Output	300	450 watts
D.C. Grid Current	75	75 ma.
Grid Driving Power (Approx.)	32	34 watts
Grid Bias Loss	13	15 watts

450TH 450TL

Eimac high power triodes. The 450TH has an amplification factor of 32, the 450TL has an amplification factor of 16. These tubes are especially designed for broadcast and commercial transmitters. Tantalum plates and grids.

Filament Voltage	7.5 volts
Filament Current	12 amps.
Maximum D.C. Plate Current	500 ma.
D.C. Plate Voltage	4000 volts
Normal Plate Dissipation	450 watts
Grid to Plate Capacity	4.5 μμfd.
Base	Standard 50 watt type

Plate out through top and grid through side of glass envelope.

500T

Eimac general purpose triode for audio and high-frequency amplifiers. Its low inter-electrode capacities allow effective r.f. amplification at high radio frequencies.

Frequency Range: 100% ratings up to 40 mc.

Note: Values of r.f. grid excitation vary over wide limits so this should be taken into account when designing the driver stage.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	20 amps.
Amplification Factor (Average)	13
Normal Plate Dissipation	500 watts
Maximum Plate Voltage	4000 volts
Maximum Plate Current	600 ma.
Maximum Grid Current	125 ma.
Grid to Plate Capacity	4.5 μμfd.
Grid to Filament Capacity	6 μμfd.
Plate to Filament Capacity	0.8 μμfd.
Base	Special EIMAC

Plate through top, grid through side of envelope.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	1500	2000	3000	4000 volts
D.C. Grid Voltage (Approx.)	—110	—150	—225	—310 volts
Maximum Signal D.C. Plate Current	1200	1150	900	800 ma.
Load Resistance (plate to plate)	2400	3000	6800	11300 ohms
Grid Driving Power	90	90	85	80 watts
Power Output	900	1200	1800	2300 watts

Class C R-F Amplifier (1 Tube) Telephony or Telegraphy:

D.C. Plate Voltage	2000	3000	4000 volts
D.C. Grid Voltage	—350	—550	—800 volts
D.C. Plate Current	450	450	450 ma.
D.C. Grid Current	90	90	90 ma.
Grid Driving Power (Approx.)	60	80	110 watts
Grid Bias Loss	31.5	40	72 watts
Power Input	900	1350	1800 watts
Power Output (Approx.)	650	1000	1350 watts

F-100A

Federal Tel. Co. general purpose triode for high frequency transmitters.

Useful up to 100 mc.

Characteristics:

Filament Voltage	11 volts
Filament Current	25 amps.
Amplification Factor	14
Grid to Plate Capacity	10 μμfd.
Grid to Filament Capacity	4 μμfd.
Plate to Filament Capacity	2 μμfd.
Maximum Plate Dissipation	500 watts
Maximum D.C. Plate Voltage	4000 volts
Maximum D.C. Plate Current	300 ma.

887, 888

RCA UHF water-cooled triodes. Designed for use as oscillators or amplifiers in the ultra-high frequency spectrum. Either tube may be used at full input as an oscillator up to 240 Mc. or as an amplifier at full input to 300 Mc. Operation at higher frequencies is permissible with reduced input. The characteristics of the 887 are given; those of the 888 are almost identical except that the latter tube has an amplification factor of 30 and has slightly higher interelectrode capacities.

Characteristics:

Filament voltage .... 11 volts
Filament current .... 24 amps.
Amplification factor 10
Plate dissipation (max.) .... 600 watts

Direct interelectrode capacities:

Grid-plate .... 6.9 μμfd.
Grid-filament .... 2.5 μμfd.
Plate-filament .... 2.7 μμfd.
Type of cooling .... Water and forced air

Class B R.F. Amplifier:

D.C. plate voltage (max.) .... 3000 volts
D.C. plate current (max.) .... 200 m.a.
Plate input (max.) .... 600 watts

Typical operation:

D.C. plate voltage	2500	3000 volts
D.C. grid voltage	—250	—300 volts
Peak r.f. grid voltage	290	320 volts
D.C. plate current	200	200 m.a.
D.C. grid current	2	1 m.a.
Driving power	45	50 watts
Power output	165	200 watts

Class C Modulated Amplifier—Modulation factor of 1.0 Maximum Conditions:

D.C. plate voltage (max.) .... 2000 volts
D.C. plate current (max.) .... 200 m.a.
D.C. grid bias (max.) .... —500 volts
D.C. grid current (max.) .... 75 m.a.
Plate input (max.) .... 400 watts
Plate dissipation .... 400 watts

Class C. Amplifier—C.W. Telegraphy Maximum Conditions:

D.C. plate voltage .... 3000 volts
D.C. grid voltage .... —500 volts
D.C. plate current .... 400 m.a.
D.C. grid current .... 75 m.a.
Plate input .... 1200 watts
Plate dissipation .... 1000 watts

851

RCA—Amperex—United. High power air cooled triode for AF or RF service.

Frequency Range: 100% ratings up to 3 mc. 50% at 6 mc.

Characteristics:

Filament Voltage .... 11 volts
Filament Current .... 15.5 amp.
Amplification Factor 20
Grid to Plate Capacity .... 55 μμfd.
Grid to Filament Capacity .... 30 μμfd.
Plate to Filament Capacity .... 7 μμfd.
Maximum Plate Dissipation .... 750 watts
Maximum D.C. Plate Voltage .... 2500 volts
Maximum D.C. Plate Current .... 1 Amp.
Maximum D.C. Grid Current .... 200 ma.
Base .... Standard 250 watt
Plate through top of envelope.

HK-1554

Heintz & Kaufman general purpose triode. Designed for commercial transmitters in the high frequency range.

Note: Air-cooled plate. With forced ventilation, plate dissipation may be increased to 1500 watts.

Characteristics:

Filament Voltage .... 11 volts
Filament Current .... 17 amps.
Normal Plate Dissipation .... 750 watts
Amplification Factor .... 14.5 watts
Grid to Plate Capacity .... 11 μμfd.
Grid to Filament Capacity .... 15.5 μμfd.
Plate to Filament Capacity .... 1.2 μμfd.
Base .... Special HK
Plate through top of envelope.

Class B Audio Amplifier:

D.C. Plate Voltage	2500	3000	4000	5000 volts
D.C. Grid Voltage	—160	—200	—275	—350 volts
Zero Signal D.C. Plate Current (2 tubes)	.050	.050	.050	.050 amps.
Maximum Signal D.C. Plate Cur. (2 tubes)	1.74	1.59	1.34	1.15 amps
Peak Driving Power	106	104	100	87 watts
RMS Signal Voltage	375	389	413	445 volts
Power Output (2 tubes)	2850	3260	3860	4260 watts
Load Resistance (plate to plate)	3000	4200	7000	10400 ohms
Maximum Signal D.C. Grid Current (2 tubes)	122	122	98	72 ma.

Class B R-F Telephony:

D.C. Plate Voltage	2500	3000	4000	5000 volts
D.C. Grid Voltage	—160	—200	—275	—350 volts
D.C. Plate Current	448	378	293	242 ma.
Plate Loss	750	750	750	750 watts
Load Resistance	750	1100	2000	3200 ohms
Peak Grid Driving Power	53	45	42	36 watts
Carrier Power	370	385	420	460 watts
Efficiency	33	34	36	38%

Class C Operation (3000 Max. Plate Voltage for Plate Modulation):

D.C. Plate Voltage	2500	3000	4000	5000 volts
D.C. Grid Voltage	—600	—610	—700	—760 volts
D.C. Plate Current	1.00	.930	1.00	1.00 amps.
D.C. Grid Current	110	95	104	95 ma.
Grid Driving Power	117	125	124	120 watts
Grid Bias Loss	66	58	73	72 watts
Load Resistance	1120	1460	1960	2500 ohms
Power Input	2500	2780	4000	5000 watts
Power Output	1750	2030	3040	3950 watts
Plate Efficiency	70	73	76	79%
Plate Loss	750	750	960	1050 watts

WE-251A

Western Electric H.F. triode broadcast or police transmitter tube for r.f. or a.f. service.

Frequency Range: 100% ratings up to 30 mc. 66% plate voltage ratings at 50 mc.

Characteristics:

Filament Voltage .... 10 volts
Filament Current .... 16 amps.
Amplification Factor 10.5
Grid to Plate Capacity .... 8 μμfd.
Grid to Filament Capacity .... 10 μμfd.
Plate to Filament Capacity .... 6 μμfd.
Maximum Plate Dissipation .... 1000 watts
Maximum D.C. Plate Voltage .... 3000 volts
Maximum D.C. Plate Current .... 600 ma.
Maximum D.C. Grid Current .... 150 ma.
Air-cooled tube.

R-F Service

	Class B R-F	Class C Telephony	Class C Telegraphy
D.C. Plate Voltage	3000	2250	3000 volts*
D.C. Grid Voltage	—300	—470	—550 volts
D.C. Plate Current	400	400	600 ma.
Power Input	1200	900	1800 watts
Power Output	400	600	1200 watts

*(Maximum).

WE-279A

Western Electric H.F. triode broadcast or police station operation for AF or RF service.

Frequency Range: 100% ratings up to 20 mc. 50% plate voltage ratings at 40 mc.

Characteristics:

Filament Voltage .... 10 volts
Filament Current .... 21 amps.
Amplification Factor 10
Grid to Plate Capacity .... 18 μμfd.
Grid to Filament Capacity .... 15 μμfd.
Plate to Filament Capacity .... 7 μμfd.
Maximum Plate Dissipation .... 1200 watts
Maximum D.C. Plate Voltage .... 3000 volts
Maximum D.C. Plate Current .... 800 ma.
Maximum D.C. Grid Current .... 150 ma.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	2000	2500 volts
D.C. Grid Voltage	—150	—200 volts
Maximum Signal D.C. Plate Current	1600	1600 ma.
Zero Signal D.C. Plate Current	220	300 ma.
Load Resistance (plate to plate)	2240	2800 ohms
Power Output	1760	2200 watts
Driver Power	100	100 watts

R-F Service

	Class B R-F	Class C Tele-phony	Class C Telegraphy
D.C. Plate Voltage	3000	2250	3000 volts
D.C. Grid Voltage	—325	—450	—600 volts
D.C. Plate Current	600	600	800 ma.
Power Input	1800	1350	2400 watts
Power Output	600	900	1600 watts

HK-3054

Heintz & Kaufman general purpose triode for commercial application. Largest air-cooled tube made.

Note: Plate dissipation may be increased to 3 KW by forced ventilation, air cooled H.F. tube construction.

Characteristics:

Filament Voltage	16 volts
Filament Current	50 amps.
Normal Plate Dissipation	1.5 kw.
Amplification Factor	20
Grid to Plate Capacity	15 μμfd.
Grid to Filament Capacity	25 μμfd.
Plate to Filament Capacity	2.5 μμfd.
Maximum D.C. Plate Voltage	5000 volts
Maximum D.C. Plate Current	2 amps.
Maximum D.C. Grid Current	0.5 amps.

RECTIFIERS

866-866A-872-872A

Note: The 866-A and 872-A rectifiers are limited to 5,000 peak inverse voltage if the temperature near the base of the tube is below 15° C, or above 50° C.

Uses: Half wave rectifiers, of the mercury vapor type, for high voltage plate supplies in radio transmitters. Two or four tubes may be connected in full wave rectifier circuits. (See power supply chapter.)

Max. Peak inverse voltage is the highest peak voltage that the rectifier tube can safely stand in the opposite direction to which it is supposed to pass current. In a single phase, full wave choke input circuit, the peak inverse voltage is approx. 1.4 times the RMS voltage applied to the tube. In a single phase, half wave circuit with condenser input, the peak inverse voltage may be 2.8 times the RMS value.

Max. peak plate current is the highest value of peak current that the rectifier tube can safely pass. With large choke inductance input to the filter, the peak current is not much higher than the load current. With condenser input, the peak current may be four times as high as the load current.

Characteristics:

	866	866-A	872	872-A
Filament Voltage	2.5	2.5	5.0	5.0 volts
Filament Current	5.0	5.0	10	6.75 amps.
Peak Inverse Voltage	7500	10000	7500	10000 volts*
Peak Plate Current	.6	.6	2.5	2.5 amps.*
Tube Voltage Drop (Approx.)	15	10	15	10 volts
Base	4 pin	4 pin	50 watt	50 watt

*Maximum

Characteristics:

Filament Voltage	2.5 volts
Filament Current	2.5 amps.
Maximum RMS A.C. Voltage	1250 volts
Maximum D.C. Load Current (Choke Input)	250 ma.
Base	Standard 4 pin, UX, Isolantite

RK-19, RK-21, RK-22

Raytheon Rectifiers. Intermediate between 83 and 866 rectifiers, but of high vacuum type construction. Designed for 1000 volt DC supplies.

Characteristics:

	Full Wave RK-19	Half Wave RK-21	Full Wave RK-22
Heater Voltage	7.5	2.5	2.5 volts
Heater Current	2.5	4.0	8.0 amp.

Maximum RMS Voltage Per Plate	1250 volts
Maximum Peak Inverse Voltage	3500 volts
Maximum Peak Current	600 ma.
Maximum D.C. Load Current (with Cond. Input)	200 ma.

866 Jr.

Taylor Tube Co. Mercury vapor half wave rectifier for operation in full wave or bridge rectifier systems. Intermediate in load capability between the type 866 and 83 rectifiers.

866B

Taylor mercury-vapor half-wave rectifier for operation in full-wave or bridge rectifier systems.

Intermediate in load capacity between 866 and 872A rectifiers.

Characteristics:

Filament Voltage	5 volts
Filament Current	5 amps.
Peak Inverse Voltage	8500 volts
Peak Inverse Current	1 amp.

Reactivation of Transmitting Tubes

Thoriated tungsten type transmitting tubes that have had their filaments temporarily "poisoned" or "paralized" by insufficient filament voltage or temporary overload can be permanently reactivated by "flashing" the filament at a voltage considerably higher than the rated filament voltage and then "cooking" the filament for a period at slightly more than the rated filament voltage. No voltage is applied to any of the other elements during either the "flashing" or "cooking" processes. An attempt at reactivation is a waste of time if gas has been liberated during the overload.

Tubes that have lived a long and useful life, tubes that have "seen better days," can be only temporarily reactivated. The emission will fall off worse than ever after a few hours use. In buying used tubes it is wise to make certain you are not purchasing reactivated "duds," as their apparently good emission will be short lived.

If you have an expensive tube that has been "paralized" but is otherwise in good condition (in other words, if the tube is not gassey and has seen only a fraction of its expected useful life), write to the manufacturer for specific reactivation data on that particular type before attempting to "bring it back."

Filament voltmeters can be surprisingly inaccurate, especially when mounted on a steel panel. With expensive tubes it is highly important that the filament voltmeter be checked carefully for accuracy. Excessive filament voltage will greatly shorten the life of a tube. Insufficient voltage may result in the filament's being paralized. Continued deficiency in filament voltage is just as damaging to a tube as is excessive filament voltage.

Chapter 10

Transmitter Theory

● Introduction

EARLIER in this text it was indicated that all electrical circuits conducting alternating currents radiate some electrical energy in the form of radio, or electromagnetic waves. The amount of this radiation depends upon the ratio of the dimensions of the circuit to a wave length. Thus it can be seen that with higher frequencies, and consequently shorter wavelengths, it becomes increasingly possible to radiate more and more electrical energy. Physical limitations in radiator dimensions prevent the efficient radiation of truly low-frequencies; an efficient radiator of ordinary 50 or 60 cycle currents would require circuit dimensions to be thousands of miles in length. Radio frequency radiators however, may be measured in feet. The transmitting antenna is just such a radiator.

The amount of radiated energy released from any antenna is proportional to the square of the radio frequency current flowing in that antenna. Resonating the antenna circuit to the frequency of the wave to be transmitted greatly increases this current. This, then, ordinarily is attempted. Antenna problems are considered more fully in a later chapter. The transmitter, essentially a generator of the radio frequency power, is considered here.

Various methods have been used in the past to generate r.f. power. Today, however, such power virtually always is obtained from *vacuum tube* oscillators and amplifiers. The transmitters are of two general types: c.w. (continuous wave) or code transmitters; and 'phone, or voice transmitters. We shall consider them in that order.

● The C. W. Transmitter

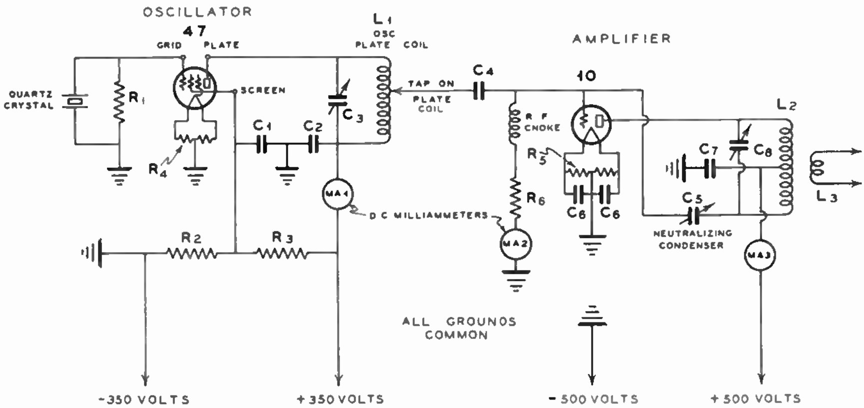
The essential portions of a c.w. transmitter are the crystal oscillator, frequency doubler or doublers, and r.f. amplifiers. The crystal oscillator determines the frequency in the short-wave spectrum at which the transmitter will operate; frequency doublers multiply the relatively low frequency of the crystal oscillator when high-frequency operation is desired; the r.f. amplifier increases the output of the source of frequency control to the desired value before connection to the antenna circuit. Intermediate r.f. amplifiers are called *"buffer amplifiers"*; their use is necessary where the output of the crystal oscillator or frequency doubler is insufficient to drive the final r.f. amplifier for normal operation. The final r.f. amplifier stage is a converter of direct current power into radio-frequency power, which then is supplied to the antenna system for transmission of signals.

● Circuit Analysis

A simple c.w. telegraph transmitter is shown schematically in figure 1. The *crystal oscillator* portion of the transmitter consists of the tuned circuit L_1-C_3, the type-47 pentode tube, various resistors and condensers, and the *quartz crystal.* The quartz crystal has *piezo-electric* properties; i.e., the crystal will vibrate physically at a *resonant frequency* as long as some electrical stimulus is applied to it. This stimulus is obtained from r.f. feedback through the plate-to-grid interelectrode capacity of the type-47 tube. The tuned circuit L_1-C_3 is tuned to a point near *resonance.* A surge, such as is obtained when the plate voltage is applied to the type-47 tube, will start an oscillation which is controlled by the frequency of the quartz crystal. Only a small portion of the oscillating energy in the plate circuit L_1-C_3 is needed to maintain the crystal in oscillation. the main portion of the power output can be used to drive the grid circuit of a buffer-amplifier, as shown in figure 1, or to drive the grid circuit of a frequency doubler, as explained later in this chapter. The actual frequency of the crystal-controlled oscillator is either very slightly higher or lower than the exact *mechanical* resonant frequency of the quartz plate. The type of feedback circuit determines which side of resonance this oscillation will occur; the actual difference of frequency from the resonant point is very small and practically constant for various outputs and plate voltages applied to the oscillator tube.

The quartz crystal circuit acts as a sharply tuned resonant circuit which has a very high "Q." The latter is an index of the ability of the crystal to maintain constant frequency of oscillation. The "Q" is much higher for the crystal than for an ordinary tuned circuit. A crystal-controlled oscillator therefore has much better frequency stability than self-excited oscillators of the tuned-grid-tuned plate, *Hartley*, or *Colpitts* variety.

of pentodes suitable for crystal oscillator service. The main requirement of the tube is that very little grid drive or r.f. excitation be necessary to maintain stable oscillation in the tuned plate circuit L_1-C_3. As a general rule, pentode or tetrode tubes require and have less r.f. feedback into the quartz crystal circuit than is needed with triode tubes.



CRYSTAL OSCILLATOR — BUFFER - AMPLIFIER CIRCUIT

Figure 1

Each of the various resistors and condensers in the oscillator circuit of figure 1 serves a separate and distinct function. Resistor R_1 provides a path for the direct current component in the grid circuit of the type-47 tube. When the tube is oscillating, the grid circuit is positive with respect to the filament for a portion of each cycle, which causes a flow of electrons to the grid electrode; the resultant pulsating direct current flows through the resistance R_1. The direct current cannot flow through the quartz crystal because the crystal, acting like a condenser in this respect, prevents direct current flow. The current which flows through R_1 causes a voltage drop proportional to the current, and provides a *negative grid-bias* for proper oscillator action of the type-47 tube.

The *center-tap resistor* R_4 in the type-47 tube circuit supplies a balanced point of connection to the filament: the filament normally is operated from an alternating current source and the 60-cycle variation at the center point of the resistor R_4 is zero and does not introduce a.c. hum into the output of the oscillator.

The type-47 tube is only one of a number

The screen-grid in a tetrode or pentode tube tends to shield the plate circuit electrostatically from the control-grid circuit, and also causes the tube to operate with less grid excitation than that used by a similar tube without a screen-grid. This screen-grid must be *bypassed* to the filament (or cathode) of the tube, which, in turn, is connected to a common ground and negative B supply. The screen-grid of a type-47 tube should be operated at a positive potential of from 100 to 125 volts, and this voltage is obtained from the 350 volt plate supply by connecting two resistors (R_2 and R_3) across the positive and negative terminals of the 350-volt supply in the manner of a voltage divider.

The tuned plate circuit, L_1-C_3, must be connected from the plate to the filament of the vacuum tube. This is accomplished by means of the condenser C_2, which bypasses the r.f. to filament, yet at the same time prevents the plate circuit from being short-circuited. The plate circuit r.f. power output ranges from 25% to 50% of the d.c. power input for different types of crystal oscillators. A *meter* or meter jack should be connected in the plate circuit of the crystal oscillator to aid in tuning of the circuit.

● Buffer-Amplifier

The r.f. power from the crystal oscillator usually is amplified to secure greater output. A large variety of tubes can be used for amplifier circuits. For the purpose of illustration, a type-10 triode tube is shown in figure 1. This tube has its grid to filament circuit connected across part of the plate circuit of the crystal oscillator. The filament of the type-10 circuit is connected to the common ground by means of a center-tap resistor R_5, or by a center-tap connection on the filament transformer proper. The filament voltage of a type-10 tube is three times as high as that required for a type-47 tube, and the resistance R_5 therefore is made from three to five times as high in value as the 47 filament resistor. This increase in resistance adds an appreciable amount of *impedance* to the flow of r.f. current from the center point of R_5 to the actual filament of the type-210 tube. To provide a low impedance path for r.f., two filament bypass condensers C_6 should be connected from filament to ground. The grid of the amplifier tube is connected to the oscillator circuit L_1-C_3 through a *coupling* condenser, C_4, which isolates the grid circuit from the oscillator plate supply, and yet enables r.f. current to flow to the grid circuit. The position of the *tap* on the coil L_1 and the capacity of condenser C_4, determines the amount of grid circuit drive. The closer this tap is to the bottom end of coil L_1 (which is at r.f. ground potential) the lower will be the r.f. voltage on the grid of the amplifier tube.

The grid circuit of the amplifier requires actual power to operate the tube in the usual form of Class-C operation. When the grid circuit is driven positive it has an average finite value of impedance, and this forms the *output load* for the crystal oscillator.

The grid of the type-10 amplifier tube for Class-C operation must be biased to more than cut-off voltage, which is a function of the plate voltage and amplification constant of the amplifier tube. The rectified current flows through the r.f. choke, resistor R_6 and meter $M.4_2$ to ground, the latter being the return circuit to the filament. This rectified current flowing through R_6 must be sufficient to bias the amplifier tube at least to cut-off, and normally is made high enough to reach twice this value. Correct values of grid current and grid bias voltage are listed in the *Transmitter Tube Tables.* The radio-frequency choke in series with R_6 is needed in cases where the resistance of R_6 is relatively low, for instance only one-fourth of the ohmic resistance of R_1. Actual values of resistances and capacities are shown in numerous circuits throughout this *Handbook*, and also in the *Tube Tables.*

The type-10 amplifier tube is a triode: it has a capacity of several micro-microfarads between its grid and plate electrodes. When the plate circuit is tuned to the same frequency as the grid-driving circuit L_1-C_3, the type-10 tube will act as a regenerative self-excited oscillator, unless it is *neutralized.* When the grid-to-plate capacitance of the tube is balanced by means of a neutralizing condenser C_5, connected in a circuit of the type shown in figure 1, there is no feedback from the plate to the grid circuit. The tube acts as a stable r.f. amplifier and power can be taken from the tuned plate circuit L_2-C_8 by means of the coil L_3.

The tuned plate tank circuit L_2-C_8 must be center-tapped to supply a radio-frequency voltage 180 degrees out-of-phase across each end of the inductance L_2 so as to obtain the desired neutralizing action. The r.f. voltage fed back through the tube elements from plate to grid is exactly neutralized by the feedback through the small variable condenser C_5, which is adjusted to the same capacitance as the actual grid-to-plate capacitance of the tube. A split-stator tuning condenser often is used as a substitute for C_8, which is shown as a single-section variable condenser in figure 1. This provides a center-tap connection to the tuned circuit L_2-C_8 for neutralizing purposes the same as does a bypassed center tap.

● Frequency Multipliers

It is repeated here that quartz crystals are not suitable for direct control of the output frequency of high-frequency transmitters. *Frequency multipliers* are needed to multiply the frequency to the desired value. These multipliers operate on exact multiples of the crystal frequency: a 3.6 megacycle crystal oscillator can be made to control the output of the transmitter on 7.2, or 14.4 megacycles, or even on 28.8 megacycles, by means of one or more frequency multipliers. When used at twice-frequency, as they most usually are, they are often termed *frequency doublers.* A simple doubler circuit is shown in figure 2. It consists of a vacuum tube with its plate circuit tuned to *twice* the frequency of the grid driving circuit. This doubler can be excited from a crystal oscillator, or connected to another doubler or buffer amplifier stage.

Doubling (*frequency multiplication*) is accomplished by operating the tube with extremely high grid bias in order to make the output plate circuit rich in harmonics. The grid circuit is driven approximately to normal values of d.c. grid current through the r.f. choke and grid-leak resistor, shown in figure 2. The resistance value generally is from two to five times as high as that used with the tube for simple amplifying. For the same value of grid current the grid bias is several times as high, and should be at least six times cut-off bias. *Cut-off* is calculated by dividing the d.c. plate voltage by the amplification constant of the tube. It is that value of bias which will cut off the d.c. plate current when no r.f. excitation is present in the grid circuit.

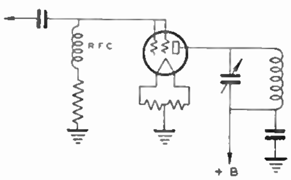


Figure 2—Simple doubler circuit with type 46 Tube

No neutralization is necessary in a doubler circuit, since the plate is tuned to twice the frequency of the grid circuit. The feedback from the doubler plate circuit to the grid circuit is at *twice* the frequency of the grid driving circuit to which the coupling condenser (figure 2) is connected. The impedance of this external tuned grid driving circuit is very low at the doubling frequency and thus there is no tendency for self-excited oscillation when ordinary triode tubes are used. At very high frequencies however, this impedance may be great enough to cause regeneration, or even oscillation, at the tuned output frequency of the doubler.

A doubler can either be neutralized, or made more regenerative by adjusting C_2 in the circuit shown in figure 3.

When condenser C_2 is of the proper value to neutralize the plate-to-grid capacity of the tube, the plate circuit can be tuned to twice the frequency (or to the same frequency) as that of the source of grid drive: the tube is operated as a neutralized amplifier or doubler. The capacity of C_2 can be

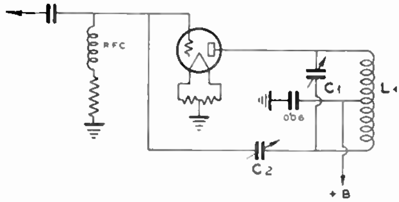


Figure 3—Regenerative Doubler or Neutralized Buffer

increased so that the doubler will become *regenerative,* if the r.f. impedance of the external grid driving circuit is high enough at the output frequency of the doubler. This doubler is regenerative at its output frequency; regeneration will increase the efficiency when there is a lack of sufficient grid excitation. A doubler which receives sufficient grid excitation does not require regeneration to obtain efficiencies of from 50% to 60%. This efficiency refers to the ratio of r.f. power output to d.c. power input of the doubler plate circuit. The circuit in figure 3 generally is operated with the condenser C_2 adjusted for exact neutralization, so that the tube can be operated either as an amplifier or doubler for two-band operation.

Frequency doublers require *bias* of several times cut-off, and high-μ tubes therefore are desirable for this type of service. Tubes which have amplification constants of from 20 to 200 are suitable for doubler circuits. Tetrodes and pentodes usually have amplification constants of approximately 200. Low-μ triodes, having amplification constants of from 3 to 10, are not applicable for doubler service because in some cases the grid voltage must be as high as the plate voltage, for efficient doubling action. The necessary d.c. grid voltage for high-μ tubes can be obtained more easily from average driver stages in conventional exciters.

• Push-Push Doublers

Two tubes can be connected with the grids in push-pull, and the plates in parallel.

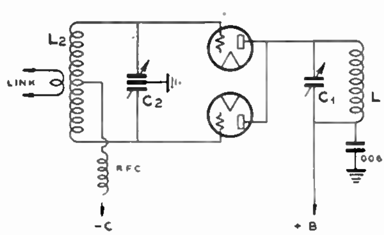


Figure 4—Push-Push Doubler

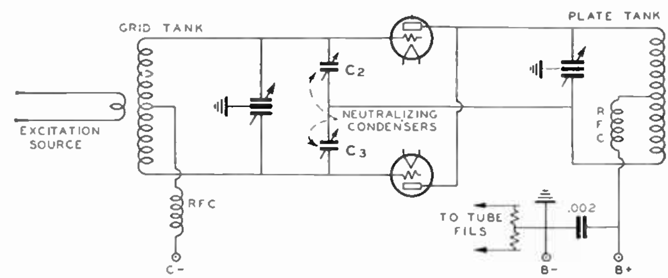


Figure 5

for operation in a so-called *"push-push" doubler,* as shown in figure 4.

This doubler circuit will deliver twice as much output as a single-tube circuit; it has proven popular in amateur transmitters because of its *operating ease.* In previous doubler circuits, capacitive coupling was shown. *Link coupling* to the tuned circuit in a preceding stage is shown in figure 4. This coupling arrangement simplifies the push-pull connection of the two grid circuits. The circuit C_2-L_2 is tuned to the same frequency as that of the preceding tuned circuit, and the doubler plate circuit C_1-L_1 is tuned to *twice* the frequency. The grid circuit should be tuned by means of a split-stator condenser, connected as shown in figure 4, rather than by means of the single-section tuning condenser and bypassed center-tapped coil arrangement. The latter would provide a relatively high impedance at the doubling frequency. The push-push doubler then would be highly regenerative, and in most cases it would break into self-oscillation. The split-stator tuning circuit provides a *capacitive* reactance at the doubling frequency, so that there is very little regenerative action, and the circuit therefore is quite stable.

Some multi-grid crystal oscillators are designed so that frequency doubling can be accomplished directly in the oscillator tube circuit by connecting the various grids in push pull (2 tubes) and the output plates in parallel.

High power push-push doubler stages for use with such tubes as the HK-354D or 250-TH will become too highly regenerative and therefore should be neutralized, as shown in the circuit in figure 5. Each tube is separately neutralized (the plate voltage having first been removed) with the plate circuit tuned to the *same frequency* as that of the grid circuit. The plate circuit then can be tuned to twice the frequency of the grid circuit (*after* the neutralizing process has been completed) without danger of self-oscillation.

Cathode Regeneration

Another form of regenerative doubler is shown in figure 6. This circuit employs a pentode tube with its cathode only partially bypassed for radio frequencies. This provides a common impedance for both plate and grid circuits and causes a regenerative effect at high frequencies, such as 14 or 28 megacycles. The circuit tends to be *degenerative,* rather than *regenerative,* at the low frequencies.

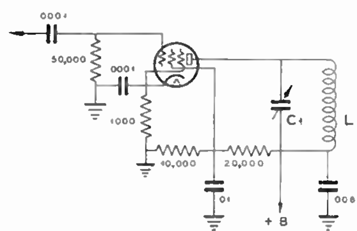


Figure 6—Regenerative Doubler

Neutralizing Circuits

Those screen-grid tubes which have a plate-to-control-grid capacitance of a small fraction of one micro-microfarad require no neutralization. All triodes and some multi-grid tubes must be neutralized for r.f. amplifier service. Single-tube amplifiers can be either plate or grid neutralized. A typical *grid neutralized* circuit is shown in figure 7.

The out-of-phase neutralizing voltage is obtained by using a "split-tank" connection in the grid, rather than in the plate circuit.

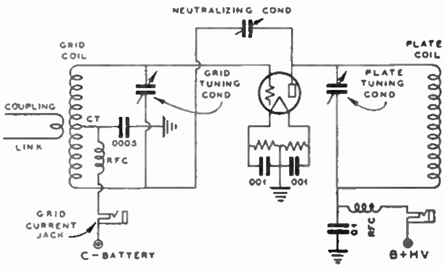


Figure 7—Grid neutralizing with series feed

The circuit shown in figure 7 is suitable for low or medium-C tubes, in which the grid-to-filament capacitance is less than 8 or 10 $\mu\mu$fds. Tubes with higher interelectrode capacitance cannot be satisfactorily neutralized in circuits which have a single-section tuning condenser in both plate and grid circuits. The circuit in figure 7 becomes more regenerative as the frequency increases, and cannot be used at frequencies of the order of 28 megacycles. The tuning condenser which is connected across the neutralizing circuit should be of the split-stator variety for frequencies above 7 Mc. The *electrical*

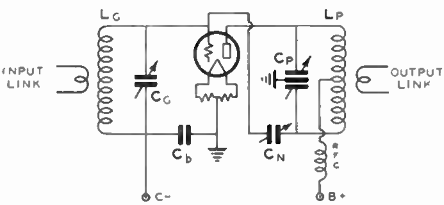


Figure 8—Plate, or Hazeltine neutralization

center of the tuning condenser (rotor of a split-stator condenser) is connected to ground, or bypassed to ground, but the center-tap of the coil is *not* bypassed to ground. This holds for either plate or grid neutralization. An r.f. choke is necessary at the center-tap for external connection to the plate supply or grid-bias supply. Grid and plate neutralization are equally efficient, and the choice between the two usually depends upon the type of equipment available when building the r.f. amplifier. This point is emphasized later in this chapter, where a number of c.w. amplifier designs are treated.

A comparison between split-stator and single-section plate neutralized circuits can be seen in figure 9.

As was previously stated, the single-section condenser tuned circuit is somewhat regenerative, and therefore is more easily driven from a low power source of grid excitation. Some regeneration can be tolerated in an amplifier for c.w. transmission, but not for radio phone service. The split-stator tuned circuit *always* should be used in modulated r.f. amplifiers which operate at high frequencies. The single-section condenser tuned circuit only requires about half as much grid driving power as the split-

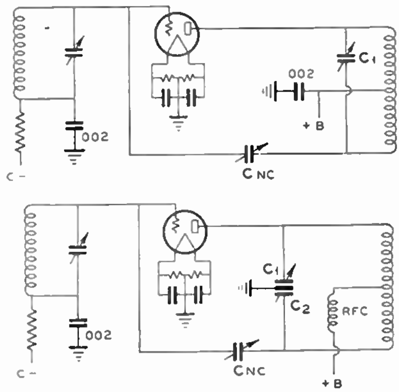


Figure 9—The upper circuit has a center-tapped plate coil bypassed to ground; the lower circuit uses a split-stator plate tuning condenser with r.f. choke in the coil center-tap connection

stator tuned circuit. In c.w. transmitter design this may eliminate one buffer stage, or allow higher efficiencies to be obtained from the final amplifier. The efficiency of the final amplifier is dependent to a large extent upon the amount of grid drive; if there is a deficiency in the latter, the amplifier efficiency may drop to a low value, with attendant low r.f. power output and excessive plate dissipation.

The same grid excitation requirements hold true for the two types of grid neutralized circuits as well as for the two types of plate neutralized circuits.

• Push-Pull R. F. Circuits

Two tubes can be connected for *push-pull* operation so as to obtain twice as much output as that of a single tube. A push-pull connection, such as that shown in figure 10, also has an advantage in that the circuit can be more easily balanced than a single-tube r.f. amplifier. The various interelectrode capacities and neutralizing condensers are connected in such a manner that those on one side of the tuned circuits are exactly equal to those on the opposite side. For this reason, push-pull r.f. amplifiers can be more easily neutralized in very-high-frequency

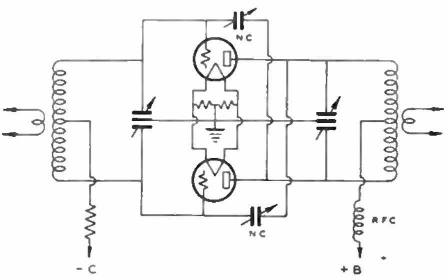


Figure 10—Push-pull r.f. amplifier stage

transmitters; also they usually remain in perfect neutralization when tuning the amplifier to different bands.

The center-tap of the grid coil is sometimes bypassed to ground; in other cases it can "float." It is possible to use a single-section plate tuning condenser with twice the plate spacing between adjacent plates as that of a normal split-stator tuning condenser, providing a *split-stator grid* tuning condenser is used in the push-pull amplifier. The center-tap of the plate tuned circuit should be bypassed to ground in this case. The plate tuning condenser, as a general rule, should be of the split-stator type, with the stator connected to ground, or bypassed to ground by means of a high-voltage .002 μfd. mica condenser in series with the rotor of the variable condenser and ground. The latter connection is particularly desirable because it prevents a d.c. arc from being formed and damaging the r.f. choke and power supply components in the event of r.f. flashover across the plates of the tuning condenser.

● Neutralizing Procedure

The r.f. amplifier is neutralized to prevent self-oscillation or regeneration. A neon bulb, a flashlight lamp and a loop of wire, or an r.f. galvanometer can be used as a *"null indicator"* for neutralizing low power stages. Plate voltage is disconnected from the r.f. amplifier stage while it is being neutralized. Normal grid drive then is applied to the r.f. stage; the neutralizing indicator is coupled to the plate coil, and the plate tuning condenser is tuned to resonance. The neutralizing condenser (or condensers) then can be adjusted until *minimum* r.f. is indicated for optimum settings of both grid and plate tuning condensers. Both neutralizing condensers are adjusted simultaneously when a push-pull stage is being neutralized.

A final check for neutralization should be made with a d.c. milliammeter connected in the grid-leak or grid-bias circuit. There will be no movement of the meter reading as the plate circuit is tuned through resonance (without plate voltage being applied) when the stage is completely neutralized. The milliammeter check is more accurate than any other means for indicating complete neutralization and it also is suitable for neutralizing the stages of a high power transmitter.

Push-pull circuits usually can be more completely neutralized than single ended circuits when operating at very high frequencies. In the intermediate range of from 3 to 15 megacycles, single-ended circuits will give satisfactory results. Operation in the 3-to-15 megacycle range calls for a split-stator tuning condensers; for example: a grid-neutralized circuit requires a split-stator grid tuning condenser, while a plate-neutralized circuit requires a split-stator plate tuning condenser.

● Neutralizing Problems

If a stage cannot be completely neutralized, the difficulty can be traced to one or more of the following causes: (1) The filament leads may not be bypassed to the common ground bus connection of that particular stage. (2) The ground lead from the rotor connection of the split-stator tuning condenser to filament may be too long. (3) The neutralizing condensers may be in a field of excessive r.f. from one of the tuning coils. (5) Electromagnetic coupling may exist between grid and plate coils, or between plate and preceding buffer or oscillator circuits. (6) Insufficient shielding between stages, or between grid and plate circuits in compact transmitters may prevent neutralization or give false indications of neutralizing adjustments. (7) If shielding is placed too close to plate circuit coils, neutralization will not be secured because of induced currents in the shields. (8) Parasitic oscillations may take place when plate voltage is applied. The cure for the latter is to rearrange the parts, change the length of grid or plate or neutralizing leads, insert an ultra-high-frequency r.f. choke in the grid lead or leads, or eliminate the grid r.f. chokes which may be the cause of a low-frequency parasitic (in conjunction with plate r.f. chokes).

High power amplifiers can be neutralized under normal operating conditions, when necessary, by means of a cathode-ray oscilloscope. The neutralizing condenser or condensers can first be adjusted to approximate settings from available data on grid-to-plate capacities, and a knowledge of the maximum and minimum capacities of the neutralizing condensers. The latter can be adjusted for exact neutralization under normal conditions by observing the wave pattern on the oscilloscope.

• Grid Excitation

Sufficient grid excitation must be available for class-B or class-C service. The excitation for a plate modulated class-C stage must be sufficient to drive a normal value of d.c. grid current through the bias supply of about 2½ times cut-off. The bias voltage preferably should be obtained from a combination of grid-leak and fixed C-bias supply. Cut-off bias can be calculated by dividing the amplification constant of the tube into the d.c. plate voltage. This is the value normally used for class-B amplifiers (fixed bias, no grid-leak). Class-C amplifiers use from 1½ to 5 times this value, depending upon the available grid drive, or excitation, and the desired plate efficiency. Less grid excitation is need for c.w. operation, and the values of fixed bias (if greater than cut-off) may be reduced, or the value of the grid-leak resistor can be lowered until normal d.c. grid current flows. This value should be between 75% and 100% of the value listed under tube characteristics.

The values of grid excitation listed for each type of tube may be reduced by as much as 50% if only moderate power output and plate efficiency is desired. When consulting the tube table, it is well to remember that the values listed are those actually used by the tube for grid excitation. The power lost in the grid bias supply in the form of I^2R loss, or charging current, plus that lost in the tuned circuits, must be taken into consideration when calculating the available grid drive. At very high frequencies, the r.f. circuit losses may be greater than the power lost in the grid-bias, plus that which is useful for grid drive.

Readjustments in the tuning of the oscillator, buffer, or doubler circuits, will result in greater grid drive to the final amplifier. The actual grid driving power is proportional to the d.c. voltage developed across the grid-leak (or bias supply) multiplied by the d.c. grid current.

Link coupling between stages, particularly to the final amplifier grid circuit, normally will provide more grid drive than can be obtained from other coupling systems. The number of turns in the coupling link and the location of the turns on the coil can be varied with respect to the tuned circuits to obtain the greatest grid drive for allowable values of buffer or doubler plate current. Slight readjustments sometimes can be made after plate voltage has been applied.

Power output and efficiency, within limits, are proportional to the grid drive in class-C amplifiers. Excessive grid current will damage the tubes by overheating the grid structure; beyond a certain point of grid drive no increase in power output can be obtained for a given plate voltage.

• Plate Circuit Tuning

When the amplifier is completely neutralized, reduced plate voltage should be applied before any load is coupled to the amplifier. This reduction in plate voltage should be at least 50% of normal value because the plate current will rise to excessive values when the plate tuning condenser is not adjusted to the point of resonance. The latter is indicated by the greatest dip in reading of the d.c. plate current milliammeter; the r.f. voltage across the plate circuit is greatest at this point. With no load, the r.f. voltage may be several times as high as when operating under conditions of full load; this may result in condenser flash-over if normal d.c. voltage is applied. The no-load plate current at resonance should dip to 10% or 20% of normal value if the plate circuit losses are not excessive, and if no *parasitic oscillations* are taking place.

The load (antenna or succeeding r.f. stage) then can be coupled to the amplifier under test. The coupling can be increased until the plate current at resonance (greatest dip in plate current meter reading) approaches the normal values at which the tube is rated. The value at reduced plate voltage should be proportionately less in order to prevent excessive plate current load when normal plate voltage is applied. Full plate voltage should not be applied to an amplifier unless the r.f. load also is connected, otherwise the condensers will arc-over or flash-over, thereby causing an abnormally high tube plate current which will damage the tube. The tuned circuit impedance is lowered when the amplifier is loaded, as are the r.f. voltages across the tuning condenser.

• Tank Circuit Capacities

The plate tank circuit of any transmitting r.f. amplifier consists of a parallel resonant tuned circuit. The ratio of actual capacity to inductance of a tuned circuit in a class-C amplifier is of considerable importance. The capacity must be great enough at a desired frequency to give a certain "fly-wheel" effect to the tuned circuit. The tube furnishes power during only a small part of the time of each r.f. cycle; the *LC* circuit must have a sufficient "fly-wheel" effect to carry on during the remainder of the r.f. cycle if approximate sine wave output is desired. The latter is necessary because an irregular wave-form of the carrier frequency will produce excessive harmonic power output. For example: 70% fundamental carrier frequency and 30% in the form of harmonics of the carrier frequency is obtained easily by using very low C circuits when operating a class-C amplifier at high values of grid drive. Radiation of harmonics is illegal, not to mention the power that is wasted. Proper L-to-C ratios will reduce the harmonic content to values of less than 5%, and further reduction is possible by means of r.f. filters or antenna tuned circuits.

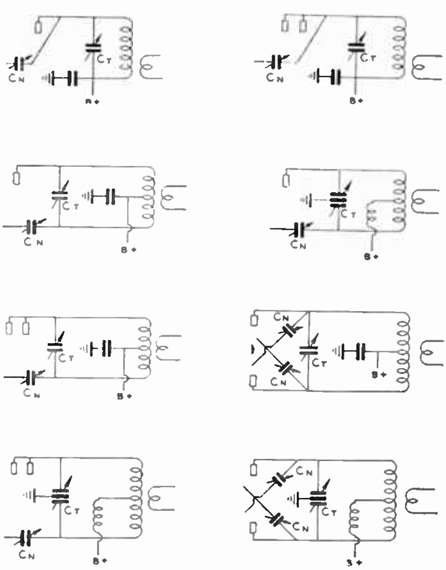


Figure 11—Typical Tank Circuits

The "flywheel-" effect normally is defined as the ratio of radio-frequency volt-amperes to actual power transferred to the antenna circuit, or $\frac{VA}{W}$. For all practical purposes, this value is equal to the circuit Q and should not be less than 10, even for c.w. operation. Values of from 15 to 20 are more appropriate for phone operation in order to prevent distortion of the modulated carrier wave output.

The ratio between the inductive reactance of a coil and its effective resistance gives a measure of its efficiency and is called Q, where

$$Q = \frac{\omega L}{R}$$

The value of R depends largely upon the degree of antenna loading, because Q for an unloaded circuit may be over 100, and may drop to 5 or 10 as the load is increased to normal. By properly proportionating the value of C and L, the circuit Q can be made from 15 to 20 at normal values of tube plate current. The effective series resistance in the tuned circuit is $R = \frac{1}{Z(\omega C)^2}$, therefore $Z = \frac{1}{R(\omega C)^2}$ which is the load impedance into which the tube should work. Practically, this value of Z is one-half of the d.c. tube impedance, calculated by dividing the d.c. plate voltage by the d.c. plate current.

$$\text{Since } Q = \frac{\omega L}{R} = \frac{1}{\omega CR} = \omega CZ = \frac{\omega CR_p}{2}$$

$$\text{then } C = \frac{2Q}{\omega R_p} = \frac{Q}{\pi f R_p}, \text{ because } \omega = 2\pi f.$$

where f is the frequency of operation and π is the constant 3.1416. For phone operation, C in micro-micro-farads can be calculated if the d.c. plate voltage and current and frequency of operation are known.

$$C = \frac{6,400,000}{fR_p}$$

C = $\mu\mu$fd.
f = frequency in megacycles.
R_p = d.c. plate resistance = $\frac{E}{I}$

This formula applies for single-ended grid neutralized amplifiers. For plate neutralization, these values of plate tuning capacities should be divided by 4, since in this case the tube is across only one-half of the tuned circuit, or one-fourth of its impedance.

Push-pull circuits are similar to plate neutralized circuits, except for greater plate current, therefore lower plate resistance. Somewhat lower values of Q are permissible

Plate Neutralized Circuit Class C Modulated Amplifier Tuning Capacity

DC Plate Resist. E_{dc}/I_{dc}	2 Mega-cycles (Capac. in μμfd.)	4 Mega-cycles (Capac. in μμfd.)	14 Mega-cycles (Capac. in μμfd.)	28 Mega-cycles (Capac. in μμfd.)
2,000	400	200	57	28
3,000	267	133	38	19
4,000	200	100	28	14
5,000	160	80	23	11
6,000	133	66	19	10
7,500	107	53	15	8
10,000	80	40	11	6
15,000	53	27	8	4
20,000	40	20	6	3
25,000	32	16	5	2
30,000	27	13	4	2

Grid Neutralized Circuit Modulated Class C Amplifier Plate Tuning Capacity

DC Plate Resist. E_{dc}/I_{dc}	2 Mega-cycles (Capac. in μμfd.)	4 Mega-cycles (Capac. in μμfd.)	14 Mega-cycles (Capac. in μμfd.)	28 Mega-cycles (Capac. in μμfd.)
2,000	1600	800	228	114
3,000	1064	532	152	76
4,000	800	400	114	56
5,000	640	320	92	46
6,000	533	266	76	38
7,500	427	213	60	30
10,000	320	160	46	22
15,000	217	108	30	15
20,000	160	80	23	11
25,000	128	64	18	8
30,000	106	53	15	7

Push-Pull Class C Modulated Amplifier Plate Tuning Capacity

DC Plate Resist. E_{dc}/I_{dc}	2 Mega-cycles (Capac. in μμfd.)	4 Mega-cycles (Capac. in μμfd.)	14 Mega-cycles (Capac. in μμfd.)	28 Mega-cycles (Capac. in μμfd.)
2,000	200	100	29	14
3,000	133	66	19	9
4,000	100	50	14	7
5,000	80	40	11	6
6,000	67	33	10	5
7,500	53	27	8	4
10,000	40	20	6	3
15,000	27	13	4	2
20,000	20	10	3	1.5

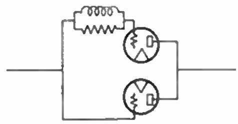
since the tank circuit receives impulses during a portion of each half cycle in a push-pull circuit. A Q of 10 is sufficient in the case of a plate modulated class-C amplifier. Tables are given for grid neutralized, plate neutralized, and plate-modulated amplifiers. The d.c. plate resistance, in all cases, is calculated by dividing the d.c. plate voltage by the total d.c. plate current.

The values given in these tables can be divided by two for c.w. transmitters.

Parasitic Oscillations in R. F. Amplifiers

"Parasitics" are undesirable oscillations either of very high or very low frequencies which occur in radio-frequency amplifiers. Their presence reduces the operating efficiency and output at the desired frequency, and introduces *distortion* in radiophone transmitters. Parasitics can be detected by excessive values of plate current in comparison to the r.f. output at the desired frequency; difficulty will be experienced in obtaining a satisfactory dip in plate current when tuning the r.f. amplifier circuit to resonance when unloaded.

Parallel or push-pull operation of two tubes often will form a *Tuned-Grid-Tuned-Plate* oscillating circuit which will be resonant at from 3 to 6 meters. This u.h.f. circuit is formed by the two plate leads and grid leads. Parasitic oscillations of this type can be prevented by making one of the grid leads longer than the other, or by the in-



PARASITIC SUPPRESSOR FOR PARALLEL OR PUSH-PULL R F AMPLIFIERS

Figure 12

stallation of a *parasitic suppressor* in one of the grid or plate leads, as shown in figure 12.

From six to eight turns of No. 14 wire, ½-inch in diameter and slightly spaced in will provide a suitable parasitic choke. A 100 to 200 ohm 2-watt carbon resistor sometimes is shunted across the parasitic r.f. choke, as shown in fig. 12. Parasitic elimination requires considerable experimenting with each individual amplifier. An all-wave diode-type *field strength meter* or *absorption wavemeter* is of great convenience in locating the frequency of the undesired oscillation, and also an aid in making tests to remove the parasitic.

Low frequency parasitic oscillations may occur in an r.f. amplifier in which r.f. chokes are in both the bias and plate supply leads. The r.f. chokes form a tuned-grid-tuned-plate circuit at some very low r.f. frequency, as determined by the natural period of the plate and grid r.f. chokes.

The leads to the plate tank condenser and neutralizing condenser may form an ultra-high-frequency oscillator circuit in a single-tube amplifier. A change in physical layout, and use of shorter leads, are the best cure for most parasitic oscillations of these types. Parasitic oscillations, in general, are more troublesome in high power transmitters.

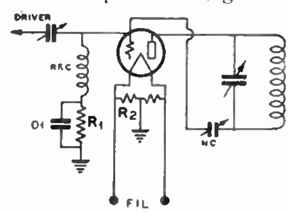
Grid Bias

All amplifiers require some form of *grid bias* for proper operation. Practically all r.f. amplifiers operate in such a manner that plate current flows in the form of short, peaked impulses which have a duration of only a fraction of an r.f. cycle. The plate current is cut-off during the greater part of the r.f. cycle, which makes for high efficiency and high power output from the tubes, since there is no power being dissipated by the plates during a major portion of each r.f. cycle. The grid bias must be sufficient to cut-off the plate current, and in very high efficiency class-C amplifiers this bias may be several times cut-off value. Cut-off bias, it will be recalled, is that value of grid voltage which will reduce the plate current to zero, and the method for calculating it has been indicated previously. This theoretical value of cut-off will not reduce the plate current completely to zero, due to the "variable μ" tendency which is characteristic of all tubes as the cut-off point is approached. This factor, however, is of no importance in practical applications.

Radiophone class-C amplifiers should be operated with the grid bias adjusted to values between two and three times cut-off at normal values of d.c. grid current. C.w. telegraph transmitters can be operated with bias as low as cut-off, if limited excitation is available and high plate efficiency is not a factor. In a c.w. transmitter the bias supply, or resistor, should be adjusted to the point which will allow normal grid current to flow for the particular amount of grid driving r.f. power available. This form of adjustment will allow more output from the under-excited r.f. amplifier than when twice cut-off, or higher bias is used with low values of grid current.

Grid Leak Bias

A resistor can be connected in the grid circuit of an r.f. amplifier to provide grid-leak bias. This resistor R_1 in figure 13 is part of the d.c. path in the grid circuit.

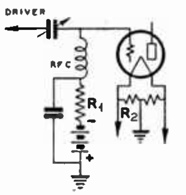


GRID LEAK BIAS

Figure 13

The r.f. excitation is applied to the grid circuit of the tube. This causes a pulsating d.c. current to flow through the bias supply lead and any current flowing through R_1 produces a voltage drop across that resistance. The grid of the tube is positive for a short duration of each r.f. cycle, and draws electrons from the filament or cathode of the tube during that time. These electrons complete the circuit through the d.c. *grid return*. The voltage drop across the resistance in the grid return provides a *negative bias* for the grid. The r.f. chokes in figures 13, 14, 15 and 16 prevent the r.f. excitation from flowing through the bias supply, or from being short-circuited to ground. The bypass condenser across the bias source proper is for the purpose of providing a low impedance path for the small amount of stray r.f. energy which passes through the r.f. choke.

Grid-leak bias automatically adjusts itself even with fairly-wide variations of r.f. excitation. The value of grid-leak resistance should be such that normal values of grid current will flow at the maximum available amount of r.f. excitation. Grid-leak bias cannot be used for grid-modulated or linear amplifiers in which the d.c. grid current is approximately zero and constantly varying. Grid-leak bias alone provides no protection against excessive plate current in case of failure of the crystal oscillator, or failure of any other source of r.f. grid excitation.



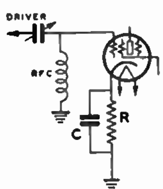
COMBINATION BATTERY & GRID LEAK BIAS

Figure 14

A *C-battery* or *C-bias* supply can be connected in series with the grid leak, as shown in figure 14. This additional C-bias should at least be made equal to cut-off bias. This will protect the tube in the event of failure of grid excitation.

• Cathode Bias

A resistor can be connected in series with the cathode or center-tapped filament lead of an amplifier to secure *automatic bias*. The plate current flows through this resistor, then back to the cathode or filament, and the voltage drop across the resistor can be applied to the grid circuit by connecting the grid-bias lead to the grounded, or power supply end of the resistance *R*, as shown in figure 15.



CATHODE BIAS

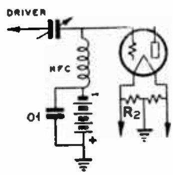
Figure 15

The grounded (B-minus) end of the cathode resistor is negative relative to the filament by an amount equal to the voltage drop across the resistor. The value of resistance must be so chosen that the desired plate current flowing through the resistor will bias the tube for proper operation at that plate current.

This type of bias is used more extensively in audio-frequency than in radio-frequency amplifiers. The voltage drop across the resistor must be substracted from the total plate supply voltage when calculating the power input to the amplifier, and this loss of plate voltage in an r.f. amplifier may be excessive. A class-A audio amplifier is biased only to approximately one-half cut off, whereas an r.f. amplifier may be biased to twice cut-off, or more, and thus the plate supply voltage loss may be a large percentage of the total available voltage when using low or medium μ tubes.

• Separate Bias Supply

C-batteries, or an external C-bias supply sometimes are used for grid bias of an amplifier, as shown in figure 16.



BATTERY BIAS

Figure 16

Battery bias gives very good voltage regulation and is satisfactory for grid modulated or linear amplifiers, which operate nearly at zero grid current. In the case of class-C amplifiers which operate with high grid current, battery bias is not very satisfactory. This d.c. current has a charging effect on the dry batteries; after a few months of service the cells will become unstable, bloated and noisy.

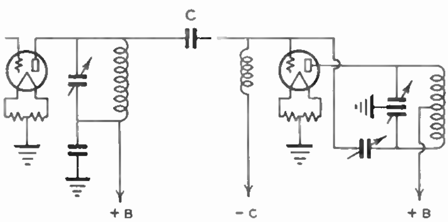
A separate a.c. operated power supply can be used as a substitute for dry batteries. The bleeder resistance across the output of the filter can be made sufficiently low in value that the grid current of the amplifier will not appreciably change the amount of negative grid-bias voltage. This type of bias supply is used in class-B audio and class-B r.f. linear amplifier service where the voltage regulation in the C-bias supply is important. For a class-C amplifier it is not so important, and an economical design of components in the power supply therefore can be utilized.

● R. F. Coupling Systems

Energy is coupled from one circuit into another in several ways. These various systems are called "couplings," and are of three general types; *capacitive coupling, inductive coupling* or *link coupling*. The latter is a special form of inductive coupling. The choice of a coupling method depends upon the purpose for which it is to be used.

● Capacitive Coupling

The grid circuit of an amplifier or doubler circuit can be coupled to a preceding driver stage by means of a fixed or variable condenser, as shown in figure 17.



CAPACITIVE COUPLING
Figure 17

Condenser C isolates the d.c. power supplies from each other and provides a low impedance path for the r.f. energy between the tube being driven, and the driver tube. This method of coupling is simple and economical for low power amplifier or exciter stages, but has certain disadvantages for the coupling of a final amplifier to the preceding stage. The grid leads in a neutralized amplifier should be as short as possible, but this is difficult to attain in the physical arrangement of a high power amplifier with respect to a capacitively coupled driver stage.

The r.f. choke in series with the C-bias supply lead must offer an extremely high impedance to the r.f. circuit, and this too is difficult to obtain when the transmitter is operated on several harmonically related bands. Another disadvantage of capacitive coupling is the difficulty of adjusting the load on the driver stage. Impedance adjustment can be accomplished by tapping the coupling lead a part of the way down on the plate coil of the tuned stage of the driver circuit, as can be seen by referring back to figure 1. However, when this lead is tapped part way down on the coil, a *parasitic oscillation* tendency becomes very troublesome and is difficult to eliminate. If

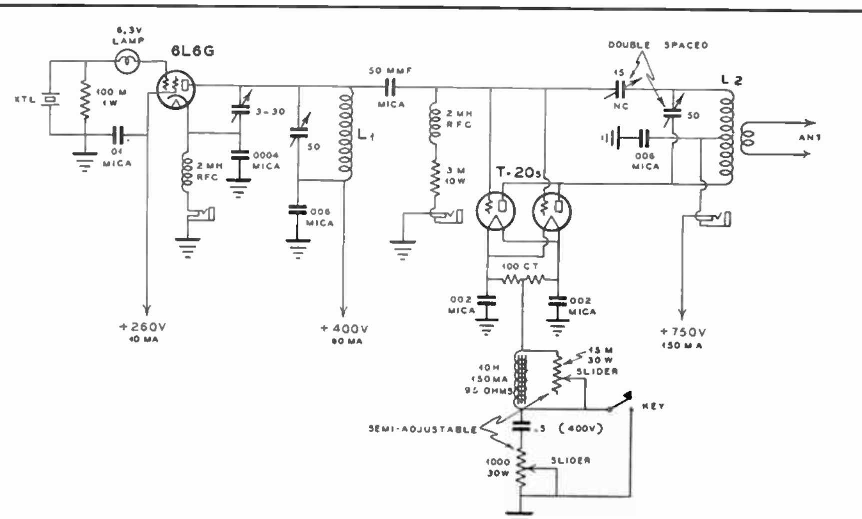


Figure 18—Typical Capacitive Coupling Circuit between 6L6-G Oscillator and T-20 R. F. Amplifier. The 50 MMF Coupling Condenser Can Be Made Variable, If Desired

the driver stage has sufficient power output so that an impedance mismatch can be tolerated, the condenser C in figure 17 can be connected directly to the top of the coil. and made small enough in capacity for the particular frequency of operation that not more than normal plate current is drawn by the driver stage.

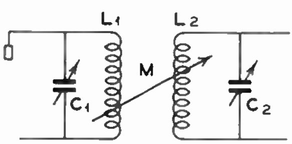
The impedance of the grid circuit of a class-C amplifier may be as low as a few hundred ohms in the case of a high-μ tube, and may range from that value up to a few thousand ohms for low-μ tubes.

Capacitive coupling places the grid-to-filament capacity of the driven tube directly across the driver tuned circuit, which reduces the L-C ratio and sometimes makes the r.f. amplifier difficult to neutralize because the additional driver stage circuit capacities are connected into the grid circuit.

Capacitive coupling can be used to advantage in reducing the total number of tuned circuits in a transmitter so as to conserve space and cost. It also can be used to advantage between stages for driving tetrode or pentode amplifier or doubler stages. These tubes require relatively small amounts of grid excitation.

• Inductive Coupling

The r.f. amplifier often is coupled to the antenna circuit by means of *inductive coupling*, which consists of two coils electromagnetically coupled to each other. The antenna tuned circuit can be of the series-tuned type, such as is illustrated for *Marconi* type 160 meter antennas in the chapter on *Antennas*. Parallel resonant circuits sometimes are used, as shown in figure 19, in which the antenna feeders are connected across the whole or part of the circuit L_2-C_2.



INDUCTIVE COUPLING

Figure 19

The degree of coupling is controlled by varying the mutual inductance of the two coils, which is accomplished by changing the spacing between the coils.

Inductive coupling also is used extensively for coupling r.f. amplifiers in radio receivers, and occasionally in transmitting r.f. amplifier circuits. The mechanical problems involved in adjusting the degree of coupling in a transmitter make this system of limited practical value.

• Link Coupling

A special form of inductive coupling which is applied to radio transmitter circuits is known as *link coupling*. A low impedance r.f. transmission line, commonly known as a *"link,"* couples the two tuned circuits together. Each end of the line is terminated in one or more turns of wire, or *"loops,"* wound around the coils which are being coupled together. These loops should be coupled to each tuned circuit at the point of zero r.f. potential. This *nodal* point is the center of the tuned circuit in the case of plate neutralized for push-pull amplifiers, and at the positive-B end of the tuned circuit in the case of screen-grid and grid neutralized amplifiers. The nodal point in an antenna tuned circuit depends upon the type of feeders, and the node may be either at the center or at one end of the tuned circuit. The nodal point in tuned grid circuits is at the C-bias or grounded end of plate-neutralized r.f. or screen-grid amplifiers, and at the center of the tuned grid coil in the case of push-pull or grid-neutralized amplifiers. The link coupling turns should be as close to the nodal point as possible. This ground connection to one side of the link is used in special cases where harmonic elimination is important, or where all capacitive coupling between two circuits must be minimized.

Typical link coupled circuits are shown in figures 20, 21 and 22.

Some of the advantages of link coupling are listed here:

(1) It eliminates coupling taps on tuned circuits.

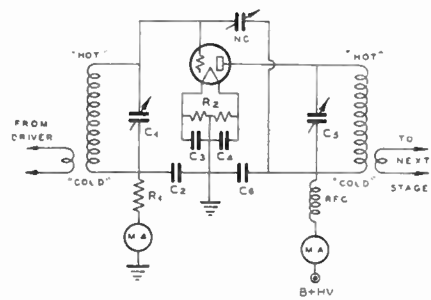


Figure 20—Link coupling between single-ended stages

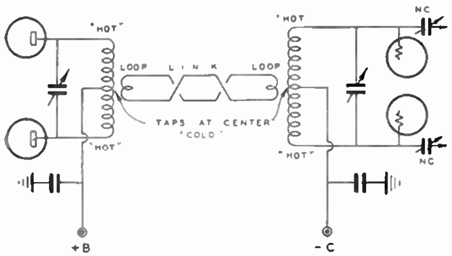


Figure 21—Link coupling between push-pull stages

(2) It permits the use of series power supply connections in both tuned-grid and tuned-plate circuits, and thereby eliminates the need of r.f. chokes.

(3) It allows separation between transmitter stages of distances up to several feet without appreciable r.f. losses.

(4) It reduces capacitive coupling and thereby makes neutralization more easily attainable in r.f. amplifiers.

(5) It provides semi-automatic impedance matching between plate and grid tuned circuits, with the result that as much as 50% greater grid "swing" can be obtained in comparison to capacitive coupling.

(6) It effectively reduces harmonic radiation when a final amplifier is coupled to a tuned antenna circuit, due to the additional tuned circuit and, particularly, it eliminates capacitive coupling to the antenna.

The link coupling line and loops can be made of no. 18 or 20 gauge push-back wire for coupling low power stages. High power circuits can be link coupled by means of no. 8 to no. 12 rubber-covered wire, or EO-1 cable.

The impedance of a link coupling line varies from 75 to 200 ohms, depending upon the diameter of the conductors and the spacing between them.

Grid Saturation

Excessive grid excitation is just as injurious to a vacuum tube as abnormal plate current or low filament operation. Too much grid driving power will overheat the grid wires in the tube, and will cause a release of gas in certain types of tubes. An excess of grid drive will not appreciably increase the power output and increases the efficiency only slightly after a certain point is reached. The grid current in the tube should not exceed the values listed in the *Tube Tables*, and care also should be exercised to have the bias voltage low enough to prevent flashover in the stem of the vacuum tube.

Grid excitation usually refers to the actual r.f. power input to the grid circuit of the vacuum tube, part of which is used to drive the tube, and part of which is lost in the C-bias supply. There is no way to avoid wasting a portion of the excitation power in the bias supply.

R. F. Chokes

Radio-frequency chokes are connected in circuits for the purpose of preventing r.f. energy from being short-circuited, or escaping into power supply circuits. They consist of inductances wound with a large number of turns, either in the form or a solenoid or "universal" pie-winding. These inductances are designed to have as much inductance and as little distributed or shunt capacity as possible, since the capacity bypasses r.f. energy. The unavoidable small amount of distributed capacity resonates the inductance, and this frequency normally should be lower than the frequency at which the transmitter or receiver circuit is oper-

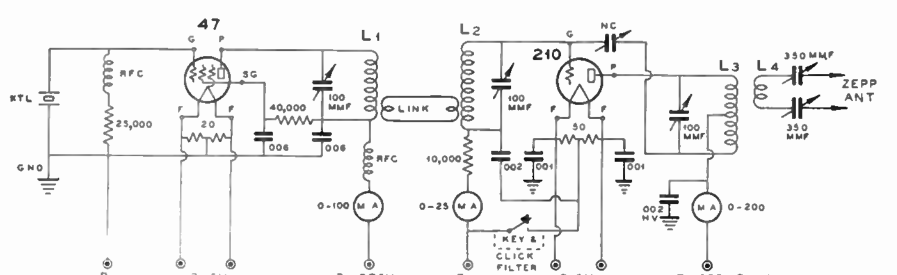


Figure 22—Complete Circuit Diagram of 47 Oscillator link coupled to 210 amplifier stage. One or two turns of wire are wound around coils L1 and L2 to form the coupling loop. The two loops are connected through a twisted-pair feed line, made with hook-up wire.

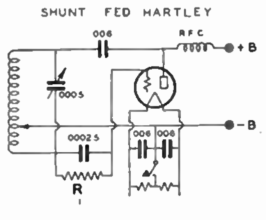


Figure 23

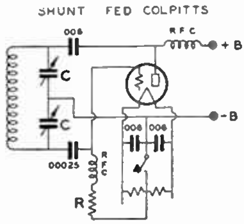


Figure 24

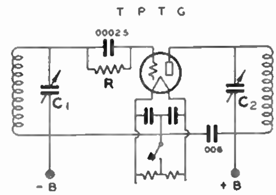


Figure 25

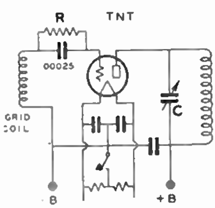


Figure 26

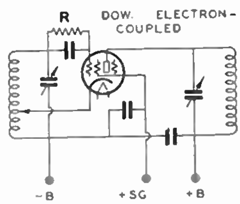


Figure 27

COMMON TYPES OF SELF-EXCITED OSCILLATORS

ating. R.f. chokes for operation on several harmonically-related bands must be designed carefully so that the impedance of the choke will be extremely high (several hundred thousand ohms) in each of the bands.

The r.f. choke is resonant to the harmonics of its fundamental resonant frequency; however, the *even* harmonics have a very low impedance, so that an r.f. choke designed for maximum impedance in the 80 meter amateur band would not be satisfactory for operation in the 40 meter band. The harmonic resonance points of the r.f. choke usually are made to fall *between* frequency bands, so that a *reasonably* high value of impedance is obtained on *all* bands. The d.c. current which flows through the r.f. choke largely determines the size of wire to be used in the windings. The inductance of r.f. chokes for very short wavelengths is much less than for chokes designed for broadcast and ordinary short-wave operation, so that the impedance will be as high as possible in the desired range of operation. A very high inductance r.f. choke has more distributed capacity than a smaller one, with the result that it will actually offer *less* impedance at very high frequencies.

● Self-Excited Oscillators

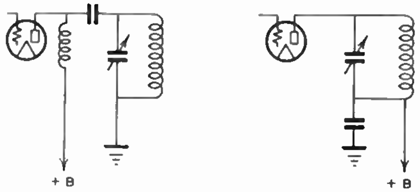
A continuously variable range in frequency control often is desirable for a radio transmitter. Some form of *self-excited oscillator* (s.e.o.) is a practical means of accomplishing this purpose. The *electron-coupled oscillator* is to be preferred because of its greater stability with respect to power supply voltage variation. Good design of a self-excited oscillator requires the use of good parts, solid connections, freedom from vibration, and a power supply with a built-in voltage regulator. The construction of an exciter of this type is more difficult and costly than is that of a crystal-controlled oscillator, for comparative stability of frequency control. For this reason it is not in general use.

In many cases a self-excited oscillator is used as a complete transmitter, especially on the 80 meter c.w. band, employing a fairly large size transmitter tube. Simplicity and variable frequency control are its only virtues. The output efficiency is less than can be obtained in an r.f. amplifier, and the frequency *stability* can be very poor under certain conditions.

● Shunt and Series Feed

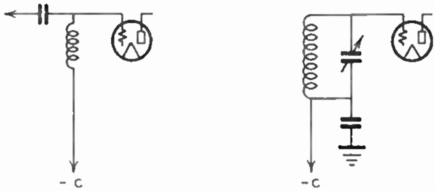
Direct-current grid and plate connections are made either by *shunt* or *parallel feed* systems. Simplified forms of each are shown in figures 28 and 29.

Series feed can be defined as that in which the d.c. connection is made to the grid or plate circuit at a point of very low r.f. po-



PARALLEL FEED SERIES FEED

Figure 28



SHUNT BIAS FEED SERIES BIAS FEED

Figure 29

tential. Shunt feed always is made to a point of high r.f. voltage and always requires a high impedance r.f. choke or resistance in the connection to the high r.f. point in order to prevent loss of r.f. power.

Series feed is more popular than shunt feed, since r.f. choke coils can usually be omitted.

● Parallel and Push-Pull Tube Circuits

The comparative r.f. power output from parallel or push-pull operated amplifiers is the same if proper impedance matching is accomplished and if sufficient grid excitation is available in both cases.

Parallel operation of tubes has some advantages in transmitters designed for operation on 40, 80 and 160 meters, or for broadcast band operation. Only one neutralizing condenser is required for parallel operation, as against two for push-pull. However, on wavelengths below 40 meters, parallel tube operation is not advisable because of the unbalance in capacity across the tank circuits. Low-C types of vacuum tubes can be connected in parallel with less difficulty than the high-C types, in which the combined interelectrode capacities might be quite high in the parallel connection.

Push-pull operation provides a well-balanced circuit insofar as miscellaneous capacities are concerned; in addition the circuit can be neutralized more easily, especially in high-frequency amplifiers. The L-C ratio in a push-pull amplifier can be made higher than in a plate-neutralized parallel-tube operated amplifier. Push-pull amplifiers, when perfectly balanced, have less second-harmonic output than parallel or single-tube amplifiers. In actual practice, undesired capacitive coupling and circuit unbalance usually nullifies this theoretical advantage of push-pull r.f. circuits.

● C. W. Telegraphy Keying

The carrier frequency signal from a c.w. transmitter must be broken into dots and dashes in the form of *keying* for the transmission of code characters. The carrier signal is of a constant amplitude while the key is closed, and is entirely removed when the key is open. If the change from the *no-output* condition to *full-output* occurs too rapidly, an undesired *key-click* effect takes place, which causes interference in other signal channels. If the opposite condition of full output to no output condition occurs too rapidly, a similar effect takes place.

The two general methods of keying a c.w. transmitter are those which control either the excitation, or the plate voltage which is applied to the final amplifier. Direct plate voltage control can be obtained by connecting the key in the primary line circuit of the high voltage plate power supply. A slight modification of direct plate voltage control is the connection of the c.w. key or relay in the filament center-tap lead of the final amplifier. *Excitation keying* can be of several forms, such as crystal oscillator keying, buffer stage keying, or blocked-grid keying.

Key clicks should be eliminated in all c.w. telegraph transmitters. Their elimination is accomplished by preventing a too-rapid make-and-break of power to the antenna circuit. A gradual application of power to the antenna, and a similarly slow cessation, will eliminate key clicks. Too much lag will prevent fast keying, but fortunately key clicks can be practically eliminated without limiting the speed of manual (hand) keying. Some circuits which eliminate key clicks introduce too much time-lag and thereby add *"tails"* to the dots. These tails may cause the signals to sound chirpy, or make them difficult to copy at high speeds.

The elimination of key clicks by some of the key-click-filter circuits illustrated in the following text is not easily applied to every individual transmitter. The constants in the time-lag and spark-producing circuits depend upon the individual characteristics of the transmitter, such as the type of filter, power input, and various circuit impedances. All keying systems have one or more disadvantages, so that no particular method can be recommended as an ideal one. An intelligent choice can be made by the reader for his particular transmitter requirements by carefully analyzing the various keying circuits.

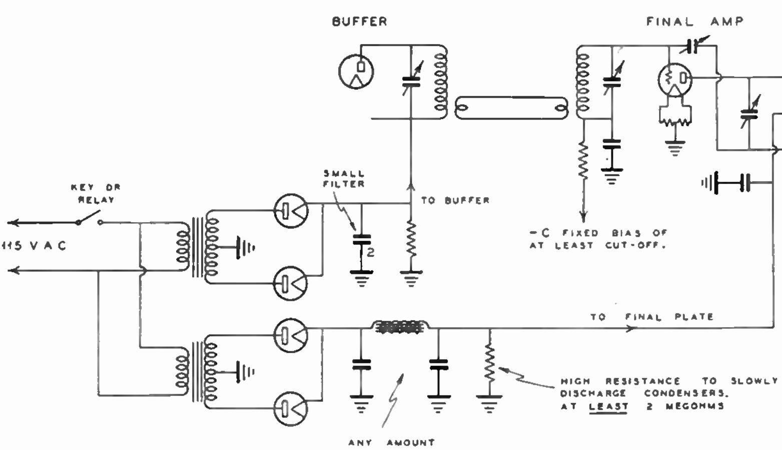
• Primary Keying

Key clicks can be eliminated entirely by means of primary keying, in which the key is placed in the a.c. line supply to the primary of the high voltage plate supply transformer. This method of keying also has the advantage that grid-leak bias can be used in the keyed stages of the transmitter. As ordinarily applied, the plate voltage to the final amplifier is controlled by the action of the key. The filter in the high voltage rectifier circuit creates a time-lag in the application and removal of the d.c. power input to the r.f. amplifier. Too much filter will introduce too great a time lag, and add tails to the dots. If a high power stage is keyed, the variation in load of the house-lighting circuits may be sufficient to cause blinking of the lights. A heavy-duty key, or keying relay, is necessary for moderate or high power transmitters to break the inductive a.c. current. The exciting current or surge current may be several times as high as the average current drawn by the transformer which is being keyed. This will cause difficulty from sticking key contacts, or burnt points on the keying relay. This effect can be minimized by proper design of the power transformer, which should have a high primary inductance and an iron core of generous size.

An improved primary keying circuit is shown in figure 30. This circuit makes high speed keying possible, without clicks or tails, and the plate supply to the final amplifier can be very well filtered without introducing tails to the dots.

The final amplifier must have a fixed bias supply equal to more than cut-off value, so that when the grid excitation from the buffer stage is removed the amplifier output will drop immediately to zero, in spite of the filter condenser's being fully charged in the final amplifier circuit. The bleeder across the final plate supply filter should have a very high resistance so that the filter condenser will hold its charge between dots and dashes. This will allow a quick application of plate voltage as soon as the grid excitation, supplied by the buffer stage, is applied to the final amplifier.

The buffer plate supply is keyed; its filter circuit consists of a single 2-μfd. filter condenser, shunted by the usual heavy-duty high-current bleeder resistor. This small



PRIMARY KEYING WITHOUT CLICKS OR "TAILS"

Figure 30

filter has no appreciable time lag, and will not add tails to the dots and dashes, but it does provide sufficient time lag for key click elimination. The small amount of filter will not introduce a.c. hum modulation into the output of the final amplifier, because the latter is operated in class-C, under saturated grid conditions. A moderate a.c. ripple in the grid excitation will not introduce hum in the output circuit under this operating condition.

Blocked Grid Keying

The negative grid bias in a medium or low-power r.f. amplifier can easily be increased in magnitude sufficiently to reduce the amplifier output to zero. The circuits shown in figures 31 and 32 represent two methods of such blocked grid keying.

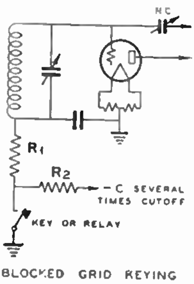


Figure 31

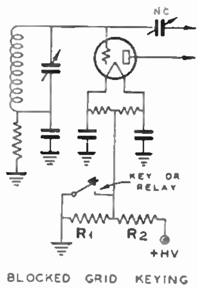


Figure 32

In figure 31, R_1 is the usual grid-leak. Additional fixed bias is applied through a 100,000 ohm resistor R_2 to block the grid current and reduce the output to zero. As a general rule, a small 300 to 400 volt power supply with the positive side connected to ground can be used for the additional C-bias supply.

The circuit of figure 32 can be applied by connecting the key across a portion of the plate supply bleeder resistance. When the key is open, the high negative bias is applied to the grid of the tube, since the filament center-tap is connected to a positive point on the bleeder resistor. Resistor R_2 is the normal bleeder; an additional resistor of from one-fourth to one-half the value of R_2 is connected in the circuit for R_1. A disadvantage of this circuit is that one side of the key may be placed at a positive potential of several hundred volts above ground, with the attendant danger of shock to the operator. Blocked grid keying is not particularly effective for eliminating key clicks.

Oscillator Keying

A stable and quick-acting crystal oscillator may be keyed in the plate, cathode, or screen-grid circuit for the purpose of minimizing key clicks, and for break-in operation. This type of keying requires either fixed or cathode bias, since the r.f. excitation is removed from all of the grid circuits. The key clicks are minimized by the presence of several tuned circuits between the antenna and crystal oscillator in a multi-stage transmitter. The key clicks act as side-band frequencies and are attenuated somewhat in a multi-stage transmitter by the resonant tuned circuits which are tuned to the carrier frequency.

If a key click filter is placed in the crystal oscillator circuit, the tone may become "chirpy" and tails may be added to the ends of the transmitted characters. A practical circuit for clickless keying is illustrated in figure 33, in which both the cathode of the crystal oscillator and the cathode of the next succeeding buffer or doubler circuit are connected through a key click filter.

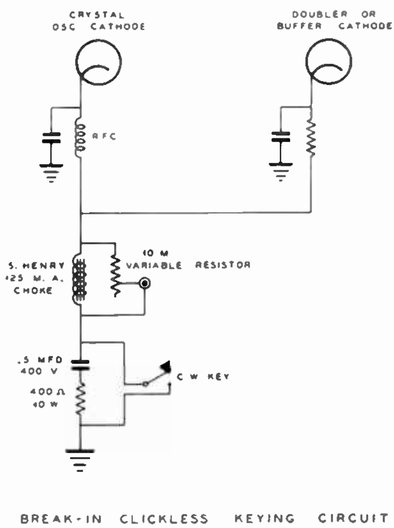


Figure 33

Two 6L6 or 6L6G tubes can be keyed very effectively with this type of circuit. The choke coil, shunted with a semi-variable resistor, provides a series inductance for slowing down the application of cathode current to the two tubes. The inductance of the choke coil can be effectively lowered to one or two henrys by shunting it with a semi-variable resistance so that the time lag will not be excessive. The 0.5 μfd. condenser and 400-ohm resistor are connected across the key contacts, as *close to the key* as possible, and these serve to absorb the spark at the telegraph key each time the circuit is opened. This effectively prevents a click at the end of each dot and dash. This same key click filter can be connected in the center-tap lead of a final amplifier or buffer-amplifier stage for the elimination of clicks.

● Center-Tap Keying

The lead from the center-tap connection to the filament of an r.f. amplifier tube can be opened and closed for keying a circuit. This opens the B-minus circuit, and at the same time opens the grid-bias return lead. For this reason the grid circuit is blocked at the same time that the plate circuit is opened, so that excessive sparking does not occur at the key contacts. Unfortunately, this method of keying applies the power too suddenly to the tube, producing a serious key click in the output circuit, which generally is coupled to the antenna. This click often can be eliminated with the simple key click eliminator shown in figures 33 and 34.

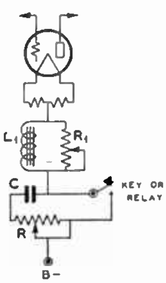


Figure 34 — Center-tap keying with an adjustable key-click filter. This system gives very good results. The actual amount of inductance and capacity in the circuit depends on the amount of current being keyed, and also on the voltage regulation of the plate power supply. L_1 should be of a value between 1 and 5 henrys; R_1 20,000 ohms; C, between ¼ and 2 μfds.; R. 2,000 ohms.

Straight center-tap keying as shown in figure 35 never should be used, because this circuit produces extremely bad key clicks. The key click filter in figure 34 always can be connected into the center-tap lead as an external unit. A more effective key click filter for the center-tap lead is made possible through the use of vacuum tubes. A simple vacuum tube keying circuit is shown in figure 36.

The keying tube is connected in series with the center-tap lead of the final r.f. amplifier. The grid of the keying tube is short-circuited to the filament when the key is closed, and the keying tube then acts as a

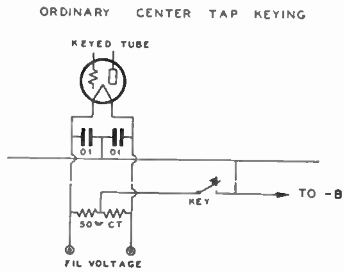


Figure 35

Ordinary center-tap keying. The center-tap of the filament transformer must not be grounded. As a general rule, the filament transformer which supplies the keyed stage will not be used to supply any of the other stages. The B minus lead from the power supply should be grounded.

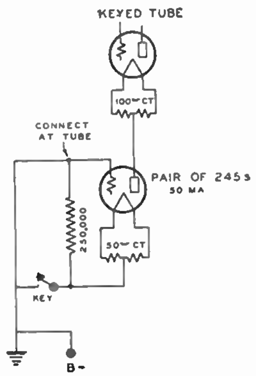
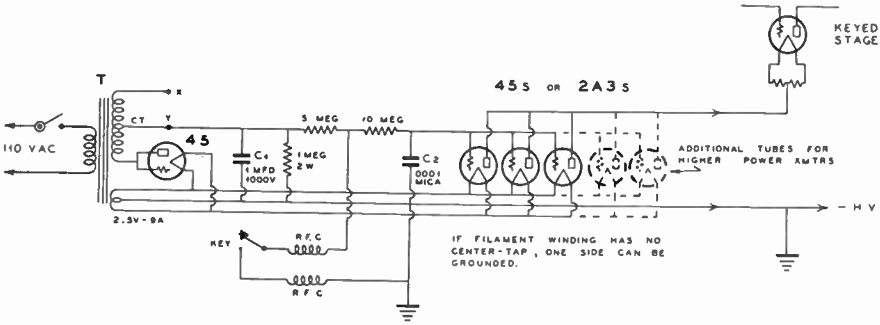


Figure 36—Vacuum Tube Keying. The circuit shows one of the more simple vacuum tube keying circuits. Some current flows through the key and this system sometimes produces clicks when the key is opened. Both filament transformers must be insulated from each other and also from ground. This circuit will not completely cut off the plate current to the keyed stage, but will reduce it to a very small value.

low resistance in the center-tap lead. When the key is opened, the grid of the keying tube tends to block itself and the plate-to-filament resistance of the tube increases to a high value, which reduces the output of the r.f. amplifier approximately to zero. A more effective vacuum tube keying system is shown in figure 37.

In this system, the grids of the keying tubes are biased to a high negative potential, when the key is open, and to zero potential when the key is closed. The fixed bias supply to the keying tubes provides very effective keying operation. The degree of time lag (key click elimination) can be adjusted to suit the individual operator, by varying both the capacity of the condenser



VACUUM - TUBE KEYING SYSTEM

Figure 37

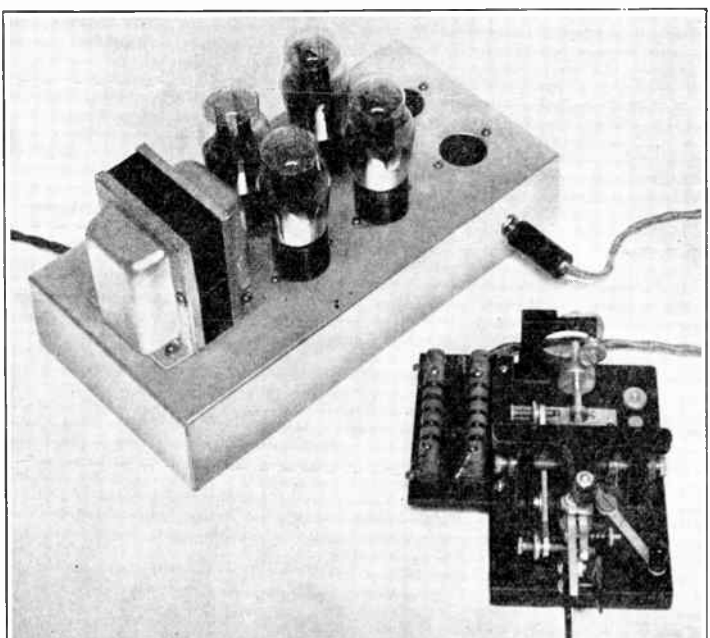


Figure 38—The vacuum tube keying system, using four 45's. Sockets for two additional (optional for higher power) tubes are provided. It is advantageous to mount the b. c. chokes directly at the key terminals, as shown.

which is shunted from grid to filament, and the values of the two high resistances in series with the grid and power supply leads. R.f. chokes can be connected in series with the key directly at the key terminals, to prevent the minute spark at the key contacts from causing interference in nearby broadcast receivers. These r.f. chokes are of the conventional b.c. type. There is no danger of shock to the operator when this keying circuit is used.

The small power supply for this keying circuit requires very little filter and can be of the half-wave rectifier type with a '45 tube as the rectifier. The negative voltage from this power supply only needs to be sufficient to provide cut-off bias to the type 45 keying tubes; potentials of from 100 to 300 volts are needed for this purpose. Approximately 50 milliamperes of plate current in the final amplifier should be allowed per type 45 keying tube. If the final amplifier draws 150 milliamperes, for example, three type 45 keying tubes will be required. A disadvantage of vacuum tube keying circuits is a plate supply potential loss of approximately 100 volts, which is consumed by the keying tubes. The plate supply therefore should be designed to give an output of 100 volts more than ordinarily is needed for the r.f. amplifier. This loss of plate voltage is encountered because the plate-to-filament resistance of the type 45 tubes, at 50 milliamperes of current and zero grid potential, is approximately 2000 ohms.

This keying system is applicable for high-speed commercial transmitters, as well as for amateur use.

• Elimination of Interference to Broadcast Reception

The troublesome interference created by amateur radiotelephones in nearby b.c. receivers usually can be eliminated by means of shunt or series type wave traps which are tuned to the frequency of the interfering signal. The wavetrap coil should have a sufficient number of turns to resonate with a compression-type mica trimmer condenser of 30 or 70 $\mu\mu$fd. maximum capacity. The coil is similar to a short-wave receiver r.f. coil and should be tapped at several places along the winding to simplify adjustment. The wavetrap should be located as close as possible to the antenna post of the b.c. receiver. The series-type wavetrap usually is more effective than the shunt-type.

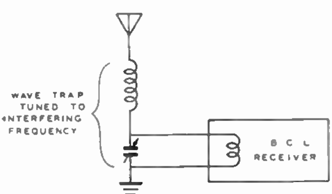


Figure 39

Horizontal doublet transmitting antennas usually cause less interference than those of the Marconi type. If a Marconi antenna is to be used, a counterpoise, rather than a ground connection, will often minimize the interference in b.c. receivers.

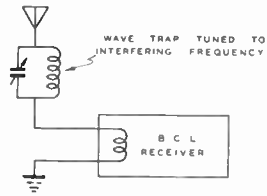


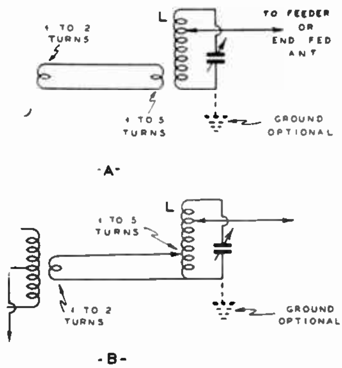
Figure 40

• Harmonic Elimination

The second harmonic of a 75-meter phone signal falls outside the amateur bands and causes illegal interference with 37.5 meter commercial transmissions. Push-pull final amplifiers rarely cancel the second harmonic in amateur transmitters, due to unbalanced circuits and insufficient tank circuit capacity to inductance ratio. Reference should be made to the *Chart of Tank Circuit Tuning Capacities* for proper circuit design. Sufficient tank circuit capacity will greatly minimize harmonic radiation.

Several circuits which will greatly reduce harmonic radiation are shown here.

Figure 41 shows link coupled antenna tuning circuits which discriminate against harmonics from the r.f. amplifier. The additional circuit is tuned to the fundamental frequency by means of a 50 $\mu\mu$fd. or 100 $\mu\mu$fd. condenser, somewhat similar to the plate tuning condenser. The coil L also is similar to the plate coil in the r.f. amplifier. Adjustments of the antenna or feeder tap, and also the link coupling, should be made with the aid of a field-strength meter.



'LING TO TUNED ANTENNA CIRCUIT

Figure 41

D in figure 42 show pi couplers
'suitable for single wire fed an-
ı these circuits the tuning condenser
he plate (or plate circuit) offers
pedance to the harmonic and prac-
ort-circuits the harmonic energy to
The tuning coil in either circuit
tively high impedance to the har-
h the result that very little har-
gy is present across the 350 $\mu\mu$fd.
pedance matching condenser. The
ircuit always is resonated to the
l frequency of operation. The
coupler must be tuned exactly
of the harmonic energy is to be
The link coupling systems in
superior to the *Collins* method
nateur use, inasmuch as they

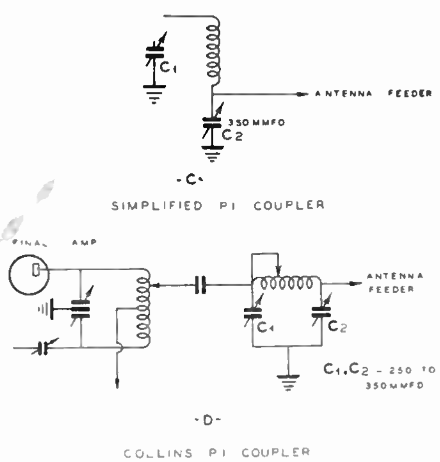


Figure 42

are not so critical of adjustment. Improper adjustment of a pi coupler will sometimes make the harmonic *worse.*

● Quartz Crystals

Quartz and tourmaline are minerals having a crystalline structure which, when cut and ground on certain crystalographic (optical) axes, possess piezo-electric properties in the influence of an oscillating electrical field. A detailed explanation of the piezo-electric effect will be found in any modern, comprehensive encyclopedia.

The mechanical activity or frequency of a piezo-electric element depends upon its physical dimensions (the frequency being inversely proportional to the thickness). The stability of the oscillatory properties depends mainly upon the optical cut and the crystal-temperature coefficient.

Piezo-electric oscillator (after the U.S.N. conference in 1929): A circuit containing a resonator (crystal) and possessing too little regeneration to oscillate itself, but which oscillates through the reaction of the crystal when the latter is vibrating near one of its normal frequencies with energy derived from the circuit. Such a circuit is often called a "crystal controlled" or "piezo-oscillator."

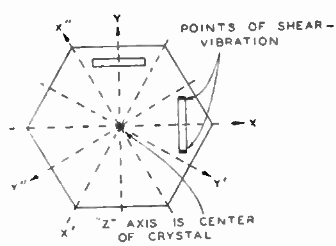


Figure 43

● Crystal Cuts

The face of an X-cut or Y-cut crystal is made parallel to the *Z* axis in figure 43. Special-cut crystals, known as AT-cut, V-cut, LD2, HF2, etc., are made with the face of the crystal having an angle with respect to the *Z* axis, rather than being parallel to it. The purpose of these special-cut crystals is to increase their power-handling ability, in some cases, but especially to reduce the temperature coefficient. There is no frequency drift in crystals which have absolute zero temperature coefficient. AT, V, and LD2-cut crystals have temperature coefficients approaching zero when correctly cut and ground, and they should be used in radio transmitters in which accurate frequency control is essential, such as edge of band operation. These crystals eliminate the need of a crystal oven for amateur work. A constant operating temperature is still required for some commercial applications, but the oven temperature need not be kept within as close limits as for an X or Y cut plate.

Frequency Drift and "Twin-Peaks"

Crystals that oscillate at more than one frequency are commonly known as crystals with "twin peaks." The dual vibrational tendency is more pronounced with Y-cuts, but to a certain degree is exhibited by many X-cuts. The use of a well-designed, space wound, low "C" tank coil in an oscillator will prohibit the crystal from oscillating at two frequencies, and in addition will increase the output. Experiments have shown that the frequency stability is not improved by large tank capacities, which only tend to augment the double frequency phenomenon.

Twin frequencies appear in several ways: sometimes the crystal will have two frequencies several hundred cycles apart, oscillating on both frequencies at the same time, and producing an acoustically audible beat note. Other crystals will suddenly "jump" frequency as the tank tuning condenser is varied past a certain setting. Operation with the tank condenser adjusted near the point where the frequency shifts is very unstable, the crystal sometimes going into oscillation on one frequency and sometimes one the other as the plate voltage is cut "on" and "off." Still other crystals will jump frequency only when the temperature is varied over a certain range. And some plates will jump frequency with a change in either tank tuning or temperature, and produce an audible beat tone at the same time, showing actually two pairs of frequencies!

Use and Care of Crystals

When operating close to the edge of one band, it is advisable to make sure that the crystal will respond to but one frequency in the holder and oscillator in which it is functioning; a crystal with two peaks can jump frequency slightly without giving any indications of the change on the meter readings of the transmitter. If the transmitter frequency is such that the operat on the edge of the band at al all conditions of room temp form of temperature control wi for the crystal unless it is of th type. When working close to t the 14 or 28 megacycle band it that the crystal temperature b fairly constant value; the freque kilocycles per degree Centigrade direct proportion to the operatin regardless of whether the fund harmonic is used. When a crysta frequency by two kilocycles, its s monic has shifted 4 kilocycles. not operating on the edge of the not concern themselves about freq due to changes in room temperat

If a pentode tube is used for oscillator having a plate potenti proximately 300 volts, the tempera crystal, regardless of cut, will no appreciably to cause any noticeab even 14 megacycles. When a cry lator is keyed on 3.5 or 1.7 mega frequency drift is not of any co even with much higher values o put, because of the keying and that the drift is not multiplied be with harmonic operation of a fier.

Crystal holders have a large e frequency; for example, the f an 80 meter crystal can vary a kilocycles in different holders. tals can be purchased in vari ers which enable the operat frequency by varying the ai or 25 kc. shift can be obt Only 80 meter AT cut cry for this purpose.

High Frequency Crystals

40 meter crystals can be treated m same as 80 meter crystals, provide are purchased in a dustproof holder fro reliable manufacturer. However, it is a go idea with 40 meter crystals to make sure the crystal current is not excessive, as it will run higher in a given oscillator circuit than when a lower frequency crystal is used in the same circuit at the same voltage. A low loss, low-C tank circuit and a pentode or beam type oscillator tube are desirable.

20 and 10 meter crystals, especially the latter, require more care in regard to circuit details, components, and physical layout. 20

and 10 meter crystals are *not* of the zero drift type, as such crystals would be too thin to be of practical use. A special thick cut is used to give the crystal sufficient mechanical ruggedness. Crystals of this cut have a drift of approximately 40-45 cycles/Mc./deg. C. This means that such crystals must be run at very low power levels not only to avoid fracture, but to prevent excessive drift. However, their use permits considerable simplification of a u.h.f. transmitter.

A type 41 tube, running at 275 volts on the plate and 100 volts on the screen, makes a good oscillator tube for a 20 meter crystal. Bias should be obtained from a 500 ohm cathode resistor rather than a grid leak. Very light loading, preferably with inductive coupling, is required. The tank coil should be low loss, preferably air-supported or wound on a ceramic form.

With 10 meter crystals it is necessary to use low capacity triodes as oscillator tubes. The high shunt capacities of multi-grid tubes makes their use impracticable with 10 meter crystals. Medium-high μ triodes with high transconductance and low input and output capacities make the best oscillators. The types RK34, 6J5G, and 955 are the most satisfactory oscillators, the 6J5G permitting the most output besides being the least expensive. The second section of an RK34 can be used as a doubler to 5 meters, thus giving about 3 watts of crystal controlled 5 meter output from one tube.

Contrary to general practice with pentode crystal oscillators,' the plate tank circuit should *not* be too low C; a moderate amount of tuning capacity should be used in a 10 meter triode crystal oscillator. The plate voltage on the oscillator tube should not be allowed to exceed 200 volts. About 2 watts output is obtainable from the 10 meter oscillator tank at this plate voltage. The tank coil can consist of 8 turns of no. 12 wire, air wound and spaced the diameter of the wire, ¾ inches in diameter. Bias should be obtained from a 200 ohm cathode resistor (bypassed) and no grid leak. Connecting leads should be short and components small physically.

Both 10 and 20 meter crystal oscillators should be followed, where practicable, b tube of high power gain, such as the ε This cuts down the number of tubes quired in a high power, stationary u.i transmitter.

A 10 meter crystal oscillator with a 6J5 driving a 6V6 doubler using a 150,000 oh grid leak, makes an excellent 5 meter m bile transmitter. The latter tube can l either plate or plate-and-screen modulate The modulation is better when doubling i both plate and screen are modulated.

Coil Winding Table For Low-C Wire-Wound Tank Coils

Band In Meters	No. 10 Wire Coils	No. 14 Wire Coils	Total Cond. Capac. in μμfds.
160	42 turns. 5 in. dia. 6 turns per inch.	38 turns. 4 in. dia. 8 turns per inch.	100
80	28 turns. 4½ in. dia. 4 turns per inch.	34 turns. 2¾ in. dia. 8 turns per inch.	50
40	20 turns. 3½ in. dia. 3 turns per inch.	22 turns. 2¾ in. dia. 5 turns per inch.	35
20	10 turns. 3¼ in. dia. 1½ turns per inch.	11 turns. 2⅝ in. dia. 2½ turns per inch.	35
10	6 turns. 2½ in. dia. 1 turn per inch.	6 turns. 2¼ in. dia. 1½ turns per inch.	25

Note: These coils are suitable for plate neutralized or push-pull amplifiers with Low-C tubes. Grid neutralized amplifiers require from 10% to 30% fewer turns than those listed above, depending upon the tube. Last column indicates smallest size tuning condenser usable.

Coil Winding Charts for Copper Tubing Tank Coils

THE values given are a close approximation to your particular requirements in each case, but exact accuracy depends on the circuit arrangement and the length of the leads in the plate circuit of the tube to be used. The two factors mentioned become more important as the frequency increases. Long leads necessitate fewer turns on the coil, but the leads should be long enough to keep the tank condenser separated from the coil by at least the coil diameter

All the values in the table are for the tubes specified when used as single-ended amplifiers with the neutralization tap near the center of the coil. If placed in the center of the coil, this tap will automatically give fixed neutralization on all bands. For push-pull amplifiers, decrease the number of turns by 25% for any given tube. The reason for this decrease will be apparent upon close comparison of single-ended and push-pull circuits. Just twice as much tube capacity is shunted across the tank in push-pull circuits as when single-ended circuits are used.

In low-C tanks, such as these, the voltage rating of the condenser should be equal to four times the plate voltage on the tube for single-section types, and twice the plate voltage (each section) for split-stator models.

CHART NO 1. For Coils Tuned With Split-Stator Condenser and Used in Circuits Employing Low-C Tubes, such as 150T, 50T, 354, 852, 800, 825, RK18.

BAND	2" Dia. Coil	3" Dia. Coil	4" Dia. Coil	5" Dia. Coil	6" Dia. Coil	Size of Tuning Condenser
160	N.S.	N.S.	N.S.	N.S.	80 Turns 36" Long 5/8" Tubing	250 Mmf. Each Section for Full Band Coverage.
80	N.S.	N.S.	60 Turns 20" Long 1/4" Tubing	50 Turns 18" Long 1/4" Tubing	40 Turns 18" Long 5/8" Tubing	100 Mmf. Each Section for Full Band Coverage.
40	N.S.	46 Turns 16" Long 1/4" Tubing	34 Turns 12" Long 1/4" Tubing	28 Turns 12" Long 1/4" Tubing	22 Turns 12" Long 1/4" Tubing	35 Mmf. Each Section.
20	32 Turns 15" Long 1/4" Tubing	20 Turns 12" Long 1/4" Tubing	16 Turns 12" Long 1/4" Tubing	14 Turns 12" Long 1/4" Tubing	10 Turns 12" Long 1/4" Tubing	35 Mmf. Each Section.
10	8 Turns 4" Long 1/4" Tubing	6 Turns 4" Long 1/4" Tubing	4 Turns 4" Long 1/4" Tubing	4 Turns 4" Long 1/4" Tubing	3 Turns 4" Long 1/4" Tubing	35 Mmf. Each Section. N.S. Indicates: NOT SATISFACTORY.

CHART NO 2. For Coils Tuned With Single-Section Condenser and Used in Circuits Employing Low-C Tubes, such as 150T, 50T, 354, 852, 800, 825, RK18.

BAND	2" Dia. Coil	3" Dia. Coil	4" Dia. Coil	5" Dia. Coil	6" Dia. Coil	Size of Tuning Condenser
160	N.S.	N.S.	N.S.	N.S.	60 Turns 36" Long 5/8" Tubing	100 Mmf.
80	N.S.	N.S.	50 Turns 20" Long 1/4" Tubing	40 Turns 18" Long 1/4" Tubing	30 Turns 18" Long 5/8" Tubing	100 Mmf. For Full Band Coverage.
40	N.S.	36 Turns 14" Long 1/4" Tubing	24 Turns 12" Long 1/4" Tubing	20 Turns 12" Long 1/4" Tubing	16 Turns 12" Long 1/4" Tubing	35 Mmf.
20	22 Turns 12" Long 1/4" Tubing	16 Turns 12" Long 1/4" Tubing	12 Turns 12" Long 1/4" Tubing	10 Turns 12" Long 1/4" Tubing	8 Turns 12" Long 1/4" Tubing	35 Mmf.
10	6 Turns 5" Long 1/4" Tubing	4 Turns 5" Long 1/4" Tubing	4 Turns 5" Long 1/4" Tubing	4 Turns 5" Long 1/4" Tubing	2 Turns 5" Long 1/4" Tubing	35 Mmf.

CHART NO. 3. For Coils Tuned With Split-Stator Condenser and Used in Circuits Employing High-C Tubes, Such as 50 Watters, 210, 204A, 849, 212D, 830, 46, RK20.

BAND	2" Dia. Coil	3" Dia. Coil	4" Dia. Coil	5" Dia. Coil	6" Dia. Coil	Size of Tuning Condenser
160	N.S.	N.S.	N.S.	N.S.	72 Turns 36" Long 5/8" Tubing	250 Mmf. Each Section for Full Band Coverage.
80	N.S.	N.S.	54 Turns 16" Long 1/4" Tubing	46 Turns 18" Long 1/4" Tubing	36 Turns 18" Long 5/8" Tubing	100 Mmf. Each Section for Full Band Coverage.
40	N.S.	36 Turns 14" Long 1/4" Tubing	24 Turns 10" Long 1/4" Tubing	20 Turns 10" Long 1/4" Tubing	16 Turns 10" Long 1/4" Tubing	35 Mmf. Each Section.
20	24 Turns 10" Long 1/4" Tubing	16 Turns 10" Long 1/4" Tubing	12 Turns 10" Long 1/4" Tubing	10 Turns 10" Long 1/4" Tubing	8 Turns 10" Long 1/4" Tubing	35 Mmf. Each Section.
10	8 Turns 5" Long 1/4" Tubing	6 Turns 5" Long 1/4" Tubing	4 Turns 5" Long 1/4" Tubing	4 Turns 5" Long 1/4" Tubing	3 Turns 5" Long 1/4" Tubing	35 Mmf. Each Section.

CHART NO. 4. For Coils Tuned With Single-Section Condenser and Used in Circuits Employing High-C Tubes, Such as 50 Watters, 210, 204A, 849, 212D, 830, 46, RK20.

BAND	2" Dia. Coil	3" Dia. Coil	4" Dia. Coil	5" Dia. Coil	6" Dia. Coil	Size of Tuning Condenser
160	N.S.	N.S.	N.S.	N.S.	60 Turns 36" Long ⅜" Tubing	100 Mmf.
80	N.S.	N.S.	50 Turns 20" Long ¼" Tubing	40 Turns 18" Long ¼" Tubing	30 Turns 18" Long ⅜" Tubing	100 Mmf. For Full Band Coverage.
40	N.S.	32 Turns 14" Long ¼" Tubing	22 Turns 12" Long ¼" Tubing	18 Turns 12" Long ¼" Tubing	14 Turns 12" Long ¼" Tubing	35 Mmf.
20	18 Turns 10" Long ¼" Tubing	14 Turns 10" Long ¼" Tubing	10 Turns 10" Long ¼" Tubing	8 Turns 10" Long ¼" Tubing	6 Turns 10" Long ¼" Tubing	35 Mmf.
10	4 Turns 5" Long ¼" Tubing	4 Turns 5" Long ¼" Tubing	4 Turns 5" Long ¼" Tubing	4 Turns 5" Long ¼" Tubing	2 Turns 5" Long ¼" Tubing	35 Mmf.

Wire Wound Coils

Coil Chart for 1½-in. and 2½-in. Dia. Coil Forms.

BAND	1½" Dia. Coil Form	Size of Tuning Condenser	BAND	2½" dia. Coil Form	Size of Tuning Condenser	REMARKS
160	Not Satisfactory		160	46 Turns No. 16 DCC. Close wound	100 MMF. or larger	The winding data shown here is for coils that are tuned with single-section variable condensers. See Chart below for coil winding data when split-stator variable condensers are used.
80	35 Turns No. 22 DCC. Close wound	100 MMF.	80	23 Turns No. 16 DCC. Spaced one dia.	100 MMF.	
40	19 to 21 Turns No. 16 DCC. Spaced one dia.	100 MMF.	40	16 Turns No. 16 DCC. Spaced one dia.	25-35 MMF.	
20	11 to 13 Turns No. 16 DCC. Spaced one dia.	25-35 MMF.	20	8 to 10 Turns No. 16 DCC. Spaced one dia.	25-35 MMF.	
10	5 to 6 Turns No. 16 DCC. Spaced one dia.	25-35 MMF.	10	5 Turns No. 16 DCC. Spaced one dia.	25-35 MMF.	

Coil Winding Chart for 1½-in. and 2½-in. Dia. Coil Forms and Split-Stator V.C.

BAND	1¼" Dia. Coil Form	Size of Tuning Condenser	BAND	2½" dia. Coil Form	Size of Tuning Condenser	
160	Not Satisfactory		160	59 Turns No. 16 Enameled Close wound. Tap at center.	250 MMF. Each Section (smaller condenser can be used).	35 mmf. Each section split-stator double-spaced midget variable condensers are satisfactory.
80	Not Satisfactory		80	55 to 57 Turns No. 16 DCC. Close wound. Tap at center.	35 MMF. Each Section	
40	35 Turns No. 16 DCC. Close wound. Tap at center.	35 MMF. Each Section	40	29 Turns No. 14 Enameled Space wound. To cover 3 inches.	35 MMF. Each Section	
20	19 Turns No. 16 DCC. Spaced one dia. Tap at center.	35 MMF. Each Section	20	15 Turns No. 14 Enameled Spaced one dia. Tap at center.	35 MMF. Each Section	

TRANSMITTER ADJUSTMENT CHART

Quick Reference for Tuning and Meter Scale Readings

Band of Operation	Oscillator Plate or Cathode Current in M. A.	Doubler Grid Current in M. A.	Doubler Plate Current in M. A.	Buffer Grid Current in M. A.	Buffer Plate Current in M. A.	Final Grid Current in M. A.	Final Plate Current in M. A.
160							
80							
40							
20							
10							
5							

	Oscillator Plate Tuning Dial	Doubler Plate Tuning Dial	Doubler Grid Dial	Buffer Plate Dial	Final Grid Dial	Final Plate Dial	Antenna Coupler Dials
160							
80							
40							
20							
10							
5							

Miscellaneous Adjustment Notes

Coil Winding and Condenser Capacity Notes

Fill-in Your Own Coil Data in Pencil

Band In Meters	Oscillator Plate Coil	Doubler Plate Coil	Buffer-Doubler Grid Coil	Buffer-Doubler Plate Coil	Final Grid Coil	Final Plate Coil
160	Wire Size					
	Turns					
	Spacing					
	Condenser					
80	Wire Size					
	Spacing					
	Turns					
	Condenser					
40	Wire Size					
	Spacing					
	Turns					
	Condenser					
20	Wire Size					
	Spacing					
	Turns					
	Condenser					
10	Wire Size					
	Spacing					
	Turns					
	Condenser					

Danger—High Voltage

The high voltage power supplies even in a low power transmitter are potentially lethal. They are also potential fire hazards. Pages could be written on "don'ts" and precautionary measures, but the important thing is to *use your head;* don't fool with any part of your transmitter or power supply unless you know exactly what you are doing and have your mind on what you are doing.

Not only should your transmitter installation be so arranged to minimize the danger of accidental shock for your own safety, but also because "haywire" installations that do not pass the underwriter's rules will invalidate your fire insurance. You have no claim against the insurance company if they can prove that the installation did not meet underwriters' specifications.

Some of the most important things to remember in regard to the high voltage danger are the following:

Do not rely upon bleeders to discharge your filter condensers; short the condenser with an insulated-handle screwdriver before handling any of the associated circuits. Bleeders occasionally blow out, and good filter condensers hold a charge a long time.

Beware of "zero adjuster" devices on meters placed in positive high voltage leads. Also be careful of dial set screws if the rotor shaft of the condenser is "hot." Both of these situations represent poor practice to begin with.

Don't touch any transmitter components without first turning off all switches. If you do insist on making coupling adjustments, etc., with the transmitter on (very bad practice), keep ONE HAND BEHIND YOU.

Do not work on the high voltage circuits or make adjustments where it is necessary to reach inside the transmitter UNLESS SOMEONE ELSE IS PRESENT. 90% of the deaths of amateurs due to electrocution could have been prevented if someone had been present to kill the high voltage or remove the victim and to call the doctor and administer first aid before he arrived.

High voltage gear should be so fixed that small children cannot manipulate the switches or come in contact with any of the wires or components. Either keep the radio room or gear under lock and key or else provide an "interlock" system whereby all primary circuits are broken when the transmitter cabinet is opened.

Familiarize yourself with the latest approved methods of first aid treatment for electrical shock. It may enable you to save a life some time.

Don't attempt to hurry too much if a companion comes in contact with high voltage and cannot extricate himself. Act quickly but do not act without deliberation or you may be in as bad a fix as the person you are trying to help. Do not touch the victim with your bare hands if things are wet. Otherwise it is safe to grab him by a loose fold of clothing to pull him free, first making sure that you are well insulated from anything grounded. Turning off the voltage is simpler, when possible. However, do not waste precious moments dashing around trying to discover how to open the circuit. If you do not already know, try to remove the victim if it can be done safely.

A main primary switch at the entrance to the radio room, killing all primary circuits, will reduce the fire hazard and help your peace of mind, provided you make it an iron-clad rule always to throw the switch when leaving the room.

Beware of strange equipment. It may contain unconventional wiring or circuits. Do not take for granted that it is wired the way you would do it.

Chapter 11

Exciter Construction

ONE OF the most important portions of a radio transmitter is the means of controlling its frequency of operation. This *frequency* determines the place in the radio spectrum in which the transmitter operates. Some form of *oscillator* is needed for this purpose.

The most practical method of frequency control is by means of a quartz crystal oscillator, because the oscillation frequency is determined by the physical dimensions of the quartz plate. Quartz is a very hard substance which is not easily affected by temperature or pressure changes, and for this reason the quartz crystal oscillator has a better frequency stability than other forms of oscillators.

Relatively low-frequency crystal oscillators are often followed by *frequency-doublers* or triplers, in order to obtain frequency control for high-frequency transmitters. That portion of the transmitter which supplies the actual control of frequency, in most cases, is defined as the *exciter;* therefore, the exciter includes the crystal oscillator and any frequency-multipliers of medium or low power output.

• Crystal Oscillators

Crystal oscillators can be divided into three classifications: (1) low power circuits, which require several additional buffer stages to drive medium or high power final amplifiers; (2) high power crystal oscillators, which minimize the number of buffer stages in a transmitter; (3) harmonic crystal oscillators, which operate on more than one harmonically-related band from one quartz crystal.

Low power crystal oscillators are often required in transmitter design where extremely accurate frequency control is needed. The crystal oscillator tube is operated at low plate potential, such as 200 volts, with the result that oscillation is relatively minute. This weak or moderate crystal oscillation means that there will be less heating effects in the quartz plate; the frequency drift, due to changes in temperature, is therefore minimized.

Mere operation of a quartz crystal oscillator tube at relatively low plate voltage does not necessarily mean a low degree of frequency drift; a type of crystal oscillator tube must be used which has high power sensitivity, high μ, and low feedback (inter-electrode) capacity. The amount of feedback determines the value of r.f. current flowing through the quartz plate, and thus determines the amplitude of the physical vibration of the quartz plate. Any tube which requires only a very small amount of grid excitation voltage and neutralizing capacity can be used to supply relatively high power output in a crystal oscillator without heating of the quartz plate.

High power crystal oscillators are those which operate with as high a plate voltage as can be used with only moderate heating of the quartz crystal. Many transmitters, such as those used for c.w. telegraphy, do not require as high a degree of frequency stability as for radiotelephone transmitters used for commercial services. The relatively high output from such crystal oscillators usually means the elimination of one or two buffer-amplifier stages. This simplifies the transmitter, and may result in more trouble-free operation. There are a great many types of tubes for high power crystal oscillators, some of which are also used in high stability low power crystal oscillators by merely reducing the electrode voltages.

The crystal oscillator circuits in figures 1 and 2 are of the standard pentode-tube type. They operate on one frequency only, and the plate circuit is tuned to approximately the frequency of the quartz crystal.

The plate circuit in most crystal oscillators is tuned to a frequency somewhat higher than the frequency of the crystal itself. The actual power output of crystal oscillators, such as those shown in figures 1 and 2, is from one to five watts, depending upon the values of plate and screen voltage. The use of *AT-cut* or low temperature coefficient quartz plates allows higher values of output to be obtained without exceeding the safe r.f. crystal current ratings or encountering frequency drift. *X-cut* and *Y-cut* crystals must be operated with comparatively low

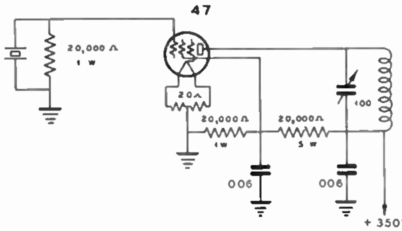


Figure 1—Pentode Oscillator with Type '47 Tube

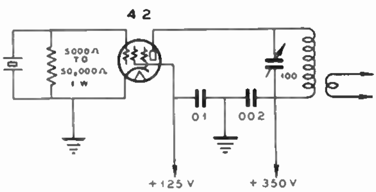


Figure 2—Pentode Crystal Oscillator with Type '42 Tube

crystal current, because they not only will not stand as much r.f. crystal current, but also have a higher temperature coefficient.

Push-Pull Crystal Oscillators

The type 53 twin-triode tube (2.5 volt heater) and its 6.3 volt companion tubes, 6A6 and 6N7, are very efficient for push-pull crystal oscillators. A typical twin-triode oscillator circuit is shown in figure 3.

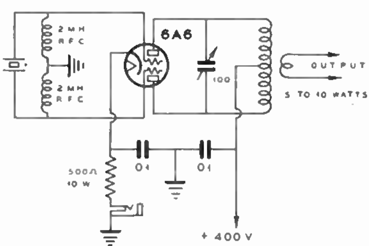
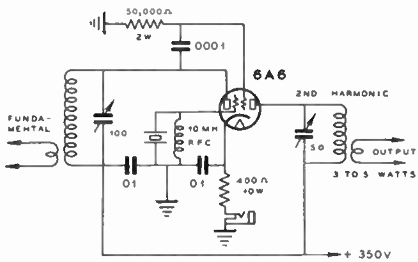


Figure 3—Dual-Triode 6A6 (or 53) High-Output Push-Pull Oscillator

Outputs of from 5 to 10 watts can be obtained from the above circuit without exceeding the ratings of the usual X-cut crystals. The crystal current for a push-pull oscillator is but little higher than for a single tube of the same type, and twice the output can be obtained.

Oscillator-Doubler Circuit

The type 53 and 6A6 twin-triode tubes are very popular for circuits where one triode acts as a crystal oscillator which drives the other triode as a frequency doubler; one tube therefore serves a dual purpose, supplying approximately 5 watts output on either the fundamental frequency or the second harmonic of the quartz crystal. Two applications of the twin-triode tube in a crystal oscillator circuit are shown in figures 4 and 5.



JONES CRYSTAL OSCILLATOR-DOUBLER

Figure 4

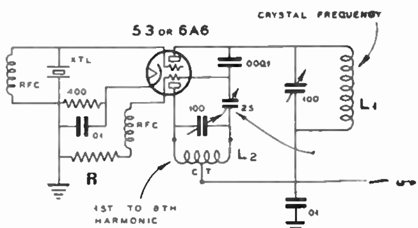


Figure 5—Jones Regenerative Exciter for all-band operation. R-50,000 ohms

Figure 4 is a circuit which can be used with quartz crystals cut for 160, 80, 40 or 20 meter operation. The circuit shown in figure 5 can be made regenerative in the frequency-multiplier section in order to use the second triode as a tripler or quadrupler. By reducing the capacity of the 25 $\mu\mu$fd. condenser (shown with an arrow pointing to it) to a low enough value, the second triode can be neutralized for use as a buffer stage. A suitable condenser for this purpose is a small mica-insulated trimmer condenser having a capacity range of from 3-to-30 $\mu\mu$fds. The resistor *R* shown in figure 5 should be from 30,000 to 50,000 ohms in value, and generally the r.f. choke shown in series with this resistor can be omitted. Coil data for any of these exciters can be obtained from those circuits (shown in the following pages) for which constructional details are given.

• Tritet Crystal Oscillator

Any of the screen-grid tubes can be used in a tritet oscillator circuit, such as the one shown in figure 6.

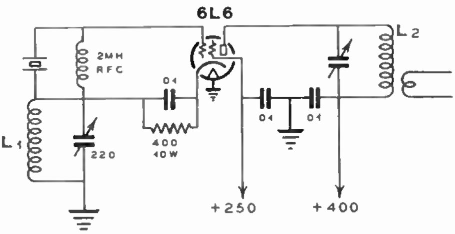


Figure 6 Tritet Crystal Oscillator

The tritet consists of a triode oscillator circuit with an additional tuned circuit connected in series with the cathode. This allows the screen-grid circuit to be bypassed to ground, and the tetrode or pentode plate circuit is *electron-coupled* to the oscillator circuit. The plate circuit is generally tuned to the second harmonic and outputs of from 5 to 15 watts can be obtained without damage to the quartz crystal. This circuit is an improvement over the older forms of tritet in which a grid-leak was used in place of the grid r.f. choke, and in which no cathode resistor and bypass condenser were included. The improved circuit (figure 6) decreases the crystal current as much as 50%, and thereby protects the crystal against fracture. The cathode circuit is "high C" and tuned to a frequency which is 40% or 50% higher than that of the crystal. If an 802 or RK-25 is substituted for the 6L6 tube, the plate circuit can be tuned to the fundamental frequency of the crystal without making it necessary to short-circuit the cathode tuned circuit.

6L6G Tritet Coil Data

All Coils Wound on 1½ in. Diameter Forms

Wave-length	L2 Plate Coil	L1 Cathode Coil	Crystal
160	78 turns no. 24 d.s.c. close-wound	Short-circuited	160
80	38 turns no. 18 Enam. close-wound	25 turns no. 22 d.s.c. 1½ in. long	160
40	20 turns no. 18 Enam. 1½ in. long	12 turns no. 18 Enam. 1½ in. long	80
20	9 turns no. 18 Enam. 1¼ in. long	7 turns no. 18 Enam. 1¼ in. long	40

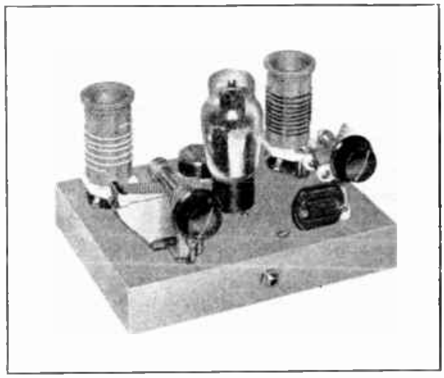
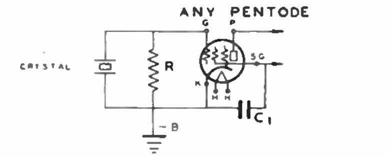


Figure 7—6L6G Tritet Oscillator for Operation on Both Fundamental Frequency and Second Harmonic

• Regenerative Oscillators

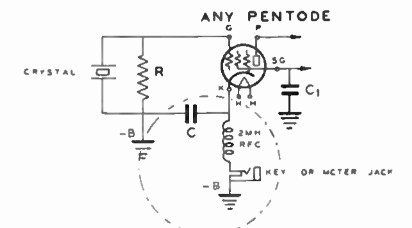
When a crystal oscillator circuit is made regenerative by means of a r.f. choke in the cathode-circuit bypassed to ground with a small mica condenser, nearly twice as much output can be obtained from the plate circuit without loss of crystal oscillation, and the r.f. crystal current is reduced. The cathode circuit produces a regenerative effect depending upon the capacity of the cathode bypass condenser, which varies in capacity from .0001 μfd. up to .0004 μfd. in different tube circuits. Figures 8 and 9 show the conventional and regenerative pentode oscillator circuits.

The regenerative crystal oscillator becomes a good harmonic oscillator by simply changing the plate coil for operation on the harmonics of the crystal frequency. The circuit in figure 10 can be used on 40 and 80 meters with an 80 meter crystal. If the plate tuning condenser has a maximum capacity of at least 150 μμfds. this oscil-



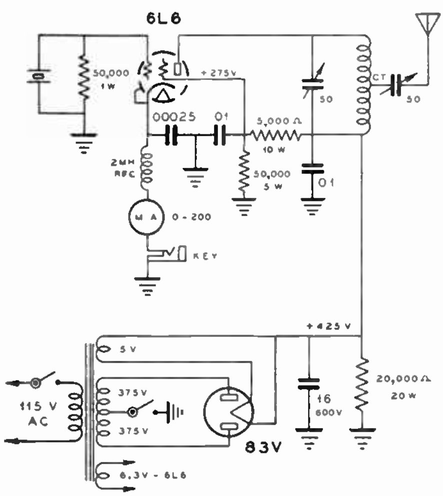
CONVENTIONAL LOW OUTPUT PENTODE CRYSTAL OSCILLATOR WITH GRIDLEAK BIAS RESISTOR

Figure 8



HIGH OUTPUT PENTODE CRYSTAL OSCILLATOR WITH REGENERATIVE FEATURE AS DEVELOPED BY JONES

Figure 9
C—.0001 or .00025 μfd. (mica)
C1—Screen By-Pass Condenser
R—Grid-Leak, 50,000 ohms



25 WATT CW TRANSMITTER

Figure 10

lator can be used on two bands with a single plate coil, the two extreme ranges of the condenser being used to tune the respective bands. A coil suitable for covering both the 40 and 80 meter bands would have approximately 20 turns of No. 20 d.c.c. wire on a 1½ in. dia. form, over a winding space 1½ in. long.

Reinartz Crystal Oscillator

This regenerative crystal oscillator has a fixed-tuned cathode circuit which is resonated to approximately *one-half* the crystal *frequency*. For example, with an 80 meter crystal the cathode circuit is tuned to 160 meters, the plate circuit to 80 meters. Either an 802 or a 6F6 tube can be used in a Reinartz crystal oscillator circuit. The output will be from 5 to 25 watts, depending upon the values of plate and screen voltages. The 6F6 is used as a high-μ triode in this same type of circuit, whereas the 802 is used as a pentode oscillator with additional control-grid-to-plate capacity feedback. The circuit is shown in figure 12.

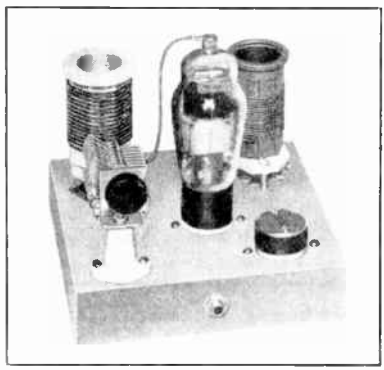


Figure 11—Reinartz 802 Oscillator

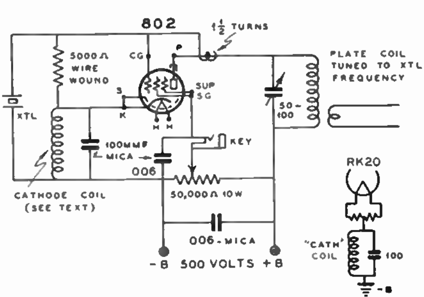


Figure 12—Reinartz 802 Oscillator Circuit

The crystal r.f. current is quite low in this circuit, in comparison with the output power which can be obtained. The cathode circuit is tuned to half the frequency of the crystal, and the reactive effect produces regeneration at the harmonic frequency. This increases the operating efficiency of the

802 Reinartz Coil Data

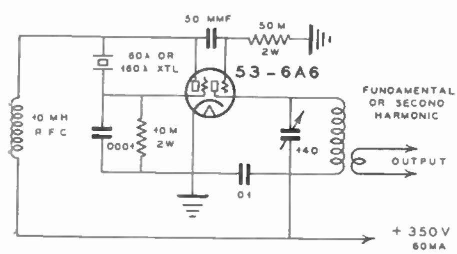
Wave-length Meters	Plate Coil	Cathode Coil
160	70 turns no. 22 d.s.c. 2 in. long 1¾ in. diam.	116 turns no. 26 Enam. close-wound 1½ in. diam.
80	34 turns no. 18 Enam. 2 in. long 1¾ in. diam.	55 turns no. 24 d.s.c. close-wound 1½ in. diam.
40	16 turns no. 18 Enam. 1½ in. long 1¾ in. diam.	27 turns no. 24 d.s.c. 1½ in. long 1½ in. diam.
20	8 turns no. 18 Enam. 1½ in. long 1¾ in. diam.	14 turns no. 24 d.s.c. 1½ in. long 1½ in. diam.

Figure 13

tube without danger of uncontrollable oscillation at frequencies other than that of the crystal.

New 6A6 Harmonic Oscillator

A type 6A6 or 53 twin-triode tube will supply output on either the fundamental or second harmonic of the crystal frequency in the circuit shown in figure 14.



NEW 6A6 HARMONIC OSCILLATOR

Figure 14

The crystal is connected between the grid and plate of one of the triodes of the twin-triode tube, and the same grid is connected to cathode and ground through a 10,000 ohm grid-leak. The circuit should be used only with 80 and 160 meter crystals. A .0001 μfd. mica condenser is connected across the grid-leak in order to obtain highest possible r.f. voltage at the plate of this triode section.

The grid of the second section of the tube is capacitively-coupled to the plate of the first section; the plate circuit of the second section is tuned to either the fundamental or second harmonic, depending upon whether fundamental or second harmonic output is desired. This oscillator circuit requires an active crystal and will not function satisfactorily with 40 or 20 meter crystals. An output of approximately 7 watts can be obtained with an active 80 or 160 meter crystal. The r.f. choke is non-resonant, and should have an inductance of about 10 millihenrys.

5 to 160 Meter Exciter

An exciter which will supply from 3 to 7 watts on any of the amateur bands from 5 to 160 meters is shown in figure 15.

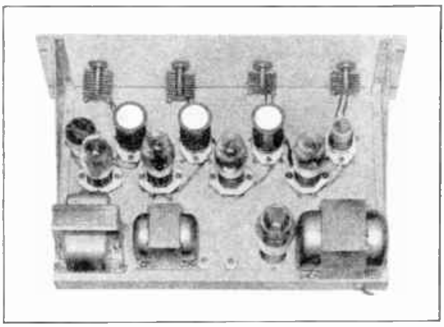


Figure 15—Top View of 6-Band Exciter. 5 to 160 Meter Operation

It consists of a 42 regenerative oscillator and three type 6A6 frequency doublers. Each 6A6 has its grids and plates connected in parallel in order to obtain as high an output as possible. A type 42 pentode regenerative oscillator will supply approximately 5 watts of output, in addition to exciting the succeeding 6A6 doubler stage. No neutralizing problems are involved, and when the exciter is operated on low frequencies the unused frequency doubler stages can be cut-out of the circuit by inserting an open plug in all unused cathode jacks. The circuit diagram is shown in figure 16, the coil construction data in figure 17. 160, 80 and 40 meter crystals are necessary for all-band operation in conjunction with the six coils shown in the coil-winding chart.

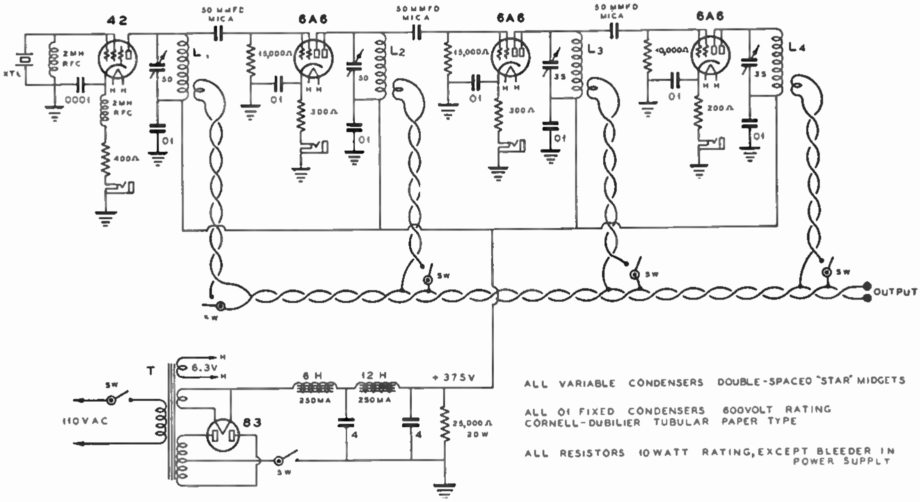
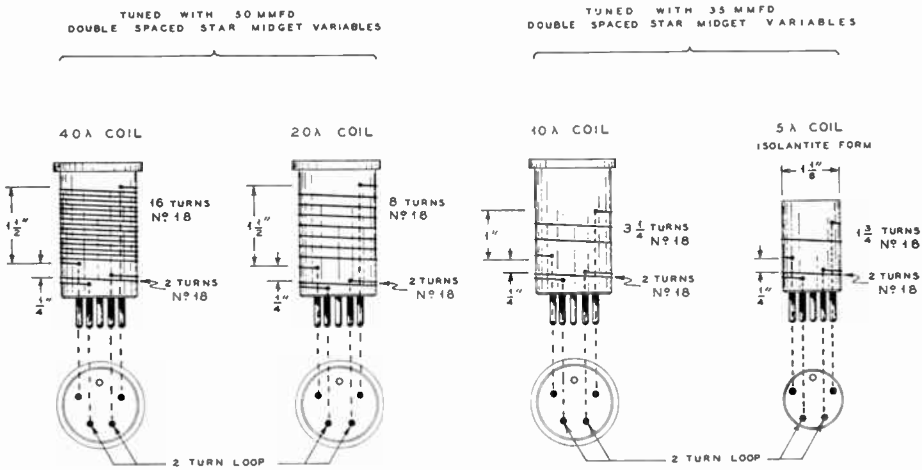


Figure 16

JONES 6 BAND EXCITER
DELIVERS 2 TO 5 WATTS OUTPUT ON 5 METERS



COILS FOR 40, 20, 10 AND 5 METER OPERATION
(40λ CRYSTAL IN OSCILLATOR)

FIGURE 17

Coil Winding Specifications

All coils, except the 5 meter coil, are wound on standard five prong 1½ in. diameter low-loss plug-in coil forms. The 5 meter coil is wound on a 1⅛ in. diameter ceramic 5-prong plug-in form. Coils for 160, 80, 40, 20 and 10 meter operation have a 2-turn winding at the bottom of the form. This 2-turn winding is the coupling loop, and the ends of the loop are connected to two of the prongs on the coil form. The pictorial drafting (figure 17) shows a complete group of coils for 40, 20, 10 and 5 meter operation with a 40 meter crystal in the oscillator stage.

160 Meter Coil: 60 turns, no. 24 d.s.c., close-wound.

80 Meter Coil: 30 turns, no. 18 d.s.c., close-wound.

40 Meter Coil: 16 turns, no. 18 d.s.c., space-wound over a winding length of 1½ inches.

20 Meter Coil: 8 turns, no. 18 d.s.c., space-wound over a winding length of 1½ inches.

10 Meter Coil: 3¼ turns, no. 18 d.s.c., space-wound over a winding length of 1 inch.

5 Meter Coil: 1¾ to 2½ turns, no. 18 d.s.c., spaced approximately ⅜ in. between turns. Some readjustment of this spacing may be necessary in order to permit the plate tuning condenser to resonate the circuit.

• 10 to 160 Meter Exciter

The exciter shown in figure 18 can be highly recommended for any c.w. or phone transmitter because of its simplicity and relatively high output.

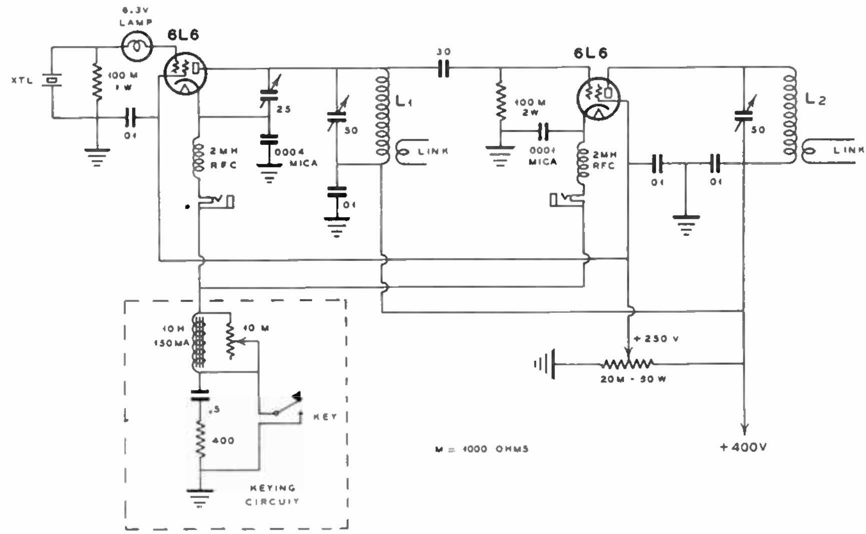
Two type 6L6 or 6L6G tubes are used as a harmonic crystal oscillator and regenerative frequency doubler, respectively. The harmonic oscillator circuit is an improved design which can be easily adjusted for stable operation with 160, 80 or 40 meter crystals, though some 40 meter crystals are not sufficiently active for use in this circuit. The plate circuit of the crystal oscillator may be tuned to either the fundamental frequency or the second harmonic of the crystal, and the degree of regeneration is controlled by means of a small 3-to-30 μμfd. trimmer condenser connected between the cathode and plate of the oscillator tube.

The ratio of the capacity of this condenser to that of the .0004 μfd. (mica type) cathode-to-ground bypass condenser determines the degree of regeneration. Excessive regeneration will cause the plate circuit to oscillate at frequencies other than those controlled by the crystal, whereas insufficient regeneration will result in low output when operating on the second harmonic. The regeneration condenser can be set with a particular crystal to a value which will cause the tuned plate circuit output (as checked with a flashlight lamp and a loop of wire) to be the same for either the fundamental frequency or the second harmonic. Once adjusted, crystals can be changed from 160 to 40 meters, the plate coils changed for output on any band from 160 to 20 meters without further adjustment of the regeneration condenser. An output of 10 to 15 watts can be obtained from the plate circuit of either tube by means of link coupling.

The second tube is capacitively coupled to the oscillator and its plate circuit is always tuned to the second harmonic of the frequency applied to its grid circuit.

The cathode circuit is bypassed with a relatively small condenser of only .0001 μfd. capacity in order to obtain regeneration. This regeneration increases the output on 10 meters, and to some extent on 20 meters. It has practically no effect when the second tube is used as a doubler for 80 or 40 meter output. The r.f. choke in series with the cathode circuit is needed in order to confine the r.f. path through the .0001 μfd. condenser. The cathodes of both tubes are connected to a common keying circuit, which is very effective in removing all traces of key-click and back-wave for c.w. operation. The keying circuit is shown in the diagram of figure 18, and allows break-in operation for either c.w. or phone communication. The succeeding stages in the transmitter should have fixed C-bias equal to at least cut-off when using this keying circuit. The coils

Band	Coils 1½ in. Dia. Forms
160	65 turns, no. 24 d.s.c., close-wound.
80	35 turns, no. 29 d.c.c., 1½ in. long.
40	18 turns, no. 20 d.c.c., 1½ in. long.
20	10 turns, no. 16 Enam., 1½ in. long.
10	4 turns, no. 16 Enam., 1-in. long.



15 WATT EXCITER

Figure 18

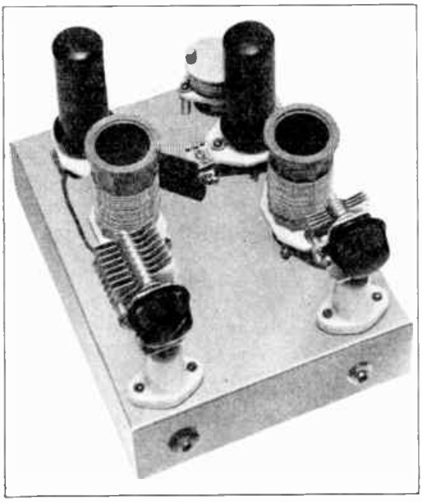


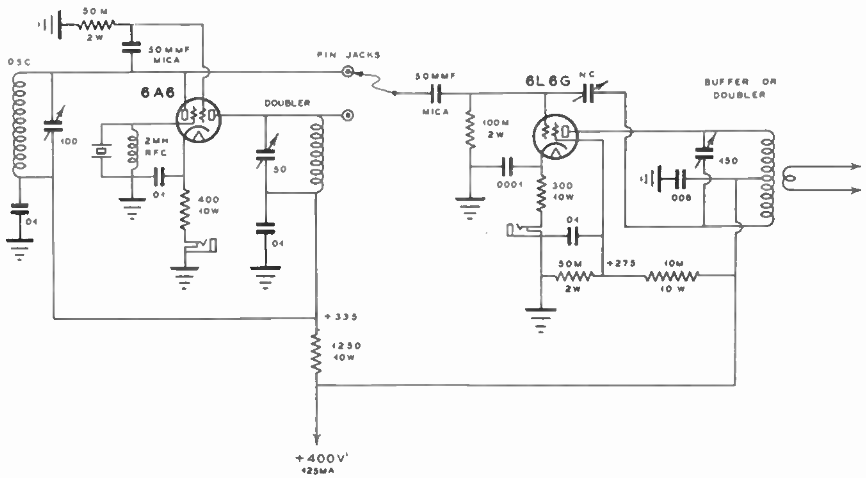
Figure 19—The Two Tube, 10 to 160 Meter 15-Watt Exciter

for this exciter are very simple to construct and only five are needed for five-band operation. The data is listed in the coil table.

● 6A6-6L6 Five-Band Exciter

The standard *6A6 Oscillator* already described drives a 6L6G buffer or doubler stage for output on any band from 160 to 10 meters. The circuit diagram is shown in figure 20, and a photograph of the complete unit in figure 21.

This exciter has several advantages over other types, in that the 6L6G tube serves as a buffer even when operating on 160 meters. This makes it particularly desirable for driving a medium-power final amplifier for 160 meter phone operation. The crystal oscillator is a 6A6, which is not at all critical with respect to crystals, and since the 6A6 is only required to furnish sufficient power to drive the 6L6G, the plate potential can be reduced to around 300 volts. This means that the r.f. crystal current, even with 40 meter crystals, will be quite low. It is more sure-fire with average 40-meter crystals than the harmonic types of crystal oscillators using 6L6 or 6L6G tubes. This exciter is recommended for average amateur use because of the ease with which it



FIVE BAND 6A6-6L6G EXCITER

Figure 20

can be made to operate, and also because it will work with 80 and 40 meter crystals that do not show high activity.

The 6L6G tube is capacitively-coupled through a plug and a pair of pin-jacks to either of the two tuned circuits of the 6A6 crystal oscillator. The 6L6G tube is neutralized, so that it can be used as a buffer or doubler. The cathode condenser is smaller than customary (.0001 μfd. in value) in order to obtain a little regeneration when the exciter is operated on 10 meters. This condenser is rather small for perfect neutralization when working "straight through," but the neutralization need only be sufficient to prevent any tendency for self-oscillation when the plate circuit is tuned to the same frequency as the grid circuit. This can be accomplished with the circuit constants shown in figure 20. The neutralizing condenser consists of a 3-to-30 μμfd. mica trimmer with the movable plate bent-out and the adjusting screw removed so as to secure a very low minimum capacity. The plate tuning condenser in the 6L6G circuit has a maximum capacity of 150 μμfd., so that two-band operation can be secured without

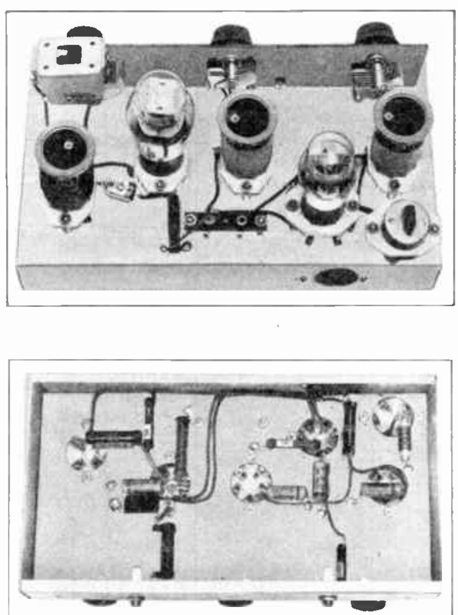


Figure 21—Showing Construction of the 6A6-6L6 Five Band Exciter, Top and Bottom Views

any coil change. For example, the output can be tuned to 160 meters with the condenser near maximum capacity, and to 75 or 80 meters with the condenser set near its minimum capacity. The output as a buffer or doubler will be around 15 watts on any band.

This unit can be built on a 13" × 7" × 2" zinc-coated metal chassis, with a bakelite sub-panel for mounting the tuning condensers. All bypass condensers are connected directly to the tube and coil sockets, the other end of these condensers being soldered to the nearest point on the chassis.

Coil Data

All of the coils are wound on standard 1½ in. diameter plug-in forms. Coils can be chosen for only the desired bands of operation.

Band	Oscillator and Doubler Coils	6L6G Stage
160	65 turns, no. 22 d.s.c., close-wound.	
80	30 turns, no. 22 d.s.c., 1¾ in. long.	50 turns, no. 22 d.s.c., close-wound and center-tapped. (For 80 and 160 Meters).
40	17 turns, no. 22 d.s.c., 1½ in. long.	26 turns, no. 18 Enam., center-tapped. 1½ in. long. (For 40 and 80 Meters).
20	8 turns, no. 22 d.s.c., 1¾ in. long.	12½ turns, no. 18 Enam., center-tapped. 1½ in. long. (For 20 and 40 Meters).
10		6 turns, no. 18 Enam., center-tapped. 1⅝ in. long. (For 10 and 20 Meters).

6A6-6L6 Exciter Coil Table

30-Watt Exciter

Operation from 80 to 10 meters can be secured from the exciter circuit shown in figure 22. The construction of the unit is shown in figure 23.

Coil Data for High Power 6L6G Exciter

All Coils Wound on 1¾-inch Ceramic Forms

160 Meter Oscillator
70 turns no. 24 d.s.c., with C. T., 2" long, 1¾" diameter

80 Meter Oscillator or Doubler Coil
34 turns no. 16 E., with C. T., 2" long, 1¾" diameter

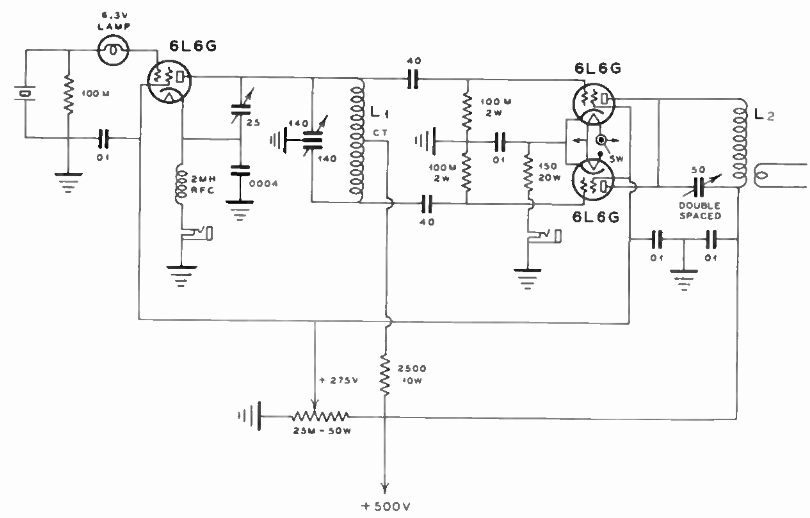
40 Meter Oscillator or Doubler Coil
16 turns no. 16 E., with C. T., 1½" long, 1¾" diameter

20 Meter Oscillator or Doubler Coil
8 turns no. 16 E., with C. T., 1½" long, 1¾" diameter

10 Meter Doubler Coil
4½ turns no. 16 E., 1½" long, 1¾" diameter

This exciter is suitable where fairly high output is desired. A 6L6G harmonic crystal oscillator employs a split-stator plate tuning condenser which tunes the plate circuit to either the fundamental or second harmonic of the crystal, by merely changing the plug-in plate coil. The split-stator tuning condenser provides a balanced circuit for coupling into the push-pull grids of the frequency-doubling stage. The two grids are capacitively coupled to each end of the oscillator plate circuit, and the two plates of the doubler stage are connected in parallel in a standard push-push frequency-doubling stage. With the plate and screen voltages shown in the circuit diagram, outputs of 30 watts can be obtained on bands of from 80 to 10 meters.

The crystal oscillator adjustments are similar to those described under the discussion for figure 18. This exciter can be used to obtain outputs of about 15 watts at the crystal frequency by opening-up the *heater* circuit of one of the 6L6G doubler tubes with an on-off switch. With one tube inoperative, the other tube may be used as a neutralized buffer, since the "cold" tube acts as a neutralizing condenser. The plate circuit in this case would be tuned to the same



30 WATT EXCITER

Figure 22

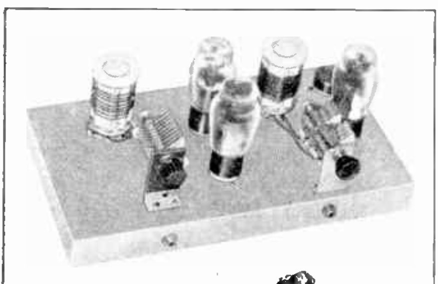


Figure 23—30-Watt Two-Band Exciter

frequency as the plate circuit of the crystal oscillator.

● Bi-Push Exciter

The *Bi-Push* exciter, introduced recently in "*RADIO*" and widely popular among amateurs, is shown in figure 24.

Only three five-prong coils are needed for operating this exciter on 40, 20 or 10 meters from a 40 meter crystal. The coil prongs should be connected with jumpers between prongs as shown in the sketch of the schematic circuit diagram, figure 24.

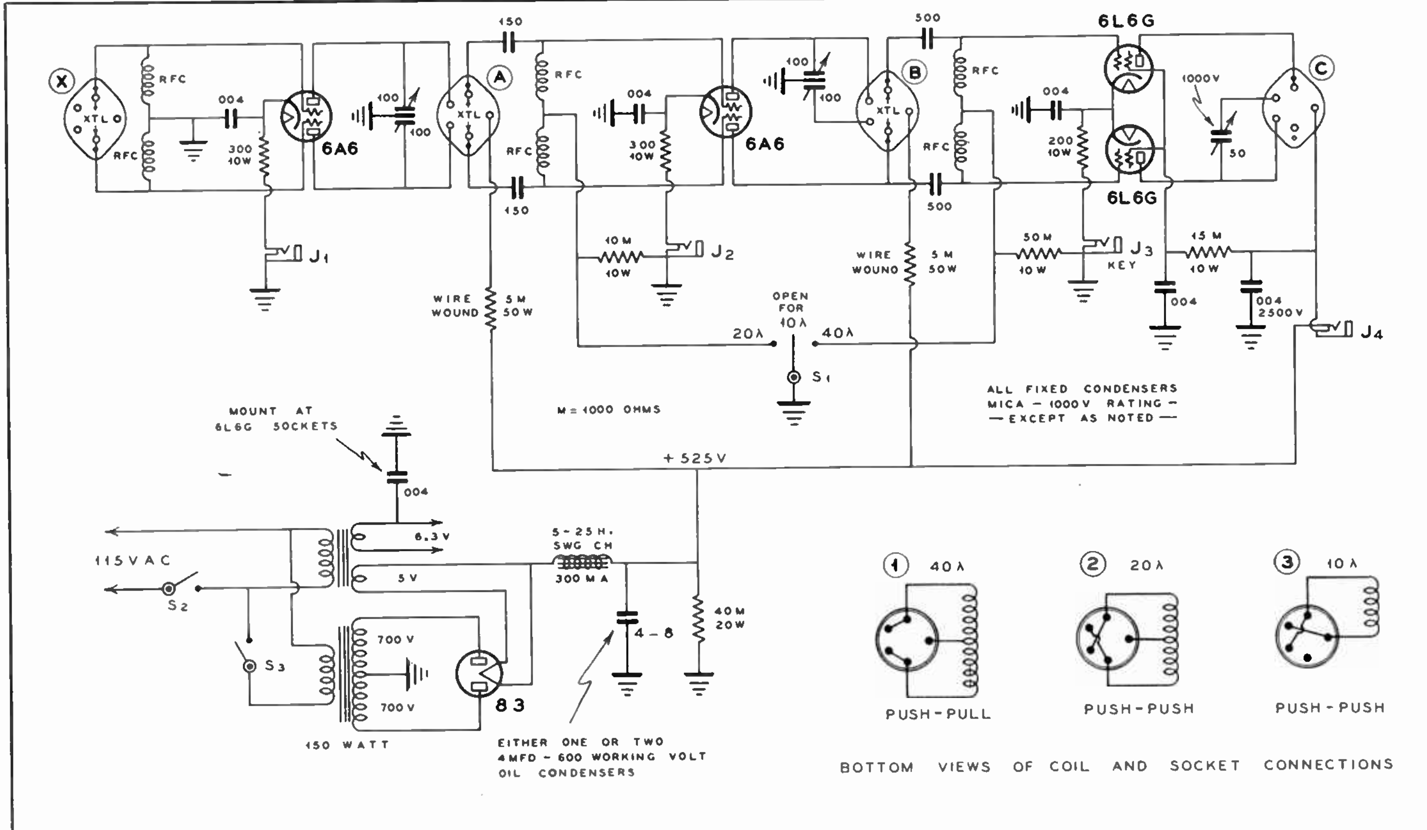
For 10 meter operation, a 40 meter crystal is plugged-into the first 5-prong socket and the three coils are plugged-in for operation as a 40 meter push-pull crystal oscillator driving a 20 meter push-push doubler, then driving a 10-meter push-push doubler to approximately 40 watts output. The output power depends upon the plate voltage available from the power supply.

For 20 meter operation, the crystal is plugged into socket *"A"*, coil No. 1 is plugged into socket *"B"*, coil No. 2 into socket *"C"*. This results in the second 6A6 tube operating as a push-pull crystal oscillator which drives the two 6L6G tubes as a 20-meter push-push doubler.

For 40 meter operation, the crystal is plugged into socket *"B"* and the 40 meter coil into socket *"C"*. This results in a push-pull 6L6 crystal oscillator.

A band-changing switch is needed to change from grid-leak to cathode bias on whichever tube is acting as the crystal oscillator in order to prevent the r.f. crystal current from rising to excessive values. The additional grid-leak bias is necessary for operation as frequency-doublers, but should be short-circuited with the band switch when the particular tube is used as a crystal oscillator.

It is very important that the bandswitch be thrown to the *proper position* when changing bands; *if it is not done before the*



"BI-PUSH" TRI-BAND EXCITER OR TRANSMITTER
Figure 24

plate voltage is applied the crystal may be fractured.

The power supply used should deliver from 450 to 550 volts under load, and have *good regulation.* Otherwise the voltage will rise to an unsafe value when the first two tubes are not working or when the plate voltage is removed from the 6L6's as would be the case during keying of that stage. A mercury vapor rectifier and low-resistance choke input filter will give sufficiently good regulation.

Modulation can be applied for 10 or 20 meter phone at J_4. Approximately 30 watts of audio power will be required for operation at the plate voltage specified (525 volts). The modulation will be satisfactorily linear up to 90%, in spite of the fact that the tubes are running as doublers.

Plate current for the 6L6's may be measured either at J_3 or J_4. Keying should be attempted only at J_3, and not in one of the 6A6 stages. Very short leads will be necessary in the 6L6 stage for good operation on 10 meters. The 6L6 50 μμfd. tuning condenser should be so connected that the rotor is cold and the stator "hot" with r.f. on 10 meters, rather than vice versa (rotor "hot"). If you can draw pencil sparks off the rotor on 10 meters, the connections to the condenser should be reversed. On other bands, both rotor and stator will always be "hot." For maximum 10 meter output, the 10 meter coil form, the 6L6 sockets, and the last coil socket should be of ceramic material.

• Coil Data

The coils are wound on 1½ in. diameter isolantite coil forms. The "stubby" type of coil form is desirable in order to simplify soldering the jumper connections between prongs.

Bi-Push Exciter Coil Table

160 Meters
70 turns c.t. no 22 Enam. close-wound, 1½" diameter

80 Meters
34 turns c.t. no. 22 d.c.c. close-wound, 1½" diameter

40 Meters
18 turns c.t. no. 18 d.c.c. close-wound, 1½" diameter

20 Meters
8 turns c.t. no. 16 bare, spaced to 1⅛", 1½" dia., or 11 turns same 1⅛" dia. spaced to 1⅜"

10 Meters
3½ turns no. 16 bare, spaced to 1⅛", 1½" dia., or 4½ turns same 1⅛" dia. spaced to 1⅜"

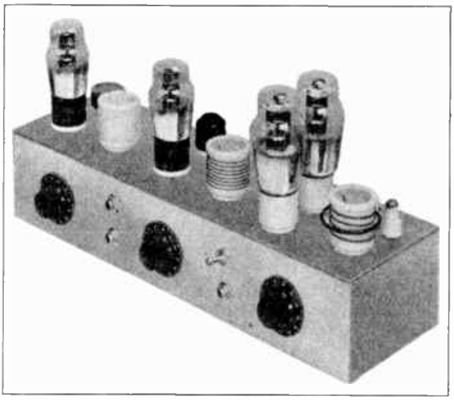


Figure 25—Illustrating Physical Layout of Parts in the "Bi-Push" Exciter

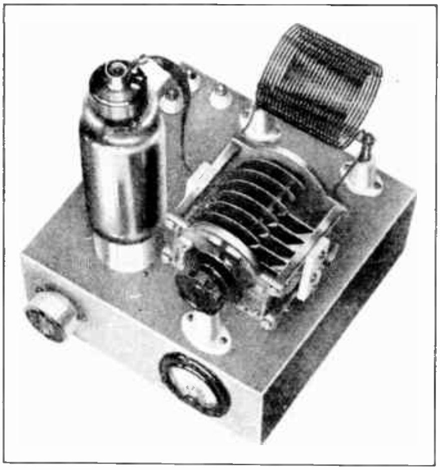
Any three bands, such as 160, 80 and 40 meters, or 80, 40 and 20 meters, can be used with 160 or 80 meter crystals, respectively, in the same manner as that previously described for a 40 meter crystal.

If trouble from parasitic oscillations is encountered, a small parasitic choke can be placed in one of the 6L6G plate leads. This choke can consist of 5 turns of No. 16 hookup wire, wrapped around a *pencil* as a winding form, with slight spacing between turns. This self-supporting coil should be connected directly at one 6L6G tube socket. It will usually be found more effective in one plate lead than the other. Which lead will be determined by the individual mechanical layout.

• High Power Regenerative Oscillator

From 100 to 150 watts of output can be obtained on 80 meters from the regenerative crystal oscillator illustrated below. Cathode bias and cathode regeneration make this high output possible, and without overloading the crystal. The crystal r.f. current measures only 40 milliamperes through an AT-cut crystal; this current is so low that no frequency drift is encountered. No external feed-back capacity is needed between the control grid and plate circuit in order to obtain oscillation, because the cathode or filament center-tap r.f. choke and variable condenser arrangement produces the necessary feed-back.

This oscillator will serve as a complete one-tube transmitter, with the key in either the cathode or screen circuit. The screen and suppressor of the RK-28 are tied to-



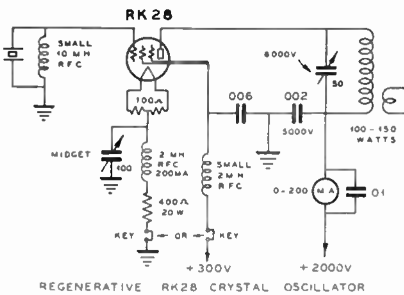


Figure 26—RK-28 Oscillator 100 to 150 Watts Output on 80 Meters

gether and operated with approximately 300 volts on the screen. The 100 μμfd. midget variable condenser connected from center-tap to ground should be set towards maximum capacity. Too much capacity will reduce the output, and the circuit cannot be properly keyed.

• Crystal Oscillator Tuning Procedure

Every oscillator circuit is generally tuned for maximum output, by means of an indicator of some form, such as d.c. milliammeter in the grid-bias lead of the tube being driven by the oscillator. Maximum meter reading indicates maximum output from the crystal oscillator. Other indicators are: (1)—A small neon bulb held near the plate end of the oscillator tuned circuit; maximum glow of the bulb indicates maximum oscillator output. (2)—A flashlight bulb, or a pilot light bulb, connected in series with a turn of wire, can be coupled to the oscillator coil for indicating r.f. output. Maximum brilliancy of the lamp denotes maximum output from the oscillator.

The type-53 or 6A6 oscillator-doubler circuit is adjusted by tuning the oscillator section for maximum output, and the doubler section for greatest dip in cathode or plate current. The crystal plate section should generally be tuned until the circuit approaches the point where oscillation is about to cease; this is towards the higher-capacity setting of the oscillator plate tuning condenser and operation in this manner provides most output in proportion to r.f. crystal current and frequency drift. The cathode current should never exceed 75 milliamperes and safe limits for plate current in each section is 30 milliamperes. With cathode bias in this oscillator circuit, the plate current will drop to 20 or 30 milliamperes when the tube is not oscillating. The plate voltage for a 6A6 or 53 oscillator-doubler or push-pull oscillator may range from 250 to 400 volts, depending upon the power output which is needed. The heater voltage should be at least 2½ volts for a type 53 tube, under full load conditions, but should not exceed this value by more than 10%.

Harmonic crystal oscillators, such as the 6L6 or 6L6G circuits, are always tuned for maximum output and minimum plate, or cathode current. The regeneration or feedback condenser between plate and cathode is increased from its minimum capacity up to a point which will provide a good plate-current dip when the plate circuit is tuned to the second harmonic of the crystal oscillator. Too much regeneration condenser capacity will cause the tube to oscillate for all settings of the plate tank condenser, without any sharp dip at the harmonic frequency of the crystal. Too low a capacity will cause insufficient regeneration and very low second harmonic output. A plate potential of 400 volts is generally considered a safe upper limit for a type-6L6 oscillator tube. The screen-grid voltage affects the degree of regeneration and harmonic output; this voltage should generally range between 250 and 275 volts. The cathode current will run between 50 and 60 milliamperes for fundamental frequency operation, and 60 to 75 milliamperes for harmonic operation, at these plate and screen voltages. The crystal r.f. current normally runs between 25 and 75 milliamperes in this type of oscillator, depending on the frequency and plate voltage used.

Block Diagrams, Showing Comparative Output of C. W., Radiotelephone, and Combination C. W.-Radiotelephone Transmitters

It is often desirable to ascertain, at a glance, the approximate output which can be secured from such combinations of tubes as the experimenter may have on hand. Likewise, when a new transmitter is to be designed, the approximate output can be determined in advance by selecting such tube combinations as are shown in the numerous block-diagrams in these pages. These diagrams are divided into three classifications: (1) c.w., (2) radiotelephony, (3) combination c.w. and radiotelephony.

The *legend* is a guide to the method used in compiling these diagrams. Single tubes, tubes in push-pull or parallel connection, coupling of the circuits by link, capacitive or unity methods are clearly defined in *legend* and diagram alike.

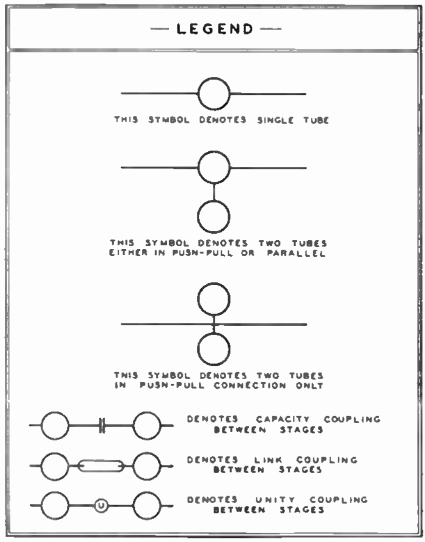
Directly under each tube symbol is a notation which states the service that the tube is asked to perform; the plate voltage is clearly indicated and the output rating from the final stage is to the extreme right of each block diagram. Relative power output, rather than power input, is shown in each diagram, beginning with low power and ending with high power combinations.

Block diagrams for radiotelephone transmitters begin where the diagrams for c.w. transmitters are ended. Then follow the diagrams for combination c.w.-radiotelephone transmitters.

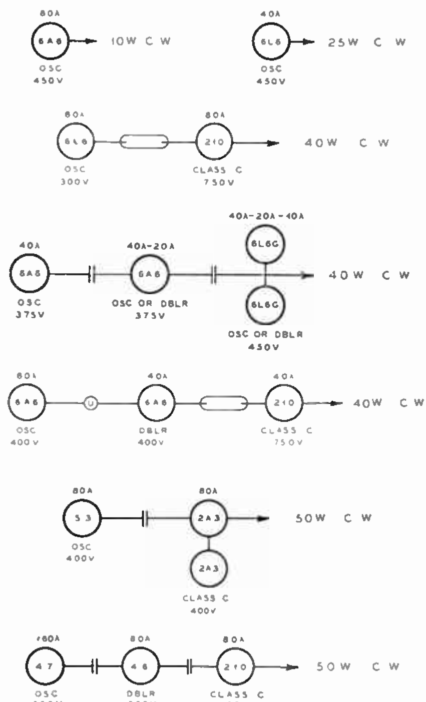
The method used in presenting these simple block-diagrams can be illustrated by the following example, when considering the very first diagram of the c.w. group, directly following this text: It is seen that a 6A6 oscillator, operating on 80 meters, with a plate potential of 450 volts on the oscillator tube, will deliver a power output of 10 watts for c.w. operation. Proceed, then, to the diagram with two tubes, directly below the aforementioned one-tube diagram. It is here seen that a 6L6 tube acts as a crystal oscillator on 80 meters, with a plate potential of 300 volts on the oscillator tube; the oscillator tube, in turn, is *link coupled* to a type 210 tube, which serves as a class-C amplifier, on 80 meters, with a plate potential of 750 volts. The result is a power output of 40 watts for c.w. operation.

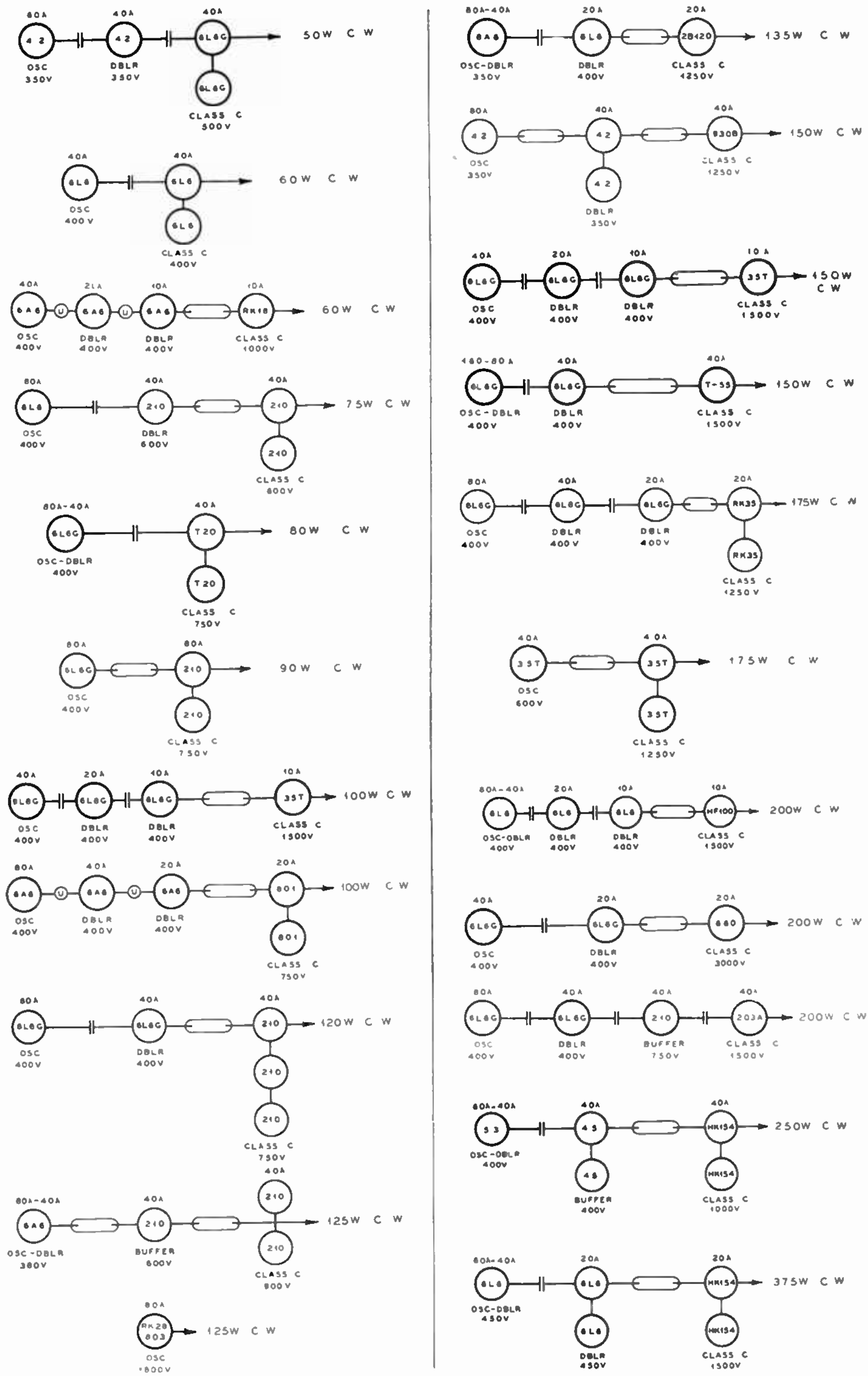
Capacitive coupling between tubes is indicated by the conventional fixed capacity (condenser) symbol, unity coupling by a letter "U" within a circle.

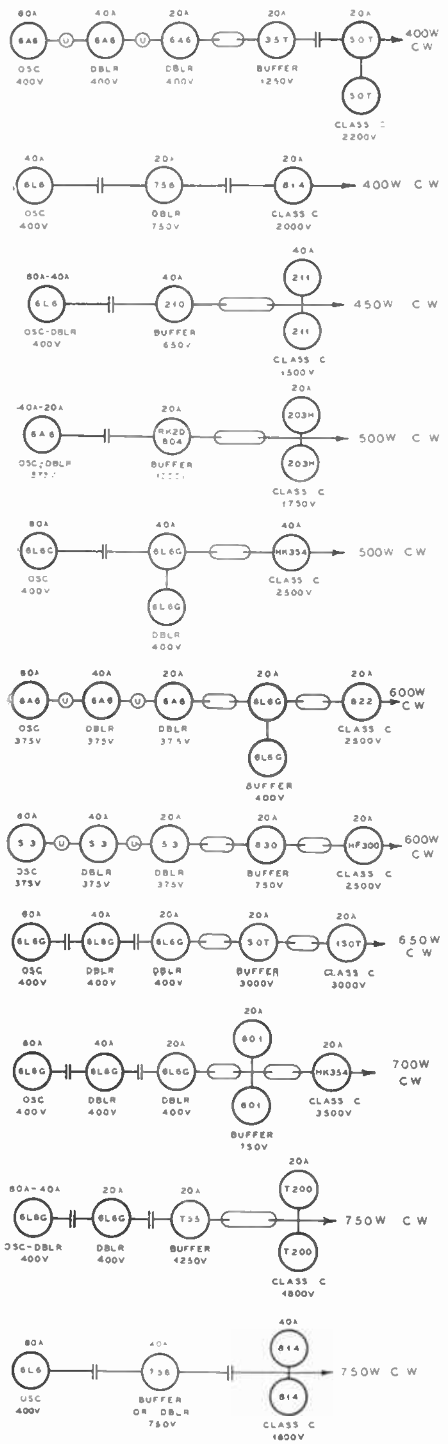
The attention of the reader is invited to a group of newer combinations which were not shown in previous editions of this *Handbook*.

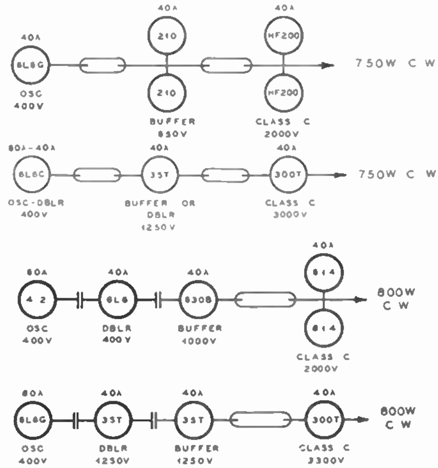


C.W.

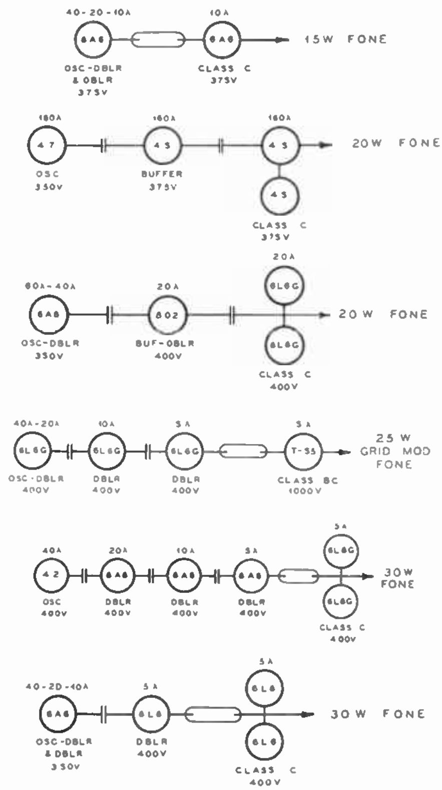


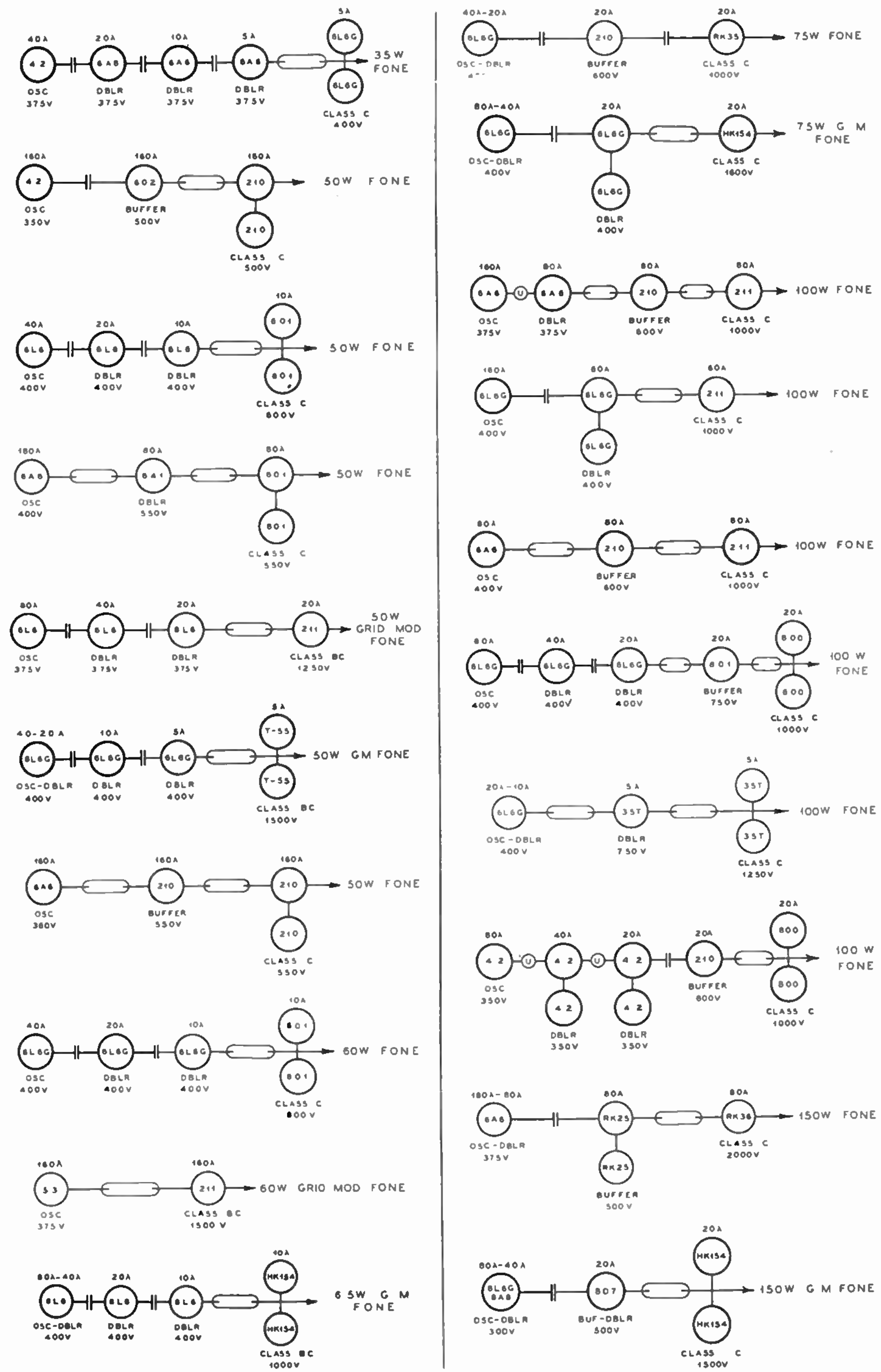

80A 42 OSC 350V — 40A 42 DBLR 350V — 40A 6L6G, 6L6G CLASS C 500V — 50W CW
40A 6L6 OSC 400V — 40A 6L6, 6L6 CLASS C 400V — 60W CW
40A 6A6 OSC 400V — 20A 6A6 DBLR 400V — 40A 6A6 DBLR 400V — 10A RK18 CLASS C 1000V — 60W CW
80A 6L6 OSC 400V — 40A 210 DBLR 600V — 40A 210, 210 CLASS C 600V — 75W CW
80A-40A 6L6G OSC-DBLR 400V — 40A T20, T20 CLASS C 750V — 80W CW
80A 6L6G OSC 400V — 80A 210, 210 CLASS C 750V — 90W CW
40A 6L6G OSC 400V — 20A 6L6G DBLR 400V — 40A 6L6G DBLR 400V — 10A 35T CLASS C 1500V — 100W CW
80A 6A6 OSC 400V — 40A 6A6 DBLR 400V — 20A 6A6 DBLR 400V — 20A 801, 801 CLASS C 750V — 100W CW
80A 6L6G OSC 400V — 40A 6L6G DBLR 400V — 40A 210, 210, 210 CLASS C 750V — 120W CW
80A-40A 6A6 OSC-DBLR 380V — 40A 210 BUFFER 600V — 40A 210, 210 CLASS C 800V — 125W CW
80A RK28 803 OSC 1800V — 125W CW
80A-40A 6A6 OSC-DBLR 350V — 20A 6L6 DBLR 400V — 20A ZB120 CLASS C 1250V — 135W CW
80A 42 OSC 350V — 40A 42, 42 DBLR 350V — 40A 830B CLASS C 1250V — 150W CW
40A 6L6G OSC 400V — 20A 6L6G DBLR 400V — 40A 6L6G DBLR 400V — 10A 35T CLASS C 1500V — 150W CW
160-80A 6L6G OSC-DBLR 400V — 40A 6L6G DBLR 400V — 40A T-55 CLASS C 1500V — 150W CW
80A 6L6G OSC 400V — 40A 6L6G DBLR 400V — 20A 6L6G DBLR 400V — 20A RK35, RK35 CLASS C 1250V — 175W CW
40A 35T OSC 600V — 40A 35T, 35T CLASS C 1250V — 175W CW
80A-40A 6L6 OSC-DBLR 400V — 20A 6L6 DBLR 400V — 10A 6L6 DBLR 400V — 10A HF100 CLASS C 1500V — 200W CW
40A 6L6G OSC 400V — 20A 6L6G DBLR 400V — 20A 860 CLASS C 3000V — 200W CW
80A 6L6G OSC 400V — 40A 6L6G DBLR 400V — 40A 210 BUFFER 750V — 40A 203A CLASS C 1500V — 200W CW
80A-40A 53 OSC-DBLR 400V — 40A 45, 45 BUFFER 400V — 40A HK154, HK154 CLASS C 1000V — 250W CW
80A-40A 6L6 OSC-DBLR 450V — 20A 6L6, 6L6 DBLR 450V — 20A HK154, HK154 CLASS C 1500V — 375W CW

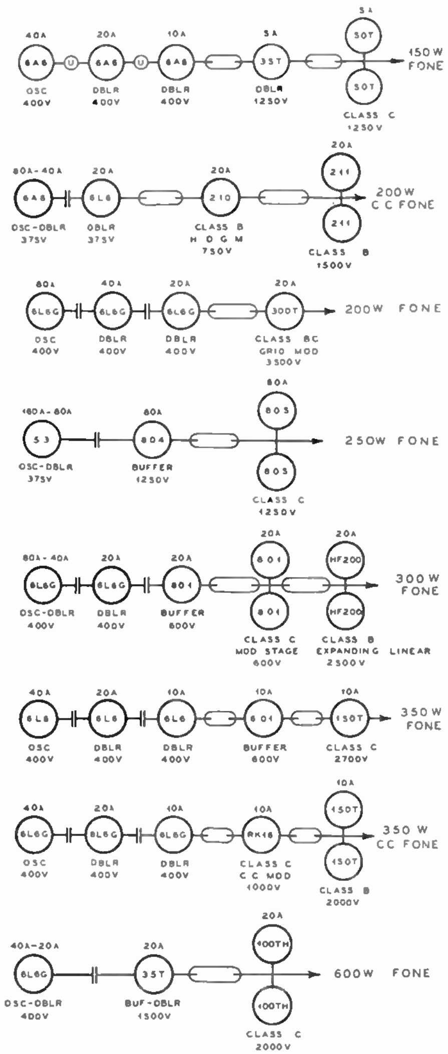




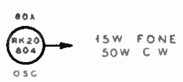
Radiotelephony Block Diagrams

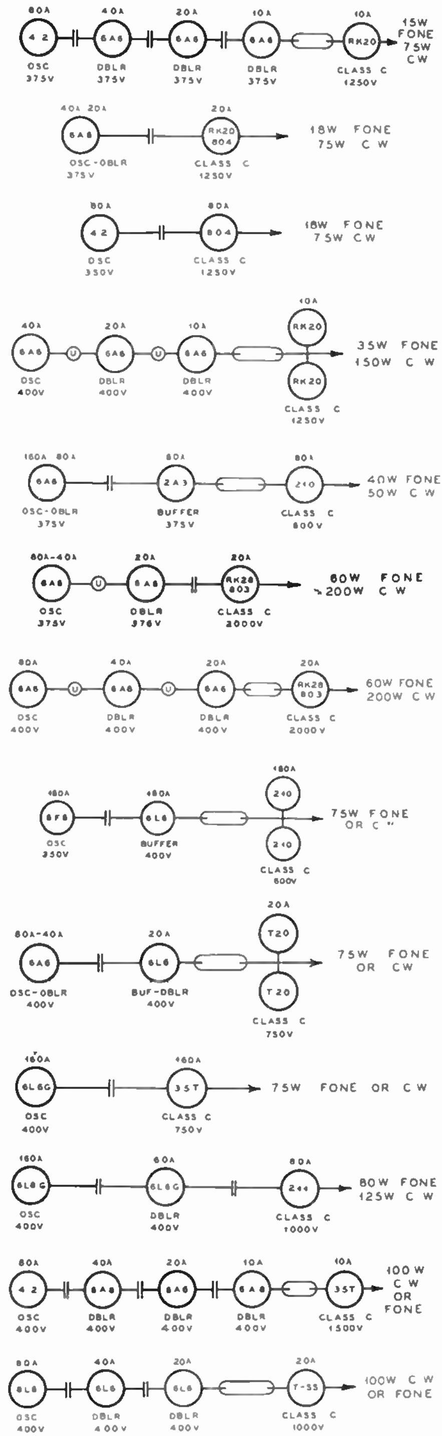


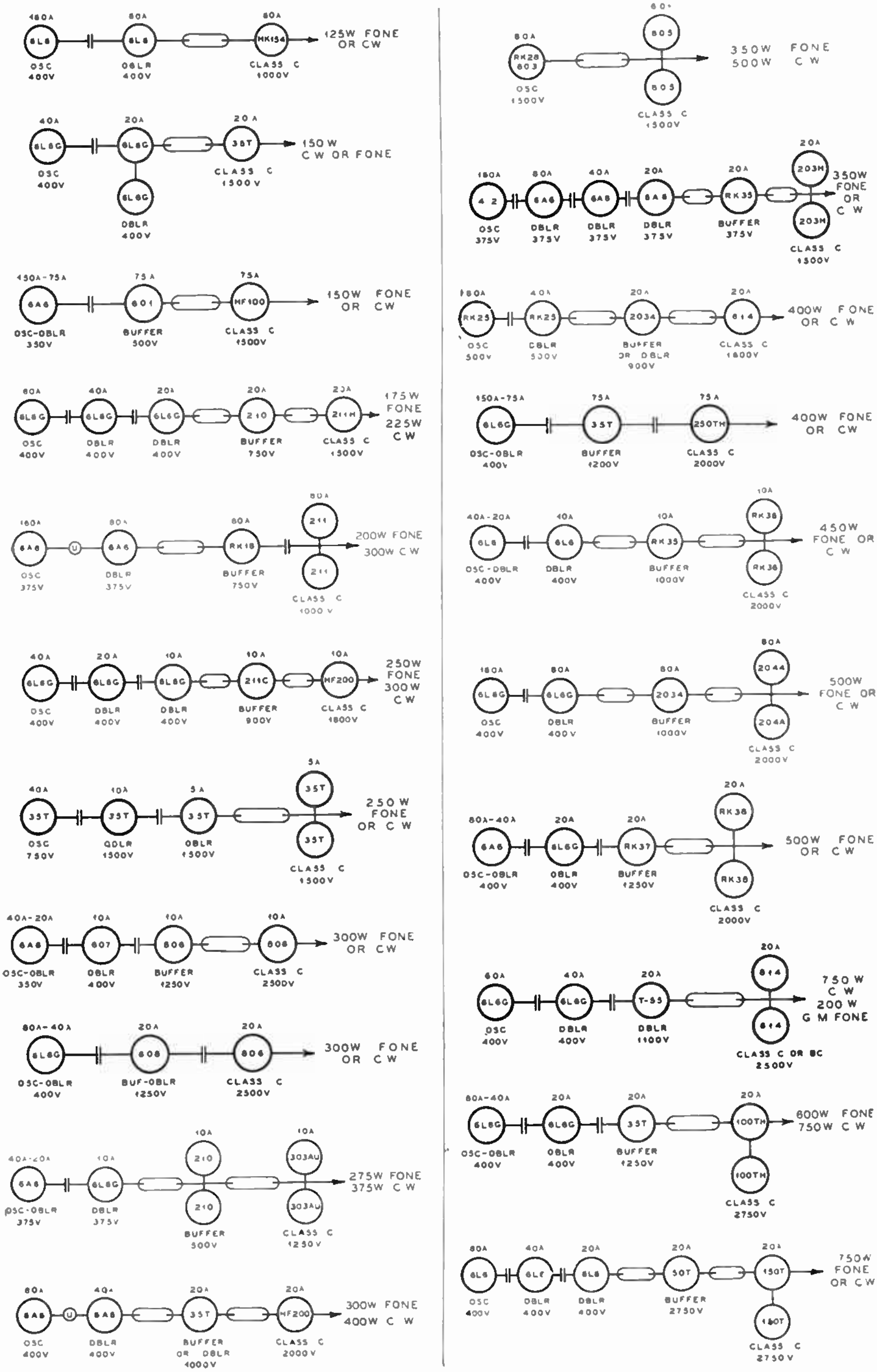

40A 20A 10A 5A 5A
42 6A6 6A6 6A6 6L6G 6L6G
OSC 375V DBLR 375V DBLR 375V DBLR 375V
CLASS C 400V
35W FONE
160A 160A 160A
42 602 210 210
OSC 350V BUFFER 500V CLASS C 500V
50W FONE
40A 20A 10A 10A
6L6 6L6 6L6 801 801
OSC 400V DBLR 400V DBLR 400V CLASS C 600V
50W FONE
160A 80A 80A
6A6 6A6 801 801
OSC 400V DBLR 550V CLASS C 550V
50W FONE
80A 40A 20A 20A
6L6 6L6 6L6 211
OSC 375V DBLR 375V DBLR 375V CLASS BC 1250V
50W GRID MOD FONE
40-20A 10A 5A 5A
6L6G 6L6G 6L6G T-55 T-55
OSC-DBLR 400V DBLR 400V DBLR 400V CLASS BC 1500V
50W GM FONE
160A 160A 160A
6A6 210 210 210
OSC 380V BUFFER 550V CLASS C 550V
50W FONE
40A 20A 10A 10A
6L6G 6L6G 6L6G 801 801
OSC 400V DBLR 400V DBLR 400V CLASS C 600V
60W FONE
160A 160A
53 211
OSC 375V CLASS BC 1500V
60W GRID MOD FONE
80A-40A 20A 10A 10A
6L6 6L6 6L6 HK154 HK154
OSC-DBLR 400V DBLR 400V DBLR 400V CLASS BC 1000V
65W G M FONE
40A-20A 20A 20A
6L6G 210 RK35
OSC-DBLR BUFFER 600V CLASS C 1000V
75W FONE
80A-40A 20A 20A
6L6G 6L6G 6L6G HK154
OSC-DBLR 400V DBLR 400V CLASS C 1600V
75W G M FONE
160A 80A 80A 80A
6A6 6A6 210 211
OSC 375V DBLR 375V BUFFER 600V CLASS C 1000V
100W FONE
160A 80A 80A
6L6G 6L6G 6L6G 211
OSC 400V DBLR 400V CLASS C 1000V
100W FONE
80A 80A 80A
6A6 210 211
OSC 400V BUFFER 600V CLASS C 1000V
100W FONE
80A 40A 20A 20A 20A
6L6G 6L6G 6L6G 801 800 800
OSC 400V DBLR 400V DBLR 400V BUFFER 750V CLASS C 1000V
100 W FONE
20A-10A 5A 5A
6L6G 35T 35T 35T
OSC-DBLR 400V DBLR 750V CLASS C 1250V
100W FONE
80A 40A 20A 20A 20A
42 42 42 42 42 210 800 800
OSC 350V DBLR 350V DBLR 350V BUFFER 600V CLASS C 1000V
100 W FONE
160A-80A 80A 80A
6A6 RK25 RK25 RK36
OSC-DBLR 375V BUFFER 500V CLASS C 2000V
150W FONE
80A-40A 20A 20A
6L6G 6A6 807 HK154 HK154
OSC-DBLR 300V BUF-DBLR 500V CLASS C 1500V
150W G M FONE



Combination Radiotelephony and C.W. Block Diagrams






160A 6L6 OSC 400V
80A 6L6 DBLR 400V
80A HK154 CLASS C 1000V
125W FONE OR CW
40A 6L6G OSC 400V
20A 6L6G 6L6G DBLR 400V
20A 35T CLASS C 1500V
150 W CW OR FONE
150A-75A 6A6 OSC-DBLR 350V
75A 801 BUFFER 500V
75A HF100 CLASS C 1500V
150W FONE OR CW
80A 6L6G OSC 400V
40A 6L6G DBLR 400V
20A 6L6G DBLR 400V
20A 210 BUFFER 750V
20A 211H CLASS C 1500V
175W FONE 225W CW
160A 6A6 OSC 375V
80A 6A6 DBLR 375V
80A RK18 BUFFER 750V
80A 211 211 CLASS C 1000 V
200W FONE 300W CW
40A 6L6G OSC 400V
20A 6L6G DBLR 400V
10A 6L6G DBLR 400V
10A 211C BUFFER 900V
10A HF200 CLASS C 1800V
250W FONE 300W CW
40A 35T OSC 750V
10A 35T QDLR 1500V
5A 35T DBLR 1500V
5A 35T 35T CLASS C 1500V
250W FONE OR CW
40A-20A 6A6 OSC-DBLR 350V
10A 807 DBLR 400V
10A 808 BUFFER 1250V
10A 808 CLASS C 2500V
300W FONE OR CW
80A-40A 6L6G OSC-DBLR 400V
20A 808 BUF-DBLR 1250V
20A 808 CLASS C 2500V
300W FONE OR CW
40A-20A 6A6 OSC-DBLR 375V
10A 6L6G DBLR 375V
10A 210 210 BUFFER 500V
10A 303AU 303AU CLASS C 1250V
275W FONE 375W CW
80A 6A6 OSC 400V
40A 6A6 DBLR 400V
20A 35T BUFFER OR DBLR 1000V
20A HF200 CLASS C 2000V
300W FONE 400W CW
80A RK28 803 OSC 1500V
60A 805 805 CLASS C 1500V
350W FONE 500W CW
160A 42 OSC 375V
80A 6A6 DBLR 375V
40A 6A6 DBLR 375V
20A 6A6 DBLR 375V
20A RK35 BUFFER 375V
20A 203H 203H CLASS C 1500V
350W FONE OR CW
160A RK25 OSC 500V
40A RK25 DBLR 500V
20A 203A BUFFER OR DBLR 900V
20A 814 CLASS C 1600V
400W FONE OR CW
150A-75A 6L6G OSC-DBLR 400V
75A 35T BUFFER 1200V
75A 250TH CLASS C 2000V
400W FONE OR CW
40A-20A 6L6 OSC-DBLR 400V
40A 6L6 DBLR 400V
10A RK35 BUFFER 1000V
10A RK36 RK36 CLASS C 2000V
450W FONE OR CW
160A 6L6G OSC 400V
80A 6L6G DBLR 400V
80A 203A BUFFER 1000V
80A 204A 204A CLASS C 2000V
500W FONE OR CW
80A-40A 6A6 OSC-DBLR 400V
20A 6L6G DBLR 400V
20A RK37 BUFFER 1250V
20A RK38 RK38 CLASS C 2000V
500W FONE OR CW
60A 6L6G OSC 400V
40A 6L6G DBLR 400V
20A T-55 DBLR 1100V
20A 814 814 CLASS C OR BC 2500V
750W CW 200W GM FONE
80A-40A 6L6G OSC-DBLR 400V
20A 6L6G DBLR 400V
20A 35T BUFFER 1250V
20A 100TH 100TH CLASS C 2750V
600W FONE 750W CW
80A 6L6 OSC 400V
40A 6L6 DBLR 400V
20A 6L6 DBLR 400V
20A 50T BUFFER 2750V
20A 150T 150T CLASS C 2750V
750W FONE OR CW

Chapter 12

C.W. Transmitter Construction

TRANSMITTERS ARE constructed in two general ways: (1) *Breadboard* or (2) *Relay-Rack* or metal frame construction.

Breadboard construction is more economical than relay-racks and panels, but it sacrifices appearance and safety of operation. Metal frame construction acts as a shield around the r.f. and high voltage circuits; the metal frame is grounded and thereby protects the operator against electrical shock.

Breadboards are made of any size to suit the individual taste of the constructor. Dry hardwood should be used, and the board should be fitted with cleats at either end to prevent warping and also to provide space under the board for some of the wiring and mounting of small parts. The board can be covered with a thin sheet of metal, but in most cases a good ground connection can be made by means of a heavy copper wire or strip, which is called a "bus-bar." One common ground point should be used for *all* ground connections in each stage, the common ground points of the several stages then being connected together and carried to an external ground connection such as a water pipe.

Metal relay rack construction makes a neat installation, to which changes can be made at any future time because the individual chassis and panels can be easily and quickly removed from the rack.

• Relay Rack Dimensions

Standard relay rack panels are 19 inches long and some multiple of 1¾-inches high, such as 1¾, 3½, 5¼, 7, 8¾, 10½, 12¼, 14, etc., inches high. At least 1/64-inch clearance should be allowed between panels, so that they can be readily removed from the rack. Normally, the panels are slotted ¼ or 1½ inches from top and bottom, with center slots, when needed. A ¼-inch diameter hole is drilled ⅜-inch from the edge of the panel, and the slot itself is ¼-inch wide.

The rack on which the panels are mounted can be of any desired height and is usually made of heavy channel iron. Standard drilling of the rack begins ¼-inch from the top, with 10-32 machine-screw threads. Two rows of holes are spaced 18⅜ inches apart; the rack should have a clearance of approximately 17½ inches in order to accommodate chassis 17-inches long. The holes in the relay rack are 1¼- and ½-inch apart, respectively, beginning with the topmost threaded holes. This standard form of drilling permits the use of any standard size relay rack panel.

A standard size for chassis is 17-inches wide. The height and depth of the chassis pans depend upon the amount of apparatus which is to be mounted above and under the chassis. The chassis can be fastened to the front panels by means of machine screws and two triangular-shaped end supports, as illustrated in the accompanying photograph, figure 1.

• Parts Placement

Various sizes of standoff insulators are available for mounting variable condensers and coils at convenient heights above metal bases or chassis. Coils should preferably be mounted a coil-diameter, or more, from the metal chassis or panels. Large holes should be punched under small coils, tubes and quartz crystal sockets for convenience in wiring. Zinc-coated chassis allow small resistor and condenser leads which carry no r.f. to be soldered directly to the chassis, thus making the leads very short. Power supply leads can be brought to insulators, terminal strips, or sockets at the rear of the chassis. Variable condensers can be driven from dials on the front of the panel by means of insulated extension shafts or by flexible cable couplings. Metering jacks can be insulated from the front panels, when necessary, by means of a 1-inch diameter hole, with the jack mounted on a small strip of bakelite. Rubber grommets should be fitted to the numerous small holes in the chassis through which the individual wires pass, in order to prevent fraying of insulation or flashover from wiring to chassis.

Relay rack construction must take into consideration the proximity of power supply equipment to the audio frequency transformers or low-level grid leads. The chokes and transformers should be mounted as far as possible from power transformers and input filter chokes which have relatively large surrounding a.c. fields. The audio transformers and chokes can be properly oriented on the chassis before the holes are drilled for their mounting. A pair of headphones should be connected across the windings of the audio transformers or chokes; 110-volts a.c. is then supplied to the primaries of the power transformers, and the audio transformers or choke is then varied in position until the a.c. hum, as heard in the headphones, is no longer audible. These tests can be made before the units are permanently wired.

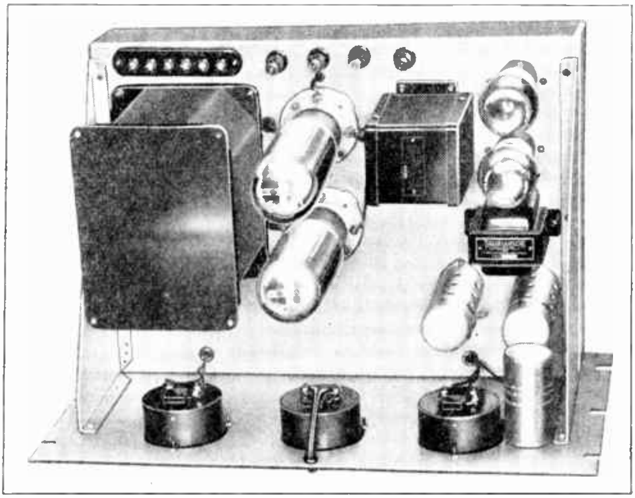


Figure 1— Relay Rack and Chassis for Mounting Heavy Modulator Components.

• Simple C. W. Transmitter

A very simple push-pull crystal oscillator makes a satisfactory c.w. transmitter of modest power output. The complete unit is illustrated in figure 2, and the circuit diagram in figure 3.

A pair of 6L6G beam power tubes is connected in a push-pull circuit which is coupled directly to an antenna; the power output is at least 25 watts with a plate potential of 400 volts, and with the antenna coupling adjusted for satisfactory c.w. keying.

The transmitter is mounted on an oak baseboard, 12-in. x 14-in. x ¾-in. with cleats secured to the bottom of the board at either end so that some of the wiring can be run under the board.

The transmitter can be operated from either an 80- or 40-meter crystal. The crystal is connected between the two control-grids of the 6L6G tubes. An r.f. choke from each grid to ground provides a path for the rectified d.c. grid current. Grid bias is obtained by means of a 200-ohm cathode biasing resistor. The c.w. telegraph key is connected in series with this resistor. The plate circuit is connected in push-pull with a single-section midget variable condenser and a conventional center-tapped plate coil which is bypassed to the common ground point.

For 80-meter operation, the plate coil has 37 turns of no. 20 d.s.c. wire, close wound, on a standard 1½-inch diameter 4-prong plug-in coil form. A center-tap connection is made to the 19th turn. The 40-meter coil has 21 turns of no. 20 d.s.c. wire, close wound, and center-tapped on the 11th turn. The center-tap connection is brought to one of the prongs of the coil form. Coil construction is shown in figure 5.

The antenna coil is wound on a slightly larger diameter tube than the coil form proper, and this coil is placed over the center of the plate coil winding, as shown in figure 3. The number of turns of wire on the antenna coil depends upon the type of antenna to be used and the amount of power that can be drawn from the crystal oscillator while keying the transmitter. An active crystal is necessary for this type of transmitter when heavily loaded by the antenna for maximum output. The number of turns of wire on the antenna coil can be increased until a point is reached where the oscillator refuses to "start" properly when keyed. Two or three turns of wire should be removed from the antenna coil in order to insure stable operation after the transmitter has been loaded to the critical point.

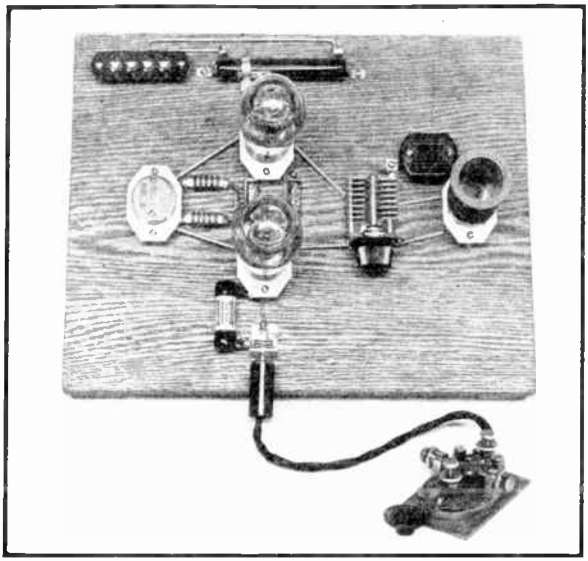


Figure 2—The Transmitter, Ready for Connection to Power Supply and Antenna.

The voltage applied to the screens of the 6L6G tubes can be adjusted to the correct operating value by changing the position of the slider on the 25,000-ohm, 50-watt resistor. The screen potential should be 250 volts, tested with a d.c. voltmeter, if possible. This adjustment can also be made without the aid of a voltmeter by observing the color of the spiral screen-grid when the key is depressed and the transmitter is in an oscillating condition. The slider on the resistor can be moved up toward the 400-volt connection until the screens of the tubes show just a trace of red and then backed off slightly.

The transmitter is tuned for the maximum output consistent with keying stability by the aid of a low-current 6.3 volt pilot lamp, which is connected in series with the antenna feeder. This lamp should light each time the key is depressed. Loss of power in the lamp is negligible, and it can, therefore, remain permanently in the antenna feeder for the purpose of giving a visual means of satisfactory operation of the transmitter.

A suitable power supply for this transmitter is one which will supply 400 volts at 125 milliamperes for the plate circuit, and 6.3 volts at 2 amperes for the heaters of the

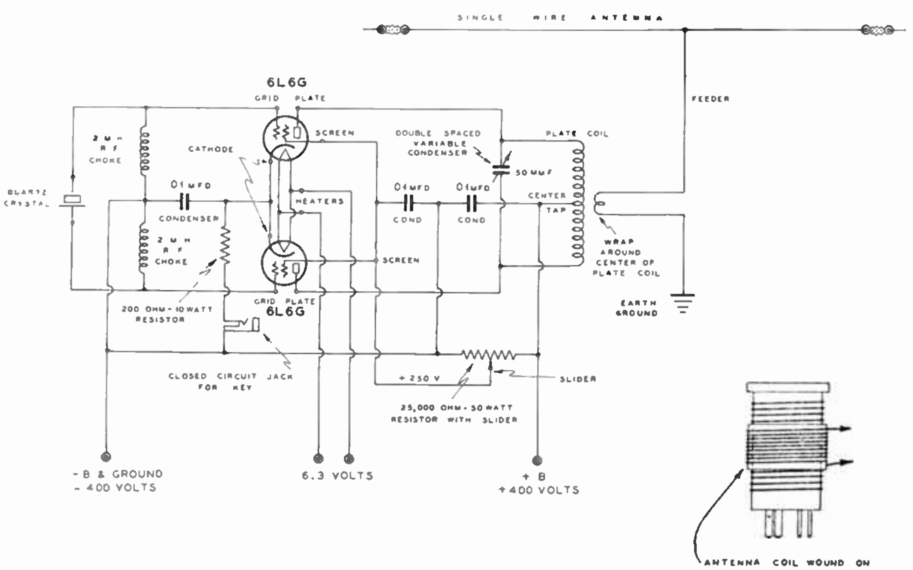


Figure 3—Schematic Circuit of Push-Pull 6L6G CW Transmitter and Pictorial Drafting of Plate Coil With Antenna Coupler.

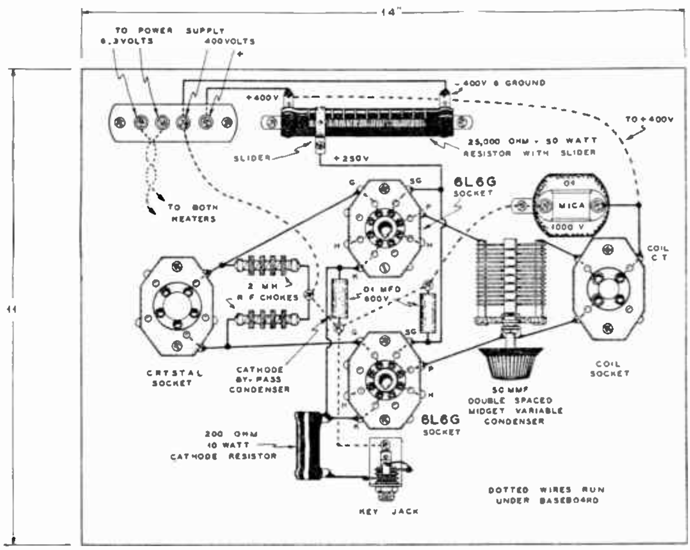


Figure 4—Pictorial Wiring Diagram, Showing Placement of Parts on the Baseboard.

6L6G tubes. The high voltage should be well-filtered in order to obtain a pure d.c. note. A suitable power supply for this transmitter is described in the *Power Supply Chapter.*

All of the wiring is above the baseboard except those wires shown in dotted lines which are run under the baseboard, through small holes drilled through the board. The diagram shows TOP of socket connections for the four sockets used in the transmitter. No connection wires are shown for the heater ("H") contacts of the 6L6G tube sockets, in order to simplify the diagram, and it is obviously necessary for the constructor to make these connections. The heaters of both tubes are connected in parallel. The connecting wires are twisted together, then carried to the terminal at the left rear of the board. The 50 $\mu\mu$fd. double-spaced midget variable condenser (which tunes the plate coil) is secured to the baseboard by means of an angle bracket. Connecting wires are soldered to the rear of the stator ends of this condenser, as the pictorial diagram shows. A very hot soldering iron is needed for this purpose. Some of the pins on the 6L6G tube sockets have no wires connected to them; this means that these pins are NOT used (except the "H" heater pins, as previously referred to). The abbreviations in the pictorial diagram are interpreted as follows: *MMF* indicates micro-micro-farads: 2 *Mh. r.f. Chokes* indicates 2 millihenry r.f.

Coil Table For 35-Watt 6L6G Transmitter

Coil	Winding Data
160 Meters	68 turns, no. 24 d.s.c., 1¾ in. winding length.
80 Meters	33 turns, no. 20 d.s.c., 1½ in. winding length.
40 Meters	16 turns, no 16 Enam., 1½ in. winding length.
20 Meters	7 turns, no. 16 Enam., 1½ in. winding length.
10 Meters	3 turns, no. 16 Enam., 1-in. winding length.

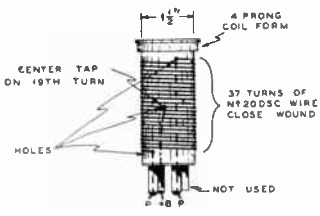


Figure 5

chokes; *MFD* indicates microfarads: COIL C. T. indicates the center-tap connection to the plate coil. The 6L6G socket connections are identified as follows: H and H are the heaters, P is the plate, G is the grid, SG is the screen-grid, K is the cathode.

Trouble Shooting

If the transmitter does not function, i. e., if the 6.3-volt lamp does not glow brightly, the difficulty can be traced to one or more of the following causes:

(1) Incorrect wiring.

(2) Crystal inserted into wrong socket pins.

(3) Slider on 25,000-ohm resistor not advanced far enough to left.

(4) Defective quartz crystal or a dirty crystal.

(5) Key not down when tuning adjustments are made.

(6) Open circuit in some resistor or condenser.

(7) Short-circuited fixed condenser.

(8) Heater voltage not supplied to tube heaters.

(9) RF chokes incorrectly wired into the circuit.

(10) Short-circuited between rotor and stator plates of variable condenser.

(11) Tube sockets incorrectly wired.

(12) Open circuit in one of the ground connections.

(13) Incorrect wiring of plate coil or its socket.

(14) Defective tube, or tubes.

LIST OF PARTS REQUIRED

2 Raytheon or Sylvania 6L6G Tubes.
2 8-prong Hammarlund Isolantite Sockets.
1 4-prong Hammarlund Isolantite Socket.
1 5-prong Hammarlund Isolantite Socket.
1 Quartz Crystal, any frequency between 3550 and 3850 KC.
1 Quartz Crystal holder.
1 4-prong Hammarlund 1½" dia. Coil Form.
2 Hammarlund 2 Mh R. F. Chokes, small type.
1 Hammarlund 50 μμfd. Double-Spaced "Star" Variable Condenser.
1 Cornell-Dubilier .01 μfd., 1000-volt Mica Fixed Condenser.
2 Cornell-Dubilier .01 μfd., 600-volt Tubular Paper Condensers.
1 Ohmite 25,000-Ohm, 50-watt Resistor with Slider.
1 Ohmite 200-Ohm, 10-watt Resistor.
1 Closed-Circuit Jack (for Key).
1 Terminal Connector Strip, 4 terminals.
1 Roll (25 feet) No. 16 push-back wire.
1 Wood Baseboard, 11" x 14" x ¾".
2 Wood Cleats, ¾" x 1½" x 11".
1 Doz. wood screws, ½" long.
8 Wood screws, 1½" long (for mounting sockets).
¼-pound spool No. 18 DCC wire for plate coil winding.

35-Watt 6L6G Transmitter

A small c.w. transmitter for either portable or fixed station operation on 80, 40, 20 and 10 meters is illustrated in figures 6, 7 and 8.

Technical Description

A harmonic 6L6G oscillator drives two 6L6G tubes in parallel as a high-efficiency doubler. This transmitter can be used as a high power exciter for driving amplifiers with outputs of approximately 500 watts. The crystal oscillator will operate on either the fundamental or second harmonic of the crystal by merely changing the plate coil. The adjustments of this type of oscillator are fully covered in the chapter on *Transmitter Frequency Control.*

Two tubes are operated in parallel in the doubler circuit in order to obtain high output. These tubes are capacitively coupled to the crystal oscillator. The plate circuit is tuned to the second harmonic of the driver frequency. An r.f. choke is connected in series with the cathodes of the tubes in the doubler stage and a .0001 μfd. mica condenser is connected from cathode to ground. This forms an automatic regenerative effect which is more pronounced in the high-frequency bands. The output on 10 meters is very nearly doubled, and less grid circuit drive is needed when there is regeneration in the doubler circuit. 160-, 80-, or 40-meter crystals can be used in the crystal oscillator.

A simple tuning indicator is connected in series with the cathode in each stage; it consists of a 2-volt 60 ma. pilot lamp in the oscillator cathode circuit and a 6.3-volt 150 ma. lamp in series with the cathode of the doubler circuit. These lamps eliminate the conventional d.c. milliammeter, and they also serve

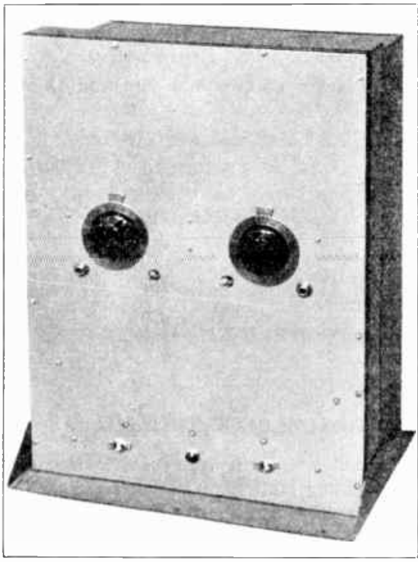


Figure 6—Front View of Housing for a Small Transmitter or High-Power Exciter. The Two Dial Lights for Tuning are Clearly Seen Between the Tuning Dials. These Dial Lights Obviate the Need of a Milliammeter.

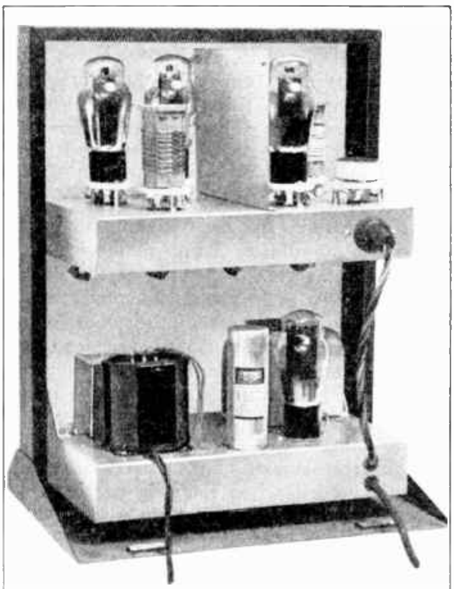


Figure 7—The Complete 6L6G Transmitter or High-Power Exciter, with Power Supply on the Lower Chassis. Five-Band Operation is Secured, with High Output for Either Direct Connection to an Antenna or Feeder System or as a Driver for a Medium Power R. F. Amplifier.

as an overload fuse. The lamps are mounted near the tuning dials and protrude through the front panel, as shown in the illustration, figure 6. Closed-circuit jacks, also in the cathode circuit, can be used for external metering when desired. The meter jack contacts are connected so as to measure the cathode current of each individual stage with an external meter, the cathode being disconnected from the common keying circuit at the same time The tuning indicator lamps light up more brilliantly when the circuits are detuned, or more heavily loaded at the resonant dip in current. The plate circuits are *tuned* for *minimum* brilliance of the lamps.

Both stages are simultaneously keyed, which allows break-in operation and prevents the doubler stage from breaking into self-excited oscillation when no grid excitation is applied. The cathode circuits are connected through a *key-click filter* which consists of a series inductance and a condenser and resistor across the key contacts. The inductance of the 10-henry 200-ma. choke would introduce too much time lag, and a semi-adjustable 10,000-ohm resistor is therefore shunted across the choke coil, the resistor usually being set to a value of approximately 5,000 ohms. This combination of inductance and shunt resistance effectively reduces the series impedance and gives clean-cut keying without clicks.

The final stage is operated with rather high plate voltage in order to increase the output. The crystal oscillator plate supply is adjusted to approximately 400 volts and the common screen voltage supply to 250 volts by means of sliders on the bleeder resistor in the filter circuit.

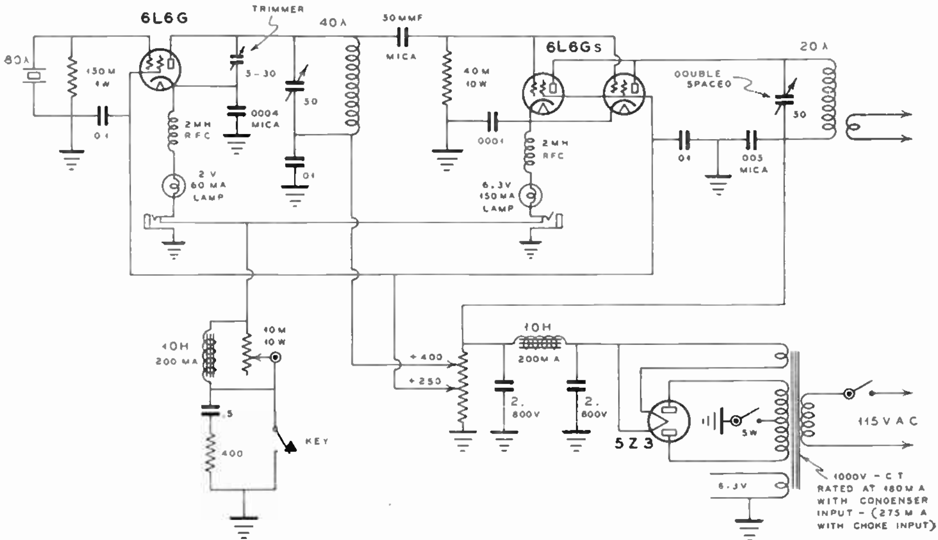
The transmitter is built into a midget relay rack, 18 in. x 13 in. x 8 in. deep, with a hinged rear cover.

• Coil Winding

All coils are wound on standard 1½ in. diameter plug-in coil forms. The oscillator and doubler coils are interchangeable. The doubler coil is always one of a higher frequency than the oscillator coil; i.e., for 40-meter output, for example, the doubler requires a 40-meter coil and the oscillator an 80-meter coil, and either an 80-meter or 160-meter crystal.

• 210 C.W. Transmitter

A 75-watt c.w. transmitter with standard type-210 tubes, or a 100 watt transmitter with the newer Taylor T-20 triodes, is shown in figures 9, 10, and 11.



SMALL CW TRANSMITTER OR HIGH POWERED EXCITER UNIT

Figure 8

The photographs and circuit diagram show the type-210 tubes. When T-20s are substituted, the plate connections are made to the tops of the tubes, and the 5,000- and 10,000-ohm grid-leak values should be changed to 2,500 ohms and 5,000 ohms, respectively. This is necessary because of the higher μ of the T-20 tubes.

● Technical Features

A regenerative crystal oscillator, for one-band operation only, is capacitively coupled to a neutralized buffer or doubler stage. This stage is then link coupled to the final push-pull amplifier.

This transmitter is designed primarily for 80-, 40- and 20-meter operation. It can be used on 160 meters by substituting a larger plate tuning condenser in the final amplifier (210 $\mu\mu$fd. per section for 160-meter operation), but without change in the capacity of the oscillator and buffer stage tuning condensers.

The crystal-oscillator cathode circuit is keyed for c.w. operation. Fixed bias is used for both buffer and final amplifier stages. If type T-20 tubes are used, the fixed C-bias voltage can be reduced to as low as 45 volts. The buffer plate voltage is obtained from the 750-volt supply through a 5,000-ohm semi-variable series dropping resistor, this resistor being adjusted so that approximately

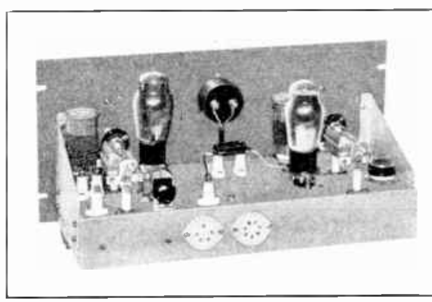


Figure 9—6L6G Exciter and 210 Buffer-Doubler.

Figure 10—Final Amplifier with Two 210 Tubes in Push-Pull. The Tubes, Grid Coil and Neutralizing Condensers are Mounted on a Separate Masonite "Deck," Supported on Small Insulators.

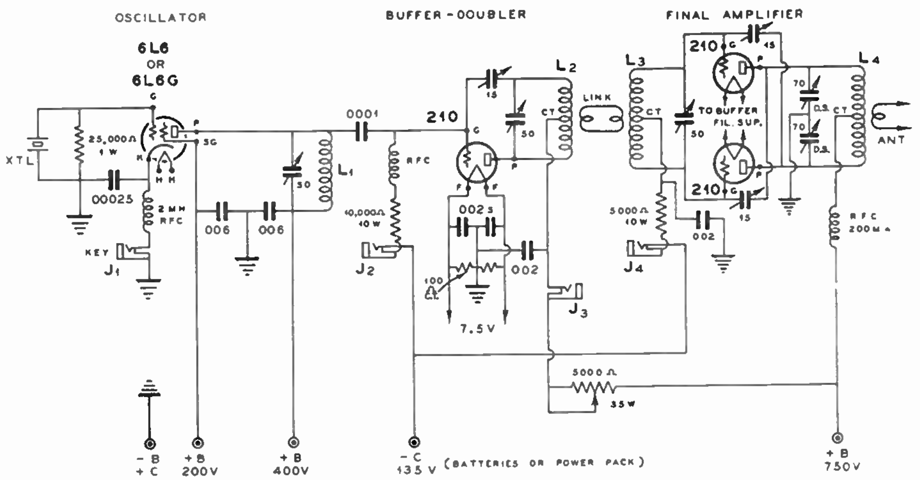


Figure 11—Circuit Diagram of R. F. Portion of 210 C. W. Transmitter.

600 volts is supplied to the buffer plate. The 400-volt supply for the crystal oscillator should be capable of handling a 75 ma. load; the 750-volt supply must handle a 200 ma. load.

Typical milliammeter readings for 80-meter operation are:

Oscillator Cathode—60 ma.
Oscillator Plate—50 ma.
Buffer-Doubler Grid—10 ma.
Buffer-Doubler Plate—60 to 75 ma.
Final Grid—25 to 30 ma.
Final Plate—150 ma. with normal antenna load.

Coil Winding Table for 75-Watt C. W. Transmitter

Band	Oscillator Plate Coil	210 Buffer Plate Coil	Final Amp. Grid Coil	Final Amp. Plate Coil
160	60 turns no. 22 d.s.c. close-wound.	72 turns no. 22 d.s.c. wire, close-wound. Center-tapped.	Same as 210 Buffer Plate Coil.	78 turns no. 18 d.s.c. 4-in. dia., 4-in. long. Center-tapped.
80	25 turns no. 18 d.s.c. Close-wound.	34 turns no. 18 d.s.c. Close-wound. Center-tapped.	48 turns no. 18 d.s.c. Close-wound. Center-tapped.	40 turns no. 14 Enam. $2\frac{5}{8}$ in. dia. $4\frac{1}{2}$ in. long. Center-tapped.
40	17 turns no. 18 d.s.c. spaced to cover $1\frac{1}{2}$-in.	21 turns no. 18 d.s.c. spaced to cover $1\frac{1}{2}$ in. Center-tapped.	24 turns no. 18 d.s.c. spaced to cover 1-inch Center-tapped.	22 turns No. 14 Enam. $2\frac{5}{8}$ in. dia. $4\frac{1}{2}$ in. long. Center-tapped.
20	Use 40-meter Oscillator coil and double in Buffer plate.	14 turns no. 18 d.s.c. spaced two diameters. Center-tapped.	13 turns no. 18 d.s.c. spaced two diameters. Center-tapped.	10 turns No. 14 Enam. $2\frac{5}{8}$ in. dia. 4-in. long. Center-tapped.

Medium Power C.W. Amplifiers

The ever increasing number of new tubes for amateur transmitters, and the ability to interchange these tubes with those of somewhat similar ratings, makes it difficult to show complete c.w. transmitters for every possible combination of tubes. For this reason, the text which follows is devoted to the design and construction of a large group of individual amplifiers which will deliver from 100 to 500 watts output. Grid neutralized, plate neutralized, and push-pull amplifiers are illustrated in conjunction with a number of the more popular medium power tubes.

Any of these single-tube amplifiers are capable of being driven for c.w. telegraph operation by means of exciters shown in the chapter on *Transmitter Frequency Control*, in which the type 6L6G tube is featured. The push-pull amplifiers can be driven by the high power exciters which have parallel or push-push doublers, or by means of a buffer amplifier with a type-210 or T-20 tube. The output from any of these amplifiers can be link-coupled to most any type of tuned antenna coupling circuit.

The result of this new method of treatment is that the experimenter is given the specific circuit constants for the tube of his choice. The coil-winding data for any of the amplifiers described can be obtained from the new air-supported coil chart shown in the *C. W. Theory* chapter, or from previously listed coil design tables.

808 Amplifier

The 808 is a low-C tantalum plate triode which can be driven by a 6L6G buffer or doubler, or any other type of exciter which will deliver 10 or 15 watts output. This amplifier is built on a 10 in. x 12 in. metal chassis. It has a single-section 6,000-volt plate tuning condenser and a double-spaced 50-μμfd. single-section midget variable condenser for tuning the grid circuit. The neutralizing condenser should have a plate spacing of approximately ¼ inch, and can be mounted to the rotor frame of the plate tuning condenser by means of a bracket, as shown in figure 12.

The .002-μfd mica condenser connected to the center-tap connection of the plate coil in figure 13 should be rated at 5,000 volts. The grid and filament bypass condensers can be of the ordinary 1,000 volt mica receiving type. Short neutralizing leads are of extreme importance. The parts should be laid out in such a manner as to provide fairly good separation without long connections in the r.f. circuits. When operated within its normal ratings, this amplifier will deliver a maximum output of approximately 140 watts.

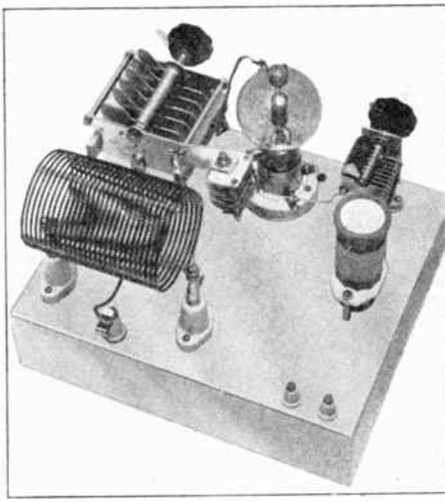


Figure 12—RCA-808 Tantalum Plate Triode in a Simple, Effective R. F. Amplifier Unit.

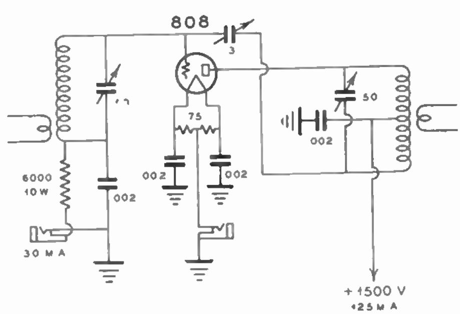


Figure 13—Circuit of Amplifier Pictured in Figure 12.

211 Amplifier

Certain tubes can be used in a circuit which has a single-section plate tuning condenser and bypassed center-tapped plate coil. These tubes will not have excessive regeneration in this form of neutralizing circuit, and they require about 50 per cent *less grid excitation* than when split-stator condenser tuning is used. This type of circuit is not satisfactory for 'phone operation, except on the lower frequencies such as 160 meters. Some regeneration can be used to advantage in c.w. transmitters in order to reduce the

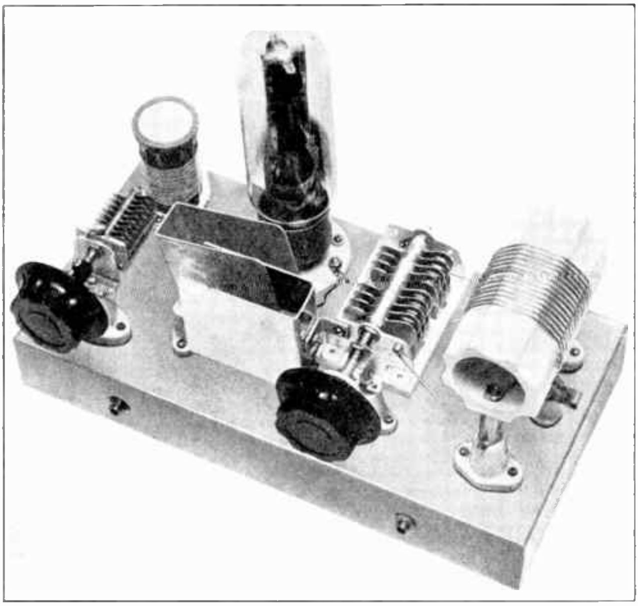


Figure 14—The "Old Reliable" Type 211 or 203A Triode is Still Widely Used by Amateurs. The Amplifier Design is Ideal for Such Tubes. The Larger-Than-Usual Neutralizing Condenser is Easily Made from Aluminum, Bent as Shown in the Photograph, with One of the Sections Attached Directly to the Stator of the Plate - Tuning Condenser. Note How Well the Parts Lend Themselves to Symmetry in This Design.

grid driving power requirement for relatively high output and efficiency.

The 211 amplifier shown in figures 14 and 15 will operate best with a 10,000 ohm grid-leak; a type-203A will require a 5,000-ohm grid-leak. These tubes can be driven to moderate output with a 6L6G driver, or to high output by a type-10 or T20 buffer. The plate tuning condenser should be able to withstand 4000 volts on peaks. The particular plate tuning condenser shown in figure 14 is a split-stator condenser with the two stator sections connected in parallel. The neutralizing condenser is made of two U-shaped pieces of no. 16 gauge aluminum, 3 in. x 7 in. When bent into the shape of a "U", the plates are 3-inches square and 1-inch apart, which gives approximately ½-inch plate spacing. One section is rigidly mounted to the rotor of the plate tuning condenser; the other is secured to a right-angle bracket made of 16-gauge aluminum, this bracket being mounted on a standoff insulator. The aluminum bracket allows this U-shaped section to be bent forward or backward, for adjusting the neutralizing capacity.

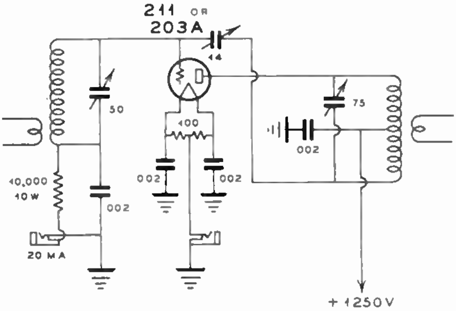


Figure 15—Circuit for 211 Amplifier Pictured in Figure 14.

The .002 μfd. mica plate bypass condenser should be rated at 5,000 volts. The grid tuning condenser is a double-spaced 50-$\mu\mu$fd. midget variable. Both tuning condensers are mounted on porcelain standoff insulators. The chassis is 8 in. x 17 in. x 2 in.

The output efficiency of a 211 or 203A amplifier will not be as high for 20-meter operation as would be secured from a low-C triode with the plate lead brought through the top of the glass envelope.

● 35-T Push-Pull Amplifier

Relatively high power output can be obtained with small tubes of the modern type. Operating at their normal ratings, the push-pull 35T's, shown in figures 16 and 17, will supply 350 watts to the antenna. These tubes are often operated at plate potentials exceeding 2,000 volts and no difficulty is experienced in obtaining over 500 watts output at such voltages from the amplifier illustrated.

The important factors which enter into the design of an efficient push-pull amplifier are

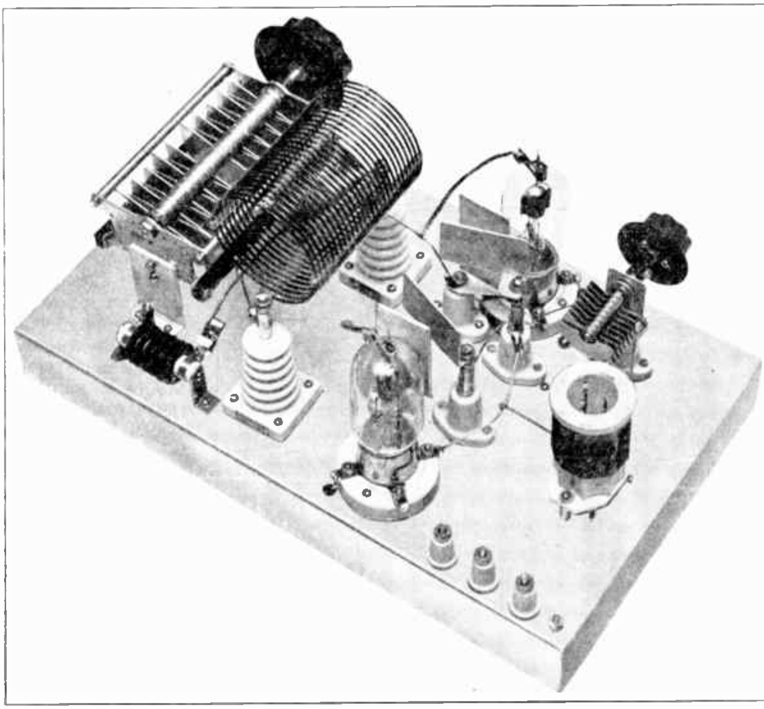


Figure 16—A Pair of 35T's, 800's, RK-35's or Other Tubes of Similar Type are Correctly Arranged in an R. F. Amplifier When the Placement is as Shown in This Illustration.

the need for symmetrical lengths of plate and neutralizing leads in each side of the amplifier. The grid circuit is often purposely made to have unequal length of leads in order to minimize the possibility of a u.h.f. *parasitic oscillation.*

A split-stator plate tuning condenser is very desirable; the plates should have a spacing sufficiently wide so that *each section* of the condenser will withstand a peak potential of 5,500 volts when the d.c. plate voltage is of any value between 1,500 and 2,000 volts.

The neutralizing condensers are made of no. 14 gauge aluminum plates, with an active plate area of 1½ in. x 1½ in. The plate spacing is varied by mounting the movable plates (grid) on ¼ in. diameter coil jacks and plugs. The spring tension in this type of coil jack is sufficient to hold the movable plate in its proper position, once the correct neutralizing adjustment is found. A double-spaced 50-$\mu\mu$fd. midget variable condenser tunes the grid circuit. This condenser is mounted on a small bracket attached to a standoff insulator.

The r.f. choke must be capable of carrying 350 ma. of d.c. plate current; the center-tap of the plate coil clips into a *Fahnestock* clip attached to one end of the r.f. choke.

The grid driving power requirements for this amplifier depend upon the plate voltage, antenna loading, and operating efficiency. For normal operation a pair of 6L6G tubes in parallel or push-pull will drive the amplifier to efficiencies of more than 75 per cent. If

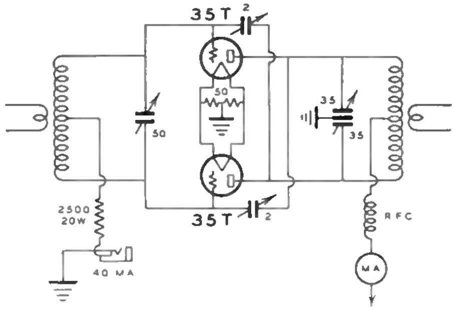


Figure 17—Push-Pull 35T Amplifier. The Mechanical Construction is Shown in Figure 16.

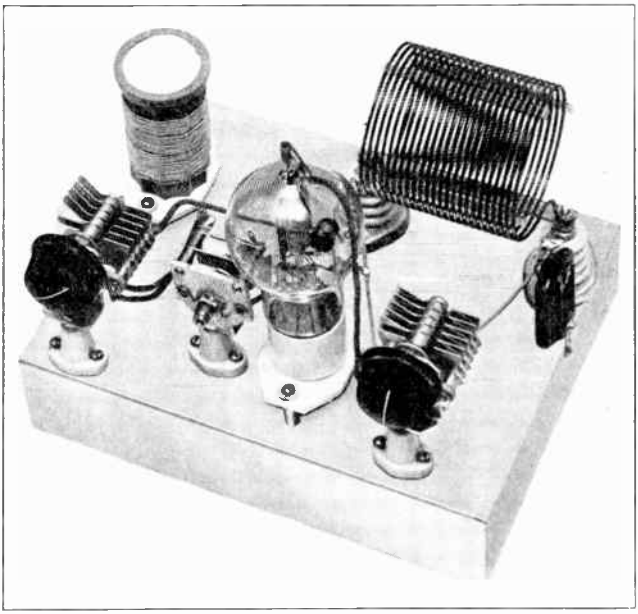


Figure 18—Standard Low-Cost Parts are Used in This Amplifier. The Tube is an RK-35 Triode. Double-Spaced 50 μμfd. Midget Variable Condensers Tune Both the Grid and Plate Circuits. Neutralizing Condenser is a Standard 4-μμfd. Wide-Spaced Midget. When Mounted Behind a Metal Relay-Rack Panel, Condenser Shafts Should be Fitted with Insulated Couplings.

the amplifier operates with 2,000 volts on the plates, the driver should be another 35T tube when used as a doubler, or a T-20 when used as a buffer.

● RK-37 Amplifier

The RK-37 is a high μ tantalum plate triode similar to the 35T, except that the plate voltage and current ratings are slightly lower. The amplifier shown in figures 18 and 19 is designed for operation at 1,000 volts in order to economize on cost. Grid neutralization makes possible the use of a small, double-spaced, midget plate tuning condenser. The peak r.f. plate voltage in a grid neutralized amplifier is generally not more than one-half of that in a similar plate neutralized amplifier, even though the power input and efficiency may be the same. If a plate neutralized circuit is to be used in this amplifier, the plate tuning condenser must have approximately twice as great an air-gap between its plates.

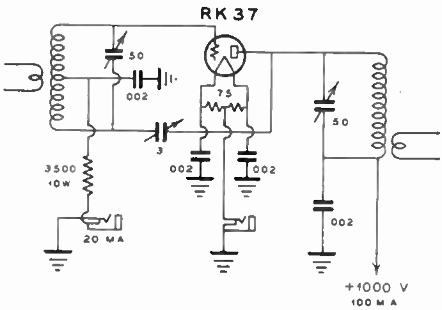


Figure 19—RK-37 Amplifier Circuit for the Unit Shown in Figure 18.

This c.w. amplifier can be driven by any exciter with a 6L6G doubler or buffer. The .002 μfd. plate circuit bypass condenser should be of the mica type, rated at 2,500 volts. The grid neutralizing condenser should have a plate spacing slightly greater than that of the plate tuning condenser; it should have a low minimum capacity in order to neutralize the low-C tube.

If this amplifier is used primarily on 10 and 20 meters, it is desirable to use a split-stator grid tuning condenser in order to provide a non-regenerative neutralizing circuit. The single-section tuned grid circuit in figure 19 requires less grid circuit drive than when a split-stator grid tuning condenser is used, but at a sacrifice in stability at the higher frequencies.

● Taylor T-55 Amplifier

A high-μ carbon plate T-55 triode is suitable for either a high power buffer or doubler stage. When operated under the conditions illustrated in figure 21, an output of 175 watts can be secured if the amplifier is driven by a

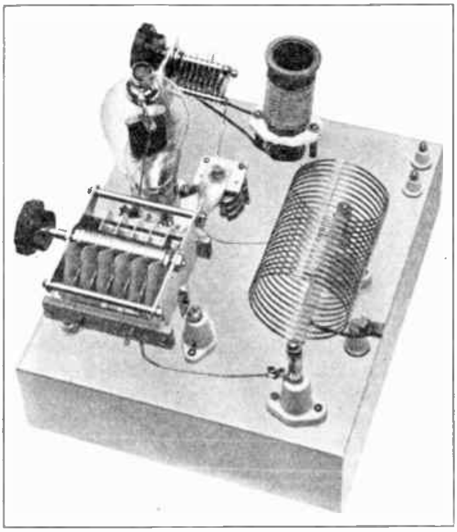


Figure 20—Single-Ended R. F. Amplifier with Taylor T-55, or Similar Triode. This Amplifier is Suitable for Buffer Service. It Will Drive a 1-Kilowatt Amplifier for C. W. Operation.

6L6 doubler or buffer. When the T-55 is used as a doubler, the value of grid-leak should be increased to somewhere between 15,000 and 50,000 ohms, depending upon the available amount of grid excitation and plate voltage. Higher efficiency can be obtained with the higher value of grid-leak if sufficient grid excitation is available. A suitable driver would then be a type T-20 tube.

The plate tuning condenser should be able

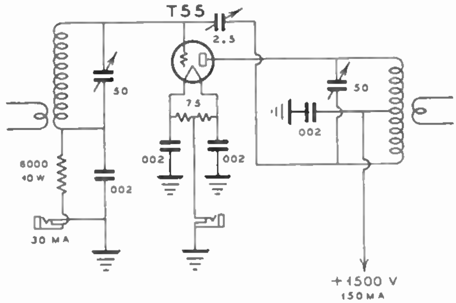


Figure 21—Single-Ended T-55 Amplifier as Pictured in Figure 20.

to withstand r.f. peak potentials of 6,000 volts. An ordinary, double-spaced, 50 $\mu\mu$fd. midget, variable condenser tunes the grid circuit, which should be link-coupled to the driver. The neutralizing condenser plates should be spaced from 0.2 to 0.25-in. between rotor and stator. The .002 μfd. mica bypass condenser in the plate coil center-tap lead should be a 5,000-volt mica; other bypass condensers can be of the mica 1,200-volt type.

• Single Tube 35T Amplifier

A typical breadboard mounted amplifier with a type 35T tube is shown in figures 22 and 23. Grid neutralization requires less spacing between plates of the plate tank condenser though the actual amount of capacity used in each band of operation should be

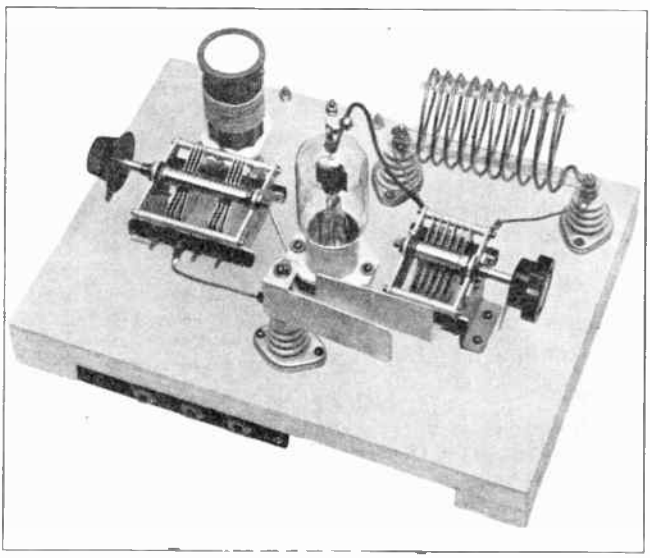


Figure 22—Medium Power R. F. Amplifier with 35T Triode. The Grid and Plate Tuning Condensers are Mounted Sidewise in Order to Facilitate Short, Direct Connecting Leads. Flexible Cable Couplings Can be Attached to the Condenser Shafts When an Amplifier of This Type is to be Relay-Rack Mounted. The 35T Can be Replaced with a T-55, 808, RK-35 or Similar Tube.

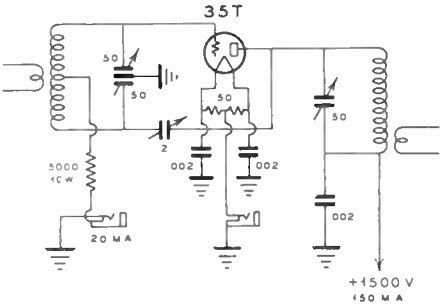


Figure 23—Single 35T Amplifier; Figure 22 Shows Its Construction.

The number of turns of wire in the plate coil of a grid-neutralized amplifier should be from 25 per cent to 40 per cent *less* than in the case of a plate-neutralized amplifier, in order to maintain the proper *L-C* ratio for the circuits. The grid coil in a grid-neutralized stage may have approximately 10 per cent to 15 per cent more turns than for a plate-neutralized amplifier, since the input capacity of the tube is connected across only one-half of the coil.

The plate bypass condenser is a .002 μfd. 5,000-volt mica type. The filament bypass condensers can be of the 400-volt size, any capacity from .001 to .01 μfd.

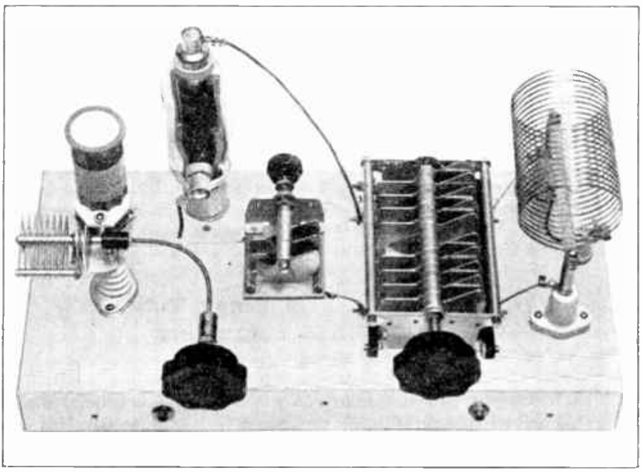


Figure 24—Flexible Cable Drive for Tuning Grid and Plate Condensers is Now Coming into Wide Use. This Arrangement Makes Possible the Mounting of Condensers in Such Positions as Will Give Greatest Efficiency in Amplifier Circuits. Here Illustrated is an R. F. Amplifier with an HF-100 Triode. This Particular Amplifier Was Built for 20 and 40 Meter Operation; the Long Plate Lead Does not Lend Itself to Operation on 10 Meters. For the Latter Band, Amplifiers Which are More Suited are Described in This Chapter.

proportionately higher than in a plate-neutralized amplifier. The split-stator grid tuning condenser enables this amplifier to operate on 10 meters with good stability. The plate-tuning condenser is rated to withstand 3,000 volts. The grid-tuning condenser is a single-spaced split-stator variable. The neutralizing condenser is made of two aluminum plates which have an exposed area of 1-in. x 2-in. One of the plates is attached to a ¼-inch coil plug and jack; this is the movable plate. The spacing of the plate-tuning condenser shown in the photograph is sufficient to withstand the r.f. voltage encountered with a 1,500-volt d.c. plate supply, *provided that the amplifier is loaded with an antenna circuit.*

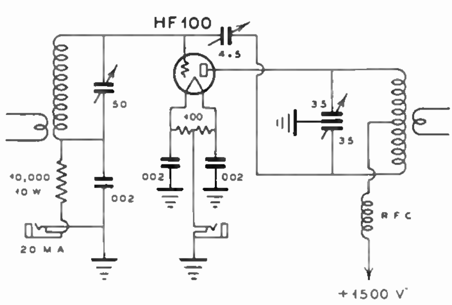


Figure 25—HF-100 Triode Amplifier. Figure 24 Shows Its Mechanical Construction.

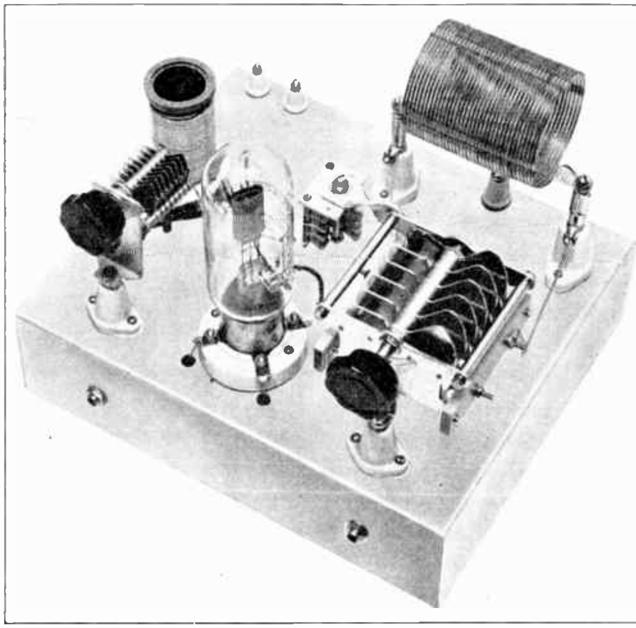


Figure 26 — Single-Ended R. F. Amplifier with HK-154 Gammatron. The Same Amplifier Adapts Itself to Other Tubes of the Same General Size and Type. Note the Uniformity of Controls, the Short, Direct Wiring Connections. Insulated Couplings Can be Attached to the Condenser Shafts When the Amplifier Chassis is Mounted Behind a Relay-Rack Panel.

This amplifier can be driven by a 6L6G amplifier or doubler which delivers an output of 15 watts or more.

● HF-100 Amplifier

Tubes with very high mutual conductance, such as the HF-100, should preferably be operated in split-stator neutralized circuits, such as the one illustrated in figure 25. A single-section plate-tuning condenser with the center-tap of the coil bypassed to ground will introduce too much regeneration on the higher frequencies when plate voltage is applied. The split-stator tuned plate circuit also has an advantage in that a neutralizing condenser seldom requires readjustment when the bands of operation are changed. The lack of regeneration in this type of neutralizing circuit under normal operating conditions means that more grid drive is required than in the case of a single-section plate-tuning condenser. The HF-100 has a very high mutual conductance and therefore requires very little grid drive even when no regeneration is present. This amplifier can be driven by a 6L6G tube, either as a buffer or doubler.

The plate-tuning condenser is rated at approximately 5,000 volts per section. The neutralizing condenser has a similar rating. A double-spaced, 50-$\mu\mu$fd. midget variable condenser tunes the grid circuit.

The amplifier is built on a metal chassis, 17 in. x 8 in. x 2 in. The two tuning controls are brought to symmetrical points on the front of the chassis by means of a flexible cable connected to the grid tuning condenser.

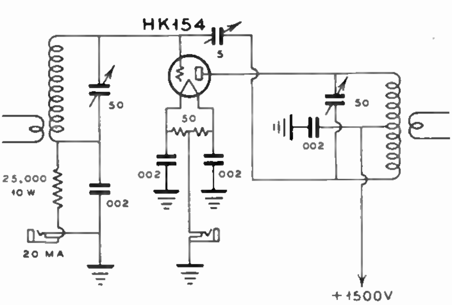


Figure 27 — HK-154 Amplifier. It Will Supply 200 Watts Output for C. W. Operation. Figure 26 Shows the Mechanical Design.

● HK-154 Amplifier

The mechanical design of an amplifier for the HK-154 tantalum plate triode can be the same as for others previously described. Figures 26 and 27 show such an amplifier.

This tube has a lower amplification constant than other tubes described in this *chapter;* for this reason it is not recommended as a *frequency doubler* but will give

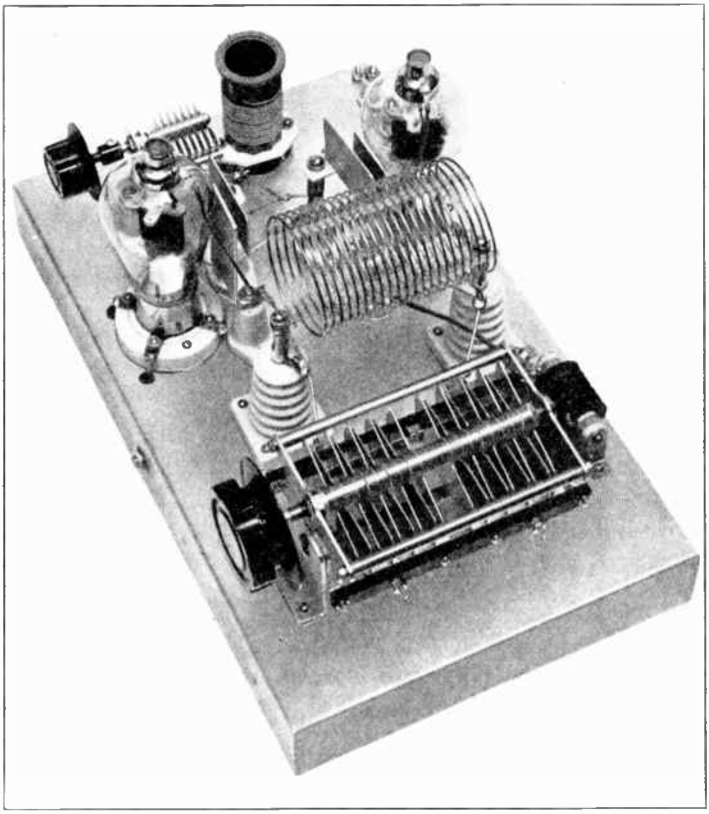


Figure 28—Push-Pull R. F. Amplifier with Taylor T-55 Triodes. Home-Built Neutralizing Condensers are Mounted on Stand-off Insulators, the Assembly Being Clearly Shown in the Photograph. The Grid Coil and Grid-Tuning Condensers are at the Extreme Left. Symmetrical Layout of Parts is All-Important in Amplifier Design. The Amplifier Illustrated Above Adapts Itself to Numerous Types of Tubes, Such as T-55s, 35T's, 808's, RK-35's, etc.

high output at low plate voltage when used as a neutralized amplifier.

The plate-tuning condenser is rated at 6,000 volts peak, the neutralizing condenser at 4,500 volts. The grid-tuning condenser is a 50-$\mu\mu$fd. double-spaced midget variable. A 5,000-volt mica condenser, .002 μfd, is required across the plate supply at the center-tap connection to the plate coil. The other bypass condensers are of the 1,200-volt mica type.

Because of the high grid impedance of this tube, a very low-C grid coil should be used in order to develop the necessary r.f. voltage swing with low excitation power.

The metal chassis for this amplifier is 10

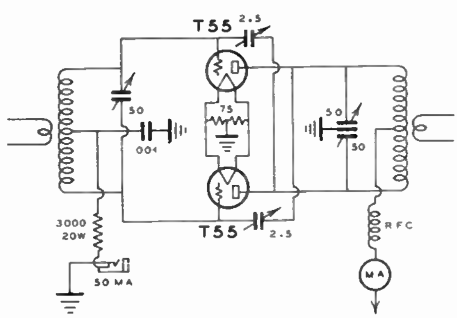


Figure 29—Push-Pull 300-Watt Amplifier with T-55 Tubes.

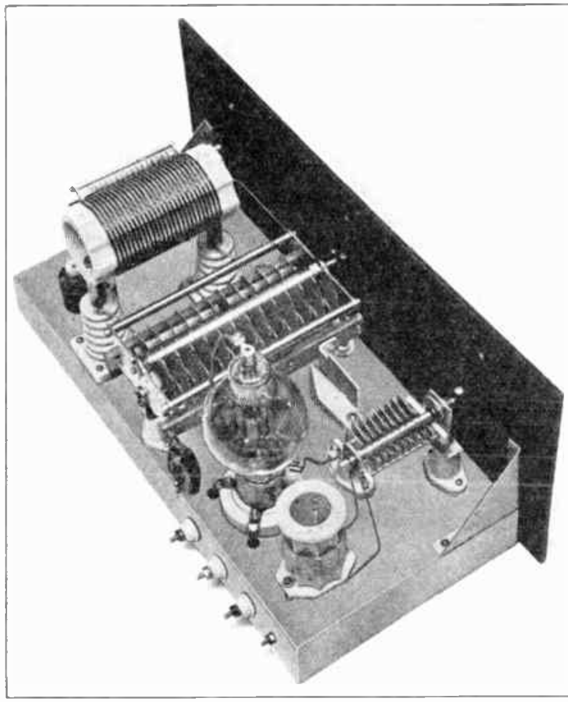


Figure 30 — Medium High-Power, Controlled Regeneration R.F. Amplifier with 100TH Triode. The Same Amplifier Design is Suitable for a Single RK-38, and, by Changing the Tube Socket and Neutralizing Condenser, for Such Tubes as the More Modern Versions of the "211," etc. The Neutralizing Condenser is Mounted with One of Its Plates Attached to the Stator of the Plate Condenser, the Other Neutralizing Plate "Floats" on a Plug and Jack, Secured to a Standoff Insulator.

in. x 12 in. x 2½ in., and can be mounted behind a relay rack panel, in which event the shafts of the tuning condensers must be fitted with insulated flexible couplings and extension rods to the tuning dials.

Push-Pull T-55 Amplifier

A neutralized T-20 driver stage will supply ample excitation for driving the push-pull T-55 amplifier shown in figures 28 and 29. An output of more than 300 watts can be realized on any band from 10 to 80 meters with a plate potential of only 1,500 volts.

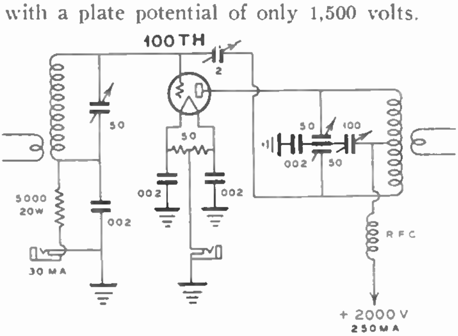


Figure 31 — 350-Watt Controlled Regenerative Neutralizing Circuit for a 100TH Amplifier, as Pictured in Figure 30.

The amplifier is built on a metal chassis, 17 in. x 10 in. x 2 in., for mounting behind a standard relay rack panel. The arrangement of the plate- and grid-tuning condensers provides a symmetrical front panel layout. In order to obtain this effect, the plate-tuning coil is placed between the tubes and the split-stator condenser, and the coil is mounted on tall standoff insulators so as to raise it high above the metal chassis, removed from the tuning condenser.

Each neutralizing condenser consists of two aluminum plates which overlap each other 1½ in. x 1½ in. The grid plates of the neutralizing condensers are secured to ¼ in. coil jacks; these are the movable plates. The r.f. choke must be able to carry a d.c. load of 300 milliamperes. The two leads in the grid-tuned circuit are made of unequal length in order to eliminate a tendency for parasitic oscillation. The split-stator tuning condenser should have a rating of 5,000 volts *per section*. The grid-tuning condenser is a double-spaced 50 μμfd. midget variable.

Medium Power 100-TH Amplifier

The r.f. amplifier circuit in figure 31 is designed with a *controlled regeneration neu-*

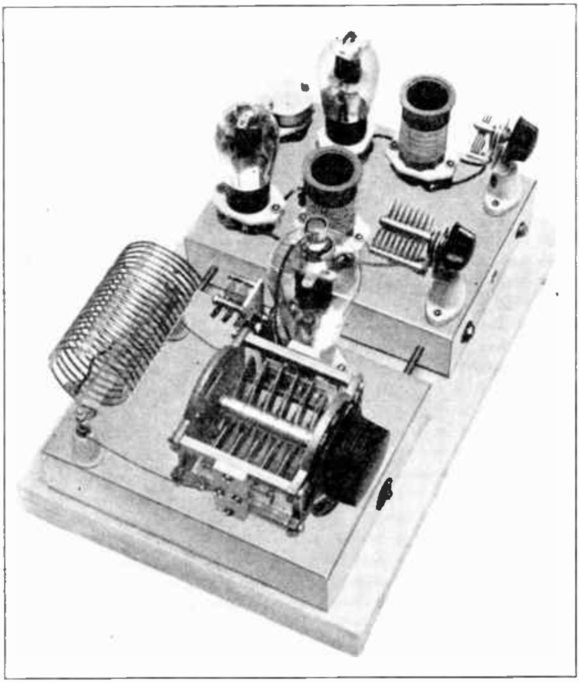


Figure 32—Oscillator, Oscillator-Doubler, Buffer and R. F. Amplifier Combination with 6A6 Twin - Triode, a 6L6G Doubler or Buffer Amplifier and a T-55 Triode in the Buffer-Driver Amplifier. An Ideal Medium Power Amateur Transmitter in Itself. It Can be Used as a Driver for the High-Powe Amplifier Shown in Figure 33. The T-55 Amplifier is Mounted on a Separate Small Metal Chassis. The Design of the Oscillator and Doubler is Given in the Chapter on Transmitter Frequency Control.

tralizing circuit which reduces the amount of grid excitation required on any short-wave band.

A split-stator tuned plate circuit is plate-neutralized, and a 100-μμfd. variable condenser is connected between the coil center-tap and the rotor of the split-stator condenser. There is no regeneration when this 100-μμfd. condenser is set at minimum capacity, but as the capacity is increased there is an introduction of regeneration similar to that obtained in some of the previous amplifier designs.

The regeneration control condenser is made variable in order to reduce the amount of regeneration when the amplifier is operated on 10 or 20 meters. This condenser is located at the extreme end of the chassis behind the plate tank coil, and, therefore, is not easily seen in the photograph, figure 30. The three variable condenser are arranged for symmetry on a 17 in. x 8 in. x 2 in. chassis. Extension shafts protrude through the front panel to the tuning dials.

Controlled regeneration in the r.f. amplifier is desirable when a low-power driver or exciter stage is used. This 100-watt high-μ triode has a very high transconductance (mutual conductance) and is very easy to drive; with the addition of a small amount of regeneration it is still easier to drive, and a type 6L6G doubler or amplifier will supply enough grid excitation to drive the amplifier to more than 350 watts of output for c.w. operation.

The split-stator plate-tuning condenser is rated at 6,500 volts per section and the rotor is insulated from the common ground by means of a 5,000-volt .002-μfd. mica condenser. The regeneration control condenser has relatively low r.f. voltage impressed across it.

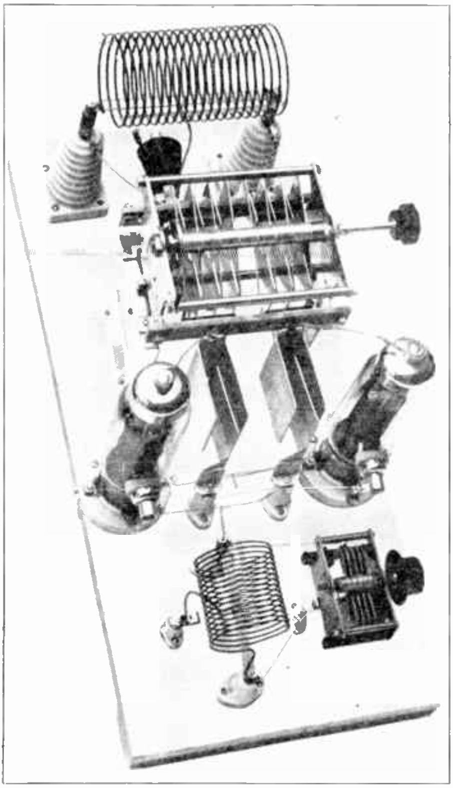
The grid-tuning condenser is a double-spaced 50-μμfd. midget variable. All tuning condensers are mounted on stand-off insulators. The neutralizing condenser is made of two aluminum plates which have an overlapping area of 2 in. x 2 in. The stationary plate is fastened directly to the rotor of the plate tank condenser and the moving plate is attached to a ¼-inch coil plug, which fits into a jack-equipped standoff insulator.

• 1-Kw. C. W. Transmitter

The construction of the radio-frequency portion of a modern, high power, c.w. transmitter is shown in figures 32 and 33. The circuit diagram for the complete transmitter is figure 34.

This transmitter can be operated on any

Figure 33—1-Kw. R. F. Amplifier with a Pair of Taylor-200 Triodes in Push-Pull. More Than Ordinary Precaution Must be Exercised in the Design and Construction of High-Power R. F. Amplifiers. The Condensers Must be Wide-Spaced so as to Prevent Flash-Over, and Complete Symmetry of the Parts is of Great Importance. The Design Pictured Here is an Excellent One, and is Suitable for a Wide Variety of High-Power Transmitting Tubes.



band, from 10 to 160 meters, with 1-kw. input on any of these bands. It utilizes the breadboard type of construction, with the final amplifier mounted on a shelf above the exciter and buffer amplifier stages. The exciter consists of two 6L6G tubes in a harmonic crystal oscillator and doubler, as described in the chapter on *Transmitter Frequency Control.* The circuit details and operation of the exciter are described in that chapter.

The 6L6G doubler is capacitively coupled through a 40-$\mu\mu$fd. condenser to a T-55 neutralized buffer-amplifier or double stage. The T-55 is normally used as a buffer, with a negative fixed bias of 75 volts. The grid bias should be increased to at least 150 volts for doubler service.

Fixed bias in these two stages makes it possible to key the exciter unit for break-in operation. A simple key-click filter is connected in series with the cathodes of the two 6L6G exciter tubes. The T-55 buffer stage is capable of supplying more than 100 watts of output for driving the grid circuit of the

Coil Table for T-200 1-Kw. Amplifier.

Band in Meters	Oscillator Coil	Doubler Coil	T-55 Plate and Final Grid Coils	Final Plate Coil
80	65 turns no. 24 d.s.c. close-wound. 1½ in. dia. (160 meter coil)	35 turns no. 20 d.s.c. 1½ in. long. 1⅓ in. dia.	28 turns no. 14 8 turns per in. 2¾ in. dia. Center-tapped.	28 turns no. 10 Enam. 4½ in. dia. 4 turns per in. Center-tapped.
40	(Use 80 meter Doubler Coil)	18 turns no. 20 d.s.c. 1½ in. dia. 1½ in. long.	16 turns no. 14 E. 5 turns per in. 2¾ in. dia. Center-tapped.	20 turns no. 10 Enam. 3 turns per in. 3½ in. dia. Center-tapped.
20	(Use 40 meter Doubler Coil)	9 turns no. 16 Enam. 1½ in. dia. 1½ in. long.	10 turns no. 14 Enam. 2½ turns per in. 2 in. dia. Center-tapped.	10 turns no. 10 Enam. 1½ turns per in. 3¼ in. dia. Center-tapped.

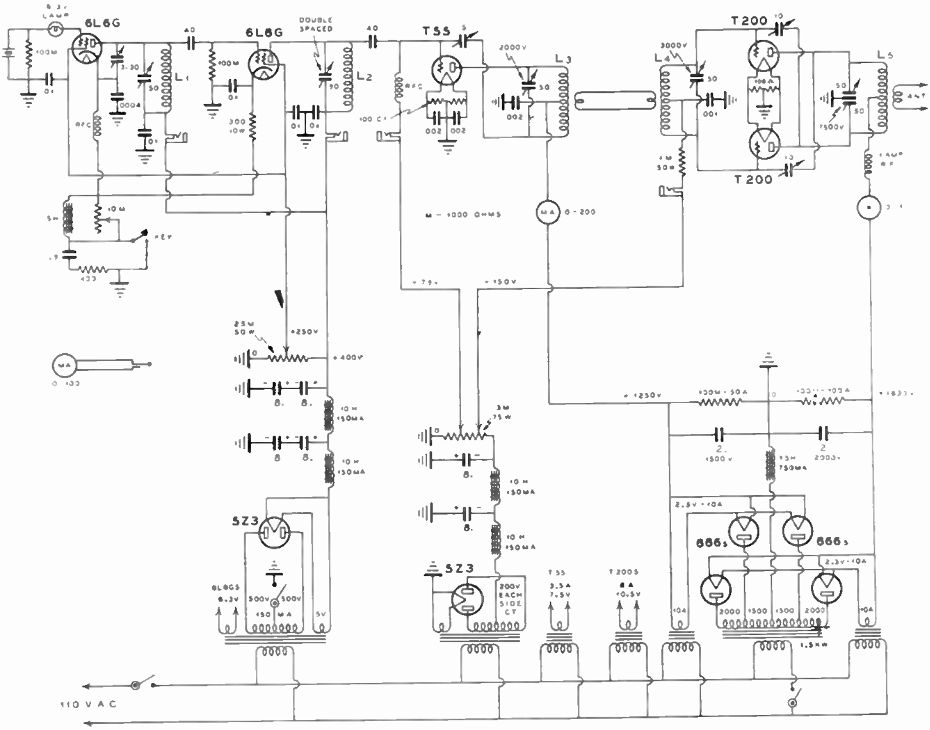


Figure 34—General Diagram of the Complete High Power Transmitter.

high power final amplifier. The plate-tuning condenser in the T-55 stage is a single-section 5,000-volt variable capacitor, and the plate bypass condenser has a capacity of .002 µfd. (mica type). The neutralizing condenser for this stage is a special *Trim-Air* condenser, rated at 5,000 volts, having a capacity range of from 2 to 5 µµfds.

One heavy duty high voltage power transformer can be used with two separate rectifier systems, as shown in figure 34, for plate supply to the buffer and final amplifier stages.

The final amplifier should be link coupled to the T-55 driver stage by a single turn of no. 11 heavy rubber-covered wire around the center of each coil. The type T-200 tubes in the final amplifier have a plate current rating of 350 ma. each; this high plate current rating allows the amplifier to be operated with 1 kw. input from an 1,800-volt power supply. The amplifier is operated with less than 300 milliamperes on each tube for an input of 1 kw. The relatively low d.c. plate voltage simplifies the final amplifier plate circuit design, since the r.f. peak voltages

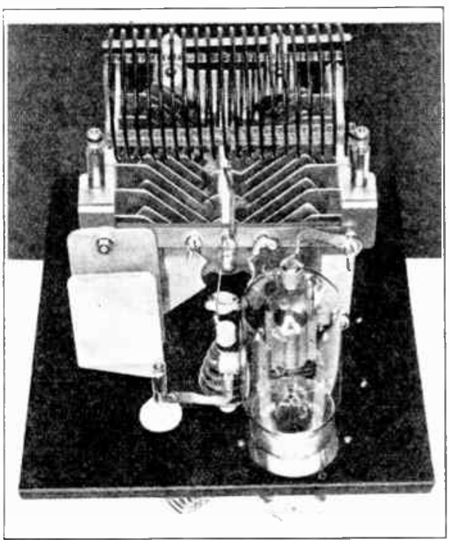


Figure 35—1-Kw. R. F. Amplifier with HK-354D Gammatron and New Atkins-Brown "Propeller-Type," Split-Stator Tuning Condenser. Note Extremely Short Connecting Leads.

are proportional to the d.c. plate voltage. The plate spacing in the split-stator tuning condenser is approximately ⅜-in. between stator and rotor plates.

The neutralizing condensers must have a capacity of 7 $\mu\mu$fds. each, which can be obtained by means of three plates in each condenser, these plates having an area of 9 sq. in. each. The two U-shaped sections are attached directly to the stators of the plate-tuning condensers, and the grid plates (movable) are made semi-adjustable by attachment to aluminum angle brackets mounted on standoff insulators.

● A Compact 1-Kw. Amplifier

One of the difficulties which enters into the design of a high power amplifier for relay rack mounting is the large physical size of the high voltage tuning condensers. A new type of transmitter condenser of compact design, capable of withstanding peak potentials of 16,000 volts per section (one-half inch airgap) has recently been made available.*

*Atkins & Brown.

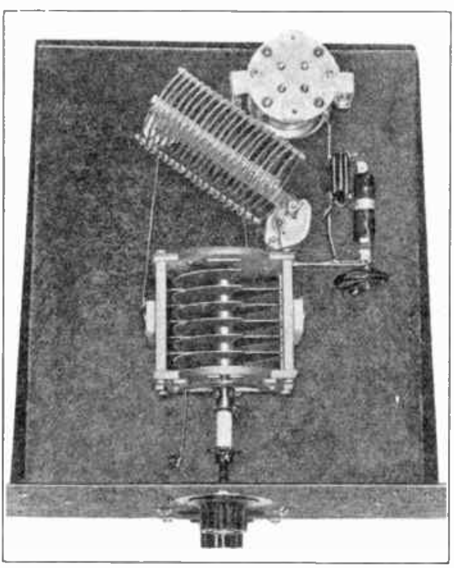


Figure 36—Under-Subpanel View of 1-Kw. R. F. Amplifier, Showing Grid Coil and Tuning Condenser, Method of Socket Mounting and Arrangement of Resistor and Bypass Condensers.

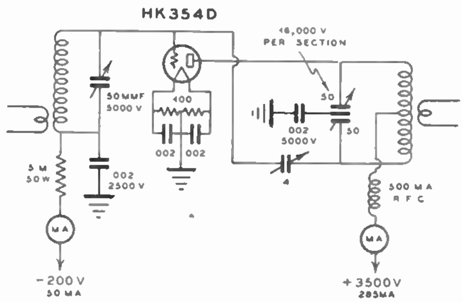


Figure 37—1-Kw. Amplifier.

This new type condenser is incorporated in a high power amplifier illustrated in figure 35. A circuit diagram of the amplifier is shown in figure 37.

The design of the new condenser makes for very short r.f. paths within the condenser proper; the rotor plates are shaped in the form of a two-blade propeller, and the unit proper is only 9¾ in. long overall.

A single HK-354 high μ triode can be used in the amplifier illustrated here for inputs up to 1-kw. without exceeding the manufacturer's rating. The tube must be operated at high plate efficiency and therefore requires a driver having an output of between 75 and 100 watts. Some of the c.w. amplifiers illustrated in this chapter are suitable for driving this amplifier.

● Construction

The complete amplifier can be built behind a 10½ in. or 12¼ in. x 19 in. standard relay rack panel, with a chassis 12 in. x 14 in. supported by the panel, as shown in figure 36. The plate tuned circuit is shielded from the grid circuit by means of this chassis. One of the grid coil standoff insulators extends through the chassis and supports the rotatable neutralizing condenser plate, which also connects to the grid cap of the tube. The stator plate of the neutralizing condenser is mounted directly on the plate tuning condenser. The exposed area of the neutralizing condenser plates is 2¾ in. x 3½ in. and the rotor plate is supported by a ¼-in. coil jack in order to adjust the position of this plate.

Coil data for this amplifier can be found in the chart for *Wire Wound Coils*, page 233.

Record of Circuit Changes Made in and New Components Installed in My Transmitter

Date

Chapter 13

Radiotelephony Theory

A C. W. TELEGRAPH transmitter has two essential components: (1) *the r.f. channel:* (2) *the power supply.* A radiotelephone transmitter, on the other hand, requires these two same components but with a third component added, the *audio frequency channel.*

Some means must first be provided to produce a source of r.f. control, then the desired r.f. frequency must be *amplified* to whatever power output is desired. A quartz crystal plate in an oscillator circuit generates the r.f. *carrier;* this carrier is then amplified and oftentimes multiplied in frequency by additional r.f. stages until the desired power output is obtained.

● Modulation

When audio frequencies are combined with the r.f. carrier frequency in the modulated stage, the process is known as *modulation.* These frequencies are *heterodyned* together into a group of radio frequencies called *side-bands,* which differ from the carrier frequency by the values of the audio frequencies. A modulated r.f. signal, therefore, occupies a band of radio frequencies which have a width of at least 3,000 cycles, assuming that none of the audio frequencies are higher than 1,500 cycles. Frequencies up to at *least* 1,500 cycles are required for good speech intelligibility, and frequencies as high as 5,000 or 6,000 cycles are required for good music fidelity. When audio frequencies as high as 5,000 cycles are to be transmitted, the radio frequency channel would have to be 10,000 cycles (10 kilocycles) in width, since both the upper and lower side-band frequencies are generated in the modulated r.f. stage.

● Side-Band Frequencies

The transmitted signal, when modulated, contains *side-band frequencies,* in addition to the carrier frequency. These side-band frequencies are adjacent to, and on either side of, the carrier frequency. The width of these side-bands depends upon the audio frequency which modulates the r.f. carrier, and the side-band frequencies are generated only when the r.f. stage is modulated by an audio frequency, or frequencies.

● Instantaneous Power Output

The *average* amplitude of the carrier frequency wave is constant in most systems, but the *instantaneous power output* varies from approximately zero to four times that of the power of the unmodulated carrier wave. In a symmetrically modulated wave, the antenna current increases approximately 22 per cent to 100 per cent modulation with a pure-tone input; the r.f. meter in the antenna circuit indicates this increase in antenna current. The *average power* of the r.f. wave increases 50 per cent to 100 per cent modulation. This indicates that in a plate-modulated radiotelephone transmitter the audio frequency channel must supply this additional 50 per cent increase in average power. If the power input to the modulated stage is 100 watts, for example, this *average power* will increase to 150 watts at 100 per cent modulation, and this additional 50 watts of power must be supplied by the *modulator,* when plate modulation is used. The actual antenna power is a constant percentage of the total value of input power.

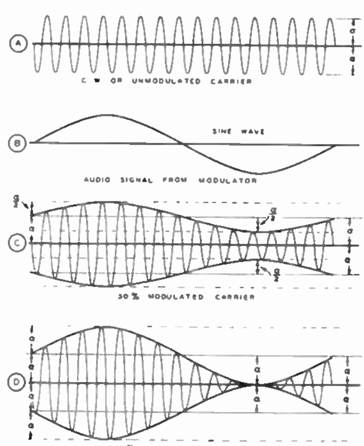


Figure 1—Graphic representation of four types of wave form, illustrating the difference between an unmodulated carrier, audio sine wave, 50 per cent modulated carrier, and 100 per cent modulated carrier.

A c.w. or unmodulated carrier wave is represented in (A), figure 1. An audio frequency wave is represented by curve (B). When this audio frequency wave (B) is applied to the modulated stage, the resultant wave may be represented as in (C) and (D). The *average amplitude* of the carrier wave remains constant because the decrease in amplitude is the same as the increase (up to 100 per cent). In (C), figure 1, the carrier wave is shown to be approximately 50 per cent modulated, and (D) shows a 100 per cent modulated wave. In order to obtain 50 per cent modulation in a plate modulated system, only one-fourth as much audio frequency power is required as for 100 per cent modulation. However, the audio signal which is received at a distant point after being *de-modulated* (detected) is in proportion to the percentage of modulation of the transmitter. If the peaks of modulation are reduced from 100 per cent down to 50 per cent, the result is a decrease in range of the transmitter.

• Audio Frequency Channel

The sound waves of speech or music must first be converted into electrical energy. This is accomplished by means of a *microphone*. The electrical power output from a microphone is very low, and must, therefore, be amplified before it is applied to the modulated radio-frequency stage. Amplification of this weak power output can be accomplished by impressing the electrical output of the microphone across a vacuum tube amplifier system which has sufficient amplification to deliver the desired output. The required audio power output from this amplifier, in the case of a plate modulated radiotelephone transmitter, is one-half that of the *power input* to the modulated r.f. stage.

The electrical power output of the microphone is impressed across the grid impedance of the vacuum tube amplifier, and the voltage is amplified by the vacuum tube. The amplified voltage can then be carried through a number of additional amplifier stages until it becomes a high enough value to develop the desired power into the output impedance.

The audio power output is the value of voltage multiplied by the audio frequency current flowing through the output impedance; in the case of a low impedance, the current is high and the voltage is relatively low, and vice versa for a high impedance.

The load impedance in the case of a plate-modulated r.f. stage is the plate circuit of the modulated amplifier tube. The impedance can be calculated by dividing the d.c. plate voltage applied to the r.f. stage by the d.c. plate current which is flowing in the tube in that stage. This is equivalent to a pure resistance if the amplifier is class C, and therefore is a constant load across the output of the audio channel.

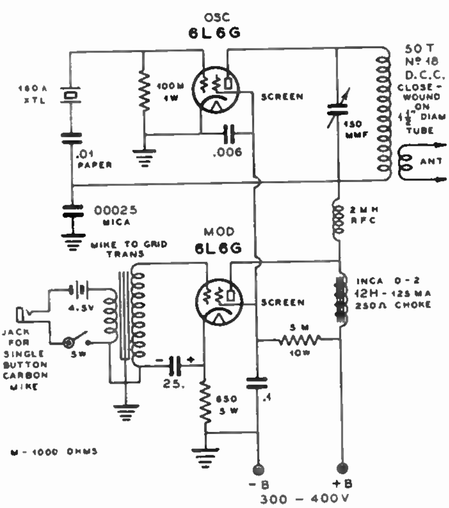
Different types of modulated r.f. stages call for vastly different amounts of audio power. Grid modulation, for example, requires only a fraction of the amount of audio power as is required for 100 per cent plate modulation of the same output of r.f. carrier power. Various types of modulation other than the most common method (plate modulation) are discussed later in this chapter.

• Frequency Control

The quartz crystal oscillator is the most satisfactory means for controlling the frequency of a radiotelephone transmitter. Greater precautions are necessary than when the same type of oscillator is used for c.w. telegraphy in order to avoid "frequency modulation."

• Amplitude Modulation

When the r.f. power output is varied by means of side-band frequency amplitude variations, the method is known as *amplitude modulation*. This is the only system of mod-



75 & 160 METER EMERGENCY PHONE
5 TO 40 WATTS
HEATERS CAN BE OPERATED FROM 6 VOLTS A.C. OR BATTERIES

Figure 2

ulation commonly used by amateurs. The carrier amplitude (except in controlled-carrier systems) should always remain constant. A change in carrier amplitude during modulation is called *carrier shift*. This produces distortion and often creates interference in adjacent radiotelephone channels.

● Frequency Modulation

Frequency modulation is just what the term implies and is undesirable for many reasons. Reaction between the modulated stage and the crystal oscillator can be prevented by the incorporation of at least one buffer or doubler stage between the crystal oscillator and the modulated r.f. amplifier. Except for emergency operation, in a circuit such as shown in figure 2, the crystal oscillator should never be modulated because frequency modulation will result from any modulation of the plate voltage.

● Frequency Drift

When the quartz crystal in an oscillator circuit is overloaded and heats, frequency drift will take place. Incorrect design of the oscillator or excessive plate voltage will cause an excessive flow of r.f. current through the quartz crystal. This excessive r.f. current will then cause a temperature rise which will change the frequency of oscillation when *X*-cut or *Y*-cut crystals are used. Some of the newer crystal cuts, such as the *V* or *AT*, have a very low temperature coefficient (change in physical dimension with change in temperature) with a result that practically no frequency drift is encountered, even when the power output from the crystal oscillator is very high.

● Frequency Multiplication

Frequency doublers or triplers are used to multiply the output frequency of the crystal oscillator to the desired frequency which is wanted in the final r.f. amplifier. These circuits are similar in all respects to those used for c.w. telegraphy, as disclosed in the chapter on *C. W. Theory*. In radiotelephony, however, a plate-modulated r.f. amplifier requires more excitation than is needed for the final stage in the usual c.w. transmitter, because the amplifier in the radiotelephone transmitter must be operated at more than twice cut-off bias and high grid current. It is common to use a buffer r.f. amplifier which operates at the *same frequency* as the final amplifier in order to secure ample grid excitation. In many cases, a frequency doubler or tripler can be made to deliver sufficient output to drive the modulated stage properly, thereby eliminating the need of a buffer stage for operation at the very high frequencies.

● Doubler Stage Efficiency

The grid bias in a doubler stage should be at least five times cut-off value in order to obtain high efficiency. The d.c. grid current should be of a normally-rated value for the tube in use, providing that this value of grid current can be obtained from the preceding stage at the high bias required. While in a neutralized stage (triode), it is best procedure to run as much bias as the excitation will allow with maximum rated grid current; in a triode doubler it is best to run as much grid current (up to maximum rating) as the excitation will allow while maintaining at least five times cut-off bias.

Regeneration in a doubler stage can be substituted for high bias and r.f. excitation, in the event the transmitter has not been conservatively designed to increase the output. Regenerative frequency doublers are satisfactory for c.w. telegraphy, but they will usually introduce operating difficulties when used for radiotelephony.

● Radiotelephony Power Supplies

A power supply for a radiotelephone transmitter should furnish non-pulsating d.c. voltage to the crystal oscillator or other source of frequency control. The amount of pulsation or ripple voltage should be less than 1 per cent of the d.c. voltage, especially for radio transmitters operating on very high frequencies. Hum or ripple voltage in the plate supply to the oscillator will frequency-modulate the r.f. output slightly. Each frequency multiplier stage increases the frequency modulation, until the carrier hum becomes objectionable in high-frequency transmitters. Many amateur 10-meter phones suffer from this difficulty, noticed especially with selective receivers.

The power supply for the "front end" of the speech channel must be thoroughly filtered in order to avoid amplification of the ripple in the succeeding audio or speech amplifier stages. The plate supply for the final audio amplifier stage does not require as much filter as the preceding stages, and, in the case of a push-pull audio modulator stage, a single-section filter will suffice.

Buffer stages of a control-grid modulated transmitter must have very well-filtered plate supplies (more than the buffers in a plate-modulated transmitter) in order to prevent hum modulation in the grid circuit on which the speech audio frequencies are impressed. On the other hand, the plate supply for the grid-modulated stage itself does not require quite as much filter as does a comparable plate-modulated stage. This indicates that a single-section filter will suffice for a grid-modulated stage, whereas a two-section filter is desirable for plate modulation. In the event that only a single-section filter is used for a grid-modulated stage, condenser input is desirable. A single-section choke input filter does not furnish sufficient ripple suppression except for a c.w. amplifier or push-pull (or push-push class B) modulator stage.

• Class B Modulator Voltage Regulation

Power supply voltage regulation of class B modulators is of great importance because the plate current varies appreciably with the amount of speech input. Choke input, utilizing preferably a *swinging-choke* with high no-current inductance rating (25 hy. or more) and low d.c. resistance, in conjunction with mercury vapor rectifiers and a husky filter condenser (at least 4 μfd.) will make a good power supply. If the "resting" plate current of the modulator tubes is high, as is the case with some of the zero bias, class B tubes, a swinging type choke is not essential, but even so, the choke should have high inductance (10 or 20 hy.).

• Microphones

The microphone, which changes sound into electrical energy, usually consists of a diaphragm which moves in accordance with the compressions and rarefactions of the air called *sound waves*. The diaphragm then actuates some form of device which changes its electrical properties in accordance with the amount of physical movement.

If the diaphragm is very tightly stretched, the natural period of its vibration can be placed at a frequency which will be out of range of the human voice. This obviously reduces the sensitivity of the microphone, yet it greatly improves the uniformity of response to the wide range encountered for voice or musical tones. If the natural mechanically resonant period of the diaphragm falls within the voice range, the sensitivity is greatly increased near the resonant frequency. The effect results in distorted output, a familiar example of this effect being found in the ordinary land-line telephone microphone.

A good microphone must respond equally to all voice frequencies; it must not introduce noise, such as hiss; it must have sufficient sensitivity to eliminate the need of excessive audio amplification; its characteristics should not vary with changes in temperature or humidity, and its characteristics should remain constant over a useful period of life.

• The Carbon Microphone

Carbon microphones can be divided into two classes: (1) *Single-button*, (2) *Double-button*. The single-button microphone consists of a diaphragm which exerts a mechanical pressure on a group of carbon granules. These granules are placed behind the diaphragm between two electrodes, one of which is secured directly to the diaphragm and moves in accordance with the vibration of the diaphragm. This vibration changes the pressure on the carbon granules, resulting in a change of electrical resistance to current flowing between the electrodes, the d.c. current being supplied from an external source. The variation in resistance causes a change in the current which flows through the primary winding of a coupling transformer, thereby inducing a voltage in the secondary winding of this transformer; this voltage is then amplified by means of vacuum tube amplifiers.

Single-button microphones are useful for operation in portable transmitters because their sensitivity is greater than that of other types of microphones, thereby requiring less audio amplification to supply audio modulating power for the transmitter. The objectionable feature of the single-button microphone is its high hiss level. Another is that the diaphragm generally resonates within the voice range, resulting in rather poor tone quality.

• The Double-Button Microphone

The double-button microphone has two groups of carbon granules arranged in small containers on either side of the diaphragm. This "push-pull" effect reduces the even-harmonic distortion, resulting in more intelligible modulation. The diaphragm is normally stretched to such an extent that its natural period may be as high as 8,000 cycles per second, which is beyond the range of the human voice. This reduces the sensitivity of the microphone and greater audio

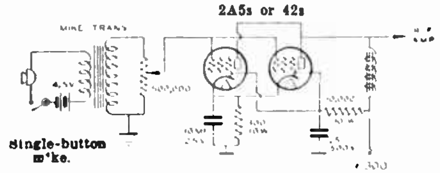


Figure 3 — 10-Watt Amplifier for Use with a Single-Button Microphone.

amplification is needed to secure the same output as from a single-button carbon microphone. On the other hand, the tone quality from the double-button microphone is better, though the hiss is still present.

The cost of a double-button microphone is a satisfactory index of its performance when purchased from a reliable concern. The output from a *high-quality* two-button microphone is rated 45 db. below that of a standard single-button microphone.

The movement of the diaphragm changes the spacing between the two electrodes, resulting in a change in electrical capacity. When a d.c. polarizing voltage is applied across the plates, an a.c. voltage will be generated when the diaphragm is actuated by reason of the change in capacity between the plates; this voltage can then be amplified by means of vacuum tubes. The diaphragm of a typical condenser microphone is made of duralumin sheet, approximately 1/1,000 in. thick, with approximately the same spacing between the diaphragm and the rear heavy plate electrode. The output is approximately 75 db. below an ordinary single-button carbon microphone with unstretched diaphragm.

The condenser microphone has a low output level, which necessitates at least two stages of pre-amplification, the first stage being located very close to the microphone.

T1 — Double Button Mike-to-Grid Trans.
T2 — 3:1 Interstage Transformer.
Choke: 20 henry, 200 M.A.

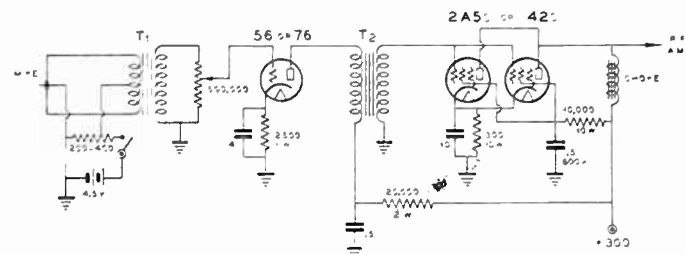
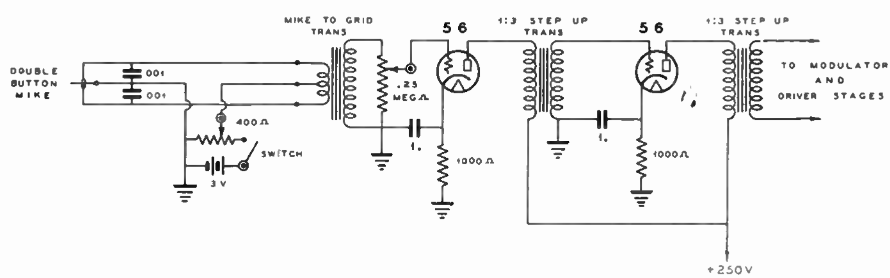


Figure 4—10-Watt Amplifier for Double-Button Microphone.

• Condenser Microphone

A condenser microphone has a better frequency response than a carbon microphone, and it does not produce a hiss. This type of microphone consists of a highly damped or stretched diaphragm mounted very close to a metal plate, but insulated from the plate. The output impedance is extremely high, and the unit must, therefore, be well shielded in order to prevent r.f. and 60-cycle a.c. hum pickup. It is sensitive to changes in barometric pressure and humidity. More modern types of microphones are replacing the condenser type, although the latter are still widely used.



TYPICAL SPEECH AMPLIFIER FOR DOUBLE BUTTON CARBON MICROPHONE OR 200Ω LINE INPUT

Figure 5

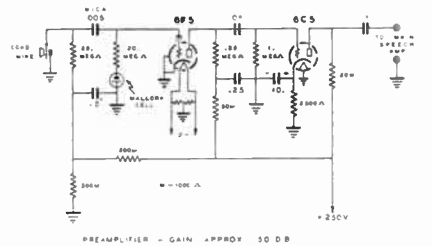


Figure 6—Condenser Microphone Pre-Amplifier. This pre-amplifier is used with a condenser microphone in order to increase its output to a sufficient level to work directly into the grid of a speech amplifier, such as one which was originally designed for carbon microphone input. No transformer is needed for coupling between the 6F5 and the speech amplifier. The 0.1 μfd. coupling condenser and the speech amplifier grid-leak should be located at the speech amplifier.

• Crystal Microphone

The crystal microphone operates on the principle that a change in dimensions of a *Piezo-electric* material, such as *Rochelle Salt crystals,* generates a small a.c. voltage which can be amplified by means of vacuum tubes. No d.c. polarizing voltage or current or coupling transformer is required for the crystal type of microphone, and thus it becomes a very simple device to connect into an audio amplifier.

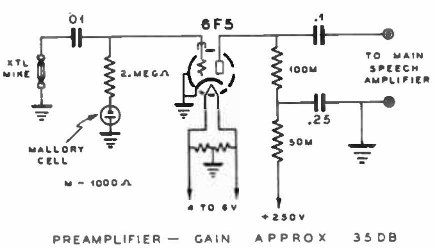


Figure 7—This pre-amplifier can be used with an inductive microphone by changing the resistance network in the input to a transformer of the correct design. If the pre-amplifier is far removed from the main speech amplifier, a plate-to-500-ohm-line transformer should be connected in the output, with a corresponding 500 ohm-to-grid transformer at the speech amplifier.

Crystal microphones can be divided into two classifications: (1) the diaphragm type, (2) the grille type.

The diaphragm type is relatively inexpensive and consists of a semi-floating diaphragm which subjects the crystal to deformation in accordance with the applied sound pressure. The fidelity is equal to that of most two-button carbon microphones and there is no background noise or hiss generated in the microphone itself.

The grille type consists of a group of crystals connected in series or series-parallel for the purpose of obtaining high electrical output without aid of a diaphragm. The output level varies between —65 db. and —80 db. for various types of crystal microphones. The grille type is less directional to sound pickup than most other types and is capable of almost perfect fidelity.

• Velocity or Ribbon Microphones

The inductive or ribbon-type microphone has a thin, corrugated, metal strip diaphragm which is loosely supported between the poles of a horse-shoe magnet. A minute current is induced in this strip when it moves in a magnetic field, and this current can be fed to the primary of a step-up-ratio transformer of high ratio because of the very low impedance of the ribbon.

The microphone output must be amplified by means of a very high gain pre-amplifier, because the output level of the older types of ribbon microphones is —100 db. and even the newer ones are around —85 db. The inductive type of microphone is rugged and simple in construction. Unfortunately, it cannot be used for close talking without overemphasizing the lower frequencies. It is a velocity, rather than a pressure-operated, microphone and should therefore, be placed at least two feet from the source of sound. It is very sensitive to a.c. hum pickup, and this is one of the principal reasons why it is not widely used in amateur practice.

The impedance of the ribbon is so low that it is difficult to design a ribbon-to-grid transformer with good fidelity. Therefore, for best quality, two transformers are usually used in cascade: ribbon-to-200 ohms and 200 ohms-to-grid.

• The Dynamic Microphone

The dynamic (moving coil) type of microphone operates on the same principle as the inductive microphone. A small coil of wire, actuated by a diaphragm, is suspended in a magnetic field, and the movement of the coil in this field generates an alternating current. The output impedance is approximately 30 ohms as against approximately one ohm for the ribbon type of microphone. The output level is about —85 db., the level varying with different makes. This type of microphone is quite rugged and its frequency response is excellent.

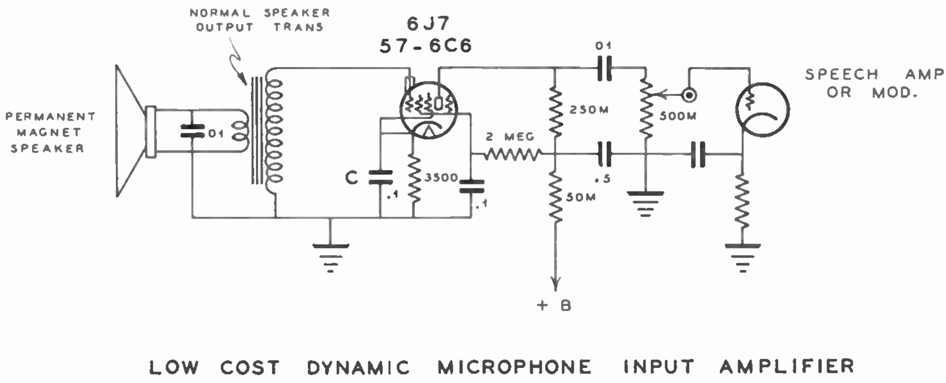


Figure 8—Low Cost Dynamic Microphone Amplifier.

A non-directional dynamic microphone can be made by enclosing it in a small spherical housing with the diaphragm at the top. An acoustic screen is mounted directly above the diaphragm for producing uniform acoustic response from all directions.

An inexpensive and very satisfactory dynamic microphone for amateur transmitters can be made from a small, permanent-magnet type, dynamic loud-speaker, as illustrated in figure 9. One of the newer 5 in. types with alloy magnet will give surprising fidelity at relatively high output level.

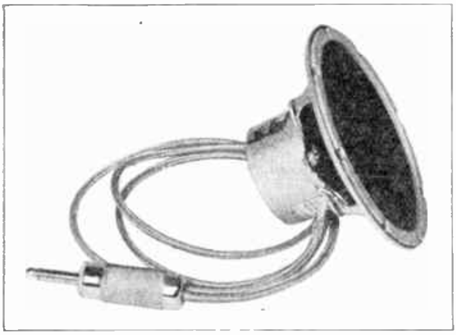


Figure 9—A Small "PM" Speaker Makes a Good Microphone.

A shielded cable and plug are essential to prevent hum pickup. The unit can be mounted in any suitable type of container. The circuit diagram is shown in figure 8.

● Directional Effects

Crystal microphones, as well as those of some other types, can be mounted in spherical housing in order to secure a non-directional effect. Decidedly directional effects may be required, on the other hand, and microphones for this purpose are commercially available.

● Speech Amplifiers

That portion of the audio channel between the microphone or its pre-amplifier and the power amplifier or power-amplifier driver stage can be defined as the *speech amplifier.* It consists of from one to three stages of *voltage amplification* with resistance, impedance, or transformer coupling between stages. The input level is generally about —50 db. in the case of a speech amplifier designed for a double-button carbon microphone or pre-amplifier input. The input level is approximately —70 db. when the speech amplifier is designed for operation from a diaphragm-type crystal microphone. A conventional speech amplifier for a double-button carbon microphone is shown in figure 5. Other speech amplifier circuits are shown in figures 10 and 11, and also in the numerous complete transmitter circuits shown throughout the chapter on *Radiotelephone Transmitter Construction.*

● Input Level

It is possible to dispense with the pre-amplifier with certain types of low-level microphones by designing the speech amplifier input to work at —90 db. or so, but it is better practice and entails less constructional care if a speech amplifier with less gain is used in conjunction with a pre-amplifier to make up the required overall amplification. Less trouble with hum and feedback will be encountered with the latter method.

Designing a speech amplifier to work at —70 db. is comparatively easy.

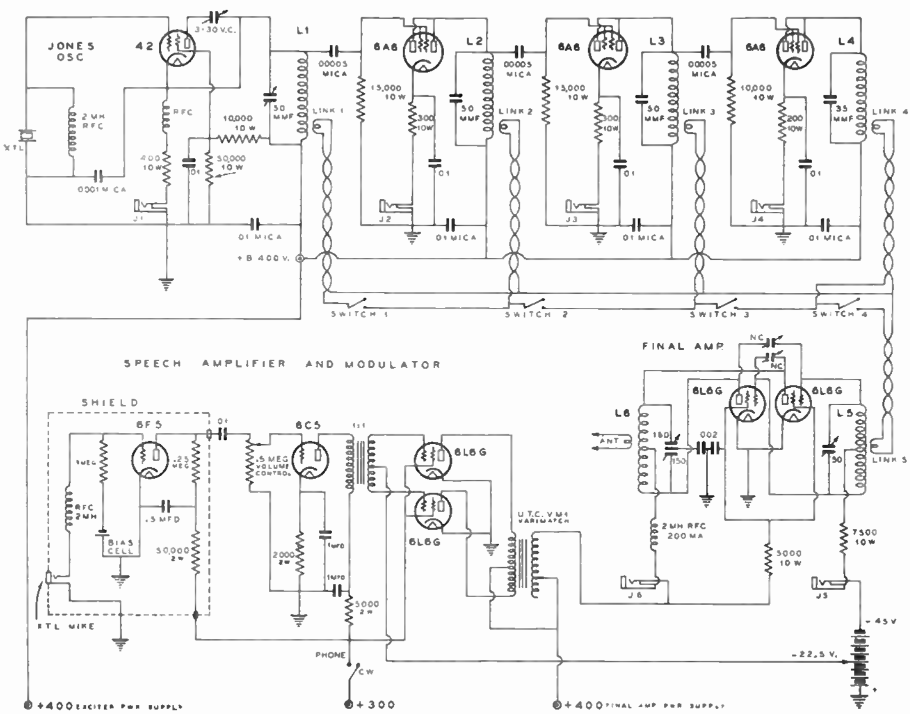


Figure 10—Typical Speech Amplifier Modulating a 50-Watt Class C Stage.

• Amplifier Gain

The power gain in amplifiers or the power loss in attenuators can be conveniently expressed in terms of db. *units,* which is an expression of two power ratios.

A formula for the calculation of db. gain or loss is here given:

$$DB = \text{Log}_{10} \frac{P_1}{P_2}$$

Since power is equal to the product of voltage times current, when the power factor is unity, db. units can be used to express voltage gain. In this case the formula is:

$$DB = 20 \times \text{Log}_{10} \frac{E_1}{E_2}$$

This provides a useful means for computing the overall voltage gain of a pre-amplifier and the speech amplifier. When adding the gain of several stages, the db. units are added or subtracted, which greatly simplifies the calculations.

For example: if a pre-amplifier has 35 db. gain, and the speech amplifier has 65 db. gain, the total gain is 35 + 65, equals 100 db. 100 db. corresponds to a voltage gain of 100,000 times. Thus, for example, if the microphone level is —100 db., the speech amplifier output will be —100 db. + 100 db., equals zero db. level. Zero level corresponds to a power level of 6 milliwatts.

In order to obtain 60 watts of audio power output, a power gain of 6,000 times will be required, which corresponds to a power gain of approximately 38 db. This amplification can be considered as part of the main power amplifier or modulator, or as part of the speech amplifier, depending upon the particular transmitter under consideration. The important point to remember is that power ratios use the expression: 10 × Log, whereas voltage gain between similar impedances is computed by the expression: 20 × Log.

Let us take a typical example of radiophone transmitter with a class C amplifier input of 200 watts. For 100 per cent plate modulation, the audio power requirement is 100 watts. This corresponds to a db. power level of + 42 db. Zero db. level is 6 milliwatts, or .006 watts.

Therefore, the formula:

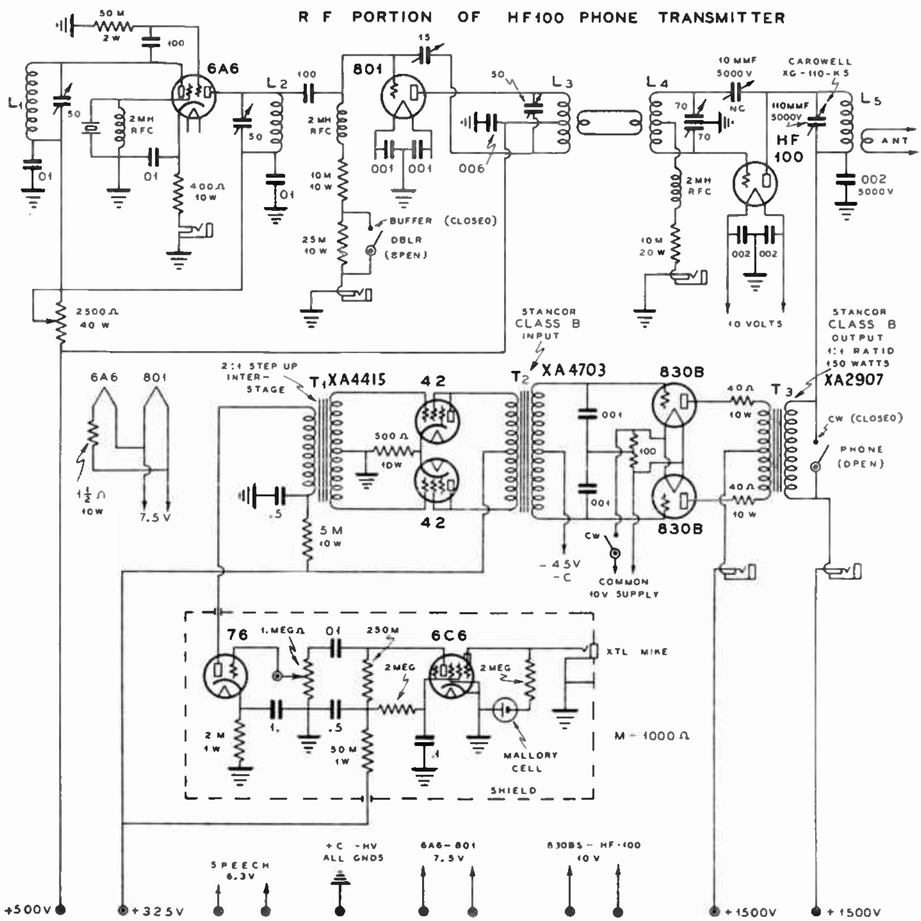


Figure 11—Speech Amplifier and Modulator for 175-Watt Class C R.F. Amplifier.

$$DB = 10 \times \text{Log}_{10} \frac{P_1}{P_2} =$$

$$10 \times \text{Log}_{10} \frac{100}{.006} = 42$$

Either a *logarithm* table or a *log slide rule* is needed for making db. calculations.

The amateur may desire to use a diaphragm type crystal microphone which is rated at —70 db. for average sound levels. This extremely low output must be brought up to a value of 100 watts, or +42 db. The total gain required will be 112 db.

No pre-amplifier would be necessary, because this amount of gain can be built into a good speech amplifier and modulator. A typical audio channel which meets these requirements is shown in the skeleton circuit, figure 15.

The first speech amplifier consists of a 6C6 connected as a high-gain pentode, resistance-coupled to a 76 speech amplifier which, in turn, is coupled through a step-up transformer into a 42 tube which operates as a triode. The latter is connected to a push-pull 45 class AB driver for the final power amplifier or modulator which consists of a pair of 35Ts.

The 6C6 stage is capable of producing a voltage amplification of 100 times, which corresponds to 40 db.

$$DB = 20 \times \text{Log}_{10} \frac{100}{1} = 40$$

The 76 and 42 triodes with a 3-to-1 step-up interstage transformer will produce a voltage gain of 240.

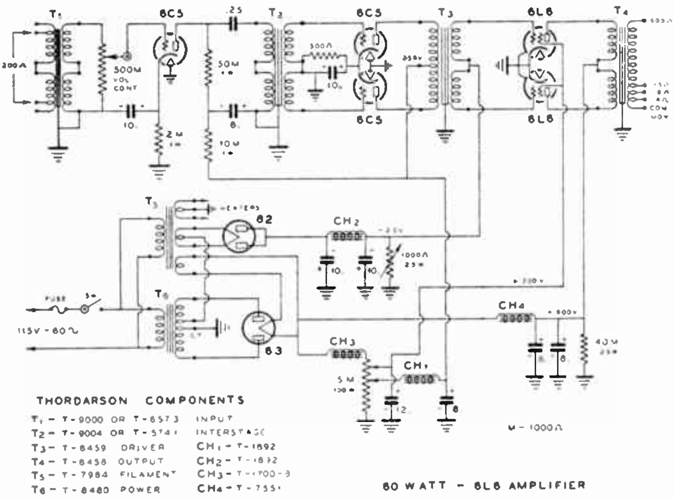


Figure 12
60-Watt 6L6 Amplifier

By incorporating the new Thordarson "Tru-Fidelity" Transformers in the amplifier here shown, the hum level with gain open is approximately 58.7 db. down from maximum output of 18.7 db. down from zero level. The slider on the voltage divider must be adjusted for 300 volts on the screen of the 6L6 tubes, with negative 25 volts bias. Voltage measured from plate to ground on the 6C5 tube should be 258 volts. Total plate current of final stage, 100 to 110 ma. with no signal.

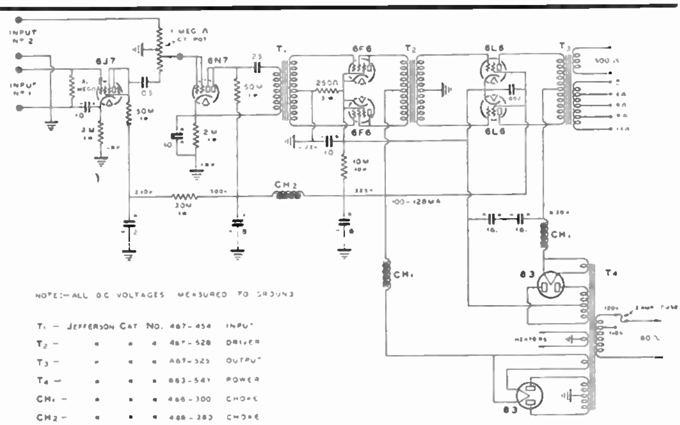


Figure 13
60-Watt 6L6 Amplifier

Two 6L6 tubes in Class AB. The power transformer has one set of windings for supplying both B current requirements for the initial stages and a steady source of fixed bias and screen voltage for the output stage. Frequency range: 30 to 12,000 cycles. Gain 120 db., or 88 db., depending upon input channel connection.

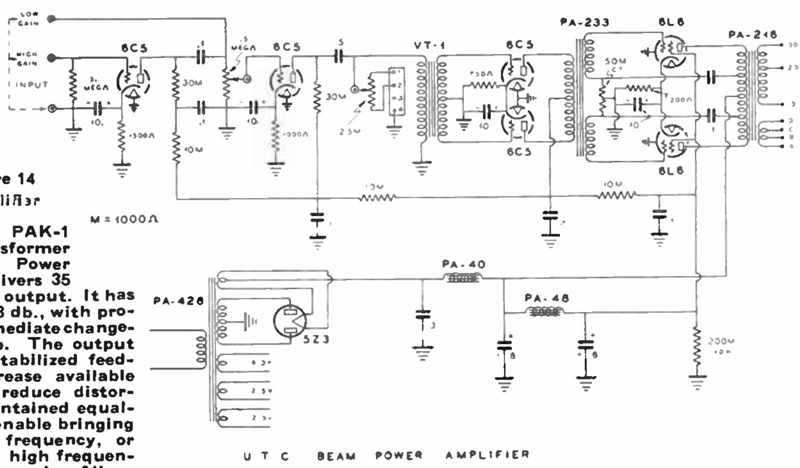
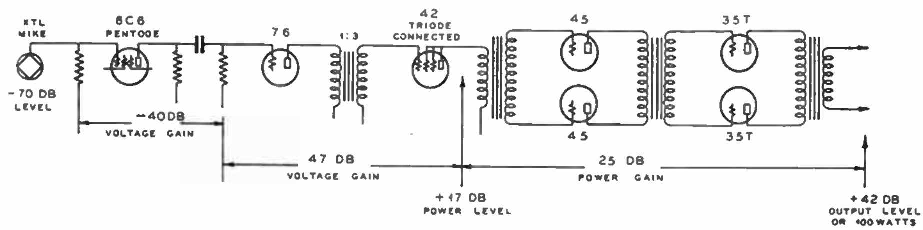


Figure 14
6L6 Amplifier

The Type PAK-1 United Transformer Corp. Beam Power Amplifier delivers 35 to 55 watts of output. It has high gain, 118 db., with provision for immediate change-over to 95 db. The output circuit has stabilized feed-back to increase available output and reduce distortion. Self-contained equalizer circuits enable bringing up the low frequency, or both low and high frequencies simultaneously. All resistors are rated at one watt, except bleeder and 6L6 cathode resistors, which are 20 watt.



COMPUTATION OF GAIN FOR AUDIO CHANNEL OF RADIO TRANSMITTER

Figure 15

$$DB = 20 \times Log_{10} \frac{240}{1} = 47$$

Actually, the db. voltage gain must be measured between like impedances in order to be correct.

The total speech amplifier gain is 40 + 47, equals 87 db. If the output level of the microphone is —70 db., the output level of the 42 triode will be 87 — 70, equals +17 db. This level corresponds to approximately 300 milliwatts, which is well within the rating of a 42 triode driver, and is sufficient to drive the 45 tubes in class AB.

$$17 = 10 \times Log_{10} \frac{P}{.006}$$

therefore, P equals 0.3 watts, or 300 milliwatts.

$$DB = 10 \times Log_{10} \frac{100}{0.3} = 25$$

This can be checked by subtracting 17 from 42, which is 25 db., the power gain between the grids of the 45 tubes and the output of the class B modulator.

With 0.3 watt input to the 45 stage, 9 watts of output can be obtained.

$$DB = 10 \times Log_{10} \frac{9}{0.3} = 15$$

The power gain through the 45 stage is 15 db., leaving a power gain of 10 in the 35T class B stage. More power gain could be secured in the 35T stage, thus requiring less gain in the 45 driver stage, and therefore the class B input transformer could have a greater step-down ratio than in the case of a circuit design in which no leeway in voltage and power gain is provided for.

• Plate Modulation Transformer Calculations

The modulation transformer is a device for matching the modulator plate impedance to the impedance of the class C r.f. amplifier.

The class C r.f. amplifier impedance is calculated by dividing the d.c. plate-to-filament voltage by the *total* d.c. plate current. For example, a pair of type 211 tubes, operating at 1200 volts and 300 milliamperes, has a load impedance of 1200 divided by 0.3 amperes, or 4,000 ohms.

$$Z = \frac{E}{I} = \frac{1200}{0.3} = 4{,}000 \text{ ohms,}$$

where Z is the load impedance of the class C r.f. amplifier.

The power input is 1200 times 0.3 or 360 watts.

The audio power required for 100 per cent modulation is one-half this value or 180 watts. This power of 180 watts can be supplied by a pair of 203A tubes in class B with a 1000-volt plate supply. From vacuum tube tables, it will be found that the load resistance or impedance (plate-to-plate) of class B 203A tubes should be 6900 ohms.

For maximum power transfer the 4000-ohm load must be transformed to 6900 ohms. The transformer changes this impedance by using a step-down turns-ratio of 1.3-to-1 total primary to secondary. This ratio is obtained by taking the square-root of the impedance ratio $\frac{6900}{4000}$.

Another example is an HK-354 operating at 2500 volts with 250 milliamperes of plate current. The load impedance is

$$\frac{2500}{.0250} = 10{,}000 \text{ ohms.}$$

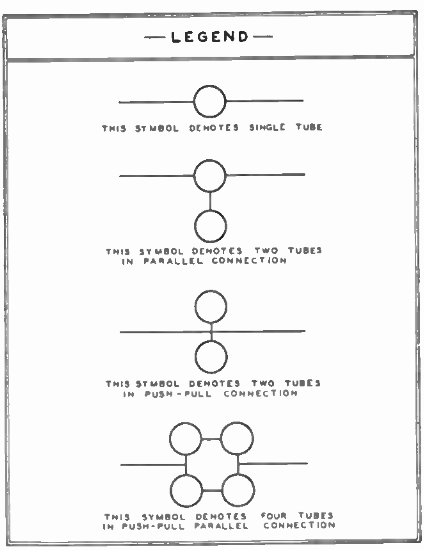
The power input is equal to $2{,}500 \times 0.250$ or 625 watts.

The modulator would be required to supply slightly more than 300 watts. RCA-805 tubes, in class B, operating with 1500 volts plate supply, will deliver ample output for this purpose.

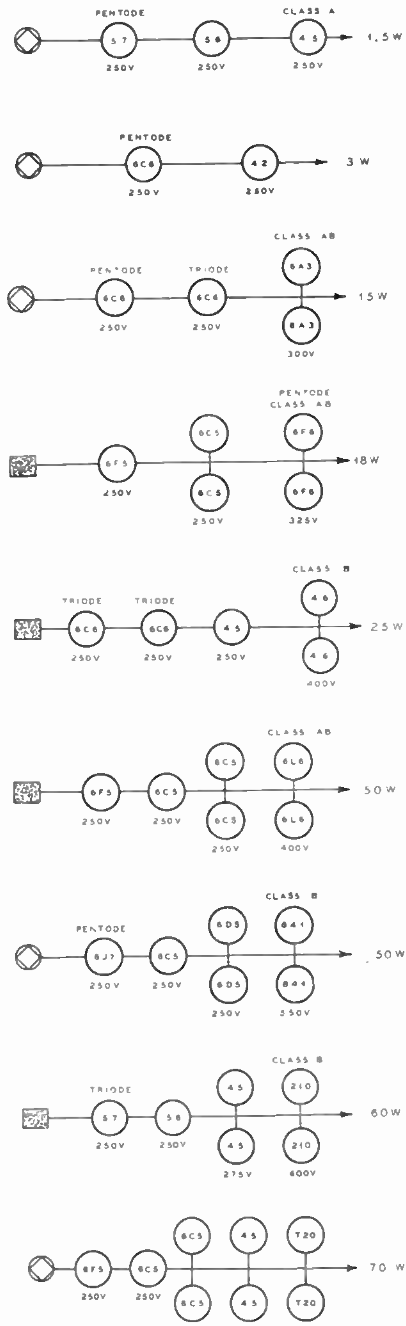
The plate-to-plate impedance of the modulator under these conditions should be approximately 8,000 ohms, as listed in the tube tables for the RCA-805s. In this case, the 10,000-ohm load impedance must be reduced to 8,000 ohms. The modulation transformer should have a total primary to secondary turns-ratio of 1-to-1.1. Thus, it is seen from these examples that the HK-354 calls for a step-up transformer, whereas the transformer for the 211 tubes is of the step-down variety.

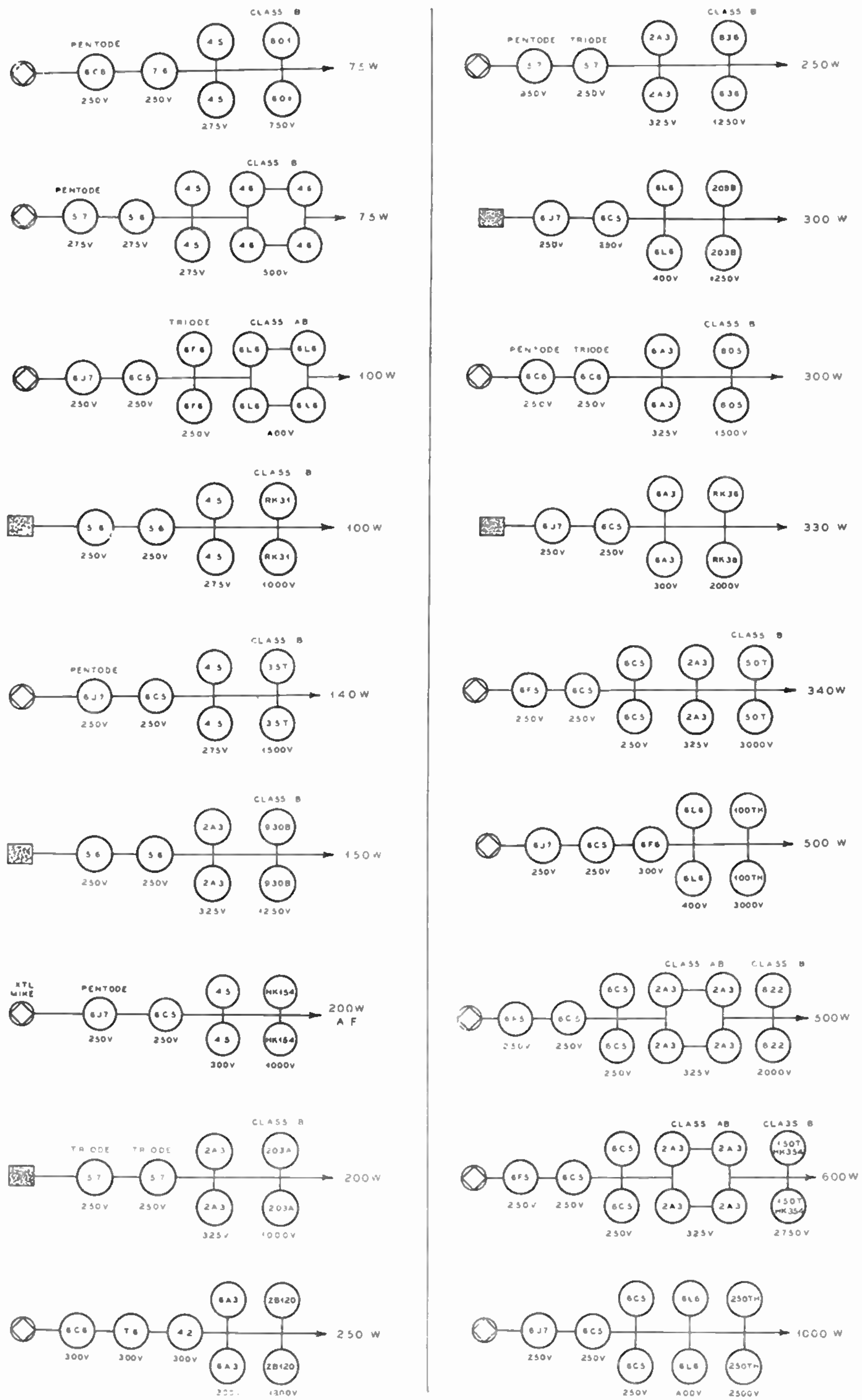
• Audio Output Block Diagrams

From the group of 27 block diagrams here shown, the reader can quickly find a satisfactory tube complement for audio outputs ranging from 1.5 watts to 1,000 watts. The *legend* explains the various connection systems shown in the block diagrams; crystal or carbon microphones or pre-amplifier are denoted by the conventional symbol, shown directly below the *legend*. Correct operating plate voltages are shown under the tube symbols in each diagram. The arrow to the far right denotes the audio output of the amplifier. Outputs are listed in the respective order of the diagrams, beginning with the lowest (1.5 watts) and ending with the highest (1,000 watts).



Block Diagrams For Modulators




PENTODE
6C6
250V
76
250V
45
45
275V
CLASS B
801
801
750V
75 W
PENTODE
57
275V
56
275V
45
45
275V
CLASS B
46
46
46
46
500V
75 W
TRIODE
6J7
250V
6C5
250V
6F6
6F6
250V
CLASS AB
6L6
6L6
6L6
6L6
400V
100 W
56
250V
56
250V
45
45
275V
CLASS B
RK31
RK31
1000V
100 W
PENTODE
6J7
250V
6C5
250V
45
45
275V
CLASS B
35T
35T
1500V
140 W
56
250V
56
250V
2A3
2A3
325V
CLASS B
930B
930B
1250V
150 W
XTL MIKE
PENTODE
6J7
250V
6C5
250V
45
45
300V
HK154
HK154
1000V
200W A F
TRIODE
57
250V
TRIODE
57
250V
2A3
2A3
325V
CLASS B
203A
203A
1000V
200 W
6C6
300V
76
300V
42
300V
6A3
6A3
2B120
2B120
1300V
250 W
PENTODE
57
250V
TRIODE
57
250V
2A3
2A3
325V
CLASS B
838
838
1250V
250 W
6J7
250V
6C5
250V
6L6
6L6
400V
203B
203B
1250V
300 W
PENTODE
6C6
250V
TRIODE
6C6
250V
6A3
6A3
325V
CLASS B
805
805
1500V
300 W
6J7
250V
6C5
250V
6A3
6A3
300V
RK38
RK38
2000V
330 W
6F5
250V
6C5
250V
6C5
6C5
250V
2A3
2A3
325V
CLASS B
50T
50T
3000V
340W
6J7
250V
6C5
250V
6F6
300V
6L6
6L6
400V
100TH
100TH
3000V
500 W
6F5
250V
6C5
250V
6C5
6C5
250V
CLASS AB
2A3
2A3
2A3
2A3
325V
CLASS B
822
822
2000V
500W
6F5
250V
6C5
250V
6C5
6C5
250V
CLASS AB
2A3
2A3
2A3
2A3
325V
CLASS B
150T HK354
150T HK354
2750V
600W
6J7
250V
6C5
250V
6C5
6C5
250V
6L6
6L6
400V
250TH
250TH
2500V
1000 W

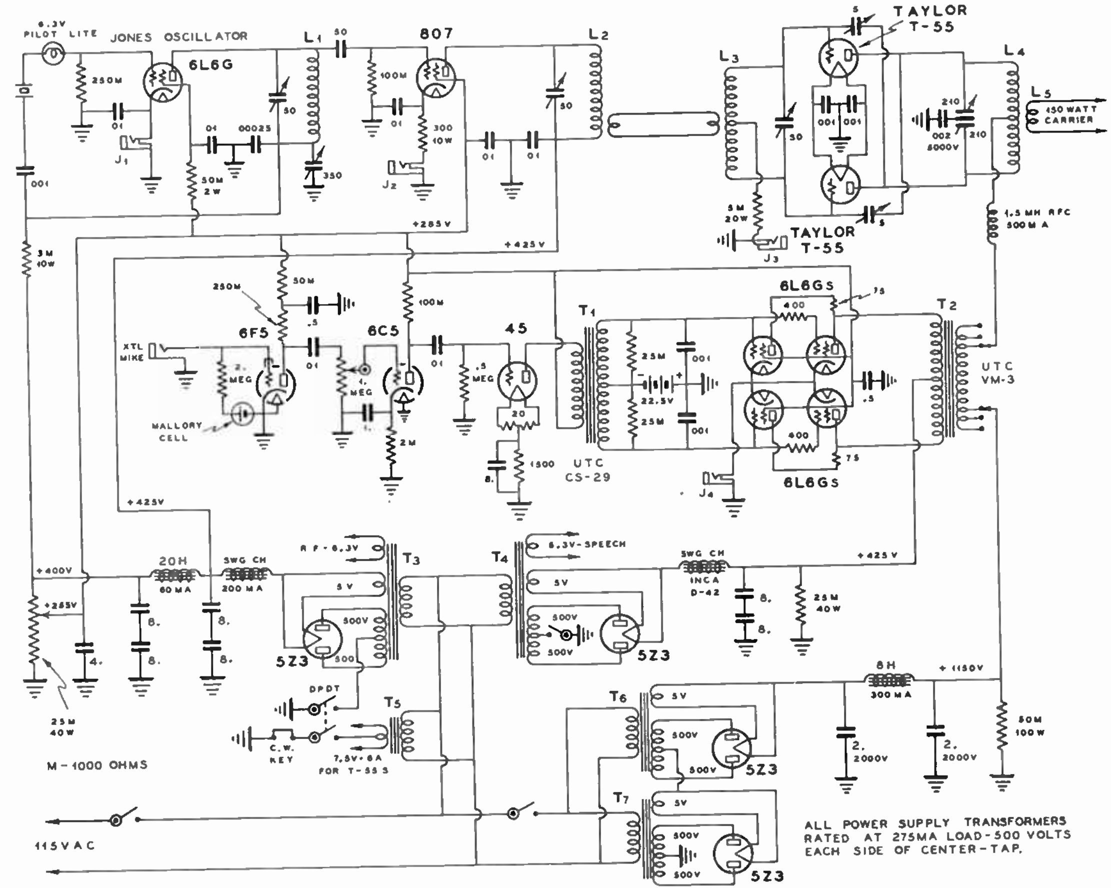


Figure 16

Plate Modulated Phone Transmitter with 150-Watt Carrier

Modulators

A modulator supplies audio power to the particular r.f. stage in the transmitter which is being modulated. A speech amplifier does not deliver sufficient power output for plate-modulating any of the conventional forms of r.f. stages. The modulator is an audio amplifier which delivers ample power output for completely modulating the d.c. input to the modulated stage. Power requirements of audio amplifiers vary from a fraction of a watt up to 500 watts, for amateur purposes. Low-power transmitters of the grid-modulated or suppressor-grid-modulated types require less than one watt of audio power, whereas a 1-kw. plate-modulated phone transmitter require 500 peak watts of audio power.

Class A amplifiers are suitable for low-power grid-modulated, or suppressor-modulated phone transmitters; class AB audio amplifiers for high power grid-modulated, or for low-power plate-modulated phones; and class B audio amplifiers for most economical operation of transmitters in which the audio requirements are greater than 60 watts. Class AB or class B modulators require a driver stage which can be considered part of the modulating system proper rather than part of the speech amplifier. The complete modulator essentially consists of a device for converting speech-amplifier output voltage into audio power.

Complete information on receiver and transmitter type tubes for modulator service, as well as for any other portion of a radiotelephone transmitter, will be found in the chapters which deal with vacuum tubes.

Plate Modulation

Plate modulation is the application of the audio modulating power to the *plate circuit* of an r.f. amplifier. The r.f. amplifier must be operated class C for this type of modulation in order to obtain a radio frequency output which changes in exact accordance with the variation in plate voltage. *The r.f. amplifier is 100 per cent modulated when the peak a.c. voltage from the modulator is equal to the d.c. voltage applied to the r.f. tube.* The positive peaks of audio voltage increase the instantaneous plate voltage on the r.f. tube to *twice* the d.c. value, and the negative peaks reduce the voltage to zero.

The instantaneous plate *current* to the r.f. stage also varies in accordance with the modulating voltage. The peak alternating current in the output of a modulator must be equal to the d.c. plate current of the class C r.f. stage at the point of 100 per cent modulation. This combination of change in audio voltage and current can be most easily referred to in terms of *audio power in watts.* By properly matching the plate impedance of the r.f. tube to the plate impedance of the modulator, the ratio of voltage and current swing to d.c. voltage and current is automatically obtained. The modulator should always be capable of supplying audio power to the extent of 50 per cent of the d.c. input to the plate-modulated stage. Complete modulation cannot be secured unless this value of 50 per cent is available, in addition to a coupling system permitting the correct "reflected" impedance to be obtained.

The plate efficiency of the plate-modulated stage is constant, and the additional power radiated in the form of side-bands is supplied by the modulator.

One of the advantages of plate (or power) modulation is the ease with which proper adjustments can be made in the transmitter. There is less plate loss in the r.f. amplifier for a given value of carrier power than with other forms of modulation, because the plate efficiency is higher. Figures 16 and 17 show two types of radiotelephone transmitters with plate modulation.

Heising Modulation

Heising modulation usually consists of a class A audio amplifier coupled to the r.f. amplifier by means of a modulation choke coil, as shown in figure 18.

The d.c. plate voltage and plate current in the r.f. amplifier must be adjusted to a value which will cause the plate impedance to match the output of the modulator, since the modulation choke gives a 1-to-1 coupling ratio. A series resistor, bypassed for audio frequencies by means of a condenser, must be connected in series with the plate of the r.f. amplifier in order to obtain modulation up to 100 per cent. The a.c. or audio output voltage of a class A amplifier does not reach a value equal to the d.c. voltage applied to the class A amplifier and, consequently, the d.c. plate voltage impressed across the r.f. tube must be reduced to a value equal to the maximum available a.c. peak voltage. A higher degree of distortion can be tolerated in low-power emergency phone transmitters which use a pentode modulator tube for securing sufficient audio output, and thus the series resistor and bypass condenser are usually omitted.

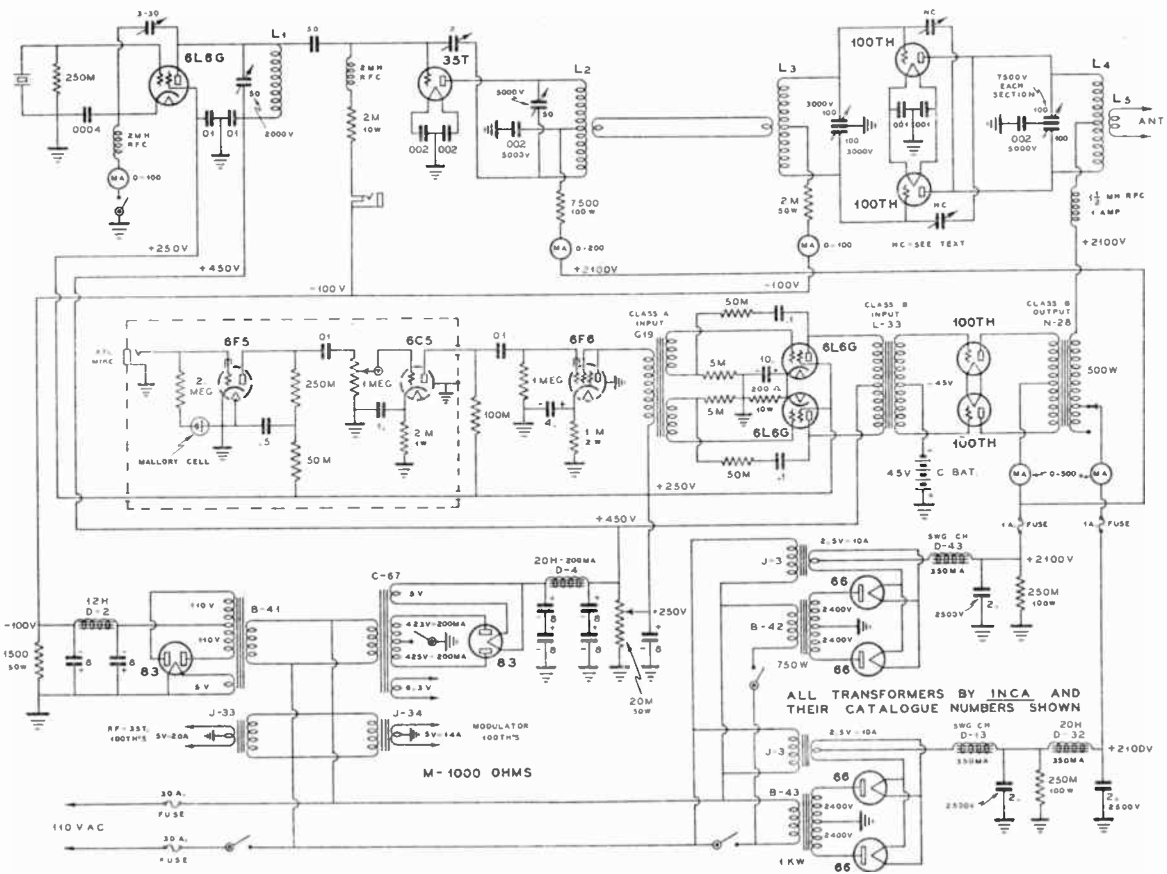
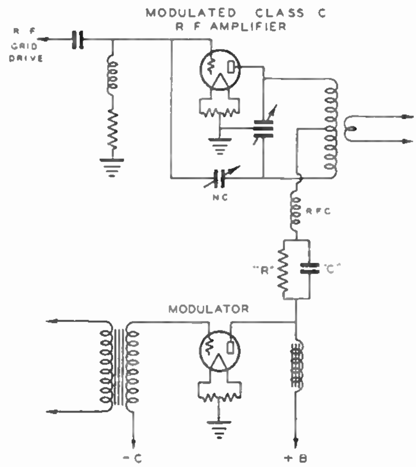


Figure 17

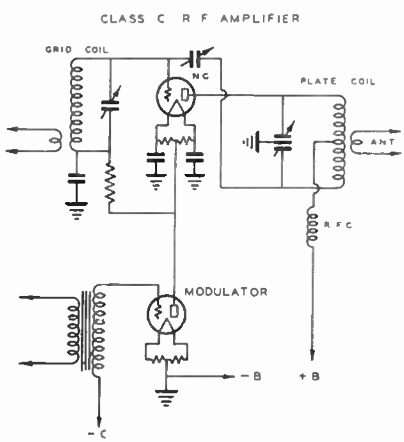
Complete Circuit Diagram for 800-Watt Plate Modulated Phone Transmitter



HEISING OR PLATE MODULATION

"R" DROPS PLATE POWER INPUT AND VOLTAGE TO CLASS C STAGE IN ORDER TO OBTAIN HIGH DEGREES OF MODULATION. "C" IS FROM 2 TO 4 MFDS TO BY-PASS THE AUDIO SIGNAL TO THE CLASS C MODULATED AMPLIFIER.

Figure 18



SERIES MODULATION

Figure 19

• Series Modulation

Another form of plate modulation is known as *series modulation*, in which the r.f. tube and modulator are in series across the d.c. plate supply, as shown in figure 19.

Series modulation eliminates the modulation choke required in the usual form of Heising modulation. Although this system is capable of very good voice quality, the antenna coupling must be carefully adjusted simultaneously with the C-bias in the modulator in order to maintain at least 20 per cent more plate voltage across the modulator than that which is measured from positive B to r.f. tube filament. It is difficult to obtain a high degree of modulation unless a portion of the total plate current is shunted by the r.f. tube through a small high-inductance choke coil. Series modulation is seldom used today except for television work.

• Efficiency Modulation

When modulation is effected by a change of r.f. tube plate efficiency, rather than by modulation of plate input power, the system is known as *efficiency modulation.* Control-grid, screen-grid, and suppressor-grid modulation operate on the foregoing principle, as does the "linear amplifier" stage used by broadcast stations to build up their power *after* modulation.

With pure efficiency modulation, the maximum efficiency at which the r.f. modulated tube can operate is less than 50 per cent, since the peak efficiency (twice the "resting" value) must be less than 100 per cent. Several methods have been devised for the operation of amplifiers at efficiencies as high as 60 per cent during periods of no modulation, and then changing the plate power supply in order to obtain 100 per cent modulation without much increase in peak plate efficiency. This is accomplished in the *expanding linear r.f. amplifier*, developed in various forms by *W. H. Doherty* of *Bell Laboratories*, and independently by *J. N. A. Hawkins.*

The method used by *Hawkins* consists of maintaining a constant r.f. grid drive, then varying the d.c. plate voltage and d.c. grid bias together in accordance with the *envelope* of the audio-frequency wave. At maximum audio input to the modulated stage, which precedes the controlled linear amplifier, the bias and d.c. plate voltage and current in the latter are normal for linear amplifier operation. When the plate and grid voltages are reduced during periods of no modulation, the modulation capability of the linear amplifier is reduced, and the plate efficiency is increased.

The method used by *Doherty* consists of expanding the linear amplifier by means of an additional r.f. tube and circuit networks. In both systems, the unmodulated plate efficiency can be made as high as 60 per cent, resulting in a considerable saving in tubes and power supply equipment for transmitters of very high power. However, it is doubtful if the system is justified for powers of less than one or two kilowatts.

Certain forms of grid modulation, while operating on the general principle of efficiency modulation, can be made to release additional power from the d.c. plate supply. These systems are discussed under grid modulation.

● Grid Modulation

The several popular forms of grid modulation operate on the same general principle, but under somewhat different conditions. In all systems, the audio-frequency power is impressed upon the grid circuit, and the r.f. amplifier operates in a modified class C arrangement. One system employs a vacuum tube as a variable grid-leak in a class C r.f. amplifier with a very small order of excitation. The modulator tube is driven by the speech amplifier, and its plate impedance varies in accordance with the speech input. The modulator tube receives its plate current from the rectified grid current of the r.f. amplifier. The grid bias of the modulator is adjusted to the point which gives best voice quality, and the r.f. excitation must be similarly adjusted for the same purpose. This system, shown in figure 20, does not give distortionless modulation and it is critical in adjustment.

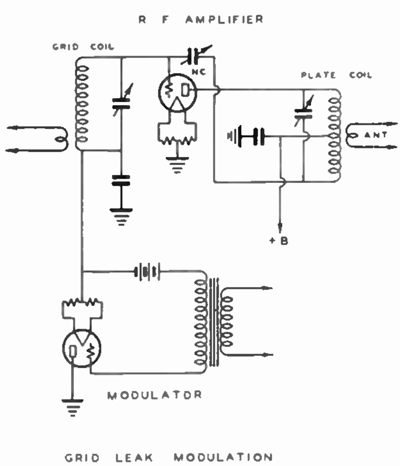


Figure 20

● The Class BC System

The *Hawkins* class BC system, shown in figure 21, is a method of grid modulation which can be adjusted to give exceptionally good quality.

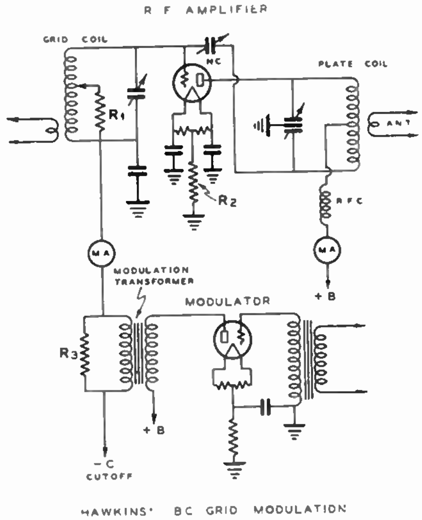


Figure 21

The r.f. amplifier is operated with fixed bias equal to cut-off. This bias is supplied either from batteries or from a bias pack. Additional bias is obtained from a cathode resistor R_2 in the modulated stage. This resistor should be bypassed for r.f., but not for audio frequencies, by means of filament bypass condensers no higher in value than .005 μfd. When an audio voltage is applied from the modulator, it is amplified in the r.f. tube, and a degenerative feedback occurs across resistor R_2. For this reason the audio power requirements are somewhat greater than for other grid-modulated systems. This degenerative effect, however, produces a very linear modulation characteristic. The d.c. plate current which flows through R_2 should provide an additional bias equal to at least half the theoretical cut-off bias. A higher value of R_2 will result in higher plate efficiency, but at a sacrifice in power output, which can be brought up by using higher plate voltage.

The r.f. grid excitation is adjusted to the point where grid current just starts to flow. Excess r.f. grid excitation can be absorbed by resistor R_1 (figure 21) connected across the grid circuit; this resistor also stabilizes the operation of the circuit and improves the quality.

Grid excitation can be conveniently controlled by means of a link-coupling adjustment. The antenna loading is greater than that required for plate modulation or c.w. operation. This coupling should be increased to a point somewhat beyond that at which maximum antenna or feeder r.f. current occurs for given excitation. The plate efficiency will be between 35 per cent and 40 per cent in a well-designed class BC amplifier. Design of the grid-modulation transformer is discussed on page 298.

The circuit constants can be calculated from a group of formulae given here:

(1) E_b = d.c. plate supply voltage, in volts.
(2) $W_{plate\ loss}$ = rated plate dissipation of the tube in watts.
(3) μ = amplification factor of the tube.
(4) W_{input} = d.c. plate input power, in watts.
(5) W_{output} = r.f. unmodulated carrier output in watts.
(6) I_p = d.c. plate current, amperes.
(7) E_{cco} = d.c. battery bias equal to theoretical cut-off bias (one-half total bias).
(8) R_k = cathode bias resistance, in ohms.
(9) $W_{input} = 1.66 W_{plate\ loss}$
(10) $W_{output} = .66 W_{plate\ loss}$

(11) $$I_p = \frac{1.66\ W_{plate\ loss}\ (1+\mu)}{\mu E_b}$$

(12) $$E_{cco} = \frac{E_b}{1+\mu}$$

(13) $$R_k = \frac{E^2_b \mu}{1.66\ W_{plate\ loss}\ (1+\mu)^2}$$

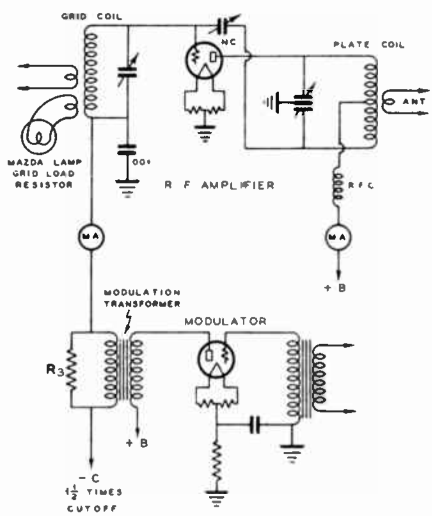
The class-BC amplifier shown for grid modulation can be operated as a linear r.f. amplifier at 40 per cent plate efficiency, which is somewhat better than the efficiency obtainable from a conventional linear amplifier (30 to 33 per cent).

Dr. F. E. Terman and *F. A. Everest* have developed a dynamic shift grid-bias modulation system which operates on the same principle as the *Hawkins* dynamic shift expanding linear amplifier. Expansion of plate and grid-bias voltages during modulation is accomplished by using saturable control reactors or grid controlled rectifiers. The maximum peak efficiency is approximately 66 per cent in practice, and the resting plate efficiency can be adjusted to some point between 40 per cent and 66 per cent, which results in less plate loss in the r.f. amplifier.

Oleson, also of *Stanford University*, has found that a grid modulated amplifier can be operated at relatively high efficiencies (50 per cent to 60 per cent) when not modulated with the d.c. grid bias at 3 times cut-off. Rather high r.f. and audio excitation are required. The antenna loading is similar to that of other grid modulation systems. Linear modulation up to values of 90 per cent are obtained, and the system apparently works on the principle of efficiency modulation plus some release of additional plate power from the power supply. The circuit, except for the value of grid bias, is exactly similar to the one shown for ordinary grid modulation.

• Ordinary Grid Modulation

Probably the most popular form of grid modulation is shown in figure 22.



ORDINARY GRID MODULATION

Figure 22

The grid bias is adjusted to 1½ times cut-off, and the r.f. excitation is set to a value which will cause approximately one milliampere of rectified grid current to flow, as indicated by a d.c. milliammeter. The antenna load is made greater than that required for maximum r.f. antenna current; or increased until linear modulation is obtained, as shown on an oscilloscope or by a phone monitor.

The plate current may increase as much as 10 per cent during peaks of modulation without objectionable distortion, and this increase of power input to the modulated r.f. amplifier will allow good quality modulation up to 90 per cent.

Modulators for Grid Modulation

The modulator tube for a grid-modulated phone transmitter is relatively small in comparison to the tube required for plate modulation. Grid-modulated phones with 200 to 400 watts output require an audio power of *less than* 15 *watts.* This is because modulation takes place in the grid circuit, in which the r.f. power is only a few per cent of that in the plate circuit of the modulated tube.

A small modulator, capable of delivering 2 to 3 watts of audio power, will modulate an r.f. stage which supplies 50 to 100 watts to the antenna circuit. A typical example is shown in one of the transmitters described in the constructional chapters of this book. The peak audio voltage of 120 volts completely modulates an r.f. tube which operates from a 1500-volt plate supply, and the carrier output exceeds 60 watts. The modulator is a type 42 or 6F6 pentode amplifier, operating well below its normal output and having a good portion of its output dissipated in a resistor R_3, which is connected across the modulation transformer. This resistor is across the output of the modulator for the purpose of providing a more constant load impedance than that reflected by the grid circuit of the modulated r.f. tube.

The modulator should preferably have a low plate impedance, unless a step-down ratio modulation transformer is available. The resistor R_3 could be eliminated in the case of a type 2A3 tube working into a transformer having a step-down ratio of 1½-to-1, or 2-to-1. The resistor R_3 should be connected across a 1-to-1 transformer when either triode or pentode audio amplifiers are used as modulators. The modulation transformer is suitable for working out of a 2A3 triode or 42 pentode into any grid modulated r.f. stage in which 50 or 100 watt tubes are used. The resistor R_3 is usually a 10,000-ohm, 2-watt type.

Small, class-AB output transformers designed for operation from 2A3's or 42 triodes into a 5,000-ohm load are suitable for push-pull modulators. The resistance R_3, in such cases, should be of some value between 7,500 and 10,000 ohms, rated at 10 watts. This push-pull modulator will drive higher power grid-modulated stages, such as a pair of HK-354's, RCA-806's, Eimac 250TL's, Taylor 814's, HF-200's or RK-36's.

A phone monitor should always be available for adjusting the r.f. grid excitation to the proper value which produces good voice quality. An overmodulation indicator is also essential for determining the amount of speech amplifier output and gain. The plate circuit of the modulated r.f. tube should have a low impedance to voice frequencies; a 2 to 4 μfd. filter condenser across the output of the power supply filter will usually suffice.

Modern grid modulation circuits are capable of supplying 500 to 600 watts of carrier output from an input of 1 kw. For this higher efficiency, more r.f. drive, more bias, and a 35-watt low impedance audio stage (push-pull-parallel 2A3's) are required.

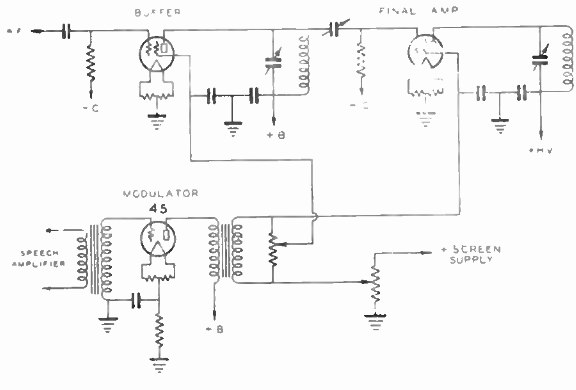
Tubes for Grid Modulated Phones

Low or medium μ triodes are more satisfactory than high μ tubes for grid modulated r.f. circuits. The high μ tubes have a high plate impedance, which makes it difficult to secure a linear dynamic characteristic; this high plate impedance limits the amount of undistorted power output. Low μ tubes have the most linear characteristics for this purpose, but the required values of bias voltage are so high that this advantage may be offset by the requirements of higher grid drive. Any screen-grid tube, tetrode or pentode, can be effectively control-grid modulated. The most satisfactory triode tubes for grid modulation are the 2A3, 10, 801, RK-35, 825, 930, HK-154, 50T, 100TL, WE-242A, RK-36, 211, T200, HF200, HK-354, 150T, 250TL, 814, WE-212-E, 300T, 849, and 500T.

Screen-Grid Modulation

Modulation can be accomplished by varying the screen-grid voltage at an audio-frequency rate in an r.f. screen-grid tube. The screen-grid voltage must be reduced to approximately one-fourth the value of that used for c.w. operation. The r.f. output is correspondingly reduced and the tube then operates as an efficiency-modulated device, somewhat similar to ordinary grid modulation.

The degree of modulation is limited to approximately 60 per cent when the screen-grid of a single stage is modulated. When two cascade stages are modulated, a level of



CASCADE SCREEN GRID MODULATION

Figure 23

100 per cent can be reached, with good quality. The r.f. excitation and screen-grid voltages must be carefully adjusted in order to secure satisfactory results. The r.f. excitation to the grid of the final amplifier must be so low that this tube will act somewhat like a class-B linear stage. It is possible to use dissimilar tubes in the cascade-modulated circuit shown in figure 23.

The buffer amplifier can be a type-807 the final amplifier an RK-47; or a single 860 can drive an 860 push-pull final amplifier. In any event, both stages should have the audio modulation voltage applied to the screens. This system of modulation is seldom used because of its complications, and because only a few types of tubes are suitable for this application.

• Plate and Screen Modulation

When *only* the plate of a screen-grid tube is modulated, it is impossible to obtain high percentage linear modulation, except in the case of certain "beam" tubes. A dynatronic action usually takes place when the instantaneous plate voltage falls below the d.c. screen voltage, and this prevents linear modulation. However, if the screen is modulated simultaneously with the plate, the instantaneous screen voltage drops in proportion to the drop in plate voltage, and linear modulation can then be obtained.

A circuit for such a system is shown in figure 24.

The screen r.f. bypass condenser, C_2, should not have a value greater than .01 μfd., preferably not larger than .005 μfd. It should be large enough to bypass effectively all r.f. voltage without short-circuiting high frequency audio voltages. The plate bypass condenser can be of any value from .002 μfd. to .005 μfd. The screen-dropping resistor, R_2, should reduce the applied high voltage to the value specified for operating the particular tube in the circuit. Condenser C_1 is seldom required, yet some tubes may require this condenser in order to keep C_2 from attenuating the high audio frequencies. Different values between .01 and 0.1 μfd. should be tried for best results.

Another method is to have a third winding on the modulation transformer, through which the screen-grid is connected to a low-voltage power supply. The ratio of turns between the two output windings depends upon the type of screen-grid tube which is being modulated. The latter arrangement is more economical insofar as modulator power is concerned, because there is no waste of audio power across a screen-grid voltage-dropping resistor, but this loss is relatively small anyway with most tubes. The special transformer is not justified except perhaps for high power.

The modulation transformer for plate-

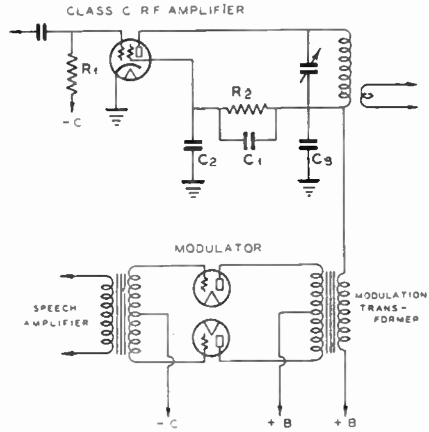
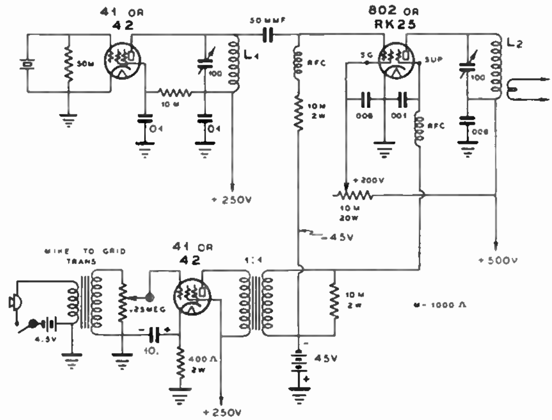


PLATE AND SCREEN MODULATION

Figure 24

and-screen-modulation, when utilizing a dropping resistor, is similar to the type of transformer used for any plate-modulated phone. In figure 24, the combined screen and plate current is divided into the plate voltage in order to obtain the class-C amplifier load impedance. The audio power required to obtain 100 per cent modulation is one-half the d.c. power input to the screen, screen resistor, and plate of the modulated r.f. stage.

Quite good linearity at high percentage modulation can be obtained with some of the larger *beam*-type transmitting tetrodes by modulating the plate voltage alone.



3 TO 5 WATT SUPPRESSOR MODULATED PHONE

Figure 25

• Suppressor Modulation

Still another form of efficiency modulation can be obtained by applying audio voltage to the suppressor-grid of a pentode tube which is operated class-C. A change in bias voltage on the suppressor-grid will change the r.f. output of a pentode tube, and the application of audio voltage then provides a very simple method of obtaining modulation.

The suppressor-grid is biased negatively to a point which reduces the plate efficiency to somewhat less than 40 per cent. The peak efficiency at the time of complete modulation must reach twice this value. It is difficult to obtain 100 per cent modulation, though 90 per cent to 95 per cent can easily be obtained and with good linearity. Adjustments are more easily made than with control-grid modulation, and the type of audio modulator and the values of audio voltage are approximately the same as for ordinary grid modulation. The same modulator design problems apply to suppressor-modulated phones. The control grid in the suppressor-modulated stage is driven to about the same degree as for c.w. or plate modulation. The r.f. excitation adjustment is not critical, but the excitation should be ample to allow distortionless modulation in this stage.

The quartz crystal should not be placed directly in the grid circuit of any suppressor-modulated stage because of a tendency for frequency modulation and poor quality due to insufficient r.f. grid excitation. A simple test with an oscilloscope will prove the fallacy of using a suppressor-grid modulated pentode as a crystal oscillator in order to minimize the number of stages in the transmitter.

One of the smallest and most simple suppressor-modulated phone transmitter circuits is shown in figure 25.

The output of this transmitter is very low; it is satisfactory for local communication only, especially in the 160-meter band.

A separate crystal oscillator is incorporated in order to secure better quality of modulation. A 250,000-ohm gain control may be required in the pentode modulator circuit if a sensitive single-button carbon microphone is used. The modulation transformer should be of the type designed for class-B input service, 1-to-1, or 2-to-1 step-down ratio. When a 2-to-1 ratio transformer is used, the 10,000-ohm loading resistor across the secondary should be reduced to about 5,000 ohms. The suppressor-grid should be bypassed with a condenser not larger in value than .001 μfd. in order to prevent loss of high audio frequencies. The screen-grid resistor of the modulated tube should be adjusted to a value which will give 200 volts between screen and cathode, during normal operation.

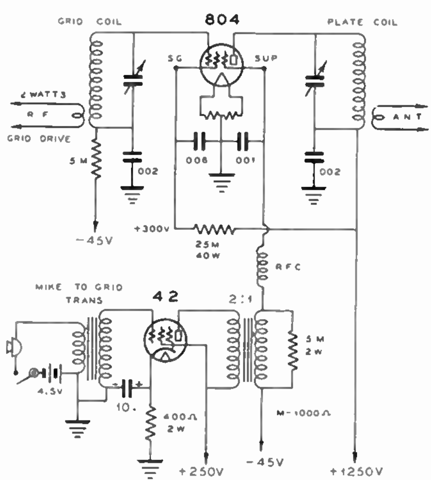
The output can be doubled by merely putting another tube in parallel with the 802 or RK-25 and using a 5000-ohm grid leak instead of the 10,000-ohm one shown. No other changes are necessary. All pentode r.f. tubes can be easily over-excited, resulting in decreased output. The amount of excitation, while not critical, should be checked with a d.c. milliammeter in the grid-leak circuit of the modulated stage. The grid current should run between 4 and 6 milliamperes for the RCA-802 or Raytheon RK-25 tubes. The antenna loading should be adjusted so that the plate current is between 20 and 30 milliamperes at resonance. Overmodulation, due to excessive audio input, can be checked with an overmodulation indicator. The peak audio voltage need not be more than 65 or 75 volts for an RK-25 or 802. This is the peak voltage which is measured across the secondary of the modulation transformer. An ordinary rectifier-type a.c. voltmeter will give an indication of approximately 50 volts of audio at this point.

Suppressor-modulated phone transmitters should not be too-heavily loaded by the antenna if linear modulation is desired. The degree of loading is comparable to that for a class-C plate-modulated stage. Typical oscilloscope trapezoidal patterns of suppressor modulated phones are shown in the Chapter on *Test Instruments*.

It is desirable to place a metal shield around the screen-grid tube; this shield should extend from the base to about halfway up the glass envelope. Plate and grid circuits should be well-shielded.

A higher power suppressor modulated phone circuit is shown in figure 26.

This transmitter uses an RCA-804 or Raytheon RK-20 pentode tube. The modulator is quite similar to the one shown in the preceding transmitter circuit. The peak audio voltage for complete modulation is



20 WATT SUPPRESSOR MODULATED PHONE

Figure 26

the same as for the smaller tubes. Slightly more grid drive is required from the crystal oscillator or exciter which may be either link or capacitively coupled to the modulated stage. The same exciter as shown for the 802-RK-25 transmitter, but with from 300 to 350 volts on the plate of the oscillator tube, will give ample excitation to drive the RK-20 or 804. The oscillator screen resistor should be increased to 30,000 or 40,000 ohms in order to keep the screen voltage of the crystal oscillator below 125 volts.

RK-28 or RCA-803 pentodes may be suppressor-modulated for carrier outputs of from 50 to 60 watts. The r.f. excitation depends upon the frequency of operation, but can be supplied by a 6L6 crystal oscillator or doubler. A type 45 or 42 pentode will serve as a modulator for either tube.

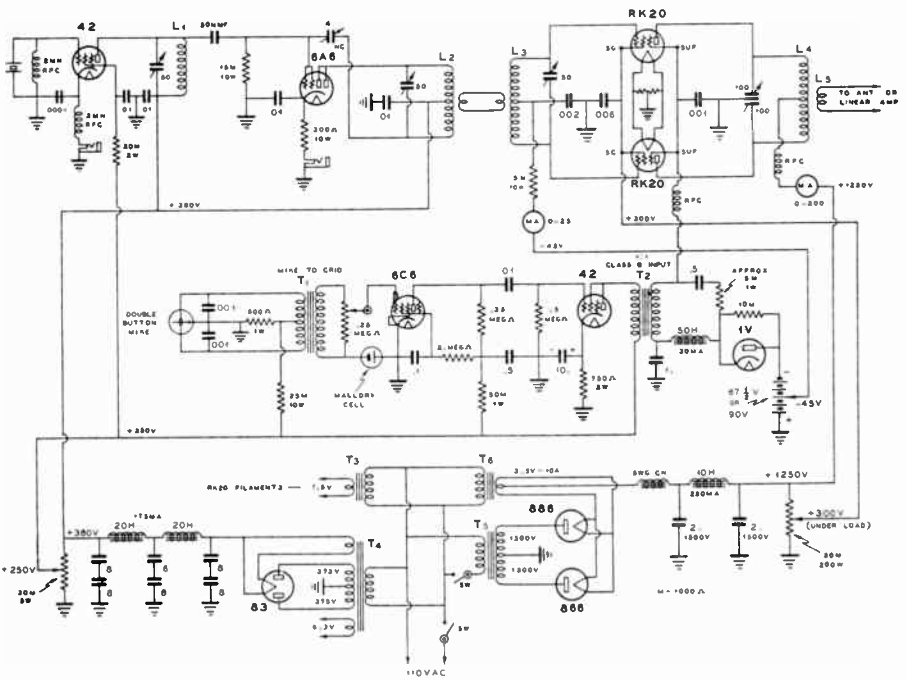
It is possible to operate a suppressor-modulated stage as a doubler. The efficiency suffers somewhat, but the quality is about as good as when working on the fundamental.

● Controlled Carrier Radiotelephony

One way in which the operating efficiency of a class-B r.f. linear amplifier can be improved is by the use of *carrier control,* in which the amplitude of the carrier wave is proportional to the voice frequency envelope. Two or three times as much peak power can be obtained from a linear amplifier with carrier control than when constant carrier is applied to the linear amplifier.

The principle of the system is the use of only enough carrier power to accommodate the actual sideband power that is being transmitted at the moment. This variation in carrier amplitude can be accomplished by a number of different methods. One is to use a saturable reactor in series with the modulated stage, another is to vary the average suppressor voltage on a suppressor-modulated stage, and another is to vary the control bias on a control-grid modulated stage. In all these cases, the control voltage is taken from a rectifier and amplifier system that is connected to the speech circuit of the transmitter.

The system has some advantages, but for amateur work the advantages are largely outweighed by the disadvantages. In the first place, it is difficult to eliminate the time lag that is introduced by the control system. The existence of this lag has a tendency to allow the first syllable of each wave train to overmodulate the transmitter. Another disadvantage of the system is that



SUPPRESSOR MODULATED — CONTROLLED CARRIER PHONE

Figure 27

the variations in line drain are quite large; unusually good line regulation is necessary to eliminate the reaction between the final plate current variations and the lower powered stages. Also, the varying carrier affects the a.v.c. circuit of a receiver tuned to it.

● Suppressor-Modulated Controlled Carrier System

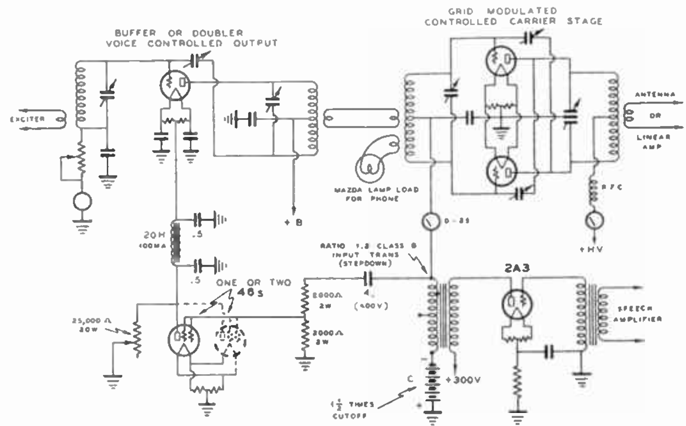
Figure 27 shows a transmitter circuit which has an output of approximately 40 watts. The circuit is not unlike a conventional suppressor-modulated phone transmitter, except for the addition of a type-1v. diode rectifier and minor components, such as resistors and condensors. The bias on the suppressor-grid is from 50 per cent to 100 per cent greater than normal in order to reduce the carrier output during the periods of no speech input.

The diode rectifier circuit decreases this bias to normal values during modulation. The audio-frequency components are filtered-out of the variable bias circuit and only the envelope of the voice frequency affects the bias. The suppressor-grid is modulated by means of the audio frequencies, the same as in any standard circuit. The output can be coupled directly to an antenna or to a high power linear amplifier. A single RK-20 tube will furnish sufficient output for driving an HK-354 push-pull linear amplifier.

● Controlled Carrier Grid Modulation

The circuit in figure 28 operates on the principle of varying the grid-bias of the buffer or doubler stage by means of a type 46 high μ tube which acts as a variable cathode bias resistor. The grid circuit of the 46 tube is driven from a portion of the grid modulator tube. Because of its high amplification constant, the tube rectifies the audio frequency, and the plate current varies in accordance with the envelope of voice frequencies. The audio frequencies are prevented from modulating the buffer stage by means of a low-pass filter which is in series with the filament center-tap.

The slow change of current which follows the pattern of the voice envelope passes through the filter and causes a change in



CONTROLLED CARRIER GRID MODULATION

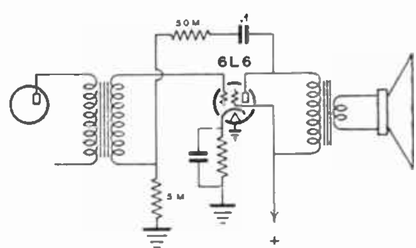
Figure 28

bias in the buffer r.f. tube. This change of bias varies the r.f. excitation to the grid-modulated r.f. amplifier. The latter operates in a manner similar to that of any other grid-modulated stage, except that the carrier output varies in accordance with the amplitude of the speech input.

• Inverse Feedback

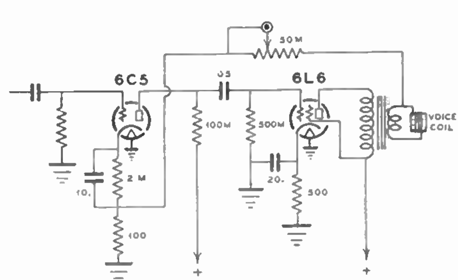
Inverse feedback or *degeneration* allows improved operation of audio amplifiers or radio transmitters. It has been found that the proper application of degeneration in an amplifier can be made to reduce greatly the harmonic distortion and otherwise improve the fidelity. Inverse feedback causes a reduction in amplifier gain, which can be offset by the addition of a stage of audio amplification in the speech amplifier. This disadvantage is more than offset by the reduction in three kinds of distortion, known as frequency distortion, non-linear distortion, and delay or phase distortion.

The principle involved in inverse feedback systems is to select a portion of the amplifier output voltage and feed it back into one of the previous circuits, exactly out of phase with the input voltage. In figure 29, a simple method of applying inverse feedback to an audio amplifier is shown. With the values of resistance as indicated, the reverse feedback is approximately 10 per cent. This reduces the gain of the audio amplifier; however, it still has approximately twice the sensitivity of a triode amplifier with similar plate circuit characteristics. The plate circuit impedance of the 6L6 is greatly reduced, an advantage when working into a loudspeaker (because a loudspeaker is not a constant impedance device).



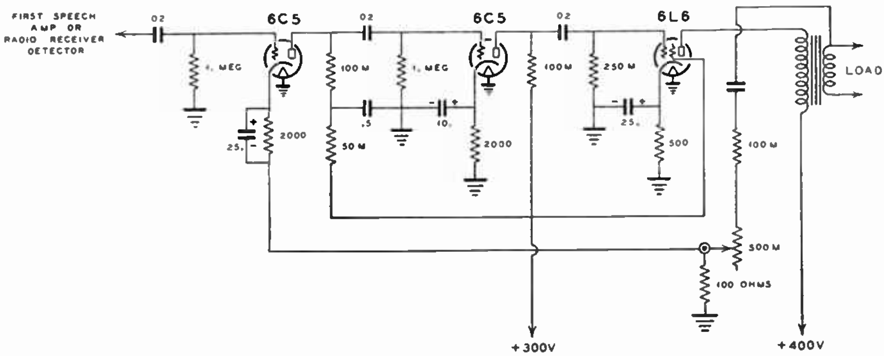
INVERSE FEEDBACK FOR SINGLE STAGE AMPLIFIER

Figure 29



INVERSE FEEDBACK FOR 2 STAGE AMPLIFIER

Figure 30



DEGENERATIVE FEEDBACK AMPLIFIER

Figure 31

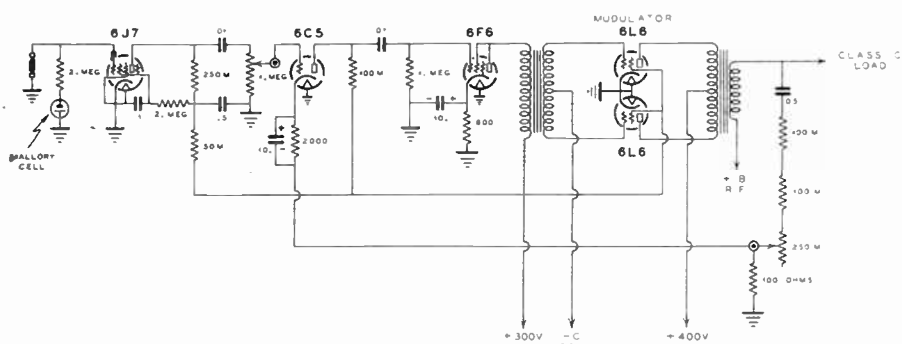
Inverse feedback can be applied in a somewhat different manner, as shown in figure 30, for a two-stage amplifier. This method is particularly desirable, in that feedback produces better results when the feedback circuit is connected from the output back to the grid of one of the *preceding* amplifier stages.

The polarity of the secondary winding of the output transformer, in all cases where the feedback connection is made to the secondary, should be that which will produce degeneration and reduction in amplifier gain, rather than regeneration and howl or increase of gain.

The circuits in figures 31 and 32 indicate methods for applying inverse feedback to three stages of amplification. These two systems are suitable for operation as speech amplifiers and modulators for grid-modulated radiotelephones, or low-power plate modulated transmitters. The 100-ohm cathode resistor should be located as near as possible to the 6C5 tube cathode terminal in order to prevent undesirable pickup and feedback at frequencies other than those desired.

• R. F. Inverse Feedback

Modulation distortion, noises, and hum level which are present on the carrier of a radiotelephone station can be reduced by inverse feedback applied as follows: This system is used in some broadcast transmitters and can be modified for amateur applications. The method consists of rectifying a small amount of the carrier signal and feeding-back the audio component in reverse phase into some part of the speech amplifier. This arrangement will reduce the hum level and improve the voice quality of



DEGENERATIVE FEEDBACK AMPLIFIER

Figure 32

most amateur radiotelephone transmitters.

The amount of inverse feedback that can be applied in this manner will depend upon the available amount of excess speech amplification and the degree to which it can be carried without oscillation at some undesired r.f. or audio frequency. The process of inverse feedback is to utilize voltages 180° out-of-phase over the band of frequencies of operation. Sometimes the feedback voltage may be in-phase, or considerably less than 180° out-of-phase for frequencies outside of the voice range, and the amount of feedback which can be applied is limited by this effect.

Two inverse feedback rectifier circuits are shown in figures 33 and 34.

Figure 33 is a simple diode rectifier which incorporates a phase-reversing switch which must be thrown to that position which will cause a slight reduction in speech amplifier gain. The actual gain of the speech amplifier can be increased by means of the manual gain control. The undesired noise or hum which is audible in the phone monitor will generally be reduced with the correct adjustment of the r.f. pickup coil and phase-reversing switch. Once adjusted, no additional changes are necessary unless the transmitter power output or frequency is varied.

In figure 34, a type-84 rectifier tube is connected so that one side serves as an inverse feedback rectifier, and the other side is a standard overmodulation indicator and phone monitor.

The circuits in figures 35 and 36 show methods of connection from the feedback rectifier into the speech amplifier.

The feedback rectifier diode rectifies the carrier, and any hum or noise modulation on the carrier appears as an audio voltage across the 100,000-ohm feedback control to the grid of the speech amplifier. A portion of this voltage is fed back into the speech amplifier so as to be out-of-phase, and thus

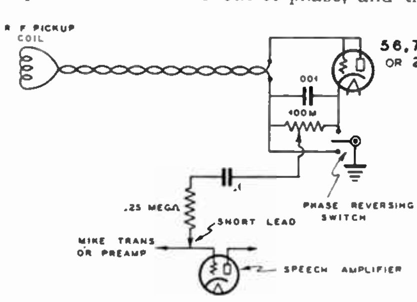


Figure 33

buck out the hum or noise in the output of the radio transmitter. This may actually introduce distortion in a portion of the speech amplifier in which there is otherwise none present, but the final result is that the distortion or hum is cancelled out in the carrier signal of the radiotelephone transmitter. This system may be applied to transmitters which use plate, suppressor or control grid modulation.

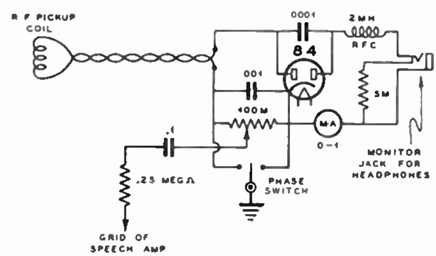


Figure 34

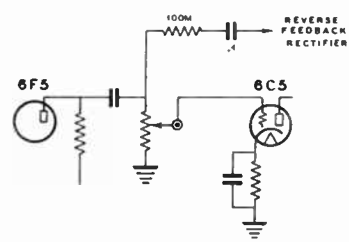


Figure 35

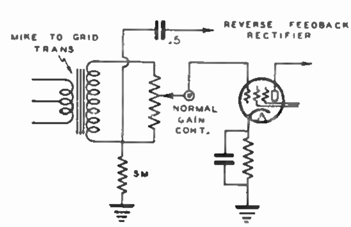


Figure 36

• Audio A. V. C. System

Automatic volume control can be applied to audiofrequency, as well as radiofrequency, amplifiers. The power output level can be limited to any desired value so that overmodulation of an amateur radiophone transmitter can be practically eliminated. Another application is for public-address amplifiers in which an automatic gain control is desirable for maintaining a fairly constant output level as the speaker turns his head

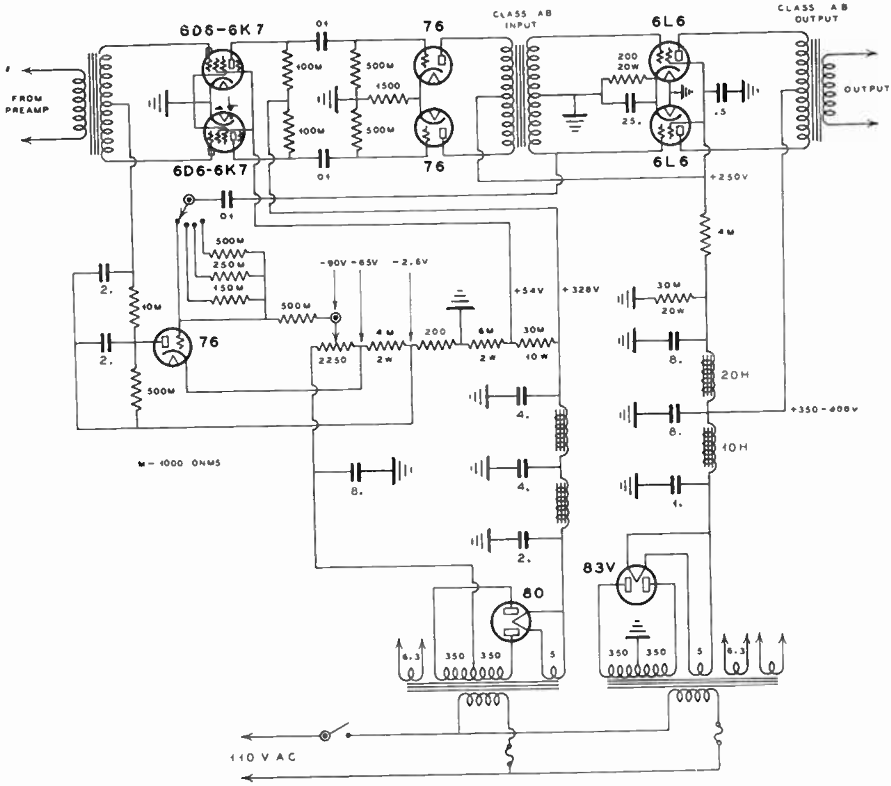


Figure 37—The gain of this amplifier varies inversely with the input signal.

or moves slightly away from the microphone.

The *Eldred* system of audio automatic volume control, shown in figure 37, consists of a three-stage push-pull audio amplifier with variable-μ tubes in the first stage. The grid bias in the first amplifier stage is varied in accordance with the average voice level by means of a type-76 automatic volume control tube.

The amplifier operates in a normal manner, and the input voltage to the grids of the final stage, at any desired level, will drive the grid circuit of the type 76 a.v.c. tube to the point at which plate current will flow in this tube. This plate current furnishes additional bias to the first audio amplifier stage and automatically reduces the gain of this stage. The action is cumulative and the total gain of the amplifier is automatically reduced for high audio input. The output power level can be maintained practically constant at any desired value by adjusting the negative bias in the grid of the type 76 a.v.c. tube. The individual voice peaks are filtered out in the plate circuit of the a.v.c. tube in order to prevent voice frequency feedback into the grid circuit of the first amplifier. The time constant in the a.v.c. system can be adjusted to a value which will follow the average voice level, rather than the individual syllables.

Other forms of audio a.v.c. make use of a diode and a.v.c. amplifier which supplies a bias voltage change to the injection-grid of a 6L7 audio amplifier tube.

The same general idea is applied to program amplifiers used by broadcast stations to give an effective increase in power. The system is similar, but it is designed with a "delayed" action that is triggered off only above a certain level, which usually corresponds to approximately 80 per cent modulation of the carrier. Above this point, compression takes place, several db. increase in input being necessary to cause one db. increase in the output of the amplifier when

100 per cent modulation is approached. This allows the operator to turn up the gain control without danger of occasional loud peaks overmodulating the carrier.

Either variable-μ tubes or non-linear copper oxide rectifiers may be used in conjunction with a triggering circuit similar to that used in the Dickert noise silencer described in the receiver chapter.

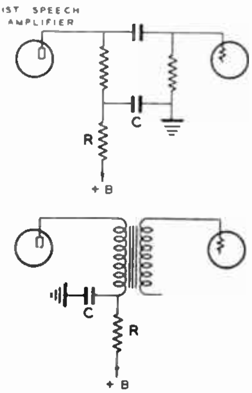
Trouble Shooting

• Feedback, Hum, and Distortion in Speech Amplifiers

Great care is necessary in the design of speech amplifiers in order to prevent hum, distortion, and feedback at radio- or audio-frequencies. Certain precautions can be taken in building the speech amplifier, as related here: (1) Shield all low-level grid and plate leads. (2) Avoid overheating the shielded wires (rubber insulation) when soldering ground connections to the shield. (3) Shield all input and microphone connections. (4) Wire the filaments with twisted conductors. (5) Mount resistors and condensers as near as possible to socket terminals. (6) Orient the input and low-level audio transformers in a position of minimum hum when a.c. power is applied to the primaries of the power supply transformers. (7) Shield the input and low-level stage tubes. (8) Use a good ground connection to the metal chassis (water-pipe or ground rod connection). (9) Ground all transformer and choke coil cores. (10) Use metal cabinets and chassis, rather than breadboard construction. (11) Bypass low-level audio stage cathode resistors with a .002 μfd. mica condenser for the purpose of preventing rectification of stray r.f. energy which will sometimes produce hum.

The power supply for a speech amplifier should be exceptionally well filtered. This may require three sections of filter, consisting of three high-capacity condensers and two or three filter chokes. When space permits, the power supply should be placed several feet from the speech amplifier.

The speech amplifier and microphone leads should be completely shielded for the elimination of r.f. feedback. A *balanced* two-wire r.f. transmission line to a remotely located antenna is the most effective method of preventing r.f. feedback into the microphone or speech amplifier circuits in the range of from 5 to 20 meters.



R-C FILTER CIRCUITS

Figure 38

The impedance of ground leads at such short wavelengths makes it impossible completely to eliminate stray r.f. currents. End-fed antennas and single-wire fed systems are particularly troublesome with respect to r.f. feedback.

Audio feedback may cause motor-boating, whistling, or howling noises in the audio amplifiers. Insufficient bypass capacity across the plate supply of a multi-stage speech amplifier is one cause of motor-boating. The first stage of a speech amplifier should have a resistance filter in its plate supply lead, which may consist of a 10,000- to 50,000-ohm 1-watt resistor in series with the positive "B" lead, with a ½-μfd. condenser connected to ground from the amplifier side of the series resistor. (See figure 38.)

A defective tube will introduce hum or distortion, as well as affect the overall gain or power output of an audio amplifier. Incorrect bias on any amplifier stage will produce harmonic distortion, which changes the quality of speech. This bias voltage should be of the correct value for the actual plate-to-cathode voltage, rather than the plate supply output voltage (these may be widely different in a resistance coupled stage. Excessive audio input to any amplifier stage will produce amplitude distortion. Incorrect plate coupling impedances, or resistances, will cause distortion. A damaged or inferior microphone is another source of distortion. Cathode resistors should be bypassed with ample capacity to provide a low impedance path for the lowest frequencies. Push-pull, and especially class B amplifiers, require balanced tubes.

Bibliography, Notes and Formulas

$$P_{(output)} = \frac{\mu^2 E_g^2 R_L}{(R_p + R_L)^2}$$

$$P_{(max)} \; \frac{\mu^2 E_g^2}{4 R_p}$$

$$P_{(max\ undistorted)} \; \frac{\mu^2 E_g^2 \cdot 2 R_p}{(9 R_p)^2} = \frac{2 \mu E_g}{9 R_p}$$

$$R_L = 2 R_p$$

Chapter 14

Radiophone Transmitter Construction

THIS chapter includes detailed information on the design, construction and operation of several modern radiotelephone transmitters of various power outputs, for operation in any of the commonly used amateur frequency bands. All of these transmitters are in actual operation at amateur stations. They include new but proved circuit improvements, and they are presented because they are representative of the type of equipment most universally chosen by the typical radio amateur.

The principal considerations in the design of an economical radiophone transmitter are the choice of the correct combinations of tubes and circuits so that the desired amount of power output and good voice quality can be secured with a minimum of components.

The components in the audio channel must be so chosen and arranged as to reduce the hum level to a minimum; the r.f. circuits must be free from parasitics; the L-C tuning ratios must be correct; and there must be a total absence of frequency modulation, instability, carrier shift, over- or under-modulation. All of these considerations were carefully considered in the design of the transmitters shown in this chapter.

30 Watt Grid-Modulated Transmitter

A very inexpensive method of modulating a small phone transmitter is by means of grid modulation, as shown in the circuit diagram of figure 1. Figures 2 and 3 show front and rear views of the complete transmitter.

Low cost tubes are used, and the driver stage for the final r.f. amplifier is designed only for sufficient drive for grid modulation in the amateur bands, from *75 to 10 meters.* The type-53 or 6A6 buffer tube can be replaced with a 6L6G if the transmitter is to be used for c.w. transmission. The 6A6 shown in figure 1 gives sufficient drive on 80 meters for c.w. operation, but not enough to secure maximum obtainable efficiency on the higher frequency amateur bands.

Circuit Considerations

The r.f. portion begins with a 2A5 or 42 harmonic type crystal oscillator which operates from a 350 volt plate supply. This crystal oscillator has an r.f. choke in the cathode circuit, and a small semi-variable condenser connected from cathode to plate of the oscillator tube so that the degree of regeneration can be made variable, when the oscillator has its plate circuit tuned to the second harmonic of the quartz crystal. The plate circuit can be tuned to either the fundamental or second harmonic of the crystal by merely changing the plate coil. Complete adjustments for this oscillator are found in the chapter on *Transmitter Frequency Control.*

The crystal oscillator is capacitively coupled to a type 53 or 6A6 in the doubler stage; the two grids and two plates of the tube are connected together, as shown in the circuit diagram. This method of connection provides ample output for driving the final amplifier. The doubler tube has a high amplification constant and derives its grid bias from a combination of grid-leak and cathode-bias resistors. The final amplifier has fixed bias, necessary for grid modulation as used in this transmitter.

The final amplifier is link-coupled to the doubler stage by means of a one-turn loop around each coil. The location of the coupling loop on the coil is adusted so as to drive approximately *one milliampere* of grid current into the final amplifier under normal operating conditions. The final amplifier utilizes two type-10 tubes in push-pull, operating from a 750-volt plate supply.

The plate tuning condenser in the final amplifier is "double spaced" (2000 volt spacing). Fixed bias for the final amplifier is obtained from the low voltage power supply by connecting the negative high voltage lead

Figure 1

Low Power Grid Modulated Radiophone Transmitter

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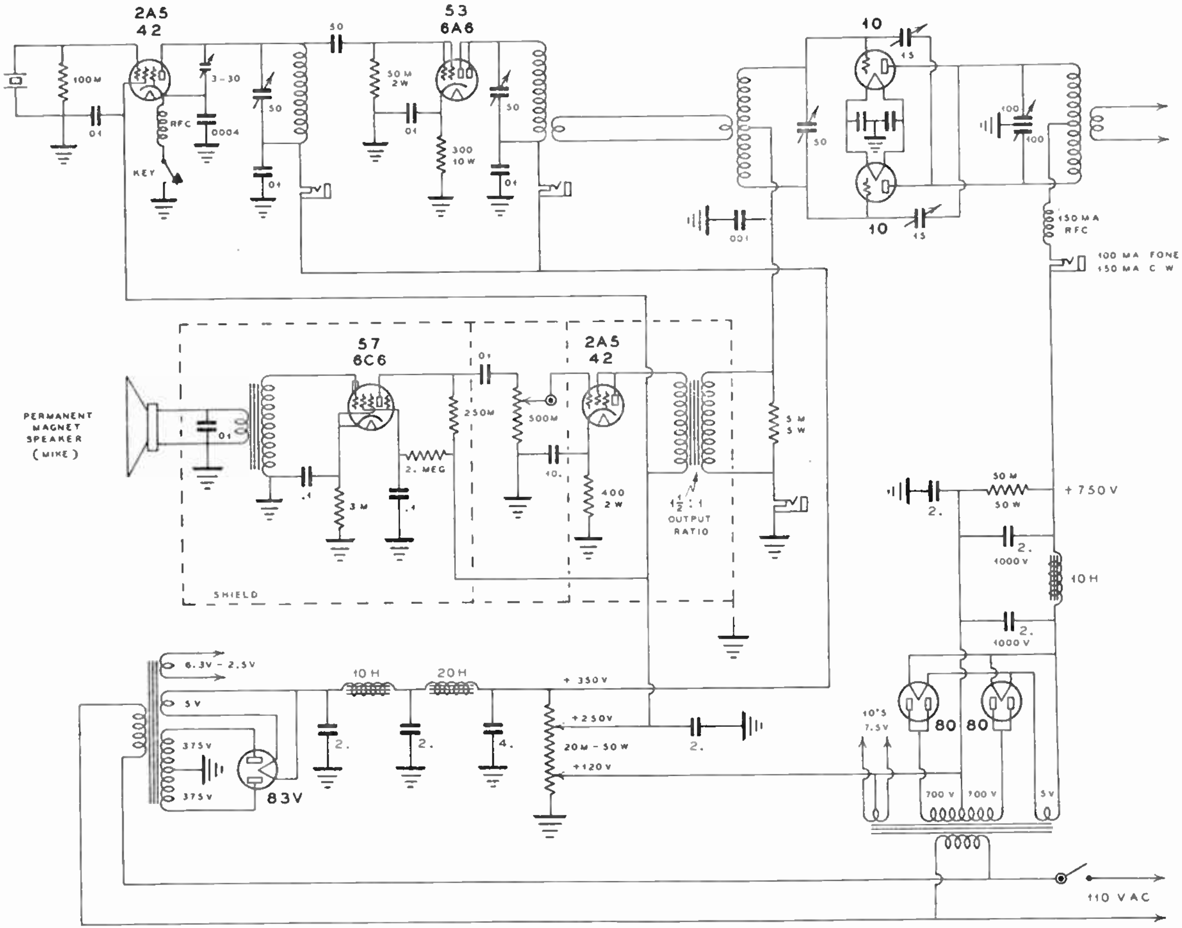
30 Watts

10-75 Meters



and the 7.5-volt filament center-tap lead to the proper point on the bleeder resistor of the 350-volt power supply. This positive 120-volt bias is obtained under normal load conditions by adjustment of the slider on the bleeder resistor. This positive bias on the filaments of the type-10 tubes provides a *negative* bias of 120 volts to the grids of the 10's. The bias is approximately 1½ times cutoff.

• The Speech Channel

The complete modulator system consists of two small receiver-type tubes, because only about *one watt* of audio power is required for modulation levels of over 90 per cent. A small 5-inch *Jensen* permanent magnet dynamic loudspeaker serves as a microphone, as described in the phone theory portion of the preceding chapter. The output transformer is used as a microphone-to-grid transformer for connection into a type-57 or 6C6 pentode speech amplifier.

This pentode amplifier uses an undersized cathode bypass condenser to attenuate the low frequencies, which tend to predominate as a result of the use of the dynamic speaker as a microphone. This audio equalizer provides a tone quality comparable with that of a good two-button carbon microphone or crystal diaphragm type microphone.

The speech amplifier drives a type-2A5 or 42 modulator tube, which is connected to the grid circuit of the final r.f. amplifier through a 1.5-to-1 ratio *stepdown* audio transformer. This transformer should be of the small class B input or output type, with relatively low d.c. resistance in both the primary and secondary windings. A 5,000-ohm resistor is connected across the secondary of this transformer for the purpose of stabilizing the load impedance across the modulator tube.

• The Power Supply

Two separate transformers are included in the power supply, one for the final amplifier, the other for the remaining components of the transmitter. The low voltage power supply must have a transformer capable of supplying a d.c. load current of 150 ma. A 750-volt center-tapped secondary winding will give approximately 350 volts d.c. output under load with condenser input to the first section of the filter circuit. A two-section filter is ample for the crystal oscillator and audio stages. The high voltage supply must be capable of supplying a d.c. load current of 100 ma. for phone operation (150 ma. for c.w.) at a plate potential of approximately 750 volts. A 1400-volt center-tapped power transformer can be used with two type-80 rectifier tubes and condenser input filter, as shown in figure 1, in order to obtain the 750-volt output.

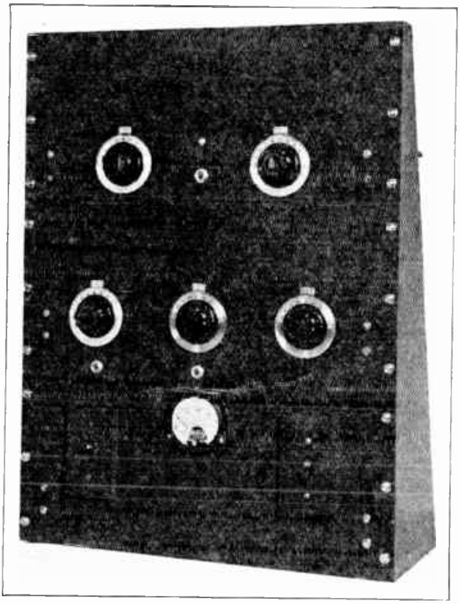


Figure 2—Front view of the inexpensive grid-modulated radiotelephone transmitter. It uses wall type on-off switches to control the power supplies. The Masonite panels are mounted on a wood rack. The two end pieces are ripped from one board by means of a single diagonal cut. Crackle paint gives both rack and panels the appearance of metal.

High voltage secondary windings are usually rated for d.c. load current with *choke input* to the filter circuit. In this circuit, condenser input is used; so therefore the current rating on the transformer should be at *least 200 ma.* if 150 ma. is to be drawn from the condenser input filter. Unless these considerations are observed, the result may be a burnt-out high voltage transformer after a few hours of operation.

• Construction

The complete transmitter is built into three separate relay rack panels of *Masonite*, black crackled, each 8¾ in. x 19 in. x 3/16 in. The power supply is built directly on the wooden base which forms a support for the rack proper. The remaining two decks are of Masonite.

The entire audio amplifier is housed in a metal can in order to isolate it completely from the r.f. fields. The gain control in the speech amplifier is brought through the front panel to a control dial in order to give a symmetrical front panel layout.

The final amplifier is constructed in such a manner that the plate and grid and neutralizing condensers are mounted under the shelf. The two neutralizing condensers are mounted directly to the Masonite chassis; close to the plate tuning condenser are the two tube sockets. Neutralizing adjustments are made with the aid of an *insulated-handle* screwdriver, the shafts of the neutralizing condensers being slotted with a hacksaw so that screwdriver adjustments can be made. The bakelite bases of the type 10 tubes should be cross-slotted with a hacksaw cut, if the transmitter is to be operated on 10 and 20 meters.

● Coil Data

The oscillator plate, doubler plate and final grid coils are wound on standard 1½ in. forms. The oscillator and doubler coils are made interchangeable, since one operates on twice the frequency of the other. The final plate coil is wire wound and air supported on strips of celluloid, to which the turns are cemented.

● Operation

When the crystal oscillator functions on its second harmonic, the plate circuit is tuned for maximum dip in plate current and the small 3-30 μμfd. regeneration condenser is increased in capacity until the dip in plate current is quite pronounced at resonance. Too much capacity in the regeneration control condenser will result in self-excited oscillation, which can be detected by a lack in dip of plate current when tuning the plate tank of the oscillator to resonance.

Second harmonic operation is used when the transmitter is operated on 10 meters from a 40 meter crystal, or in the 20 meter band with an 80 meter crystal. Operation on 75 meters (or 20 meters with a 40 meter crystal) is accomplished by tuning the crystal oscillator plate circuit to the fundamental frequency of the crystal oscillator, and by doubling in the 6A6 stage. A small neon bulb, or a flashlight globe with a turn of wire, can be used to tune the oscillator and doubler circuits for maximum output.

The doubler plate circuit is tuned for greatest dip in plate current: at no time should the plate current in the 53 or 6A6 exceed 75 ma. Ample output to drive the final amplifier stage is generally secured with 50 ma. of plate current in the 6A6 tube and approximately the same value of current for the crystal oscillator. The final amplifier is neutralized in the conventional manner. The antenna must be coupled very closely to the final plate tank circuit by tight link coupling to a tuned antenna circuit.

A carrier output of 35 watts can be obtained from this transmitter by increasing the antenna loading until approximately 100 ma. of plate current flows in the modulated amplifier stage when the d.c. grid current is 1-ma., as measured in the grid circuit jack. The plate dissipation at this power output will be approximately 20 watts per tube, with the result that the plates will show some color.

The modulated stage is operated with an idling efficiency of nearly 50 per cent in this circuit. The output can be modulated 90 per cent without appreciable distortion, and the quality compares with that of any good plate modulated phone. A slight variation in plate current of 10 or 15 ma. in the final amplifier is permissible during modulation, since one form of distortion apparently cancels that of another when the grid modulated amplifier is operated in this manner.

Even though the carrier power is relatively low, this transmitter will cause interference when overmodulated, the same as a higher powered transmitter. An overmodulation indicator is essential.

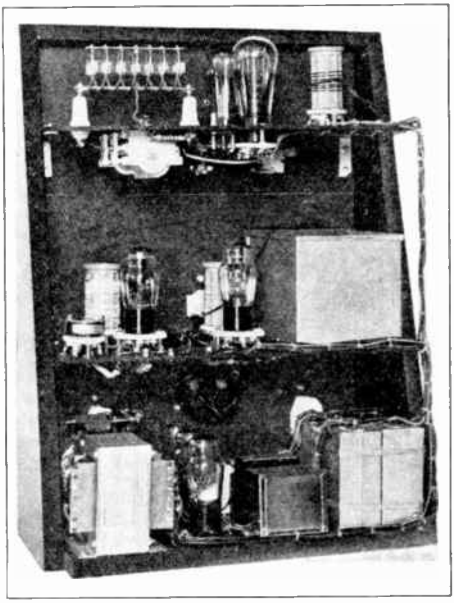


Figure 3—The continued popularity of the type 10 tube prompted the design of this grid-modulated transmitter. It will deliver a 30-35 watt carrier on phone, more on c.w. on the lower frequency bands.

COIL TABLE

Grid Modulated Low Power Phone Transmitter

Band In Meters	Oscillator or Doubler Coil	Final Grid Coil	Final Plate Coil
150	68 turns, No. 24 d.s.c., close-wound.	....	....
75	34 turns, no. 20 d.s.c., 2 in. long.	36 turns, no. 20 d.s.c., 2 in. long, center-tapped.	26 turns, no. 14 Enam., 2⅝ in. dia., 8 turns per inch, center-tapped.
40	18 turns, no 20 d.s.c., 2 in. long.	....	....
20	8 turns, no. 20 d.s.c., 1½ in. long.	10 turns, no. 20 d.s.c., 1¾ in. long, center-tapped.	8 turns, no. 12 Enam., 2½ in. dia., 4 in. long, center-tapped.
10	3½ turns, no. 20 d.s.c., 1 in. long.	4 turns, no. 20 d.s.c., 1½ in. long, center-tapped.	6 turns, no. 12 Enam., 1¾ in. dia., 4 in. long, center-tapped.

160 Meter Transmitter

For those who desire to operate only in the 160 meter phone band with an inexpensively constructed transmitter, the arrangement shown here is ideal. This transmitter will deliver up to 50 watts maximum carrier output.

• Technical Features

The crystal oscillator consists of a 6L6G tetrode in a circuit using a cathode bias resistor. An 8 mh. r.f. choke is connected across the crystal and bias is obtained by means of the 400 ohm resistor in series with the cathode, rather than with the usual grid-leak method. This bias arrangement results in protection to the quartz crystal because the r.f. crystal current is much lower than in a grid-leak oscillator. A type 42 pentode can be used in place of the 6L6G, if desired, but with a slight loss in output.

A type 10 buffer-amplifier is capacitively coupled from the crystal oscillator through a .00005 μfd. (50 μμfd.) mica condenser. This buffer stage isolates the plate modulated amplifier from the crystal oscillator and insures sufficient grid excitation for proper operation of the class-C final amplifier. This buffer stage is neutralized and operated from the same plate supply as that which supplies the final amplifier.

A variable condenser couples the final amplifier to the buffer stage in order to prevent overload of the buffer. This capacity can be varied until normal grid current flows in the final amplifier when the buffer tank circuit is tuned to resonance.

Two type-10 tubes are connected in parallel in the final amplifier; these tubes are plate neutralized. A large tank tuning condenser is required (because of the low frequency) in order to insure proper "fly-wheel" effect.

The antenna circuit should be tuned to resonance by means of an external loading coil and variable condenser. Either a ground or counterpoise can be used with a single-wire antenna 100 to 150 feet long. A suitable counterpoise can be made by means of several wires, each 60 to 100 feet long, suspended high enough above the ground to clear all low objects. The antenna circuit can be coupled to the final tank coil by wrapping a few turns of rubber-covered wire around the center of coil L_3. The exact number of turns in the coupling coil L_4 must be varied for the particular antenna system employed. Adequate coupling turns are needed so that the final amplifier will draw approximately 140 ma. of plate current when the plate tank condenser is tuned

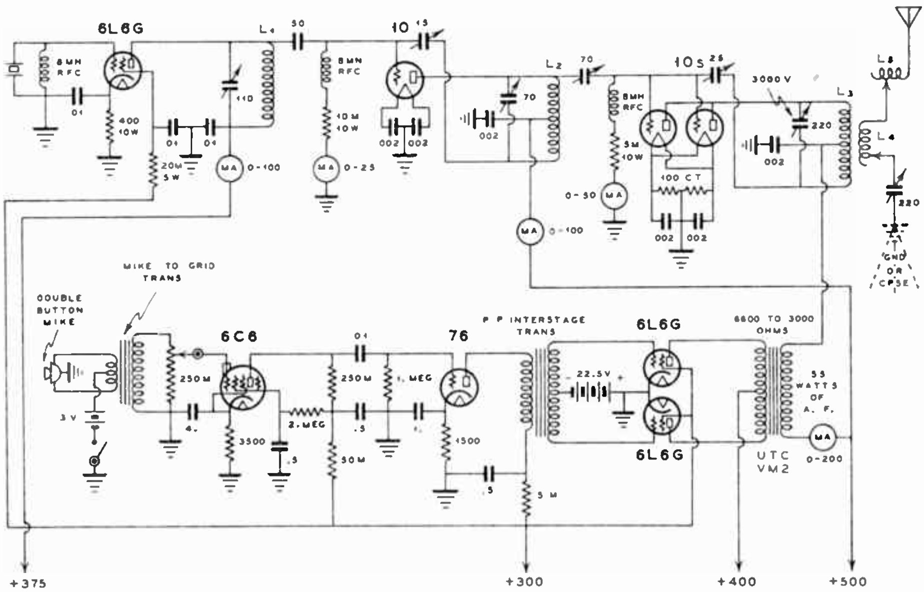


Figure 4—Radio Frequency Portion and Modulator of the 160-Meter Phone Transmitter.

for minimum plate current and the antenna tuned for maximum r.f. current, as indicated by a small flashlight bulb or r.f. meter in the antenna circuit. A combination field strength and overmodulation meter, such as the one described in the chapter on *test sets* is a necessary accessory to this or any other phone transmitter.

Plate modulation is obtained by a push-pull 6L6G modulator which is capable of supplying an output of 35 watts of audio power. This is ample power to modulate fully a d.c. power input of 70 watts. The final amplifier is operated from a 500-volt plate supply. The plate current should be 140 ma. for a normal input of 70 watts.

The push-pull 6L6G stage is driven by a type-76 triode which, in turn, is driven by a 6C6 pentode audio amplifier. The latter can be driven by a double-button carbon microphone, as shown in the circuit diagram, figure 4.

A small permanent magnet dynamic speaker and transformer can be used in place of the double-button carbon microphone and input transformer without change in the amplifier except for a reduction of the capacity of the cathode bypass condenser in the 6C6 stage; the latter should then be 0.1 μfd. instead of 4 μfd.

● Construction

The r.f. and power supply components are mounted on breadboards; the speech amplifier and modulator should be mounted on metal chassis, preferably housed in a metal cabinet

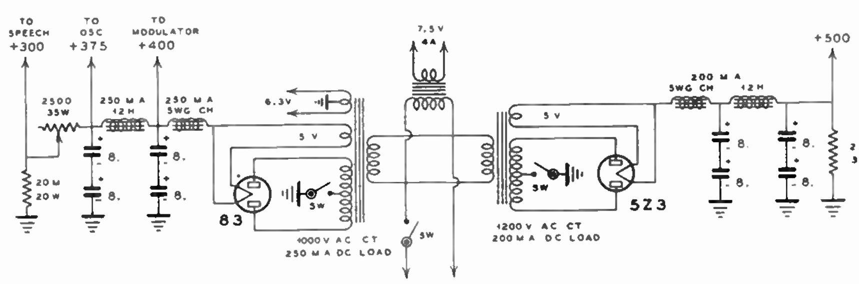


Figure 5—Two Power Supplies Provide All Necessary Power for the Transmitter.

Oscillator Coil	Buffer Coil	Final Plate Coil
45 turns, no. 18 d.c.c., spaced to cover a winding length of 3 inches.	45 turns, no. 18 d.c.c., spaced to cover a winding length of 3 inches.	36 turns, no. 14 Enamel, spaced to cover a winding length of 3 inches, and center-tapped.

Figure 6 - Coil Table.

in order to prevent r.f. feedback into the audio circuits. The r.f. portion of the transmitter can be built on a hardwood baseboard, 11 in. x 24 in. x ¾ in., with cleats at either end to raise the board above the operating table. Small resistors, filament bypass condensers, jacks and subbase wiring can be placed under the board for neat appearance. Two aluminum shields are mounted between stages, as the picture shows; these shields are connected to the common ground lead. Each stage must be isolated from the others because all are operated on the same frequency and coupling would cause feedback. The tuning condensers can be mounted on small insulators or angle brackets.

All bypass condensers are of the 600-volt paper tubular type; mica condensers (small size) are used for all values of .002 μfd. or less.

The output transformer in the 6L6G modulator stage should be capable of handling 35 watts of audio power, and the secondary winding should be so tapped that it will match properly the modulator plate impedance of 6,600 ohms plate-to-plate to the class-C load impedance of approximately 3,000 ohms.

The 400-volt power supply for the modulator must have good voltage regulation and the power transformer should be rated to supply a load of 250 ma. in order to supply the crystal oscillator as well as the audio system.

The 6L6G push-pull modulator stage is operated class-AB. It is not necessary to drive the grid circuit into the positive region in order to obtain an output of 30 to 35 watts; for this reason a conventional step-up push-pull interstage transformer can be connected between the 76 and push-pull modulator stages.

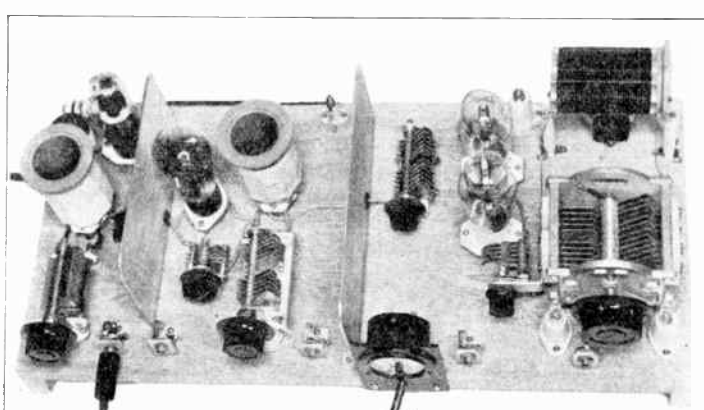
● Coil Data

Coils for all stages are wound on standard 2¼ in. diameter coil forms, either mounted horizontally and supported with angle brackets to the wood baseboard or plugged into tube sockets, as shown in figure 7.

● Operation

The crystal oscillator is tuned for maximum grid current in the buffer stage. The plate current of the crystal oscillator will read at some value between 40 and 50 ma. when the grid current to the buffer is from 10 to 15 ma. The buffer is neutralized without applied plate voltage. Complete neutralization is obtained when there is no appreciable variation of grid current as the plate tuning condenser is tuned through resonance. (The

Figure 7—The r.f. portion of the transmitter is built "breadboard" fashion. The split-stator tuning condensers seen in the photographs are used with their sections in parallel in order to secure sufficient capacity for 160 meter operation.



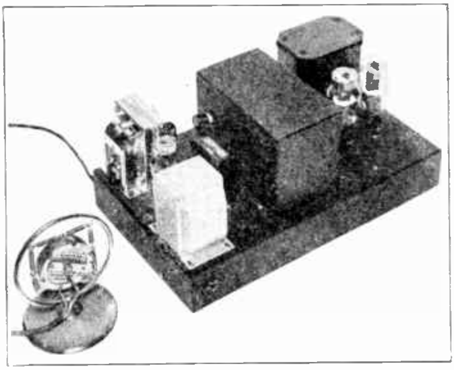


Figure 8—Speech channel, power supply and modulator for the 160 meter phone transmitter. It delivers 35 watts of audio power, sufficient to modulate over 70 watts input to the parallel 210 final amplifier.

final amplifier is neutralized in a similar manner.)

Plate voltage is then applied to the buffer stage and the plate tuning condenser adjusted for minimum plate current; the grid coupling condenser is then varied until a grid current value of approximately 30 ma. flows into the final amplifier grid circuit. The two condensers can be adjusted simultaneously, always making certain that the plate tuning condenser is set for minimum plate current indication. The plate current in the buffer stage will be approximately 50 ma. under normal load. The final amplifier plate current will be between 125 and 145 ma. when the antenna circuit is properly adjusted, with the final plate tuning condenser tuned to resonance (plate current dip).

The modulator system can be checked by connecting a 3,000 ohm 50 watt resistor across the output terminals of the modulation transformer in place of the r.f. amplifier. A loud speaker can be bridged across a small portion of this load resistor and the quality of speech can then be tested. A pair of headphones can be used in place of the loudspeaker, provided that they are connected across less than 100 ohms of the total of 3,000 ohms of the load resistor. Hum level and speech quality can be checked by this method. Hum may be introduced because of lack of shielding in the microphone and grid circuits, or lack of sufficient filter in the plate supply.

After the audio channel has been tested and found satisfactory, it can be connected into the r.f. amplifier. An overmodulation indicator and phone monitor should be used to check for quality of output, and to insure against overmodulation. The plate and grid current in all the meters shown in the circuit diagram should remain constant during modulation.

10-75 M. 400 W. Transmitter

A medium power phone transmitter with an input of 400 watts and a carrier output of from 250 to 275 watts is shown in the circuit diagrams of figures 9, 10 and 11. This transmitter incorporates numerous modern features and includes the latest type tubes. It is of standard relay-rack construction with heavy metal chassis.

The final r.f. amplifier, shown in the circuit diagram, figure 9, uses an HK-354C medium μ triode. This tube can be replaced with a pair of paralleled or push-pull HK-154's, 35T's, T55's, HF-100's or RCA 808's without change in power output or modulator requirements. The buffer-doubler stage uses a *Taylor* T-20 triode, which furnishes just sufficient power to drive the final amplifier for modulated inputs as high as 400 watts except on 10 meters. If 400 watts or more is desired for operation in the 10 meter band, the buffer can be changed to a T-55 or 35T, operating from the high voltage power supply. The transmitter as shown is capable of operating with an input of approximately 300 watts on 10 meters.

The crystal oscillator can be operated either on its fundamental frequency or on the second harmonic. The T-20 stage functions either as a neutralized buffer or doubler; power output from this stage as a doubler can be increased for a given amount of plate current by increasing the capacity of the neutralizing condenser in order to secure greater regeneration. The buffer stage is link coupled to the final amplifier with a coupling link consisting of one turn around the center of the buffer plate coil, and two turns around the lower end of the final grid coil. The final r.f. stage is operated as a neutralized class-C amplifier with a grid current of approximately 30 ma. This is sufficient for obtaining bias of somewhat more than twice cut-off across the grid leak specified because relatively low plate voltage is used on this stage. The HK-354C is a medium μ tube with an amplification constant of 14, and it is quite easily driven when operated from a 1500 volt plate supply and relatively low power input.

The modulator must be able to supply 200 watts of audio for 100 per cent modulation. A pair of 35T's or T-55's will supply this out-

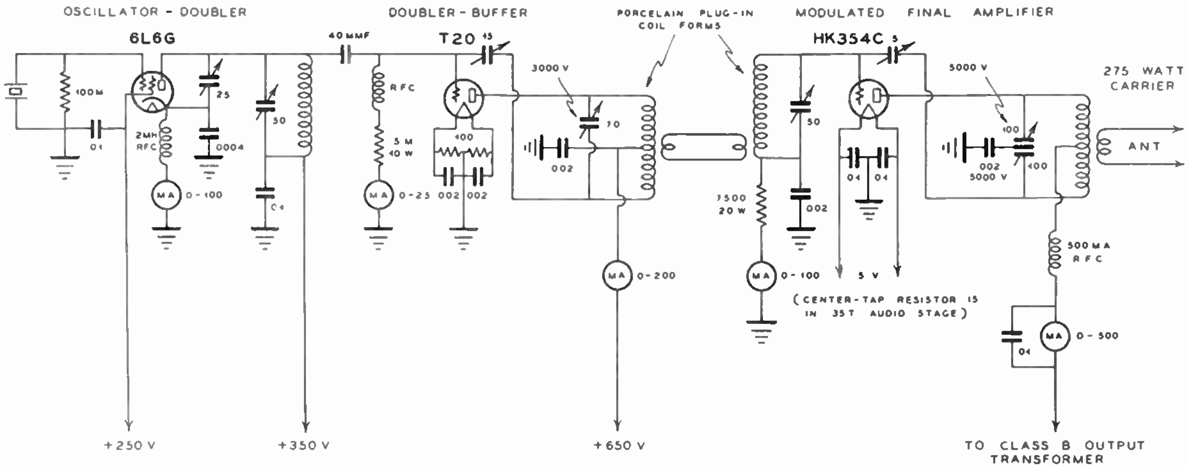


Figure 9—Schematic diagram of the radio frequency portion of the 400-watt phone transmitter.

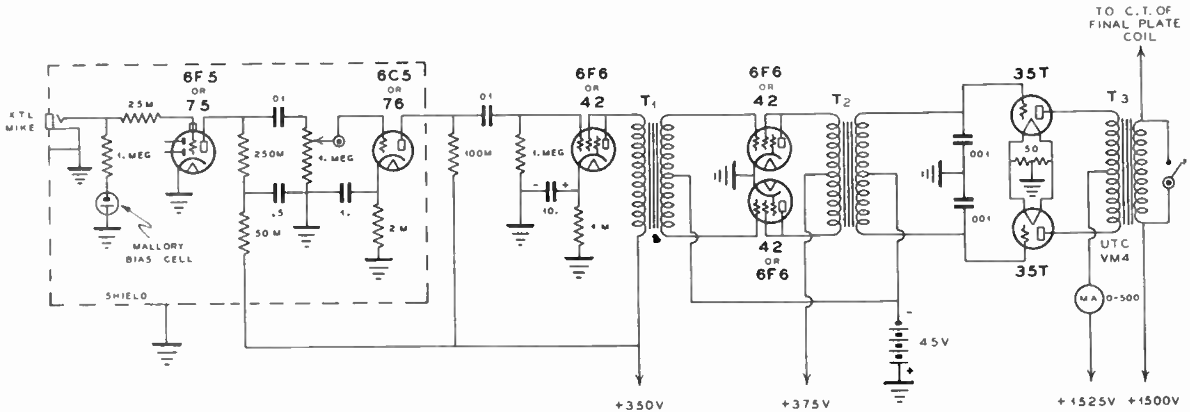


Figure 10—Audio channel and modulator for the HK-354C radiophone transmitter.

put when driven by a 6F6 or 42 push-pull driver stage. The driver stage is operated with fixed C-bias, with triode connection of the tubes. This stage, in turn, is driven by a 6F6 or 42, triode connected, which is resistance coupled to the speech amplifier. The speech amplifier proper consists of a 6F5 or type 75 in the input stage, and a 6C5 or 76 in the second stage. This portion of the audio channel is built into a separate shield can in order to prevent r.f. and hum feedback into the low-level portion of the audio channel. The input is designed for a crystal microphone.

The first driver stage transformer between the single triode and push-pull driver stage should have a primary-to-one-half-secondary turns ratio of 1.5-to-1. Any standard make of driver transformer for working into a class-AB push-pull 42 amplifier is suitable for this purpose. The class-B input transformer should have a turns ratio of total primary to total secondary of 3-to-1. This transformer must be larger than the preceding one, so that it will handle the 10 to 20 watts of audio power necessary for driving the grids of the class-B modulator tubes. A pair of .001 μfd. mica condensers is connected across the grids and filaments of the class-B stage in order to prevent undesired parasitic oscillation, which would cause audio distortion at high voice levels. The class-B output transformer must be large enough to handle the 200 watt audio power output, and be capable of carrying approximately 250 ma. of d.c. plate current through the secondary winding. The impedance ratio of total primary to secondary in the output transformer should be approximately 20,000 ohms to 6,000 ohms.

A universal type class-B output transformer with tapped primary and secondary windings should be used for this purpose. Fixed bias of 45 volts for the class-B and driver stages can be obtained from a 45 volt B battery. The regulation of the C-bias supply is quite important, and a battery is used in this transmitter for the sake of simplicity.

● Power Supply

Three plate supply units are required for this transmitter: one for the crystal oscillator and audio amplifiers; one for the buffer r.f. stage; a heavy duty 1500 volt power supply for the class-B modulator and final r.f. amplifier.

COIL TABLE

Band In Meters	Oscillator Coil	Buffer Plate Coil	Final Grid Coil	Final Plate Coil
160	65 turns, no. 24 d.s.c., close-wound.	....	....	....
80	25 turns, no. 20 d.s.c., close-wound.	36 turns, no. 18 d.c.c., spaced one diameter, center-tapped.	32 turns, no. 18 d.c.c., spaced one diameter.	28 turns, no. 10 Enam., 4½-in. dia., 7-in. long, center-tapped.
40	17 turns, no. 18 d.c.c., spaced one diameter.	20 turns, no. 16 Enam., 1½-in. long, center-tapped.	19 turns, no. 18 d.c.c., spaced one diameter.	20 turns, no. 12 Enam., 7-in. long, 3-in. dia., center-tapped.
20	8 turns, no. 18 d.c.c., spaced to cover 1½-in.	11 turns, no. 16 Enam., 1½-in. long, center-tapped.	10 turns, no. 16 Enam., 1½-in. long.	10 turns, no. 10 Enam., 7-in. long, 3¼-in. diameter, center-tapped.
10	....	5 turns, no. 16 Enam., 1¼-in. long, center-tapped.	4 turns, no. 16 Enam., one-inch long.	6 turns, no. 8 Enam., 4-in. long, 2-in. dia., center-tapped.

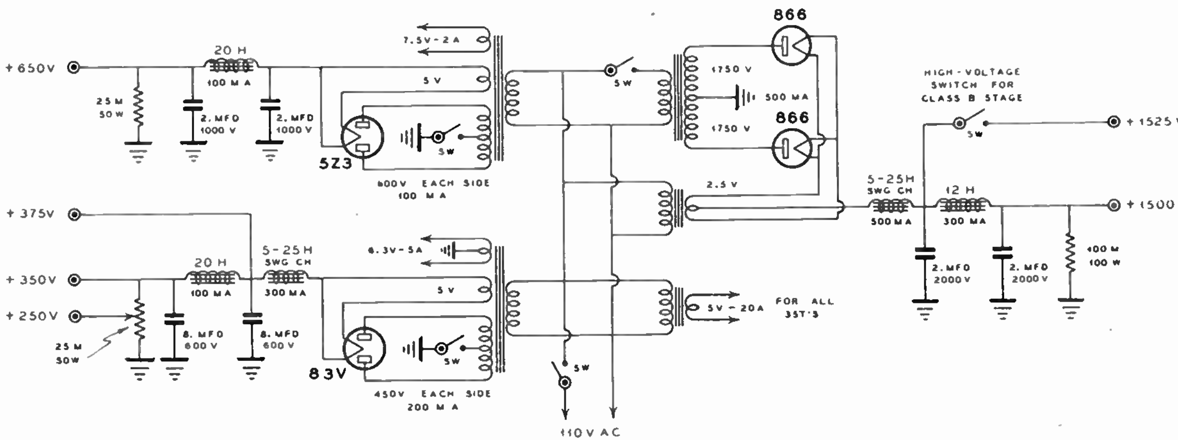


Figure 11—Low, medium, and high voltage power supplies for the medium power radiophone.

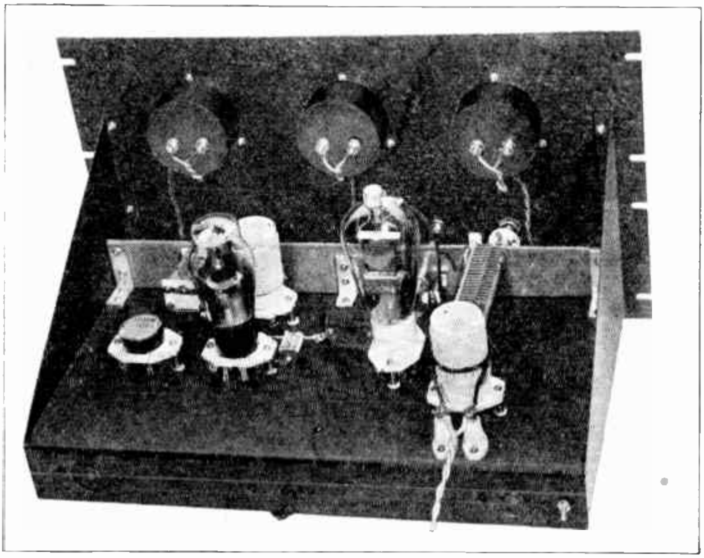


Figure 12 — 6L6 Harmonic oscillator and T-20 buffer - doubler. The plate tuning condensers for both stages and T-20 neutralizing condenser are mounted on a non - metal sub-panel (Masonite). The neutralizing condensor may be seen directly to the left of the T-20 plate tuning condenser. The shaft of this neutralizing condenser is slotted, and adjustments made through a hole in the front panel.

The low voltage power supply includes a 900 volt center-tapped transformer rated to supply a d.c. load of 200 ma. from a choke input filter. The push-pull 6F6 driver stage connection is made to the first section of filter, and the remaining audio positive-B leads are taken from the second section. Screen voltage for the 6L6G oscillator is taken from the bleeder of the low voltage power supply; this potential is adjusted to a value of 250 to 275 volts by means of a slider on the bleeder resistor. The buffer plate supply uses a 5Z3 or 83 rectifier and 1,200 volt center-tapped power transformer. The normal d.c. load of this power supply is from 75 to 85 ma. Condenser input to the filter circuit gives a potential of approximately 650 volts to the buffer. The exact value of this voltage depends upon the load current, the capacity of the input condenser, and the resistance of the 20 henry filter choke. This voltage can be any value between 600 and 700.

The high voltage power transformer should be rated at 3,500 volts center-tapped, capable of supplying a d.c. load of 500 ma. The average load is somewhat less than this value. The class-B modulator is connected to the first section of filter through a small knife switch, which can be opened when the transmitter is operated for c.w. A similar switch can be connected across the secondary of the modulation transformer in order to short-circuit this winding when keying the transmitter for c.w. If this is not done, the resulting surges may cause keying lag and flashover of the final plate tank condenser.

• Construction

The lowest deck of the relay rack ensemble holds the high voltage power supply. It is pictured in the *Power Supply* chapter. The chassis is 12 in. x 17 in. x 2 in., supported to a standard 12¼ in. relay rack panel. The second deck from the bottom holds the two low voltage power supplies. The chassis is 10 in. x 17 in. x 2 in., the panel is 9¾ in. x 19 in. The next deck supports the audio system and class-B modulator on a 12 in. x 17 in. x 2 in. chassis, with a front panel 10½ in. x 19 in. Above this deck is the crystal oscillator and buffer stage, mounted on a 10 in. x 17 in. x 2 in. chassis; the front panel is 10½ in. x 19 in. The uppermost deck holds the final r.f. amplifier, which is mounted on a 12 in. x 17 in. x 2 in. chassis; the front panel is 12¼ in. x 19 in. There is still some available space on the relay rack for an additional unit, such as an antenna tuner, which can be link coupled to the final r.f. amplifier. All high voltage leads are carried through heavily insulated wire, such as automobile high tension cable.

The final amplifier plate tuning condenser has wide plate spacing and is rated at 5,000 volts, 100 $\mu\mu$fd. per section. The rotor is insulated from the metal front panel and chassis, but is grounded through a .002 μfd. 5,000 volt mica condenser. The neutralizing condenser has two heavy circular aluminum plates, each 2⅞ in. diameter and spaced approximately ⅝ in. apart, when the stage is properly neutralized.

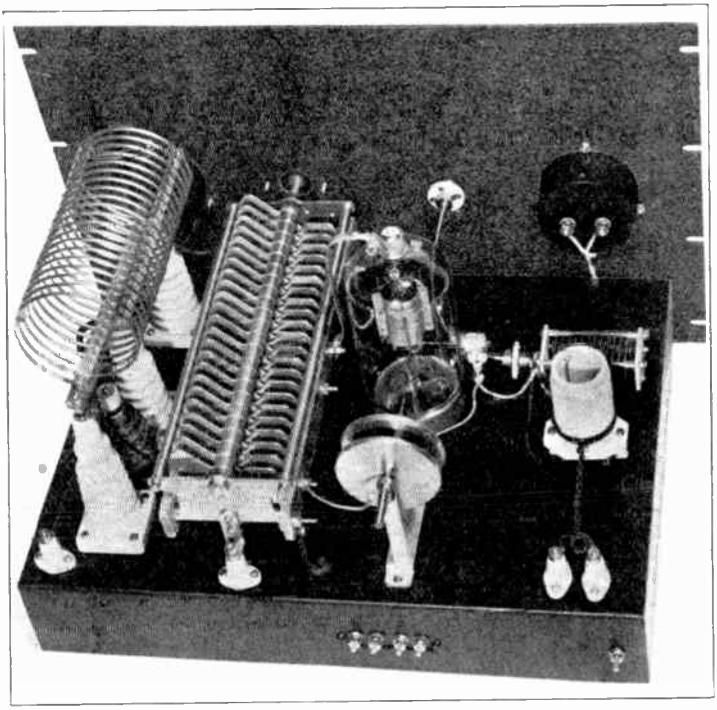


Figure 13 — The modulated final amplifier uses an HK-354C running class C. The grid tuning condenser is mounted parallel to the front panel; a flexible cable connects it to the dial on the front panel.

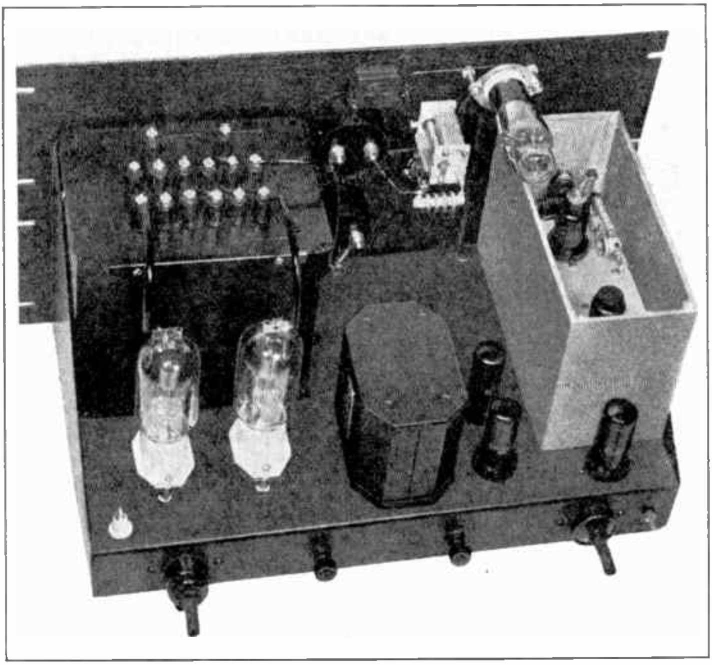


Figure 14 — Speech amplifier for crystal microphone, and 35-T modulator unit. The first two stages of the speech amplifier are housed in a grounded metal box. The overmodulation indicator components are fastened directly to the front panel.

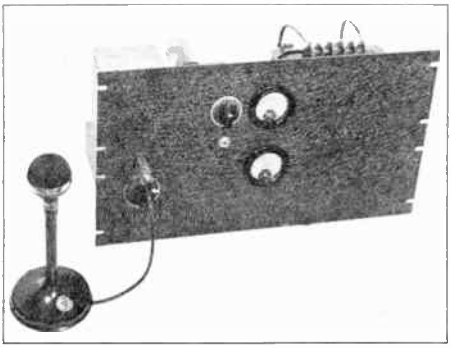


Figure 15—Front panel view of the speech amplifier and modulator unit.

• Coil Data

The oscillator plate, buffer plate and final grid coils are wound on standard 1½ in. diameter ceramic forms. The final tank coil is of the heavy wire, air-supported type, with plugs for coil changing.

• Operation

The crystal oscillator is tuned as described in the chapter *Transmitter Frequency Control.* The plate circuit can be tuned to either the fundamental or second harmonic of the crystal by merely changing the oscillator plate coil. The cathode current in this stage will run between 40 and 60 ma., and the regeneration condenser should be increased in capacity until a dip of at least 10 ma. is obtained when tuning the oscillator plate tank condenser through resonance on the second harmonic of the crystal. This same regeneration control setting is suitable for various crystals, and for operation on either the fundamental or second harmonic. The grid current to the buffer stage should be approximately 15 ma. under load, and the plate current in the buffer should be between 75 and 85 ma. under load. This plate current may run slightly higher when the stage serves as a doubler, depending upon the degree of regeneration in this stage. The final grid current should be at least 30 ma. under load. Neutralization in the buffer and final amplifier follows standard procedure, as has been previously explained. The final amplifier should be loaded to approximately 250 ma. by means of link coupling to an antenna tank circuit.

A phone monitor and overmodulation indicator is built on the modulator panel. The circuit for this device is shown in the chapter *Test Instruments.* The diode tube of the monitor should be loosely coupled to the final r.f. amplifier plate circuit, or to the antenna lead, by means of an insulated wire running from the diode connection to a position near the final plate circuit or antenna lead.

A Multi-Unit, High Power Transmitter

A thoroughly modern de-luxe radiophone transmitter of home-built amateur construction, yet closely following advanced ideas incorporated in commercial transmitters and using the latest circuit improvements as shown in this *Handbook* is profusely illustrated here. This transmitter was constructed by W6LVS* and is in active operation on the amateur bands.

The transmitter consists essentially of four units: (1) microphone and preamplifier; (2) speech amplifier and driver, (3) 250 watt complete transmitter and modulator, (4) 1-kw. r.f. amplifier and modulator.

The speech amplifier and driver is used in conjunction with either of the modulators. *The 250 watt transmitter is complete in itself,* and may be connected either to the antenna system or to the high power r.f. amplifier in the large rack by means of a rather complex system of interlocking relays, as shown in figure 34.

The two transmitter units are interconnected by means of relays, so that for normal use only the small transmitter is in service; when more power is needed a toggle switch at the control position is closed, and a time-delay relay makes the changeover with no perceptible break in voice transmission. This changeover is made by relays which switch the antenna from the small transmitter to the large amplifier; then the r.f. output from the smaller unit is switched to the grid circuit of the 250-TH push-pull high power final amplifier. The relays also cut out the modulator in the small unit, and make switch-over of the audio driver 500 ohm line to the modulator in the large rack. Overload and underload relays, as well as door interlock line switches, are additional features for protecting the operator and apparatus.

The two large units can be controlled either separately or together from the remote operating position; the speech amplifier and driver is located at this point.

The large rack is 30 in. wide, 18 in. deep and of the same height as the associated standard rack, both of which are illustrated here.

*R. J. Woollum.

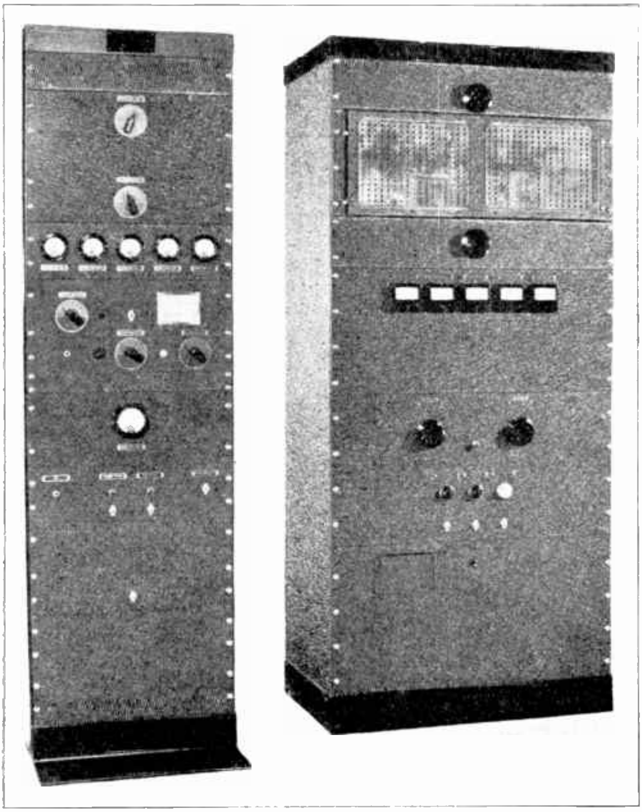


Figure 16—The 250 watt complete radiophone transmitter (left) and high power amplifier and modulator (right).

• The Speech Amplifier

A straightforward, conventional speech amplifier with tubes, resistor and condenser values such as are shown elsewhere in this *Handbook,* is diagrammed in figure 18. The speech channel consists of a preamplifier built into the microphone stand proper; it contains a 6F5 high μ triode working into a 6C5. The high impedance line runs from the preamplifier to the main speech amplifier, and consists of two stages of 76 tube amplification and a push-pull 2A3 class-AB driver stage. The output transformer works into a 500 ohm line which connects through a relay circuit to the 35-T class-B modulator in the low power unit of the transmitter, or to the 100-TH class-B modulator in the high power unit.

• The Exciter

The harmonic crystal oscillator and 6L6G doubler unit is quite similar to one of the exciters shown in the chapter *Transmitter Frequency Control.* Either tube can be used to drive the 35T buffer stage by means of a switching connection in the plug-in coil form in the oscillator stage. The oscillator can be tuned to either the fundamental or second harmonic of any of the five crystals.

The additional doubler stage is especially useful when operating on 10 meters; when this stage is not in use a switch in the cathode circuit is opened, and an oscillator coil is plugged in so that the plate of the oscillator connects to one of the coil pins through a 20 $\mu\mu$fd. condenser to the grid of the 35-T amplifier. The latter is used as a neutralized buffer at all times, and is link coupled to the push-pull 35-T final amplifier in the small rack of the transmitter.

Figure 19 shows the complete exciter unit and figure 20 gives the circuit diagram. It was found necessary to place the oscillator tuning condenser above the chassis in order to prevent feedback between the grid and plate circuits of the 6L6G doubler. This feedback may cause undesired oscillation in the doubler stage. The remaining tuning condensers are mounted below chassis, as illustrated in figure 21. Filament transformers are mounted in

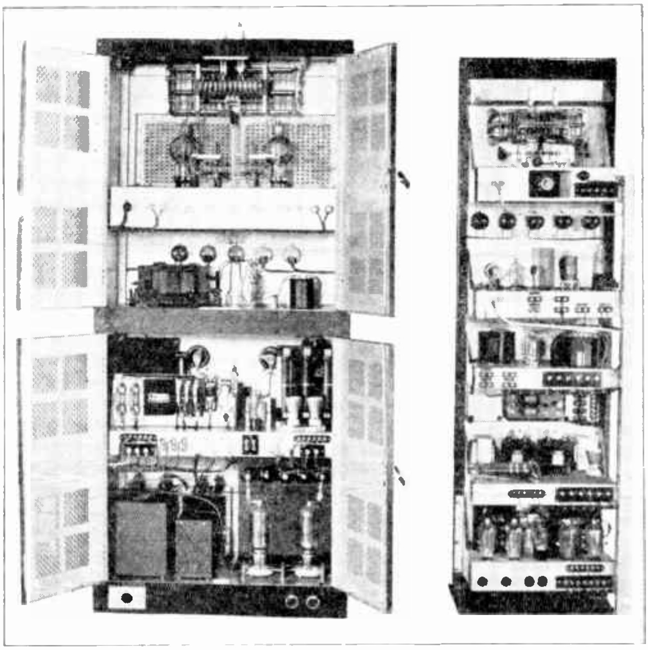


Figure 17—Looking into the "works" from the back. The 250 watt deluxe unit meets the needs of the most discriminating amateur. For those who are satisfied with nothing but the biggest and the best, and to whom cost is not an important item, the auxiliary high power amplifier is the answer.

the deck of each amplifier in order to prevent excessive voltage drop in the connecting leads to the tube sockets. The neutralizing condenser for the 35T is adjusted from the front panel by means of an extension shaft.

● The 35-T Push-Pull Amplifier

The modulated amplifier in the small transmitter rack is illustrated in figures 22 and 23, with the circuit diagram in figure 24. It consists of two 35T's in push-pull, with a combination of cathode and grid-leak bias. The tuning condensers in this stage are mounted parallel to the front panels in order to obtain a symmetrical arrangement of parts and leads. These condensers are driven from front panel controls by means of pulleys and cords.

A parasitic suppressor is connected in one grid circuit; it consists of 7 turns of wire, shunted with a 100 ohm 3 watt resistor. The grid plug-in coil is accessible through a rectangular opening at the rear of the chassis. The two neutralizing condensers are ganged together with an insulated coupling and the two stators are part of the plate tuning condenser coil mounting brackets. These two brackets are attached to the stators of the split-stator plate tuning condenser. The neutralizing condenser rotors are mounted on a sheet of *Mycalex*, below the plate tuning condenser. The neutralizing leads to the grids pass through the chassis in ceramic bushings. The plate coil assembly is supported by two heavy copper brackets which act as part of the plate tank leads. Each chassis makes use of a small disk, as shown in the bottom view of the exciter chassis, for a common grounding connection. The coils shown in the illustrations of this amplier are for the 20 meter band, while those shown in the exciter illustrations are for 10 meter operation.

● The 35-T Class-B Modulator

The 35T modulator circuit is part of figure 24, which includes both modulator and the 35-T push-pull r.f. stage. The illustrations in figures 25 and 26 show top and bottom views of the 35-T modulator unit.

This modulator supplies sufficient audio output fully to modulate the 250 watt 35-T r.f. amplifier. The output transformer in the modulator stage is mounted in a sub-base which is cushioned from the main chassis in order to prevent "talkback" from the output transformer from feeding back into the microphone when the two are in close proximity.

The C-bias supply for the 35-T modulator is diagrammed in figure 27. It consists of a small power transformer which delivers ap-

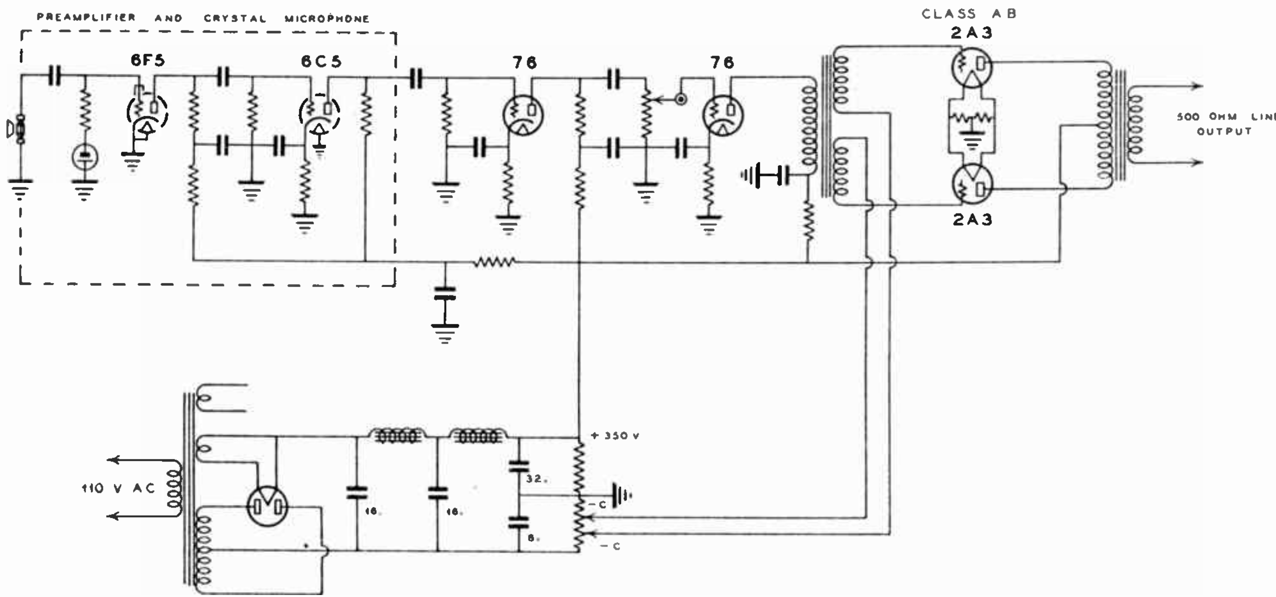


Figure 18—The Speech Amplifier-Driver Unit. It is used to drive either the medium or high power modulator. The first two stages (shown dotted) are built in a pre-amplifier can, on which the microphone is mounted. Coupling condenser and resistor values are conventional; those not familiar with them can find them elsewhere in this chapter.

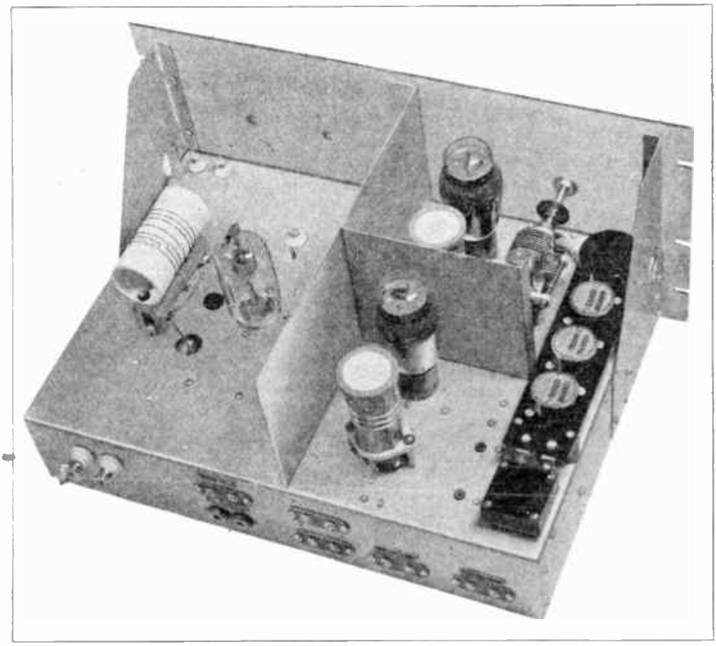


Figure 19—The exciter unit uses a 35-T, driven either directly by a 6L6-G harmonic oscillator or by a 6L6-G doubler. Most of the components are mounted on the under side of the sub-chassis (see figure 21). This unit can be used as a low power transmitter, plate modulated by the 2A3 driver stage to give about 35 watts of carrier until time or finances permit completion of the 250 watt amplifier and associated modulator.

proximately minus 75 volts at the output of the filter when the load resistance bleeder of 800 ohms is connected across its output.

• The 250-TH High Power Final Amplifier

This stage is pictured in figures 28 and 29, with the circuit diagram as figure 30.

A pair of 250-TH tubes is operated conservatively at 1-kw. input. The tuning condensers are so placed that the rotors are parallel with the front panel; they are controlled by means of worm-and-pinion drive to the plate condenser, and pulley and cord drive for the grid tuning condenser. The plate tuning condenser is home-built; it has plate spacing of ¾-in. and the insulation is *Mycalex*. The two neutralizing condensers are also home-built; the plates are 3 in. diameter, with an adjustable airgap. The coils shown in the illustrations are for 20 meter operation. The plate coil is made of copper tubing. Coil turns for all stages of this transmitter can be obtained from the data given in the chapter on *Transmitter Frequency Control,* and from the copper tubing and wire wound coil tables in the chapter on *C. W. Transmitter Construction.*

• The 100-TH Class-B Modulator

The modulator for the 250-TH r.f. stage uses a pair of 100-TH tubes in class-B, driven by the push-pull 2A3 stage previously described. This modulator is illustrated in figure 28, with the circuit in figure 32. The modulator must be able to supply 500 watts of audio, which requires a very large output transformer, as the illustration shows. The modulator plate supply is taken from a 5-kw. power transformer and rectifier system which also supplies the high power r.f. amplifier. Outputs in excess of 500 watts of audio power can be obtained by slightly exceeding the plate dissipation ratings of the 100-TH tubes. The circuit for the power supply is shown in

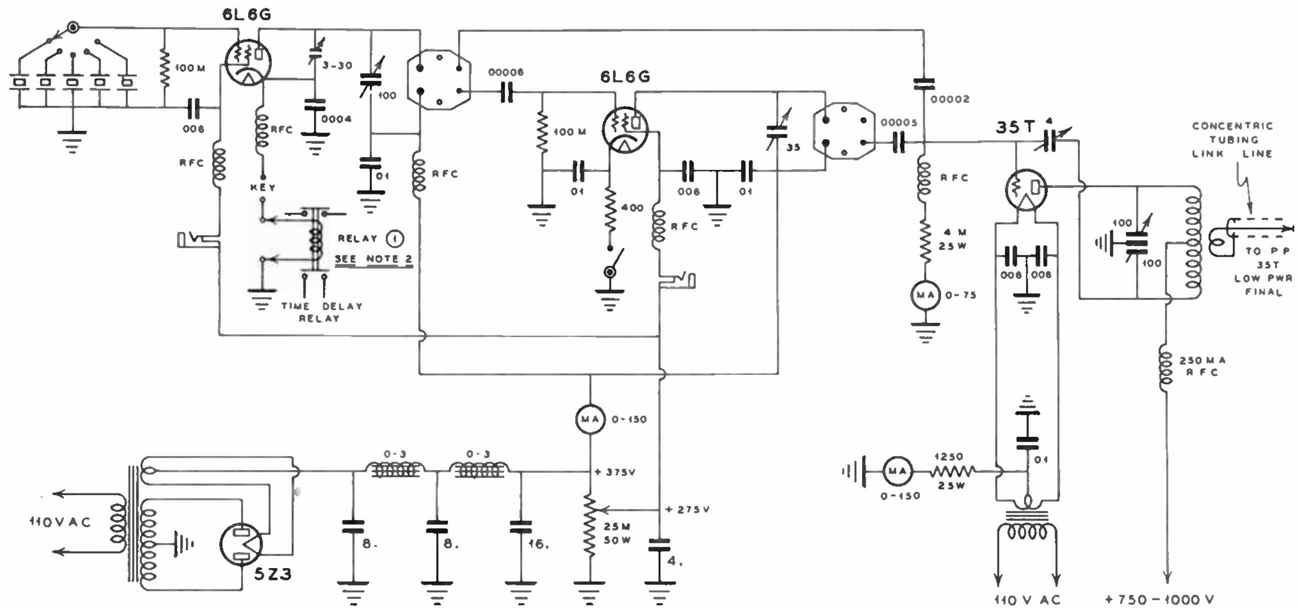


Figure 20—Schematic wiring diagram of the 35-T exciter unit and low voltage power supply for the 6L6-G's. Refer to note 2 in figure 34 regarding oscillator cathode relay. All variable condensers should be insulated from metal panel or chassis unless one side is shown grounded.

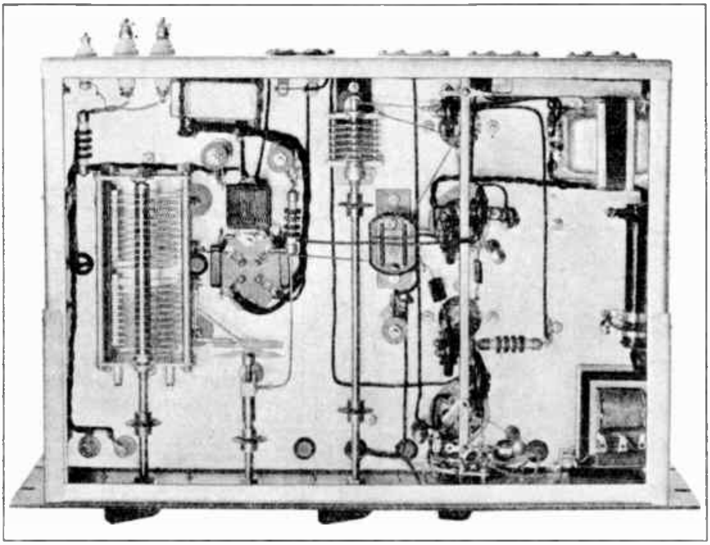


Figure 21—Underneath view of the exciter unit, showing placement of components. Extension shafts allow the various condensers to be placed closer to their associated circuits.

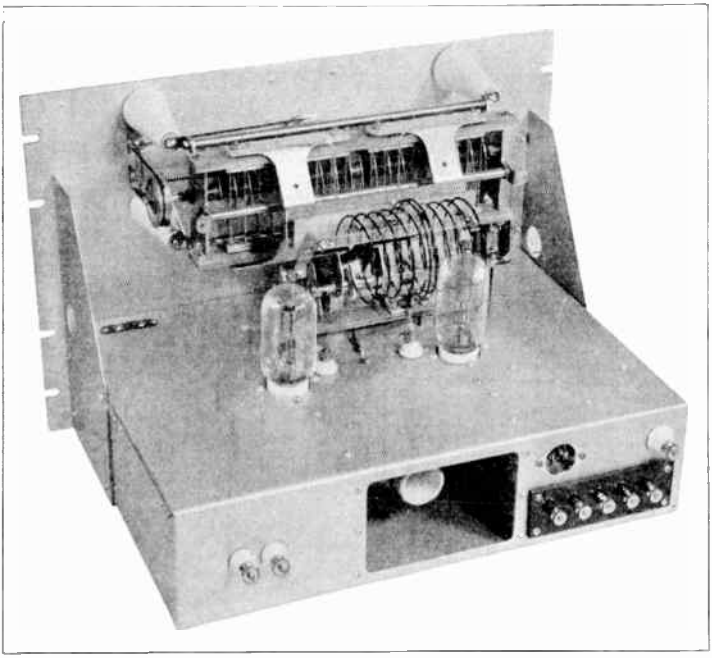


Figure 22—The 250-Watt 35-T Amplifier. This stage is either plate modulated or used to drive the high-power modulated amplifier. The plate tuning condenser is mounted parallel with the front panel to allow shorter leads, and is driven by cord and pulleys.

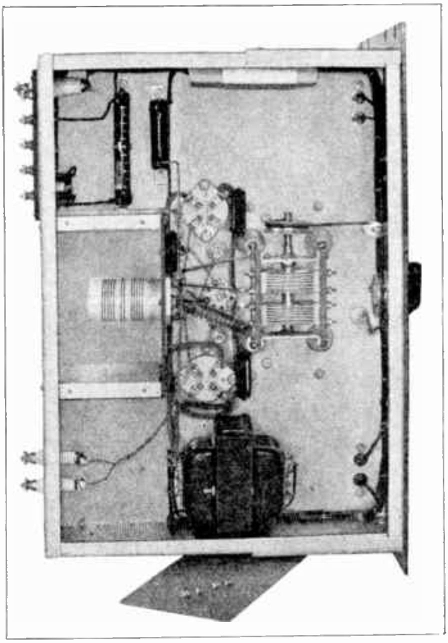


Figure 23—Under chassis view of the push-pull 250 watt amplifier. stage. The grid tuning condenser is mounted and driven in the same manner as the plate tuning condenser.

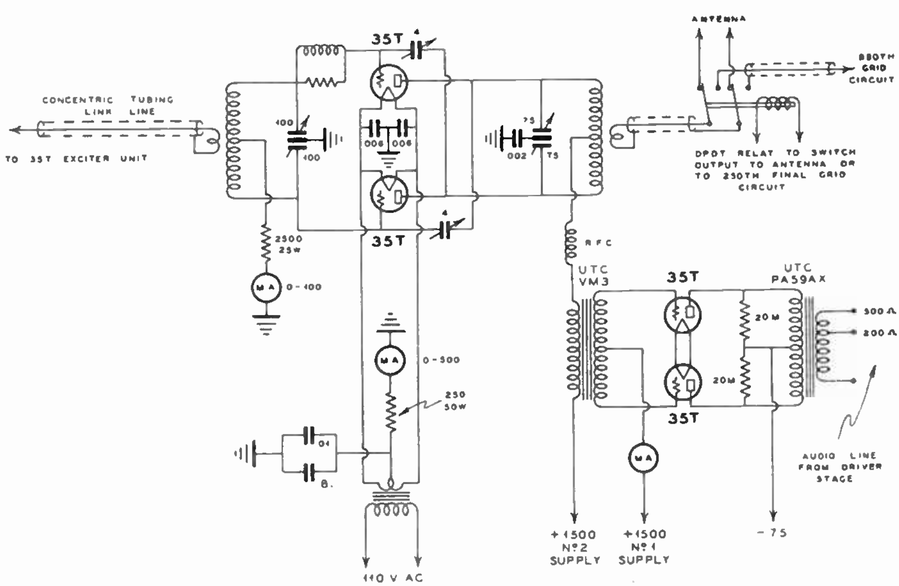


Figure 24—Schematic wiring diagram of the 250-watt amplifier and the associated class B modulator shown in figure 25.

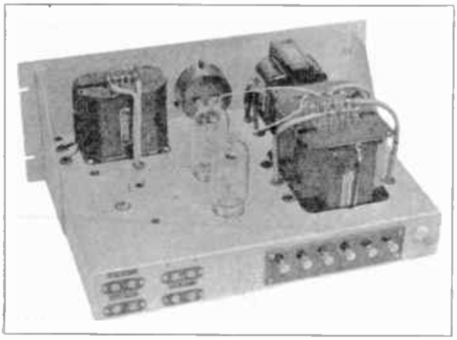


Figure 25—The 35-T class B modulator unit.

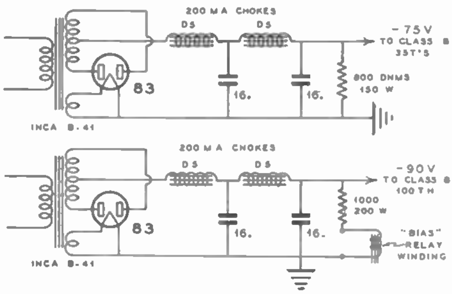


Figure 27—Showing bias supply for the 35-T modulator (above) and the bias supply for the 100-TH modulator (below).

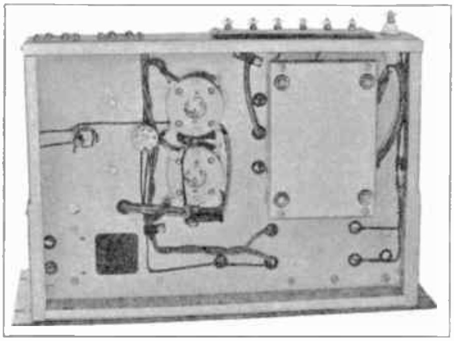


Figure 26—Bottom View of the 35-T Modulator.

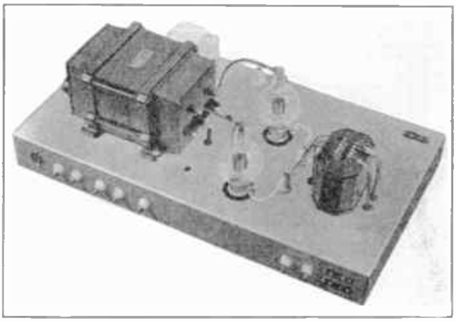


Figure 28—The 500 watt class B modulator unit.

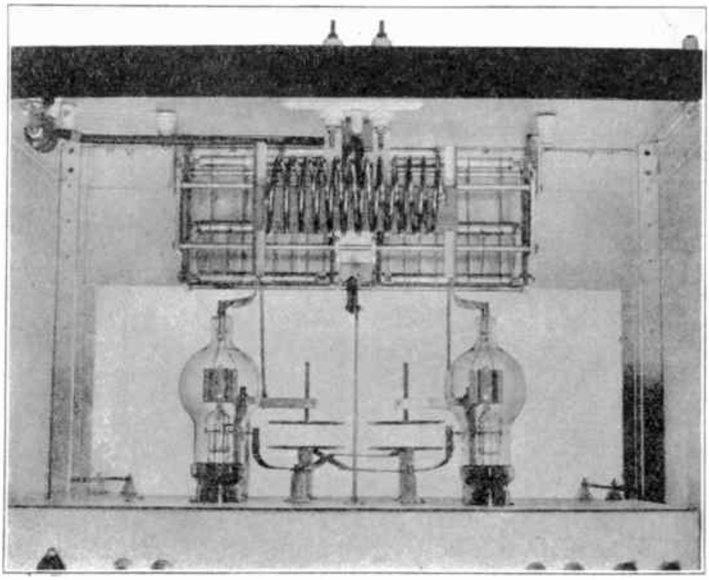


Figure 29—The high power modulated amplifier uses 250-TH's in push-pull.

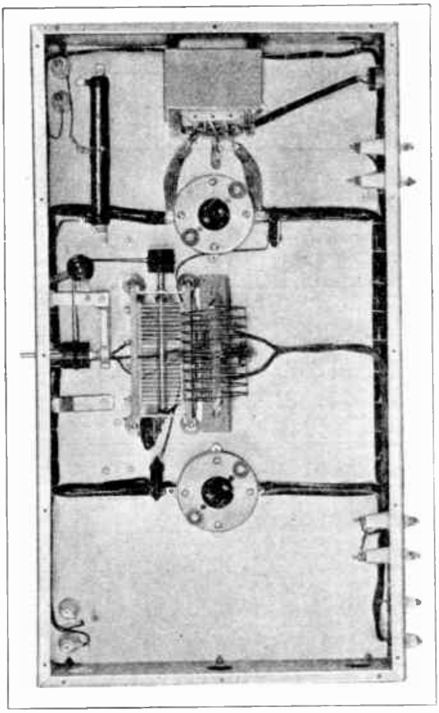


Figure 30—Under chassis view of the 250-TH amplifier, showing filament transformer, grid tank, etc.

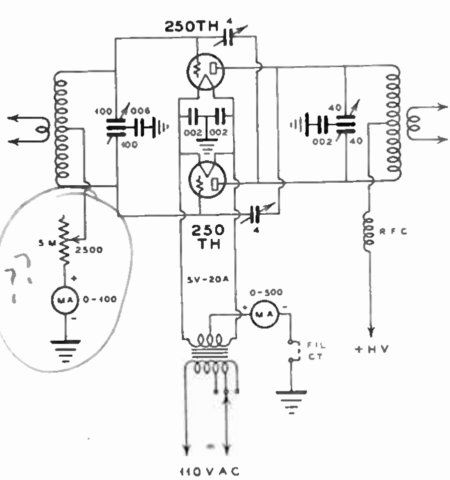


Figure 31—Schematic wiring diagram of the 1 kilowatt amplifier.

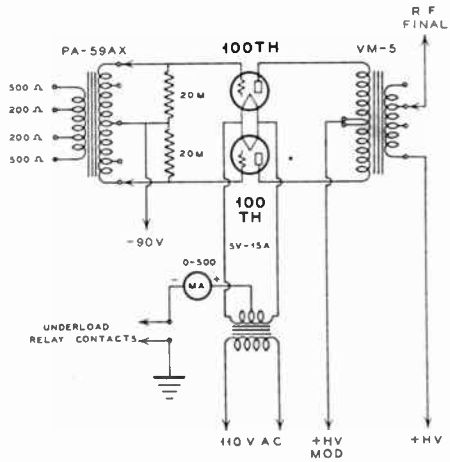


Figure 32—Wiring diagram for the high power modulator.

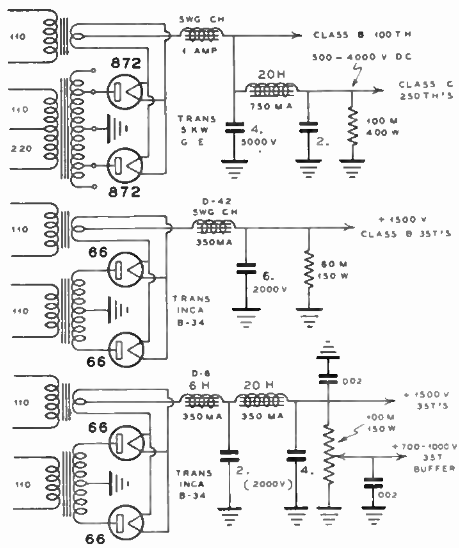


Figure 33—Connections and circuit constants for the three high-voltage power supplies.

figure 33, and a photograph of the unit appears in the chapter on *Power Supplies.* The large power unit can be adjusted in steps, from 500 to 4,000 volts, by means of taps on the secondary winding and by switching the two primary windings of the G.E. 5-kw. power transformer. A pair of 872 rectifiers is connected through a heavy duty two-section filter to the high power transmitter unit. Separate 1,500 volt power supplies are used for the 35-T audio and radio frequency stages in the small rack of the transmitter.

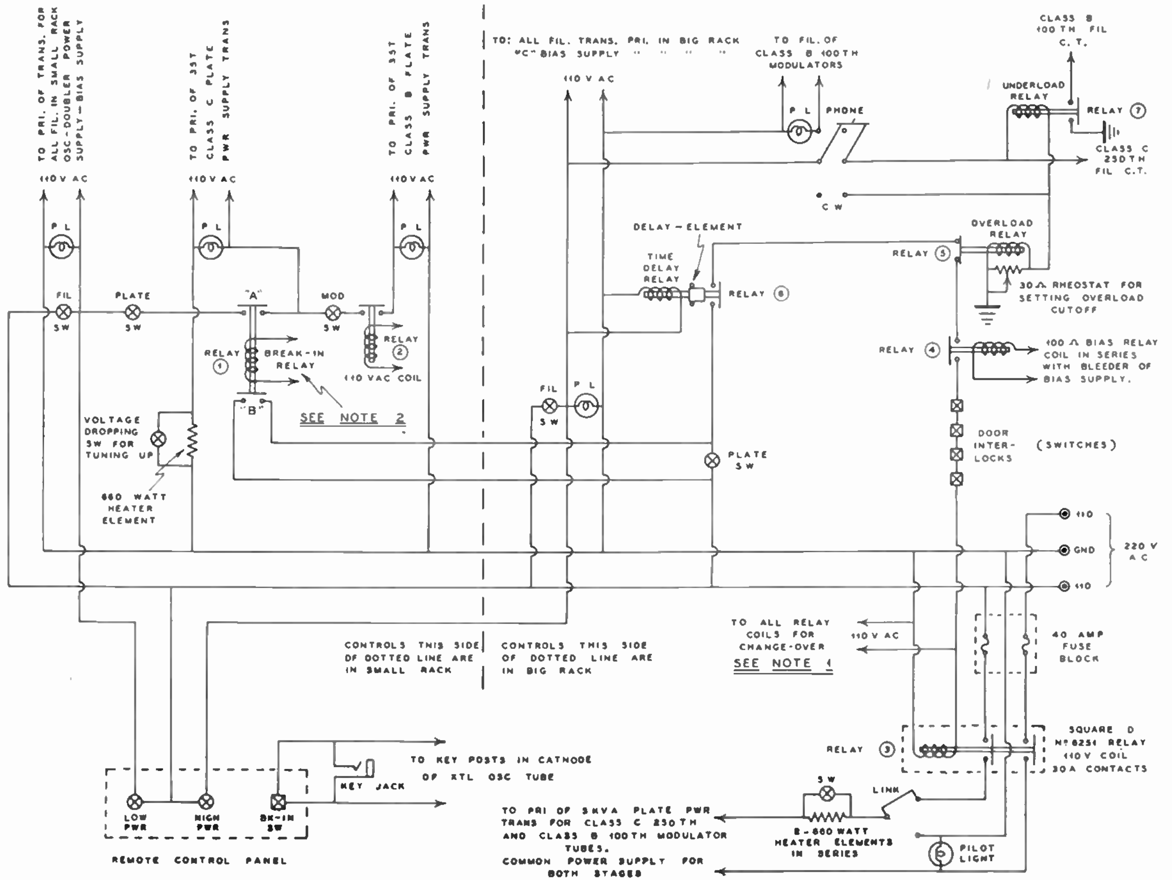


Figure 34—Connections for relays, interlock and changeover systems. If the high power amplifier is not contemplated, the changeover system will not be required.

NOTE 1: This 110 volt a.c. line supplies the current to all the changeover relays the instant the time delay relay (6) closes. Relay (2) is the only relay shown in this diagram which is affected by this line; it breaks the a.c. line to the 35-T modulator power supply. On this same line are the following relays, taking part in the changeover but not shown in the diagram: the audio line relay which switches the line from the low power modulator to the high power modulator, and the r.f. relays which switch the antenna and excitation.

NOTE 2: The 150 ohm relay in the oscillator cathode works as follows. Closing the key or break-in switch starts the oscillator. Current flow energizes relay coil, closing contacts "A" and "B." Contact "A" turns on plate and modulator voltages in the 250 watt unit if switches are closed. Contact "B" controls main relay (3) in the high power amplifier when the time-delay relay is closed.

The Federal Communications Commission Requires

in the case of amateur radiophone transmitters that means be employed to insure that the transmitter is not modulated in excess of its *modulation capability*. Very few transmitters have a modulation capability approaching 100 per cent. Many, especially the grid modulated types, may have a very low modulation capability when not correctly adjusted. Some sort of device enabling the operator to keep a continuous check on the modulation at all times is indicated. Such equipment is described in chapter 17.

The chief objection to radiotelephony as compared to c.w. telegraphy is the relatively large frequency channel required for each station, even when the telephone transmitter is properly operated. It is to their own interests that the radiophone fraternity do the utmost in their power to keep the channel widths of their signals confined to as narrow a band as the present state of the art permits.

The easiest way to take up three times the room actually required by a properly operated phone is to overmodulate. The increase in signal strength due to the higher percentage of modulation is negligible as compared to the additional room taken up by the overmodulated signal. Besides being illegal it indicates lack of consideration.

Amateurs operating on 10 and 20 meter phone will find that in many instances the readability of their signals is actually improved by using a lower percentage of modulation. The reason for this is that at times during a "selective fade" the carrier may fade to a much greater degree than the sidebands. This will result in bad overmodulation of the carrier as it arrives at the receiver, and consequent distortion and poor intelligibility, if the percentage of modulation was high to begin with. Many of the 16-19 meter broadcast stations do not attempt to modulate their antenna power over 50 or 75 percent for this very reason.

Chapter 15

U.H.F. Communication and Equipment

• U. H. F. Considerations

THE VERY-high frequency or *ultra-high frequency* range may be said to extend from 30 megacycles (10 meters) to infinity. Frequencies higher than 300 Mc. (1 meter in wave length) are usually classed as "*micro waves.*" The micro waves extend into the region of heat wavelengths, thence into the wavelengths of light. Amateur operation is permissible for both voice and c.w. communication in the range of 56 to 60 Mc., and from 110 Mc. to infinity.

The speed of light and radio waves is approximately 300,000,000 meters per second. In order to show the relation between frequency and wavelength of radio waves, the following formulae are given:

$$F = \frac{300,000,000}{\lambda}$$

or—

$$\lambda = \frac{300,000,000}{F},$$

where F is the frequency in cycles per second,
λ is the wavelength in meters,
or:—

$$\lambda = \frac{300}{f},$$

Where f is megacycles per second.

Very short radio waves behave very much like light waves and are not often reflected or refracted by the Heaviside layer. These radio waves are most useful over optical paths, i.e., between points which are in visual range with one another. The wavelength used for radio communication in the u.h.f. range, however, is thousands of times greater than that of light, and there is a greater curvature of the paths of the radio waves. For this reason the range is somewhat greater than can be obtained by means of light rays, and signals can, therefore, be received from points beyond the horizon. The range of transmission is governed by the height of the transmitting and receiving antennas. Objects that lie in the path of the transmitted wave introduce a "*shadow effect*", which often prevents reception of the transmitted signal. This shadow effect can be overcome to some extent by using higher power in the transmitter.

Occasionally, the radio waves in the range of 56 to 60 Mc. are reflected back to earth by the Heaviside layer with the result that these signals can be heard over distances of a few hundred, or even a few thousand, miles. This type of long-distance communication is extremely erratic, and the practical service of the ultra-high frequencies lies in the short-distance visual range. The occasional reflection of 5-meter signals from the Heaviside layer seems to depend upon sun spot activity and the season of the year, as well as the time of day. At distances somewhat beyond the horizon, reception is often erratic because the atmosphere changes its temperature in layers close to the earth which, in turn, may change the amount of refraction of the 5-meter signals. Refraction bends the radio waves into a curve along the earth's circumference and, therefore, increases the range of the radio wave beyond the optical distance.

Very little transmitter power is required for communication in the u.h.f. range over optical distances. The following formula can be used for calculating the optical range of transmission and reception:

$$X = \frac{2\,d^2}{3}.$$

where
X = height of the u.h.f. antenna in feet,
d = distance in miles.

This empirical formula can be used to calculate the height of an antenna in order to obtain any given distance of transmission to the optical horizon (in level country). If the receiving antenna is also located at some height above ground, the range will be increased and the same formula can again be used. For example, if the transmitting antenna is located at a height of 75 feet above ground, the transmission range will be found as follows:

$$75 = \tfrac{2}{3} \times d^2,$$

thus $d = 10.5$ miles.

If the receiving antenna is 30 feet high, the optical range can be found from the same formula, i.e., $30 = 2/3 \times d^2$ or $d = 6.7$ miles. The receiving station could, therefore, be located 6.7 + 10.5 or 17.2 miles from the transmitter and still be within the optical range. In this case, the radio wave will just graze the surface of the earth in reaching the receiving location and would tend to be reflected upward by the earth so that the signal at the receiving station would be considerably attenuated. The tendency of u.h.f. waves to be curved along the surface of the earth compensates for the tendency to be reflected upward from the surface of the earth, so that this range can be maintained, provided that no large objects lie between the transmitter and receiver locations.

• U. H. F. Transmitter Considerations

Self-excited modulated oscillators of the type shown in figure 1 are widely used for short-range 56 Mc. mobile operation. This type of circuit is typical of those used in low power transmitters and receivers.

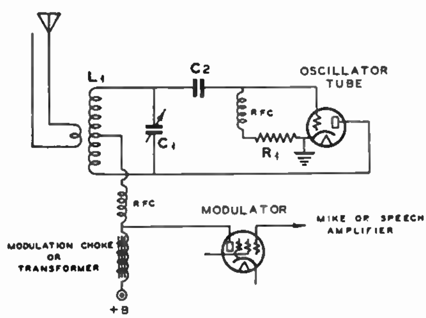


Figure 1—Self-Excited Modulated Oscillator.

Standard tubes cannot be used in this circuit for wavelengths below 2.5 meters. Special tubes of the acorn type, or those in which the element spacing is very small, can be used in this same type of circuit for wavelengths as low as 0.4 meters (40 centimeters).

Transmitters for fixed station 5-meter service should preferably have a stabilized source of frequency control. The simple modulated oscillator shown in figure 1 is subject to a high degree of frequency modulation and its signals cannot be received on a selective radio receiver. This means that relatively few transmitters of this type can be used simultaneously in the 5-meter band. Stabilized oscillator circuits, such as those described later in this chapter, can be modulated without causing excessive frequency modulation. Crystal control by means of a crystal oscillator and frequency-doubling or tripling stages is the most perfect method of stabilized frequency control for the very short wave bands. The relative cost and complexity of circuits of this type has retarded their general use.

Transmitters for portable operation can operate successfully with power outputs of one watt or less. Those for mobile operation usually have an output of from 5 to 10 watts; fixed amateur stations commonly use power outputs varying from 5 to 30 watts. Experimental and commercial stations require higher outputs; values of several kilowatts are desirable for reliable general coverage over a radius of 25 or 30 miles.

• U. H. F. Receiver Considerations

Radio and television receivers for the u.h.f. region vary in design from simple one-tube radio receivers up to as many as 25 or 30 tubes in a television receiver. In the more complex types of u.h.f. radio receivers, the superheterodyne circuits are quite similar to those used in the shortwave and broadcast ranges. The design of tuning coils and inductances is somewhat different in order to function successfully in the u.h.f. range.

• Super-regeneration

Regeneration carried beyond the point of oscillation, called *super-regeneration,* is extensively used for reception of radio waves in the range of from 10 down to ½-meter. Super-regeneration is accomplished by allowing the detector to oscillate, then damping out the oscillations a great many times per second (at a rate above audibility). This increases the sensitivity of the detector to an enormous degree for weak signal reception. Super-regeneration becomes more effective at higher frequencies, and since the selectivity of a super-regenerative receiver is very poor in comparison with ordinary regeneration, this type of receiver can be used successfully to receive the simple modulated oscillator transmitter signals which are so common in the u.h.f. range.

Super-regeneration can be obtained by means of a blocking-grid-leak action, as shown in figure 2, or by means of a separate low-frequency oscillation applied to the grid or plate of the detector, as shown in figure 3. The circuit in figure 2 can be used as a blocking-grid-leak type of superregenerator by choosing the values of

C_3, R_1 and C_1 in such a manner that the u.h.f. oscillation is started and stopped at a rate above audibility. This circuit functions as an ordinary oscillator in which the resistance of the grid-leak is too high to permit the electrons on the grid to leak-off at a rate that will give constant value of grid-bias voltage. This blocking action causes a change in the average grid-bias and stops the u.h.f. oscillation because the plate current is decreased and the mutual conductance of the tube also decreases during the blocking action. If the circuit constants are correct, this blocking action takes place at an inaudible high-frequency rate and super-regeneration is accomplished.

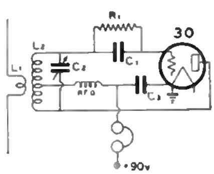


Figure 2—Fundamental U. H. F. Receiver Circuit.

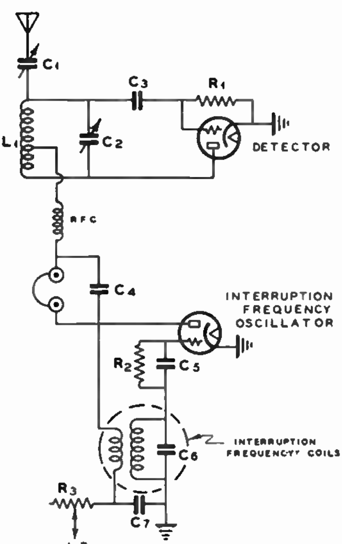


Figure 3—U. H. F. Receiver Circuit with Separate Oscillator.

Damping or "quenching" action can be obtained by means of a separate oscillator which functions at some inaudible frequency, such as 100,000 cycles per second, as shown in figure 3. The interruption-frequency circuit consists of an oscillator tuned to about 100,000 cycles per second, connected so that this oscillation modulates the d.c. plate supply to the u.h.f. detector. The latter is an ordinary oscillator which is made super-regenerative by means of the interruption-frequency oscillator. The interruption-frequency voltage varies the detector plate voltage to such an extent that the detector goes in and out of oscillation at a rate determined by the interruption-frequency oscillator circuits.

Fairly heavy antenna loading or coupling is required in either circuit in order to obtain good audio quality and sensitivity. Too much antenna coupling will pull the detector out of super-regeneration. The antenna system can be either inductively or capacitively coupled to the detector tuned circuit or to an r.f. amplifier preceding the super-regenerative detector. Super-regenerative detectors connected directly to an antenna radiate a signal fully modulated by the quenching frequency and thereby cause bad interference in other receivers for a radius of several miles. The blocking-grid-leak detector is more troublesome in this respect, and, in either case, a radio-frequency amplifier should be connected ahead of the super-regenerative detector in order to eliminate or minimize receiver radiation into the antenna system.

A super-regenerative detector has an automatic volume control effect, in that it has high sensitivity to weak signals and low sensitivity to strong signals. This action greatly reduces automobile ignition interference, since the latter is usually of very strong intensity, but fortunately of short time amplitude. The detector sensitivity automatically drops down during the small fraction of a second in which this noise impulse is present, and, although the desired signal is also reduced, the human ear will not respond to changes of such short duration. The ignition interference, therefore, does not cause an excessively loud signal in the audio output as compared with the strength of the desired phone signal. The high sensitivity of a super-regenerative detector, when no carrier signal is present, results in a loud audible hiss or rushing sound in the output circuit and is due to thermal and contact noise in the detector circuit. A fairly strong carrier signal automatically reduces the sensitivity of the detector and, consequently, reduces the background noise or hiss; a strong signal will completely eliminate the background noise.

● Antenna Systems

A great many types of antenna systems can be used for u.h.f. communication. Simple, non-directive half-wave vertical antennas are desirable for general transmission and reception in all directions. Point-to-point communication is most economically accomplished by means of directional antennas which confine the energy to a narrow beam in the desired direction. If the power is concentrated into a narrow beam, the *apparent* power of the transmitter is increased a great many times.

The useful portion of a signal in the u.h.f. region for short-range communication is that which is radiated in a direction parallel to the surface of the earth. A vertical antenna transmits a wave of low-angle radiation which is vertically polarized, and for this reason, vertical receiving antennas should be used to receive signals from a vertical transmitting antenna. Vertically-polarized radio waves are not as easily reflected upward by the surface of the earth as are horizontally-polarized waves. Horizontal antennas can be used to advantage during the occasional periods in which the 5-meter signals are reflected from the Heaviside layer.

The antenna system for either transmitting or receiving should be as high above earth as possible and clear of nearby objects. Transmission lines, consisting of concentric-line or spaced two-wire lines, can be used to couple the antenna system to the transmitter or receiver. Non-resonant transmission lines are more efficient at these frequencies than those of the resonant type.

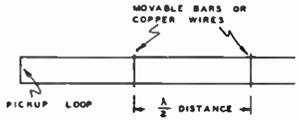
Antenna design data, charts, tables, and graphs for simple and complex antennas and arrays are covered in the chapter on *Antennas.*

Wavelength or Frequency Determination

Transmitter and receiver frequency or wavelength checking can be accomplished by means of parallel-wire measurements (Lecher wire system), by wavemeters or by means of harmonics from a crystal or calibrated low-frequency oscillator. The parallel wire or Lecher wire system is very easily applied to wavelength measurements in the micro wave region.

Lecher Wire Systems

A Lecher wire measuring system consists of a pair of parallel wires, short-circuited at one end in order to provide a pickup loop which can be coupled to the tuned circuit of the transmitter or receiver. The energy induced into the parallel wires establishes standing waves of voltage and current along the wire, and these standing waves can be located with a sliding bar or copper wire, as shown in figure 4.



LECHER WIRE SYSTEM

Figure 4

A single sliding bar can be moved along the parallel wires until two successive points are located which produce a change in the oscillator plate or grid current, or in the receiver noise level when the pickup loop of the parallel wire system is inductively coupled to the circuit under test. The distance between these two points is a half-wavelength, and this value can be converted from feet or inches into the wavelength in meters by multiplying the number of feet by 0.656 or the number of inches by 0.0547.

For micro-wave measurements, the distance between half-wave points is usually measured in inches and converted to wavelength in centimeters by multiplying the number of inches by 5.47. This conversion factor takes into consideration the conversion into the metric system and the fact that the distances are a half-wave apart. The result is the actual wavelength of the oscillator. An accuracy of approximately 1 per cent can be expected; for more accurate frequency or wavelength determination, the harmonic method should supplement these measurements.

A Lecher wire system suitable for measurement of wavelengths below 1-meter can be made by stretching two no. 12 bare copper wires approximately 1-inch apart. Each wire has a length of about 50 inches; this length will depend upon the wavelength being measured, and lengths of 35 to 40 feet will be necessary for 10-meter measurements. The spacing between wires can be as much as 3 or 4 inches for wavelength measurements above 10 meters.

A Lecher wire system can consist of a long wooden framework and some means of clamping or stretching the two parallel wires to prevent sag or change in wire spacing. No supports or insulators should be connected to the parallel wires in the actual measuring range between the two half-wave points over which the sliding bar is moved.

U. H. F. Wavemeters

Absorption-type wavemeters are easily constructed and considerable time can be saved in making oscillator wavelength measurements by this means rather than by Lecher wires. These wavemeters can be calibrated by means of a super-regenerative receiver and harmonics from a calibrated low-frequency oscillator or by means of Lecher wire comparative measurements. A simple absorption-type wavemeter which has a range of about 4.5 to 7 meters can be constructed by connecting a 5-turn coil of wire across a 25-$\mu\mu$fd. midget variable condenser which is in parallel with a 20-$\mu\mu$fd. midget fixed condenser as shown in figure 5.

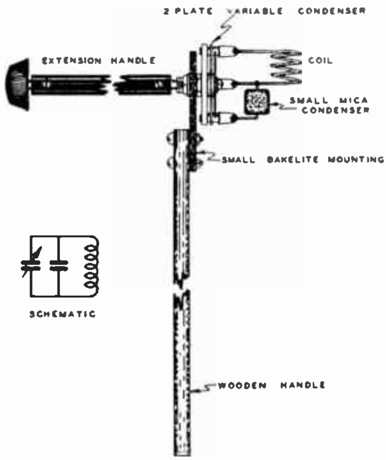
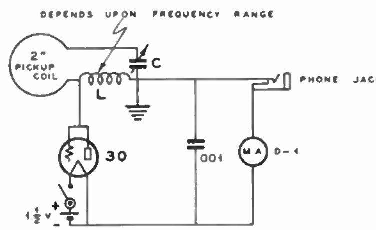


Figure 5

The turns can be squeezed in and out to "spot" the 5-meter band on the center of the condenser dial and the device then calibrated from known frequencies or Lecher wires. The coil can be wound with no. 10 wire in a winding length of 1-inch and with a diameter of about ½-inch.

A similar type of wavemeter with a range of from 4 to 14 meters can be made with a 150-$\mu\mu$fd. variable condenser connected across a 2-turn coil, 2-inches in diameter. The coil should be supported on bakelite spacers. Hand-capacity effects can be eliminated by tuning the condenser with a bakelite extension shaft. A two-turn coil, approximately ⅝-inch diameter, tuned with a 15-$\mu\mu$fd. condenser, will cover the range of 2 to 3 meters. These absorption-type wavemeters are inductively coupled to the tuned circuit in the transmitter or receiver under measurement. When the wavemeter is tuned to the same frequency or wavelength as that of the oscillator under measurement, a change in plate or grid current will be noted.

The absorption-type wavemeter with a diode indicator, shown in figure 6, is quite useful in the range of 3 to 10 meters. A type-30 tube with a single 1½-volt flashlight cell serves as a diode to rectify the radio-frequency. A 0.1 d.c. milliammeter is connected in series with the diode so as to act as a resonance indicator; a closed-circuit telephone jack enables the device to be used as a monitor for checking the quality of a phone transmitter.



WAVEMETER WITH DIODE INDICATOR

Figure 6

The coil *L* consists of from 3 to 10 turns, ½-inch diameter, no. 12 wire, space-wound, depending upon the desired range of the wavemeter. The tuning condenser *C* can have any maximum capacity of from 25 to 50 $\mu\mu$fds., depending upon the desired range of the wavemeter.

• Harmonic Frequency Determination

A calibrated low-frequency oscillator, such as a quartz crystal, will provide an accurate means of frequency determination in the range of from 2 to 10 meters. An oscillating quartz crystal in the 160- or 80-meter amateur bands will produce strong harmonics in the u.h.f. region between 2 and 10 meters. A super-regenerative receiver, when tuned to this region (while very loosely coupled to the oscillator), will indicate the harmonics by sharp reductions in hiss-level in the receiver output. An absorption wavemeter can be coupled to this receiver and calibrated by this means. More accurate measurements can be made by using an oscillating regenerative receiver or a superheterodyne receiver equipped with a beat-frequency oscillator. Such receivers can be tuned to zero-beat with the harmonics, and then to the u.h.f. oscillator or transmitter for accurate frequency determination.

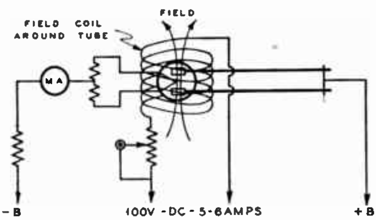
• U. H. F and Micro-Wave Transmitters and Receivers

Micro-waves, as previously related, are those whose length is less than one meter.

Micro-waves are generated by means of *Magnetrons, Electron-Orbit Oscillators,* and *Regenerative Oscillators.* Micro-waves are used by broadcast stations for remote pickup, by amateurs and experimenters, and for occasional telegraph and telephone communication, such as the British channel spanning system. The technical problems encountered in this field are numerous, yet new tubes designed for micro-waves have simplified many of these problems and have been instrumental in increasing the usefulness of the band.

The Magnetron Oscillator

The Magnetron is a specially designed tube for very-short-wave operation. It consists of a filament or cathode between a split plate, as shown in figure 7.



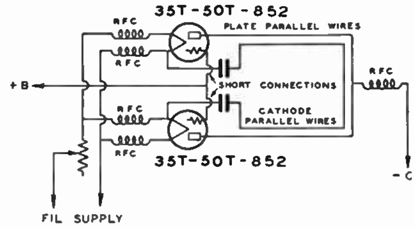
SPLIT MAGNETRON OSCILLATOR

Figure 7

A magnetic field is produced at the filament by means of a large external field coil which is energized by several hundred watts of d.c. power. Ultra-high-frequency oscillations are produced in the split-plate circuit when this magnetic field is in the correct direction and of the proper intensity. A parallel-wire tuned circuit can be used for wavelengths below one meter or for ordinary tuned circuits with wavelengths above one meter. These tubes are available for experimental purposes and will produce outputs of several watts. The frequency stability is not very good and it is difficult to obtain satisfactory voice modulation from magnetron oscillators.

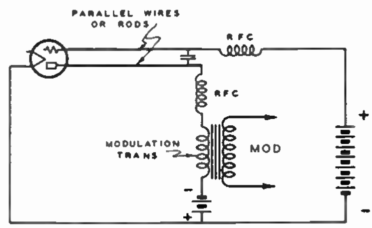
Electron Orbit Oscillator

The range of oscillation in ordinary circuits is limited by time required for electrons to travel from cathode to anode. This transit time is negligible at low frequencies, but becomes an important factor below 5 meters. With ordinary tubes, oscillation cannot be secured below 1 meter, but by means



KOZANOWSKI OSCILLATOR

Figure 8



B-K OR G-M OSCILLATOR

Figure 9

of *electron orbit oscillators,* in which the grid is made positive and the plate is kept at zero or slightly negative potential, oscillation can be obtained on wavelengths very much below 1 meter.

Parallel-wire tuning circuits can be connected to these tube oscillators in order to increase the power output and efficiency. The tubes most suitable for this type of operation have cylindrical plates and grids, and their output is limited by the amount of power which can be dissipated by the grids. For transmitting, tubes such as the 35T, 50T or 852 can be used in the circuit shown in figure 8, which is a modification of the *Gill-Morrel oscillator.* More output is obtained by using a tuned-cathode circuit instead of tuned-grid circuit. Modulation can be applied to either the plate or grid. The frequency stability is very poor. The circuit in figure 8 is an early type oscillator of this general classification.

Regenerative Oscillators

The introduction of the *RCA Acorn 955* and *Western Electric 316-A* tubes made ½-meter regenerative oscillators practical. These tubes are more efficient than ordinary types for ultra-high-frequency work. Figure 10 illustrates the RCA acorn triode. Circuits, such as that shown in figure 11 and a constructional plan in figure 12, are satisfactory for low-power transmitters and super-regen-

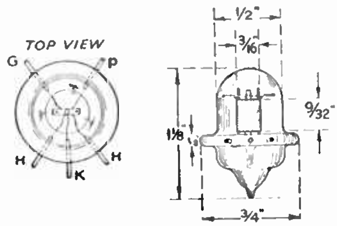


Figure 10—RCA Acorn 955

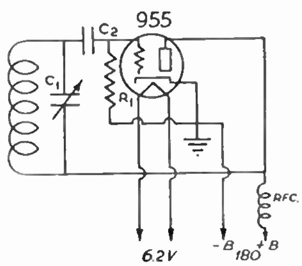


Figure 11—RCA 955—Circuit Diagram and Suggested Layout.

L1—8 turns, ½-in. outside diameter, No. 18 wire, spaced ¼-in. between turns.
C1—Tuning condenser; 2 circular brass plates ¾-in. in diameter; 10/32 thread on adjusting screws.
C2—.00025 mica condenser, postage stamp type
R1—15,000 ohms, 1 watt carbon resistor.
RFC—¼-in. bakelite rod wound 1½-in. with No. 32 DCC wire.

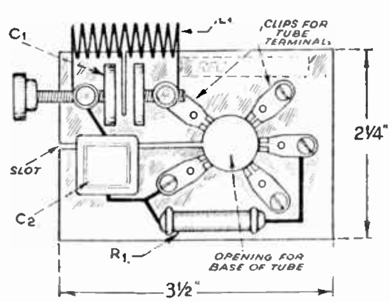


Figure 12—Plan view of transmitter.

erative receivers. The 955 acorn can be used as an oscillator in super-heterodyne receiver circuits with its companion tube, *RCA 954 (or 956) Acorn Pentode,* in the r.f. portions of the circuit. The regenerative circuits are quite similar to those for longer wavelengths, except for the physical size of condensers and coils. The tube element spacing in these acorn tubes is made so small that electron transit time becomes a negligible factor for wavelengths above 0.6 meter.

Micro-Wave Tube Characteristics

RCA 954 PENTODE

Heater voltage	6.3
Heater current	0.15 amp.
Grid-to-plate capacity	0.007 μμfd.
Input capacity	3 μμfd.
Output capacity	3 μμfd.
Max. plate voltage	250 volts
Max. screen voltage	100 volts
Grid voltage	—3 volts
Suppressor tied to cathode	
Amplification factor	over 2000
Plate resistance	over 1.5 megohm
Mutual conductance	1400 mhos.
Plate current	2 ma.
Screen current	0.7 ma.

RCA 955 TRIODE

Heater voltage	6.3
Heater current	0.15 amp.
Max. plate voltage	180 volts
Max. plate current	7 ma.
Amp. factor	25
Plate resistance	12,500 ohms
Mutual conductance	2,000 mhos.

• W. E. 316-A Micro-Wave Oscillator

Western Electric has produced a new micro-wave triode which delivers from 5 to 10 watts output on wavelengths as low as ½ meter. The element spacing is so close that the tube operates efficiently as a regenerative oscillator with negative grid and positive plate for frequencies as high as 750 Mc. The maximum plate dissipation is 30 watts. The transmitter illustrated in figure 14 delivers approximately 7.5 watts with 400 volts on the plate. This power output is

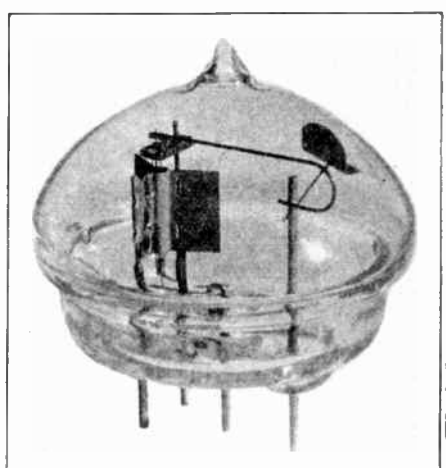


Figure 13—W.E.-316A U.H.F. Triode.

sufficient for coverage over a visual range, although in one case a ¾-meter signal was heard over a distance of 80 miles, which is far beyond the optical path

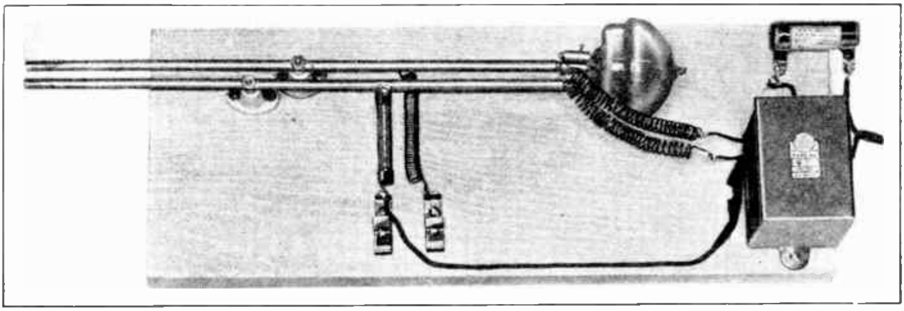


Figure 14—W.E.-316A ¾-Meter Oscillator.

A large variety of circuits could be suggested for micro-wave operation, but the most simple of these is the one shown in figure 15. It consists of two parallel half-wave rods, spaced about ¼-inch apart, to provide a ¾-meter tuned circuit of fairly-high "Q." See figure 14. The grid and plate of the tube are connected to the copper rods; this capacity causes the physical length to be less than a half wave-length. As can be seen from the photograph, the plate r.f. choke and the grid-leak do not connect to the center of the rods, but rather across the voltage node. The distance between this point and the free ends of the rods is a quarter wavelength. The other distance is shortened by the tube capacity. Filament r.f. chokes, or tuned filament leads, are desirable for operation below one meter because the filament is not strictly at a point of ground potential in the oscillating circuit. These filament chokes consist of 30 turns of no. 16 enameled wire, wound on a ¼-inch rod, then removed from the rod and air-supported, as the picture shows. The length of these chokes is approximately 3 inches. A 200-ohm resistor is placed in series with the 110-volt a.c. line to the filament transformer in order to reduce the transformer secondary voltage from 2½ to 2 volts, because the filament of the tube operates on 2 volts at 3.65 amperes. This particular oscillator gave outputs in excess of 5 watts on ¾ meters, even when no filament r.f. chokes were used.

This oscillator, when loaded by an antenna, draws from 70 to 80 milliamperes at 400-volts plate supply. An audio modulator, such as a pair of 2A3 tubes, class AB connection, will supply approximately 15 watts of audio power for modulation. The oscillator should be tested at reduced plate voltage, preferably by means of a 1000 to 2000 ohm resistor in series with the positive B lead, until oscillation has been checked. A flashlight globe and loop of wire can be coupled to the parallel rods at a point near the voltage node, in order to indicate oscillation.

A 15-inch antenna rod or wire can be fed by a one- or two-wire feeder of the non-resonant type. A single-wire feeder can be capacitively coupled to the plate rod, either side of the voltage node, through a small blocking condenser. If a two-wire feeder is employed, a small coupling loop, placed parallel to the oscillator rods, with the closed end of the loop near the voltage node of the

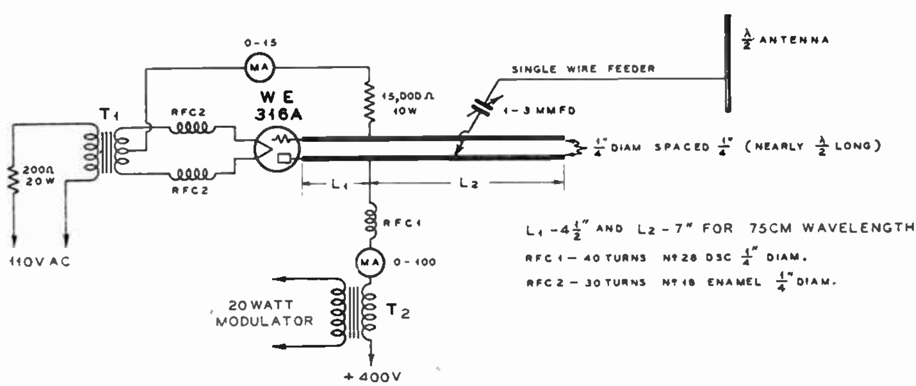


Figure 15—W.E.-316A ¾-Meter Oscillator Circuit.

oscillator, will provide a satisfactory means of coupling to the antenna. The power output is high enough so that tuning is as simple as any 40 meter c.w. transmitter.

W. E. 316-A Characteristics.

Filament voltage	2 volts a.c or d.c.
Filament current	3.65 amps.
Average thermionic emission	0.45 amp.
Amplification factor	6.5
Plate-to-grid capacitance	1.6 μμfd.
Grid-to-filament	1.2 μμfd.
Plate-to-filament	0.8 μμfd.
Max. plate dissipation	30 watts
Max. d.c. plate voltage	450 volts
Max. d.c. plate current	80 MA.
Max. d.c. grid current	12 MA.

• 1¼-Meter Transmitter with RCA-834 U.H.F. Tube

The advent of several new tubes particularly designed for the ultra-high frequencies makes possible the construction of a transmitter which will deliver from 10 to 50 watts on wavelengths below 5 meters. Raytheon RK-32, Western Electric 304-B and RCA 834 are equally suitable for use in the transmitter shown in figure 17. The characteristics of all three tubes are similar.

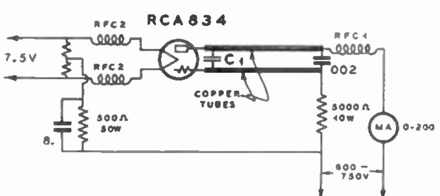


Figure 16
1¼-Meter Transmitter.

C1—Aluminum Plates, 1¼ in. square.
Copper Tubes—3-in. long for 1¼ Meters.
9-in. long for 2½ Meters.
RFC1—40 turns No. 28 DSC, ¼-in. dia.
RFC2—25 turns No. 14 Enam., ½-in. dia.

The grid and plate leads are brought out through the top of the tube envelope in all cases, resulting in operation down to ¾-meter.

The circuit in figure 16 is suitable for oscillation between 1 and 3 meters, depending upon the length of the parallel rods or pipes.

A slight variation of frequency is possible if two condenser plates each ¾ in. square are connected across the pipes near the tube leads. This type of circuit works more efficiently than a conventional coil and condenser oscillator circuit. The tube leads fit into the ends of copper pipes, and small set screws provide good electrical contact between pipe and tube leads. This type of mounting must be used with care in order to avoid breakage of the tube envelope. The tube socket mounting strip should have slotted holes in order to make correct alignment with the copper pipes.

Filament r.f. chokes are necessary below 3 meters in order to secure oscillation. At 1¼ meters, the metal shell of the tube socket, and the metal support that holds the socket, introduce excessive capacity to the filament circuit of the tube, resulting in non-oscillation if either of these metal surfaces is grounded. A non-metallic socket and socket support would be preferable if operation in the neighborhood of 1-meter is wanted. A tuned filament circuit, somewhat similar to the type used with filament tubes in a *tritet,* will work more effectively than r.f. chokes for wavelengths below 1½ meters.

The antenna feeder is coupled to the parallel pipes or tubes by means of a coupling loop. A half- or quarter-wave antenna can be capacitively coupled through a very small variable condenser to the plate rod at a point approximately one to two inches from the plate blocking condenser. Transmission ranges of 3 to 50 miles are possible if the

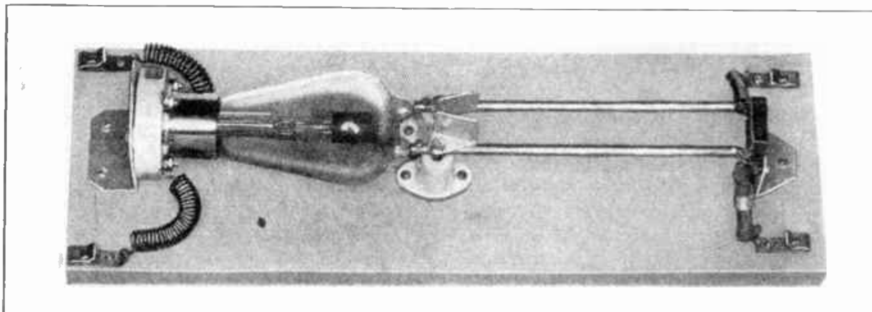


Figure 17—2½-Meter Transmitter with RCA 834 U.H.F. Triode.

antenna is located at high elevation. Even 1¼-meter waves tend to curve along the surface of the earth to such an extent that communication can often be obtained beyond the optical range.

● 2½-Meter Transmitter

An RK-34 twin-triode tube is connected in a tuned-grid-tuned-plate circuit for 2½ meter operation in the transmitter illustrated in figure 19. A parallel rod or wire tuned-plate circuit gives good efficiency on 2½ meters, proved by tests where efficiencies of

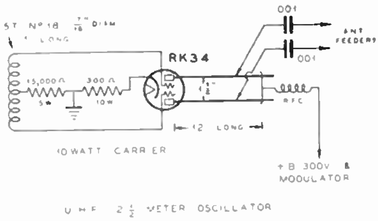


Figure 18

approximately 50 per cent were realized. A carrier power output of 10 to 15 watts is easily obtainable on 2½ meters. The circuit is shown in figure 18. If a more powerful modulator is connected to the oscillator, together with plate potentials of 500 to 600 volts, outputs of 25 to 30 watts can be secured.

A 15,000-ohm grid-leak and 300-ohm cathode resistor give stable grid bias for the oscillator. The cathode resistor prevents all tendency for the plate current to "run away" during operation. The grid coil consists of 5 turns of no. 18 wire, wound to cover a length of one inch, with an inside diameter of 7/16-inch. This coil is soldered directly to the tube socket terminals. The antenna feeders can be capacitively coupled to the plate circuit through a pair of .001 μfd. mica condensers. If a two-wire spaced feeder is used, these wires tap across the plate rods about two inches from the shorting bar.

The plate circuit is tuned to the desired frequency by sliding the shorting-bar along the rods. Antenna coupling is adjusted by sliding the antenna taps along these rods until normal plate current is drawn. The inductance in the grid circuit can be varied in order to obtain the best amount of feedback for high output.

A suitable modulator consists of a pair of type 42 pentode tubes driven by a 76 speech amplifier. The 42 tubes can be operated from the common 350-volt plate supply by means of a 30-henry, 150 ma., modulation choke. The screen voltage should be reduced through a resistor from the 250-volt supply; a 10-watt, 10,000-ohm resistor is of the correct size. A 2 μfd. or larger by-pass condenser from screen to ground will pass the audio frequencies from screen to ground for normal operation. The cathode resistor of 300 ohms, 10 watt rating, should be bypassed by means of a 25 μfd. low voltage condenser. If greater input is applied to the oscillator, a more powerful modulator is needed. Class B 46 tubes or push-pull 6L6 tubes will give ample audio power for inputs as high as 40 or 50 watts on the RK-34 tube. Normal plate current to the latter is 80 ma., although in actual practice this oscillator has been operated over considerable periods of time at 100 ma. plate current.

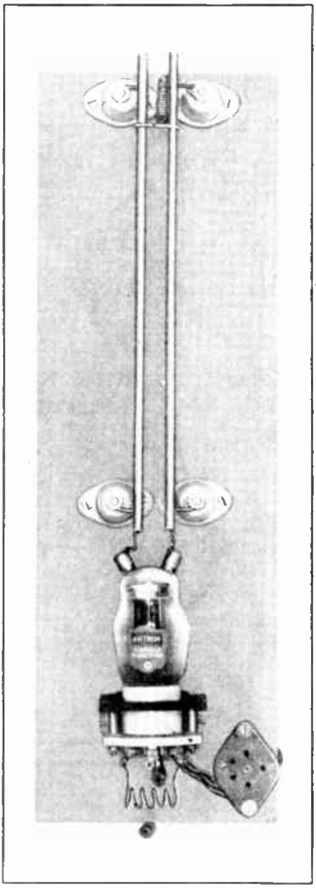


Figure 19—Raytheon RK-34 2½-Meter Oscillator.

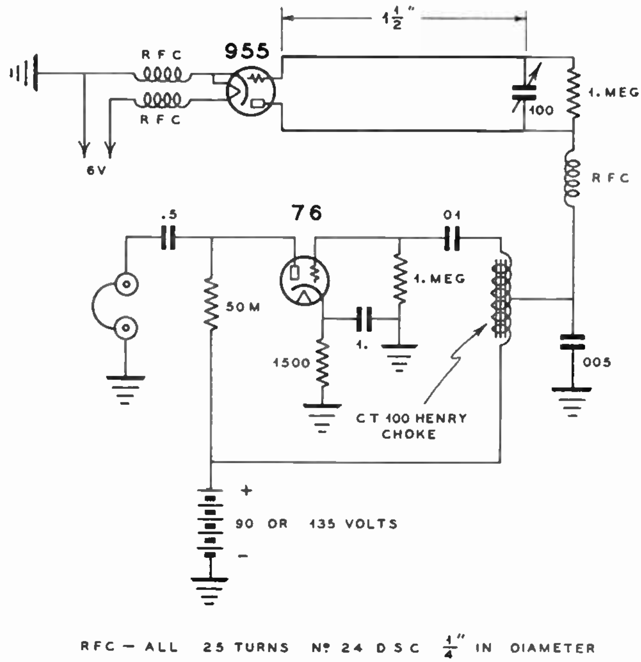
● ¾-Meter Receiver

Lack of stability and difficulty of tuning a micro-wave receiver have been the two principal obstacles in the past. Stable operation can be obtained by confining the radio frequencies to certain portions of the circuit of a parallel-wire oscillator, as shown in figure 21.

In the receiver described here, the quarter-wave parallel-wire tuning section can be tuned over a range of from 5 to 10 centimeters by means of a relatively large series tuning condenser. This condenser, when set to maximum capacity, acts as a short-circuit across the parallel wires. Settings of lower capacity tend to decrease the effective length of the parallel wires by means of series tuning. This is more satisfactory than the use of parallel tuning across the grid and plate terminals of the type-955 acorn tube.

The usual micro-wave receiver consists of a similar type of circuit with a small fixed mica condenser in place of the variable tuning condenser; this requires the use of a soldering iron to change the tuning of the receiver, because the fixed condenser must be moved along the parallel wires when the frequency or wavelength is to be changed.

The acorn tube and tuning condenser are mounted on a small panel above the aluminum chassis. Small r.f. chokes are placed in series with



¾ METER RECEIVER

Figure 21

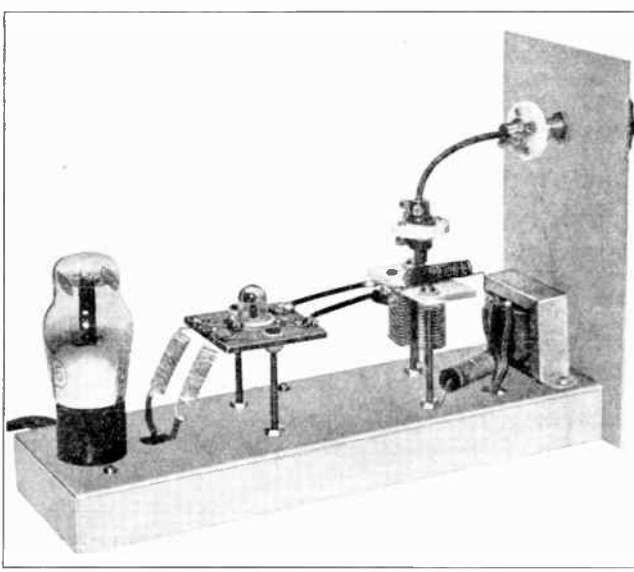


Figure 22—Practical Micro-Wave Receiver with Acorn Triode Detector and '76 Audio Stage. This design must be rigidly adhered to, and all specifications closely followed.

the heater and cathode leads of the 955 tube. These r.f. chokes consist of 25 turns of No. 24 d.c.c. wire, in the form of a self-supported winding, ¼-inch in diameter. The plate choke is similar in construction, and with the same number of turns as the other chokes.

A quarter-wave tuned circuit of two parallel wires, terminated with a small fixed mica condenser, can be used in place of the heater and cathode chokes for wavelengths of less than ¾-meter. One side of the heater connects to the cathode at the acorn tube socket. The plate and grid terminals to the 955 tube connect to two parallel wires, each approximately 1½-in. long for ¾-meter operation. These two wires are soldered directly to the leads of the sub-midget 100-$\mu\mu$fd. tuning condenser, which is designed for u.h.f. operation. The rotor of this condenser is connected through an insulated flexible coupling for front-panel dial tuning; a cable drive connects the tuning dial to the condenser coupling. About 150 volts should be used on the plate. The tuning range is approximately 70 to 80 centimeters. Super-regeneration can be obtained with a 90-volt plate supply over a range of approximately 75 to 80 centimeters. The higher plate potential of 135 volts will allow super-regeneration at lower capacity settings of the series tuning condenser, and thus permit higher frequency operation.

Super-regeneration is obtained by means of a blocking grid action, with a 1-megohm gridleak connected across the parallel wire circuit. The output of the detector can be amplified by means of an audio transformer coupled stage or by impedance coupling; the latter is used in the circuit shown in Fig. 21.

The chassis for this receiver is 3 in. x 10 in. x 1 in., and the front panel is 4 in. x 8 in. The ¾-meter tuned circuit is mounted high enough above the chassis so that there will be no effect from the metal chassis. Three resistors and the two larger fixed condensers are mounted under the chassis. A condenser and resistor in the plate circuit of the audio amplifier prevents d.c. from flowing through the headphones and allows grounding one side of the headphone jack. Either batteries or an a.c. power supply can be used to operate this receiver, provided that the plate potential is not more than 180 volts.

• Operation

The tuning range can be determined by means of Lecher wires approximately 3-feet long and spaced 1-inch apart.

An antenna can be inductively coupled to the parallel wires of the receiver by placing a ½- or 1-turn loop in the plane of the wires. The coupling should be loose enough to prevent loss of super-regeneration. A directive antenna system such as a Yagi array is very satisfactory for ¾-meter operation. The antenna wire should be approximately 14 inches long, with a two-wire feeder tapped to each side of center at a point about 2-inches each side of center. The reflector wires should be approximately 15 inches long, and the director wires 13 inches long. A quarter-wave spacing of the rear reflector wire would be approximately 7½ inches; a half-wave spacing for side reflector wires would be approxi-

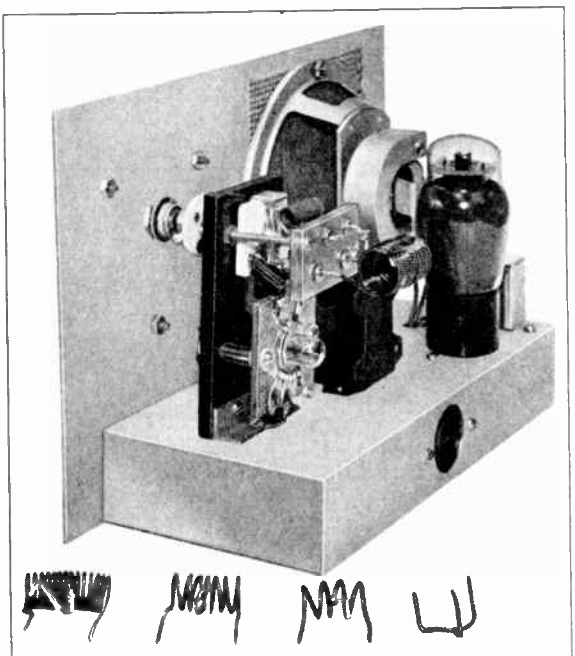


Figure 23—One-to-Ten-Meter Super-regenerative Receiver with Loudspeaker Output. A feature of this receiver is the almost complete absence of connecting leads. Note arrangement and assembly of tube socket and coil holder. In the foreground are the coils for 1-, 2½- and 5-meter operation.

mately 15 inches. The director wires would be placed in front of the antenna in the desired line of reception, and each wire would be spaced 10 inches from the next.

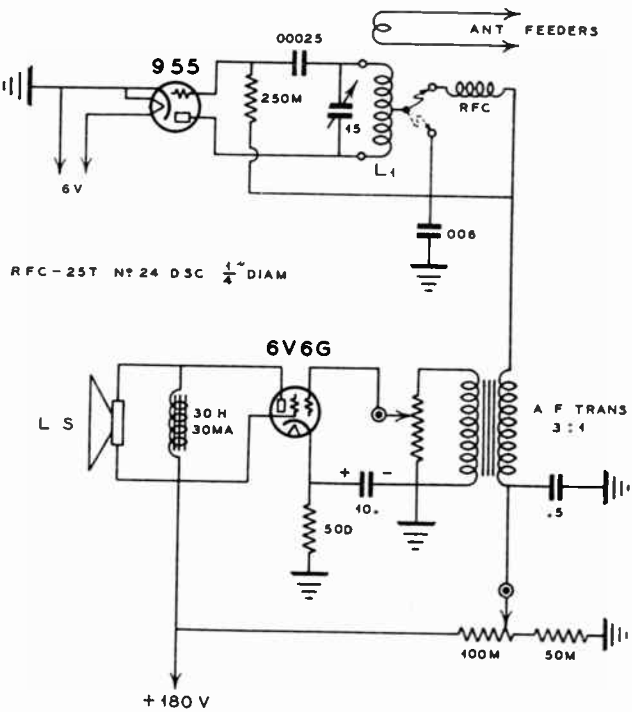
• One-to-10-Meter Super-regenerative Receiver

The problem of designing a receiver to cover a range of less than one meter up to more than 10 meters is indeed a simple one. The only important considerations are the need for extremely short r.f. leads, and the use of a standard super-regenerative circuit.

Figures 23 and 24 illustrate a practical receiver which gives moderate loudspeaker volume with either 135- or 180-volt plate supply. A type-955 acorn triode serves as a super-regenerative detector which is transformer coupled to a high gain 6V6G beam power pentode. The latter is similar to the 6L6G, except for its smaller size; it also requires less heater and plate current.

Five self-supporting coils of No. 14 enameled wire cover the range of from 1 to 11.8 meters by means of a 15 $\mu\mu$fd. tuning condenser. The coils plug into pin-jacks mounted in a strip of *Victron*, 1¼ in. x 2 in. This strip is fastened to the 2 in. x 4 in. bakelite subpanel by means of a pair of 2-inch 6/32 machine screws. This method of support brings the ends of the tip-jacks directly against the terminals of the u.h.f. variable condenser. The stator lead connects to the plate terminal of the acorn tube socket by means of a wire approximately ¼-inch long. The grid condenser is an extremely small mica fixed condenser, connected between the grid terminal of the tube socket and the rotor lead of the tuning condenser. The tuning condenser is driven by a vernier dial through an insulated coupling and extension shaft to the front panel. The tube socket is mounted on standard socket bushings, secured to the same bakelite panel that supports the tuning condenser and coil. The cathode and one side of the heater of the 955 tube connect directly to the metal chassis by means of a soldering lug attached to one of the mounting screws on the subpanel.

A .006-μfd. mica condenser connects to one of the pin-jacks and to the same ground point on the chassis, so as to provide a short r.f. lead between the tap on the coil and the cathode terminal on the tube socket. This tap is used only on the two coils which cover the longer wavelengths. The coils which tune from 1 to 4.4 meters are center-tapped and plug into the other pin jacks in order to connect the small r.f. choke into the circuit. This choke consists of 25 turns of no. 24 d.c.c. wire, close wound and self-supporting, ¼-inch in diameter. The choke is soldered directly to the two pin jacks which are used only for the coil taps. The two lower pin jacks connect to the tuning condenser and to the outer leads of the coils.



1-10 METER RECEIVER

Figure 24

The r.f. choke has a natural period of about 7 meters and must be short-circuited when the large coil (6.5 to 11.8 meters) is plugged-in This is accomplished by soldering a length of no. 14 wire to the cathode tap of the coil, so that the coil plugs into all four pin jacks. The illustration in figure 23 shows how this method of connection is made.

An audio volume control regulates the gain of the beam power amplifier and a 100,000-ohm potentiometer controls the super-regeneration for the type-955 tube. A small 20- or 30-henry choke is shunted across the magnetic loudspeaker terminals in order to provide a path for most of the d.c. plate current through the 6V6G tube.

This receiver will not super-regenerate over the entire tuning range with the one-turn coil for 1-meter reception because the capacitance-to-inductance ratio becomes too great for condenser settings of more than approximately half-scale. However, the coils are designed so that ample overlap is obtained in order to secure super-regeneration over the complete range of from 1 to 10 meters.

Coil Data

The coil which covers the range of from 1 to 1.7 meters consists of slightly less than one full turn of no. 14 enameled wire. The actual wire length is approximately one-inch from tip jack to tip jack, and is *not* plugged all the way into the tip jacks. If this coil is pushed clear into the pin jacks, so that the cathode tap to the r.f. choke coil is flush with the tip jack, the range is from 0.9 to approximately 1.6 meters. The range of from 1.7 meters to 2 meters is covered with a 4-turn coil, with a tap near the center for connection to the r.f. choke coil. This coil is space-wound to one-inch long and has an inside diameter of ⅜ in.

A 7-turn coil of the same diameter and length covers the range of from 2.5 meters to 4.4 meters. This coil is tapped near the center and the tap plugs into the r.f. choke pin jack. A 14-turn coil, ⅜-in. dia., 1¼-in. long, tunes from 4 meters up to 6.8 meters. This coil is tapped at the 6th turn from the grid end of the coil, and the tap plugs into the cathode bypass pin jack. The largest coil consists of 14 turns, ⅝-in. inside diameter, 1⅛-in. long, with a tap at 5 turns from the plate end of the coil is tapped at the 6th turn from the grid end the upper jacks in such a manner as to short-circuit the r.f. choke. The tuning range of this coil is from 6.5 to 11.8 meters. The exact dimensions of the coils and locations of the taps will depend upon the physical layout of the r.f. circuit components. Enameled or bare copper wire, no. 14, should be used in preference to tinned wire because of the lower r.f. resistance at the higher frequencies. Tinned wire has a much greater *"skin effect"* loss and should be avoided in all ultra-high-frequency receivers and transmitters.

The chassis is 5 in. x 9 in. x 1½ in., of no. 14 gauge aluminum, with a 12 gauge aluminum front panel 7 in. x 11 in. The cathode bypass condenser, cathode resistor for the 6V6G tube, and the regeneration control bypass condenser and 50,000-ohm resistor are mounted under the chassis.

2½-5-Meter Metal Tube Transceiver

Metal tubes fit readily into the design of a very compact and powerful transceiver for 5- and 2½-meter operation. This unit here illustrated transmits more power than most transceivers because heavy antenna loading is permissible for both transmitting and receiving. It is quite sensitive and the hiss level is low. The radiated interference is much less than from most transceivers while receiving, due to the separate interruption frequency coil circuit.

The set is built into a 5½ in. x 5½ in. x 4¼ in. steel can formed into two U-shapes with lips along the top and bottom edges of one of the U-shaped pieces. The chassis is 4 in. x 5⅜ in. x 1¾ in., thus making it somewhat difficult to wire-up the 4-pole-double-throw switch, but this job can be accomplished with a little patience. The tuning condenser, plug-in-coil and 6C5 tube are mounted on a vertical bakelite subpanel, 3⅜ in. high, 2¼ in. wide, 3/16 in. thick. The r.f. chokes must be wound to the correct inductance so that no resonant absorption dips occur in either band. About 75 turns of no. 34 d.s.c. wire, closewound on a piece of ⅜-in. bakelite rod, serves the purpose. The terminals of these r.f. chokes are made by drilling small holes through the ends of the bakelite rod and then soldering the fine wire to a piece of no. 22 wire twisted through and around the ends of the rod.

The interruption frequency coil provides super-regeneration in the 6C5 tube when receiving; thus heavy antenna loading and low plate voltage can be used on 5 meters. On 2½ meters, the plate voltage should be 200 volts, preferably 250 if available. The transmitter output with 135 volts supply on 5 meters will be approximately ½ watt, and 1¼ watts at 200 volts, which is greater than the output obtainable from most other transceivers. A 6F6 power pentode acts as modulator when transmitting and as an audio amplifier when receiving. The output in the

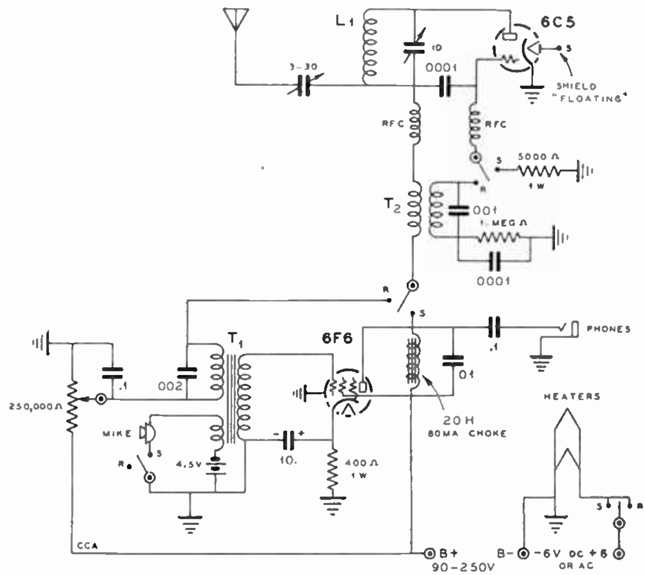


Figure 25—Metal Tube 2½-5-Meter Circuit Diagram.

latter condition is sufficient to drive a small magnetic loudspeaker to moderate volume. The detector regeneration control can be set to a point of very low hiss level and high sensitivity.

A separate 4½-volt microphone battery allows the use of either a.c. or d.c. supply for the heaters of the two tubes. Either an a.c. power supply or batteries can be used for home or portable operation. Variable antenna coupling capacity will permit the use of any type of 5- or 2½-meter antenna. The coupling condenser can be adjusted through a hole in the front panel by means of a bakelite screw driver. The shield of the 6C5 tube should "float," i.e., it is not connected to ground as is the usual practice.

The 5-meter coil consists of 9 turns no. 14 wire, ½-in. diameter and 1½ in. long. The 2½-meter coil has 3 turns, ½-in. diameter, wound to a length of between 1 in. and 1½ in., depending upon the length of r.f. leads in the r.f. tuning assembly. Pin jacks serve as terminal plug receptacles for the little plug-in coils. The send-receive switch in its center position opens the heater supply circuit, but does not disconnect the B battery; consequently, if dry cells are used, the regeneration control will absorb a small amount of current, even when the set is turned off.

This transceiver can be built on a larger chassis, if space requirements permit. The 6C5G and 6F6G large glass tube equivalents of the little 6C5 and 6F6 metal tubes can be substituted without change in circuit constants. Operation on 2½ meters should be slightly more efficient when using the glass 6C5G tube. These glass tubes have octal bases, but they require more space.

The same arrangement of horizontal r.f. tube mounting, very close to the tuning con-

Figure 26—Front View of Metal Tube Transceiver.

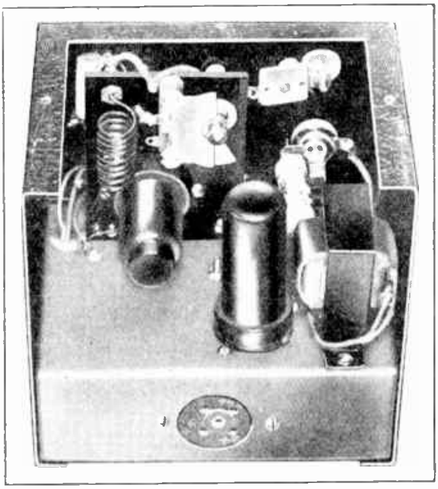


Figure 27—Interior View, showing Coil and Condenser Support, Also Horizontal Mounting of 6C5.

denser and coil, is recommended if 2½-meter operation is desired. The tuning condenser has two plates. An insulated shaft connects the condenser rotor to the dial.

The three-winding midget audio transformer is manufactured by several concerns. Any small 20 or 30 henry, 50 ma. filter choke is suitable for the modulation choke.

The performance of this unit is so superior to most other transceivers that it is highly recommended for the amateur.

● Resistance-Coupled 5-Meter Super-Heterodyne

A simple 5-meter resistance-coupled superheterodyne is shown in figures 28 and 29. The receiver has four tubes: a 6C6 autodyne detector, two stages of resistance-coupled i.f. amplification with 6D6 tubes, and a 76 triode second detector. The values of resistors and condensers in the i.f. amplifier are correct to bypass the intermediate frequencies only; the coupling condensers and resistors are too small in value to pass audio frequencies. The response curve of the amplifier is quite broad in order to receive 5-meter phone signals.

All of the .0001 μfd. condensers should be of the mica "postage-stamp" variety. The resistors can all be ½ watt in rating. The 500,000-ohm screen control potentiometer in the 6C6 detector stage should be advanced only to the point where the detector oscillates weakly, and never to the point of howling or super-regeneration.

The coupling between the antenna coil and the first detector should be adjusted for best weak-signal reception. Too much coupling to a resonant antenna will prevent detector oscillation and proper superheterodyne action. In tuning the receiver dial, it will be found that all 5-meter signals will have two points on the dial, very close to each other, because the detector functions in a simple autodyne circuit.

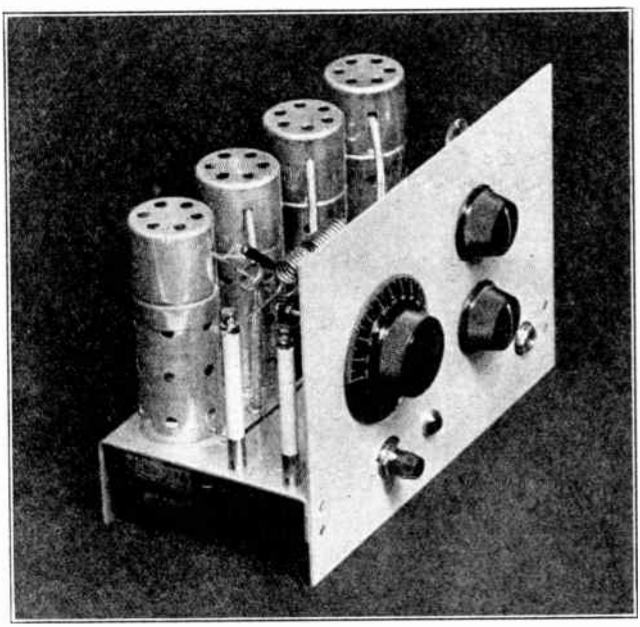


Figure 28—The Complete 5-Meter R-C Coupled Superheterodyne.

● 5- and 10-Meter Superheterodyne

The simple 5- and 10-meter super-regenerative receiver does not fill the requirements of the advanced experimenter who is interested in long-distance 5 meter pioneering. The spasmodic periods during which u.h.f. signals have been heard over great distances have en-

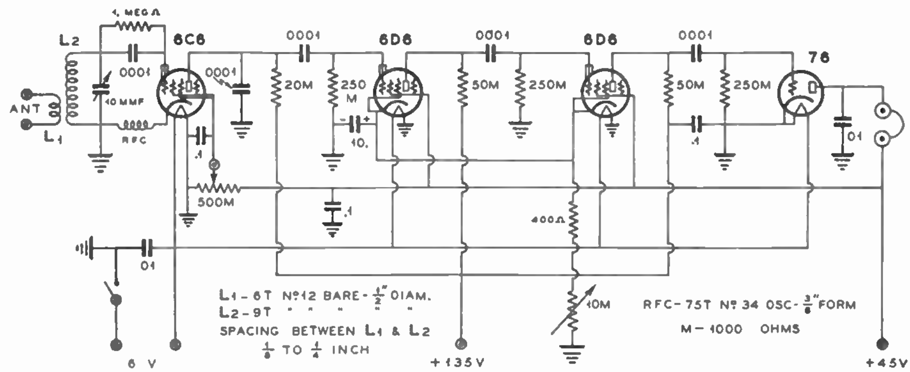


Figure 29—The Extremely Simple Circuit Diagram of the 5-Meter Resistance Coupled Super.

couraged the design of a practical receiver capable of receiving phone c.w., and i.c.w. signals. A correctly designed u.h.f. superheterodyne can be made more sensitive than a superregenerative receiver, more stable in operation, and equally free from ignition noise.

Other uses for a combination 5- and 10-meter superheterodyne of the type described here are for police and commercial services where dependability and absence of background hiss are essential requirements. This receiver incorporates the *Dickert* noise-silencer in a modified form. A Faraday screen prevents capacitive coupling between antenna feeders and the first tuned circuit in the receiver. The high-frequency oscillator and mixer circuits were especially designed for u.h.f. operation after all other practical forms of first-detector circuits were discarded.

The amplifier in this receiver uses 1,600-kc., air-tuned i.f. transformers and the frequency of the i.f. amplifier can be made any value between 1,600 kc. and 5,000 kc. by changing the i.f. transformers and slightly altering the high-frequency oscillator coils. The choice of i.f. frequency depends upon the service required of the receiver. The higher i.f. frequency, such as 3,000 kc. or 5,000 kc., would provide a more broadly tuned i.f. amplifier for 5-meter voice reception. The selectivity of the 1,600-kc., i.f. amplifier is rather great for reception of signals from an ordinary 5-meter transceiver, but is excellent for reception of m.o.p.a. or crystal-controlled 5-meter voice or c.w. signals. The high-frequency oscillator in this receiver could be crystal-controlled for police communication service where single-frequency reception is desired.

The receiver is tuned with a single dial. The r.f. stage is not of the regenerative type, thus simplifying the problem of ganging this tuned circuit with the first-detector and oscillator circuits. The r.f. amplifier has appreciable gain on 5 meters, however, because of careful circuit design. Very short r.f. leads, low "C" tuned circuits, and a 6J7 sharp cut-off tube are used to accomplish this purpose. The 6J7 tube is operated at very low bias and high screen voltage and at somewhat more than normal plate current. Under these conditions, the tube has about the same plate current as a 6K7 variable μ tube operating under normal conditions, but produces about twice as much amplification. The increased gain available from a sharp cutoff tube, such as a 6J7 or 6C6, gives a better signal to noise ratio in the front end of a superheterodyne. The sharp cutoff tube will provide at least as much r.f. gain-to-noise ratio as can be obtained from a variable μ tube connected in a regenerative r.f. amplifier.

The 6J7 tube has nearly twice as much output capacitance as a 6C6 glass tube if the latter is not shielded. The difference in output capacitance is not very great when the 6C6 tube has a metal shield around it, such as is necessary for any r.f. amplifier. The shell of the metal tube serves as the shield and the small physical size of this tube allows shorter leads. The disadvantage of a possible effective higher output capacitance in the r.f. tube can be overcome by using capacitive coupling between the r.f. and first-detector tubes. As long as this tube capacity is not too great, it does not lower the L/C ratio in the following tuned circuit, and simply becomes a part of the tuning condenser capacity. The r.f. coupling circuit shown in the schematic diagram is very effective for high-frequency r.f. amplifiers. The variable plate coupling condenser allows exact alignment of the detector tuned circuit if the oscillator and

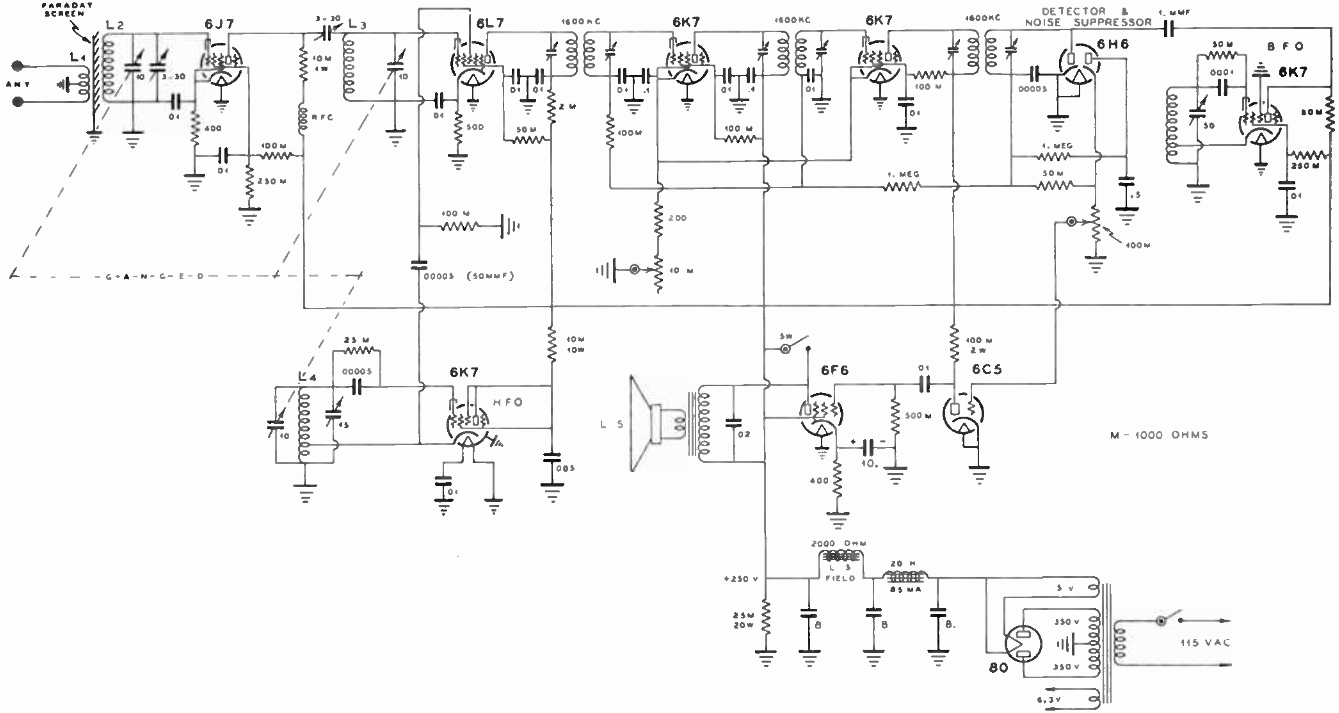


Figure 30—General Wiring Diagram of the U. H. F. Superheterodyne.

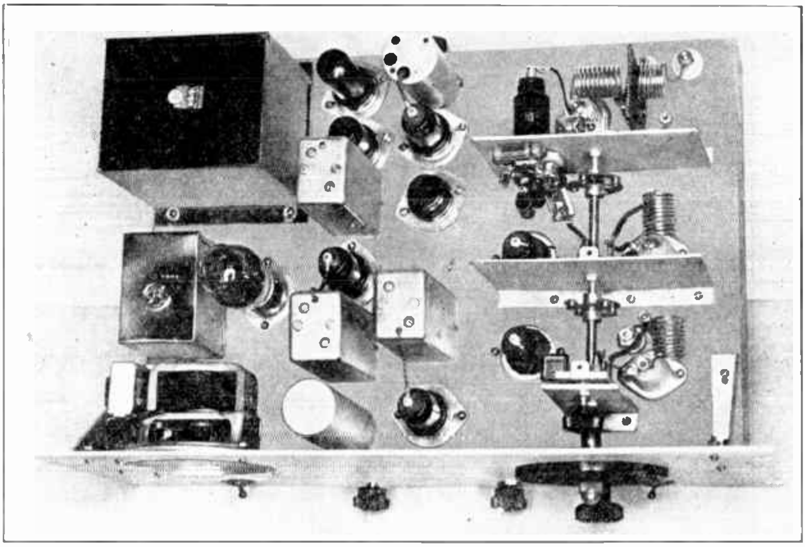


Figure 31—Top View, Showing Layout of Parts.

r.f. trimmer condensers have previously been adjusted to the correct values. This method of circuit alignment can only be applied over a very narrow range, since the variation of coupling capacity changes the r.f. gain.

The r.f. amplifer plate can be connected to the positive B through a small r.f. choke of 75 turns of no. 34 d.s.c. wire, closewound on a 3/8 in. diameter bakelite rod. This choke coil is suitable for 5- and 10-meter operation, but will not have enough inductance for use on 20 meters. The receiver can be operated on 20 and 40 meters by winding additional coils on small plug-in forms. The 10,000-ohm resistor in series with the r.f. choke in the plate circuit allows operation on 20 or 40 meters (in spite of the too small r.f. choke) and the resistor does no harm when the set is used in the 5- or 10-meter bands.

The 1,600 kc., i.f. transformers are tuned by means of air dielectric trimmer condensers. Type G-1601, G-1600, and G-1604 *Aladdin* iron-core i.f. transformers are used in the amplifier in the order given.

Grid-leak and space-charge first detectors depend upon grid rectification for their operation and the tube itself acts as an additional i.f. amplifier. For audio frequencies or very low i.f. frequencies, grid detection is very effective because the grid impedance can be made high for such low frequencies. The grid-coupling condenser bypasses the r.f. frequency to the grid of the detector in these circuits and is supposed to act as a very high impedance to the demodulated or new frequency of the plate circuit. The new frequency is formed in the grid circuit by the process of detection or mixing and part of it is lost due to the by-passing action of the grid condenser. If the i.f. frequency is very high, such as 1,600 kc., the usual value of .0001-μfd. grid condenser provides quite a low impedance to this frequency; as a result, the tube itself may provide a loss instead of a gain. If the grid condenser is made smaller in order to minimize this loss, its reactance soon becomes too great to apply the major portion of the r.f. signal across the grid-to-cathode capacitance of the tube. Space-charge detectors, such as a type 24-A or 36 tube, act as triodes which have a very low plate impedance and very high mutual conductance. This low impedance loads the first i.f. transformer to an excessive degree and tends to reduce both the i.f. amplification and selectivity. A grid-leak detector tends to have a low grid impedance as well as low plate impedance, resulting in a non-desirable load on both the r.f. tuned circuit and the first i.f. tuned circuit. Bias detection eliminates these faults at the expense of a drop in detection efficiency. The final result is a compromise in either case when a 465 kc. i.f. amplifier is used. Bias detection proved its superiority in tests made with this receiver, where a higher i.f. frequency is used.

The oscillator in this receiver has a 6K7 connected as a triode with the cathode tapped

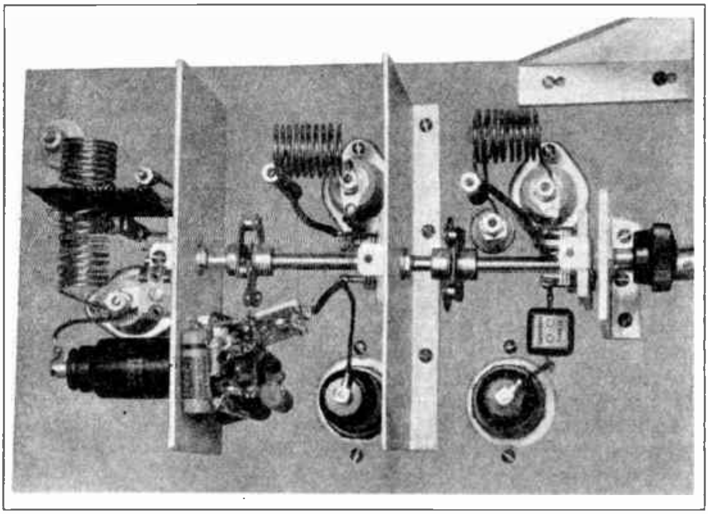


Figure 32—The Ganged High Frequency Circuits.

into the tuned grid circuit. This is a better method than the use of a 6C5 triode from the standpoint of input capacitance. The grid of the 6K7 comes out through the top of the tube and has less capacitance to ground than the grid of the 6C5, which comes out through a prong in the base.

Two stages of i.f. amplification give good selectivity and sufficient gain for satisfactory operation of the second detector and noise limiter circuit. Signal fading is minimized by applying a.v.c. voltage to the i.f. amplifier. A 10,000-ohm variable cathode-bias resistor serves as a control of sensitivity for c.w. reception. As the value of this bias resistor is increased, the a.v.c. effect becomes less, so that it is not necessary to cut out the a.v.c. for c.w. reception.

A 6H6 double-diode tube serves a dual function; one diode unit acts as a second detector and also supplies a.v.c voltage to the i.f. amplifier. The second diode in the 6H6 tube provides a noise-limiting or silencing action. This diode acts as a variable resistor shunted across the audio amplifier.

When the noise impulses, due to automobile ignition, are of a value greater than the average modulated signal, the diode acts as a short circuit across the audio output. A noise pulse of very short duration, such as that from automobile ignition interference, causes the receiver to become inoperative for a correspondingly short interval. This interval of silence is so short that it is inaudible to the ear; it only takes place on noise impulses in which the amplitude is much greater than that of the carrier signal. The 1-megohm resistor and 1-μfd. condenser in the plate circuit of the noise diode have a slow time constant, so that the tube follows the a.v.c. voltage (which is proportional to the carrier signal). This makes the noise-limiter entirely automatic in its action, and by choosing those values of resistors in the noise-limiter cathode circuit as are shown in the diagram, the noise-limiting action can be made to start only for noise pulses of an amplitude greater than the modulated component of the desired signal.

Any noise impulse of high amplitude makes the noise diode cathode circuit negative with respect to its plate and, therefore, reduces the diode impedance to a few hundred ohms. This portion of the diode is connected across the audio amplifier volume control (100,000-ohm potentiometer) and thereby tends to short circuit the audio amplifier during the noise impulse interval. This circuit does not eliminate automobile ignition of low or medium amplitude; however, it does improve reception of readable signals through strong ignition interference.

A beat-frequency oscillator is coupled to the second detector diode plate through a small capacitance consisting of a short length of hookup wire twisted twice around the plate lead of the diode. The b.f.o. consists of a standard electron-coupled oscillator tuned to produce a beat note with the 1,600-kc. signal for c.w. reception. The value of screen-grid resistor shown in the circuit diagram depends upon the type of grid tuned coil and location of cathode tap. The b.f.o. coil is made by scramble-winding 150 turns of no. 30 d.s.c. wire on a ½-inch diameter dowel rod, with a winding length of one inch. The cathode tap is made ¼ of the total number of turns up from the grounded end. The dowel rod is forced into a ½-inch diameter hole in the chassis, and this coil, grid-leak and condenser are then shielded by covering them with an aluminum shield can. The 50 $\mu\mu$fd. tuning condenser is mounted on the rear of the chassis directly below the b.f.o. coil and the b.f.o. switch is mounted on the front panel for the sake of convenience. Excessive b.f.o. injection into the second detector produces an objectionable amount of hiss and a consequent loss of sensitivity on weak signals. If the injection voltage is too low, the beat-note on c.w. reception will be weak and strong signals can not be heterodyned. The amount of injection voltage can be varied by changing the coupling capacity between the two plate circuits and by changing the value of the screen-grid resistor.

The power supply and loudspeaker are built into the chassis. The presence of the loudspeaker produces an audio howl on signals having a strong carrier if the volume control is advanced too far. If high audio volume is desired, the loudspeaker should be mounted in a separate cabinet. The howling effect is an acoustic feedback from the loudspeaker to the tuning condenser plates and is not easily remedied.

The audio amplifier consists of a 6C5 triode, resistance-coupled into a 6F6 pentode. The 6C5 obtains its grid bias from the diode voltage; this bias voltage depends upon the signal strength and position of the arm on the volume control potentiometer. The bias is automatically increased when receiving strong signals or when the volume control is advanced for a high audio level. This arrangement is desirable in preference to fixed bias because of the noise-limiter circuit. The difficulty lies in obtaining a quiet volume control, since there is a small flow of direct current through the resistor, and most types of volume controls tend eventually to become noisy under these conditions.

• Construction of Receiver

The receiver is mounted on a cast aluminum chassis, 12 in. x 17 in. x 2½ in. The front panel is 8¾ in. x 19 in., 10-gauge dural. There are three tuning condensers of the Hammarlund u.h.f. type, originally having a capacity of 35 $\mu\mu$fd. each and then reduced in capacity by removing plates until only two rotors and two stators remain in each condenser. These condensers are very efficient for u.h.f. operation because very short r.f. leads can be made; however, they are difficult to gang together for single-dial tuning. Extension shafts, two in number, each 1¾ inch long, are cut from ¼ inch round brass tubing having an *inside* diameter of ⅛ inch. These are forced-fit over the ⅛ inch shafts on the tuning condensers and then soldered in place. This is accomplished by drilling a ¼ inch hole in a block of wood which is clamped to the base plate of a drill press. The front shaft of the tuning condenser is then slipped into the ¼ inch-hole and the brass extension shaft is fastened into the chuck of the drill press. The chuck is then brought down until the brass tube slips over the ⅛ inch-condenser shaft and the two are then sweated together with a hot soldering iron and solder. This alignment procedure results in a reasonably straight extension shaft which rotates on the shaft axis without wobbling.

Each tuning condenser is then mounted on an aluminum subpanel, with flexible couplings linking the shafts. The mounting holes for the condensers are made a little large so that the condensers can be lined up with the front section and tuning dial without binding when the dial is rotated. The aluminum panels which hold the condensers (three in number) are spaced 3¼ inches apart; they also serve as r.f. shields between stages. The two larger aluminum shield brackets are 6 inches long and 4 inches high. The smaller bracket is used for the oscillator tuning condenser and padding condenser; this bracket is 2 inches wide and 4 inches high. Even when great care was exercised in lining up the condenser, the friction developed. This, plus the friction of each condenser itself, required a vernier tuning dial with a powerful driving action. If care is taken to gang the condensers properly and if a good dial is chosen, it is easy to tune without backlash, even on 5 meter c.w. reception.

The oscillator components are mounted in the compartment closest to the front of the receiver in order to minimize backlash, which is inherent even in a solid ¼ inch-brass rod. The detector is mounted in the center compartment and the r.f. tube is mounted in a horizontal position in the third compartment at the rear of the chassis. The horizontal mounting makes it possible to run a very short plate lead, so that the efficiency even on

4 meters is relatively high. Plug-in coils, "air supported," are used for the 5- and 10-meter bands. Brass standoff supports are made by drilling a 1/8 inch hole in one end of a 5/8 inch round brass rod for receiving the banana-type plug on the coil. The other end of each brass standoff (1½ inches long) is drilled and tapped to take a 6/32 machine screw, so that the standoff can be supported to the chassis. Small porcelain standoff insulators, 1½ inch high, support the grid end of each coil by means of a banana-type plug and jack.

The cathode of the oscillator feeds up through the chassis into a through-type insulator which has a plug in its end. The oscillator coil has three of the small banana-type plugs, whereas the detector and r.f. coils have only two. The antenna coupling coil is mounted on standoff insulators and the coupling remains fixed for all bands. This coil consists of 7 turns of no. 14 bare wire, 7/8 inch diameter, 3/4 inch long. This coil can be center-tapped to ground for connection to a transposed two-wire feeder or connected to ground at one end for connection to a concentric line feeder or simple antenna and ground.

A *Faraday Screen* is mounted between the antenna coil and r.f. tuned circuit. This screen consists of parallel insulated wires, spaced one diameter of the wire, cemented to a flat sheet of celluloid. *One* end of all of these wires is soldered to a no. 12 "bus" wire which serves as a common support for the screen. This end is grounded. The remaining ends of all the wires are insulated from each other. The physical size of this screen is 2¼ in. wide and 2¾ in. high.

The 5-meter detector and r.f. grid coils are both identical in size; each has 7 turns of no. 14 wire 5/8 inch diameter, and spaced to occupy a length of 1½ in. The 5-meter oscillator coil consists of 6 turns of no. 14 wire, 5/8 inch diameter, space-wound to occupy a length of 1⅛ in. The cathode tap is soldered to a point on the coil which is slightly more than one turn from the grounded end.

The 10-meter r.f. and detector coils each have 10 turns of no. 14 wire, "air wound," 7/8 in. diameter, 1¼ in. long. The 10-meter oscillator coil has 9 turns of no. 14 wire, "air wound," 7/8 in. diameter, 1⅛ in. long, with a cathode tap taken two turns from the ground end. All coils are fitted with banana-type plugs.

The oscillator padding condenser (15 μμfd. maximum capacity) is mounted directly above its tuning condenser in the compartment closest to the front of the panel, and its capacity is set so that the plates are about one-third enmeshed. The r.f. grid trimmer and r.f. coupling condensers are set with the plates between one-third and one-half enmeshed. The coil turns are then compressed or expanded until the circuit tracks over the 5- and 10-meter bands. This is a rather tedious procedure and can be accomplished most easily by means of the 5- or 10-meter harmonics from a test oscillator or signal generator.

The first detector connects to the i.f. transformer nearest to it and the high-frequency oscillator tube. The first i.f. tube is mounted close to the front panel and it feeds into the second i.f. transformer, which is directly behind the round electrolytic condenser can. The second i.f. amplifier tube and third i.f. transformer are in a line with the 6C5 and 6F6 audio tubes.

The 6H6 detector and 6K7 b.f.o. tube and coil are mounted near the last i.f. transformer and audio tubes. The power supply components are mounted far to the left on the chassis. The knob on the rear side of the chassis is the b.f.o. adjuster.

All of the .00005 μfd. (50 μμfd.) condensers are of the mica type; the remaining condensers are of the 600-volt tubular paper type, except for the ½-μfd. noise filter condenser, which has a rating of 400 volts.

● High-Output 6A6 5-Meter Transmitter-Receiver

It was previously stated that 5-meter transceivers have many disadvantages, including excessive receiver radiation, low output when transmitting, poor sensitivity, high receiver hiss level, and variation of transmitter frequency with receiver frequency shift. The unit here shown has a separate transmitting r.f. circuit, a common audio system, and separate receiver r.f. circuits. This permits the use of an r.f. stage, which increases sensitivity and prevents receiver radiation. The transmitter frequency can be set to some fixed value, and the output is several times as high as that from a transceiver.

This transmitter-receiver is not much larger than a transceiver, in spite of its being a separate receiver and transmitter for 5-meter operation. The receiver has a separate quench frequency tube and associated controls, thus the hiss level can be set at such a low value that it is no higher than the external interference noise in most locations. Regenerative r.f. amplification with regeneration control gives extremely high sensitivity when needed.

A class B 6A6 modulator supplies sufficient audio output to modulate the 5-meter oscillator at approximately 5 watts carrier output when a 300-volt plate supply is available. Either an a.c. power supply, or B batteries and a 6-volt storage battery, can be used for portable or fixed station operation. The B supply can be of any value from 150 to 325 volts, much better results being secured with the higher values around 280 to 300 volts.

A small magnetic loudspeaker is built into a cabinet only 14 in. x 7 in. x 7½ in. This set has all of the best features of mobile or medium power station units built into one, and it can be highly recommended for general 5-meter operation.

● Technical Notes

The transmitter consists of a TNT push-pull oscillator with a 6A6 tube in a cathode bias arrangement. A 6A6 speech amplifier drives a class B 6A6 modulator which delivers 8 to 10 watts output at 300 volts. The microphone is an ordinary single-button type.

The same two 6A6 audio tubes serve as an audio amplifier for the receiver when the 4-P-D-T switch is thrown to the receive position. The latter also switches the antenna from transmit to receive. The 76 super-regenerative detector is not self-quenching, but uses a separate 76 interruption frequency oscillator. The latter permits a setting of the detector plate voltage to such a value that the tube continues to super-regenerate, but with a very low hiss level. This means that a great portion of the troublesome loud hiss or roar can be eliminated, even when no station is tuned-in on the 5-meter band.

The regenerative r.f. stage has a 6K7 metal tube, requiring less space and shorter leads. A slight amount of regeneration actually gives some r.f. gain on 5 meters and very weak signals can be received which would otherwise be inaudible. A 954 acorn r.f. tube will give more gain, but at a considerable increase in cost; thus a compromise was made in the form of the 6K7 tube.

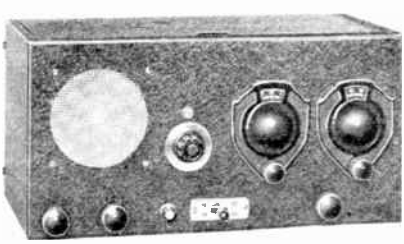


Figure 33—Front View of High-Output 6A6 Transmitter-Receiver.

The interruption frequency oscillator has two small universal-wound coils in a small shield can beneath the chassis. This oscillator functions at about 100 kc. and causes a variation at 100 kc. per second of the plate voltage on the 76 detector. This variation causes super-regeneration, with a gain of several thousand times on weak signals.

Audio volume is controlled, in the receiver only, by shunting a tapered 50,000-ohm control across the grid circuit of the first audio stage. The microphone-to-grid transformer carries the detector plate current through its secondary when receiving; it should, therefore, be wound with sufficiently heavy wire in order to carry approximately 5 ma. A push-pull pentode to dynamic loudspeaker voice coil transformer can be substituted for the "mike" transformer. The voice coil winding then becomes the microphone winding, and the detector lead can be connected through the switch to the center-tap or to the grid ends of the secondary. The loudspeaker connects from one of the class B plates through a ½-μfd. condenser back to a switch contact which disconnects it when transmitting. This send-receive switch also connects the B supply voltage to either the transmitting 6A6 oscillator or to the detector and r.f. stages.

The 6A6 oscillator draws from 30 to 60 ma., depending upon plate voltage and antenna loading. The plate impedance is some value between 5,000 and 10,000 ohms and the class B output transformer should therefore have a total primary-to-secondary turns-ratio of between 1.4-to-1 and 1-to-1. The transformer shown was rated for a 5,000-ohm load out of a 6A6 class B tube, which would indicate a 1.4-to-1 ratio. The class B input transformer can be any type designed for a 6A6 or 53 driver into a 6A6 or 53 class B amplifier.

● Construction

The sheet-iron can is 14 in. long, 7 in. high and 7½ in. deep, a standard size available from many radio supply houses. A 1¾ in. chassis depth is ample for the 4-P-D-T switch, variable and fixed resistors and fixed condensers.

The 4-prong wafer socket for the power cable and the insulated microphone jack are mounted in the rear. The class B transformers are placed in such a manner that space is available for a 4½-volt C battery for microphone supply. The separate mike battery makes possible the use of either d.c. or a.c. for the heaters without wiring changes. The

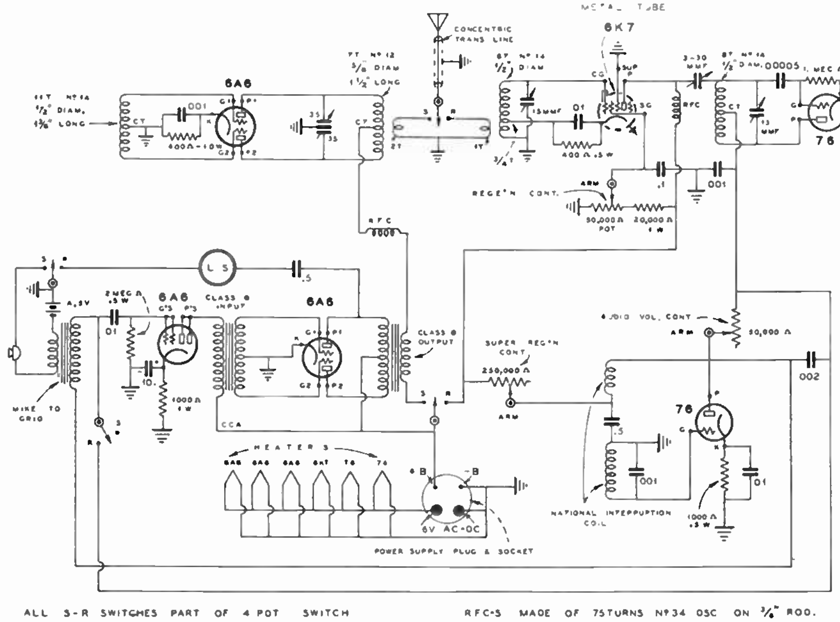


Figure 34—Complete Circuit Diagram of High-Output 6A6 Transmitter-Receiver.

5-inch magnetic speaker is covered with a metal screen grill behind a 4-inch diameter hole in the front panel.

The two receiving 15 $\mu\mu$fd. tuning condensers mount on small porcelain stand-off insulators. The two corresponding vernier tuning dials are of bakelite, thus a one-inch front panel hole insulates the tuning condensers from ground. Other types of dials would require an insulated coupling on the tuning condenser shafts in order to prevent r.f. noise, in one case, and a short circuit in the other.

The 6K7 r.f. tube mounts horizontally on a 4 in. x 5 in. no. 12 aluminum shield. The latter has a ½-in. lip bent at right angles along the bottom so that a pair of 6/32 machine screws will hold it rigidly in place. Shake-proof lock-washers should be placed under all machine screw nuts if the set is operated in mobile service. The r.f. stage by-pass condensers, r.f. choke and plate coupling condenser mount directly at the 6A7 tube socket, with short leads to the aluminum sheet for a ground connection. All ground points are bonded together with hook-up wire and connected to the minus *B* power socket terminal.

The r.f. chokes are made by winding about 75 turns of no. 34 d.s.c. wire on a ⅜-in. diameter bakelite rod. The detector coil has 8 turns, ½-in. inside diameter, tapped near the center, and the turns are spaced approximately the diameter of the no. 14 wire. The r.f. coil is similar in construction, except for the cathode tap, which is taken at about ¾-turn. The plate coil of the 6A6 oscillator has 7 turns, ⅝-in. diameter, 1½-in. long. The wire for the coils should be no. 12 or preferably no. 10 copper. The 6A6 grid coil has 11 turns of no. 14 wire, ½-in. diameter, with a center-tap. This coil mounts on small stand-off insulators beneath the chassis and the two grid leads extend through the insulators directly to the grid terminals on the isolantite socket of the 6A6. This arrangement gives equal and very short grid and plate leads to the 6A6 r.f. tube. The 6A6 r.f. tube and 76 detector both mount on isolantite sockets above the chassis in order to reduce the length of the r.f. leads.

All coils are soldered to their terminals so as to prevent loose connections, losses and noise. The two antenna coils are made of no. 18 insulated hook-up wire and the coupling can thus be varied for best results with different antennas.

• Operating Notes

When first testing the receiver, the r.f. regeneration control should be set so that the value of screen voltage is approximately

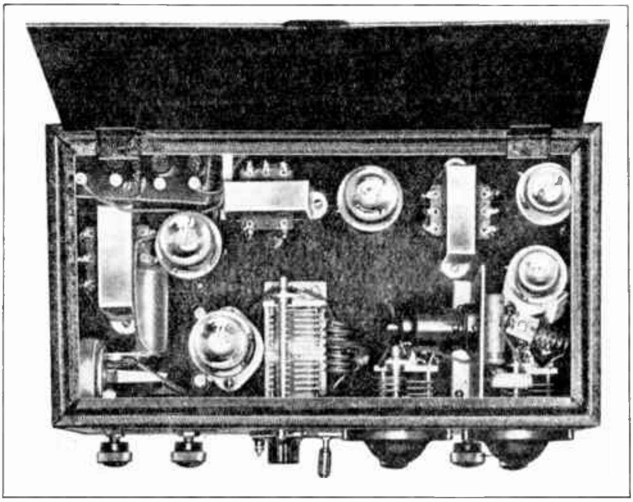


Figure 35—Looking into the High-Output Transmitter-Receiver.

zero. The super-regeneration control should be decreased in resistance until a super-regenerative hiss is audible in the loud-speaker. The r.f. control can then be rotated until r.f. oscillation takes place (without antenna), as indicated by a sudden cessation in hiss output when tuning the r.f. dial across its scale. When actually operating the receiver with an antenna, the r.f. regeneration control should never be set to the point of r.f. oscillation. A check on the operation of the r.f. stage and its tracking qualities with the detector tuning dial can be secured with the oscillation test just described.

A little practice is needed to operate the receiver for maximum sensitivity, because it has two tuning dials and two regeneration controls. For normal operation the r.f. stage tunes very broadly, and the r.f. gain control need not be set to its critical position. The detector super-regeneration control should always be set to a position where it will maintain a low degree of hiss level when no signal is received. The r.f. stage prevents radiation of super-regeneration squeals from the detector circuit and therefore serves a good purpose; careful tuning of the r.f. stage will give a decided gain in receiver sensitivity on weak signals.

The transmitter should be tuned to some frequency within the 5-meter band between 56 and 60 megacycles by means of a wavemeter or by checking it against another receiver. A diode tube field strength meter-monitor should be available for checking modulation. A single turn of wire in series with a 6-volt pilot lamp makes a good tuning indicator, in addition to the field strength meter. The lamp, when coupled to the 6A6 plate coil, should light up more brilliantly when the microphone is spoken into or energized by a whistle. Fairly heavy antenna coupling is essential for best results. The modulation percentage is greatest at a point where the r.f. current in the antenna begins to drop slightly on steady carrier due to close coupling to the antenna feeder. The lamp indicator will also show a greater variation in r.f. current when modulating with a heavy antenna load. The spacing of the grid coil turns and the value of the cathode resistor both affect the degree of modulation for a given degree of antenna coupling.

The antenna coupling system is suitable for a spaced two-wire r.f. feeder, a single-wire feeder, or to a concentric feed line. The latter is of especial benefit for automobile installations and is also best from a standpoint of minimum noise pick-up at fixed stations. The antenna can be a vertical half-wave Y-fed wire or rod, about 8 feet long, or a "J" type. A directional array will give better performance than a single element half wave antenna. For automobile installations the antenna can be 4 feet long, with the inner conductor of a concentric line feeding the lower end of the 4-foot insulated rod.

• Parallel Rod Oscillators

A parallel rod oscillator consists of two sets of quarter-wave parallel rod tuned circuits, such as shown in figures 36 and 37. The parallel grid rods act as a high Q circuit, giving a high degree of frequency stability. These rods are approximately 2¼ feet long for the 2.5-meter band and 4½ feet long for the 5-meter band. The lower ends of the grid rods are connected to a short-circuiting copper plate, and the two grid leads are tapped to the rods a few inches above the copper plate. The plate tuning rods are nearly as long as the grid rods, and a sliding short-

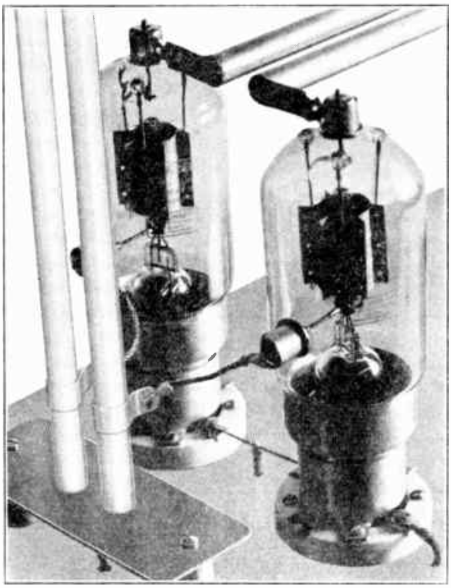
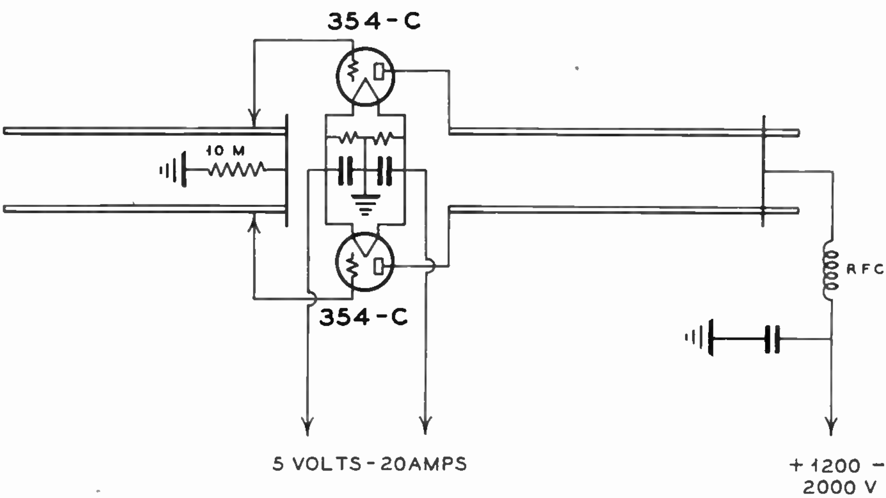


Figure 36—Parallel Rod U.H.F. Oscillator with HK-354C Gammatrons in Push-Pull. The circuit diagram is shown in figure 37.

ing-bar, or connection, tunes this circuit to resonance as indicated by minimum plate current. The oscillator is a tuned-grid-tuned-plate circuit in which the grid circuit controls the frequency of operation. The oscillator shown in the illustration is suitable for high power amateur 2.5- or 5-meter transmitters; smaller tubes can be used if lower power operation is desired.

Plate modulation can be used without excessive frequency modulation. The antenna can be inductively coupled to the plate rods or directly coupled to the rods through fixed mica condensers which are connected to the rods near the shorting bar. The coupling can be adjusted so that normal plate current is drawn. The plate circuit should always be tuned to resonance with the grid circuit, as indicated by minimum plate current. The plate tuning has some effect on the frequency of oscillation. Oscillator-amplifier transmitters of this type are particularly useful for phone.

Another form of rod oscillator is shown in figure 38. This oscillator has a pair of parallel rods which are coiled into spirals. The circuit and adjustments are the same as for a conventional parallel rod oscillator. The plates are connected to a point on the spiral about one turn from the free ends; the two grids are connected to the grid spiral coils at a point about 5 inches from the short-circuited end. Each spiral consists of four turns, the total length of each rod being approximately 4.5 feet for 5-meter operation.



2.5 METER OSCILLATOR (EXPERIMENTAL)
USING 354-C GAMMATRONS

Figure 37

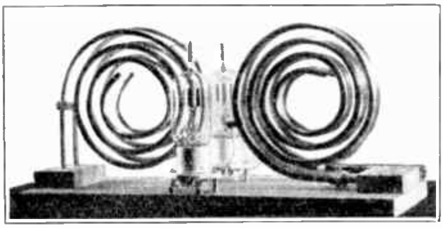


Figure 38—Spiral-Rod Oscillator.

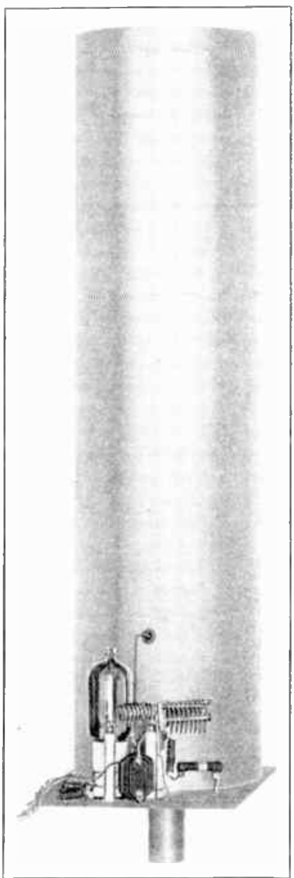


Figure 39—Low Power-Factor Line Oscillator.

Low Power-Factor Line Oscillator

Large diameter pipes, a quarter wavelength long, short-circuited at one end, are suitable for stable oscillators in the range of from 7 to 500 megacycles. Castings and heavy pipes are used in commercially-built transmitters; temperature compensation is secured by means of semi-flexible metal bellows and an invar-rod within the inner pipe.

A pipe oscillator suitable for the amateur 2.5-meter band can be made as shown in the illustrations, figures 39 and 40.

The grid of a 35T tube is connected to the inner pipe at a point about 6 inches from the short-circuited end. The outer pipe is 36-inches long and is soldered to a copper sheet through which the inner pipe slides; this inner pipe is 27-inches long and from 24- to 25-inches of the pipe extends into the larger pipe (for 2.5 meter operation). Waxed linen cords are wrapped around the inner pipe in order to center its position with respect to the outer pipe. The quarter-wave pipe tuned circuit controls the frequency of operation. Regeneration (and plate tuning, to some extent) is varied by means of a 15 $\mu\mu$fd. grid excitation condenser. The capacity of this condenser should be varied until the circuit oscillates under load over a range of pipe lengths. The plate current is relatively low when the proper adjustment is found. The entire transmitter should be suspended by a shock absorbing system in order to prevent vibration, which would impair the frequency stability. An efficiency of about 50 per cent can be obtained with this oscillator. At a plate potential of 500 volts, the plate current was 25 ma., at 700 volts 35 to 40 ma., and at 1,000 volts from 75 to 90 ma. under load, in laboratory tests.

This oscillator can be plate modulated, or it can be used as a driver for a class C amplifier.

Stabilized 5-Meter Transmitter

This stabilized 5-meter transmitter provides a means of securing good frequency stability without resorting to the use of long parallel rods or crystal control. Frequency stability is obtained by means of a high-Q tuned circuit, in conjunction with a variable grid coupling condenser. These two factors minimize the effect of changes in plate voltage in the oscillator during the process of modulation. Proper adjustment of the grid con-

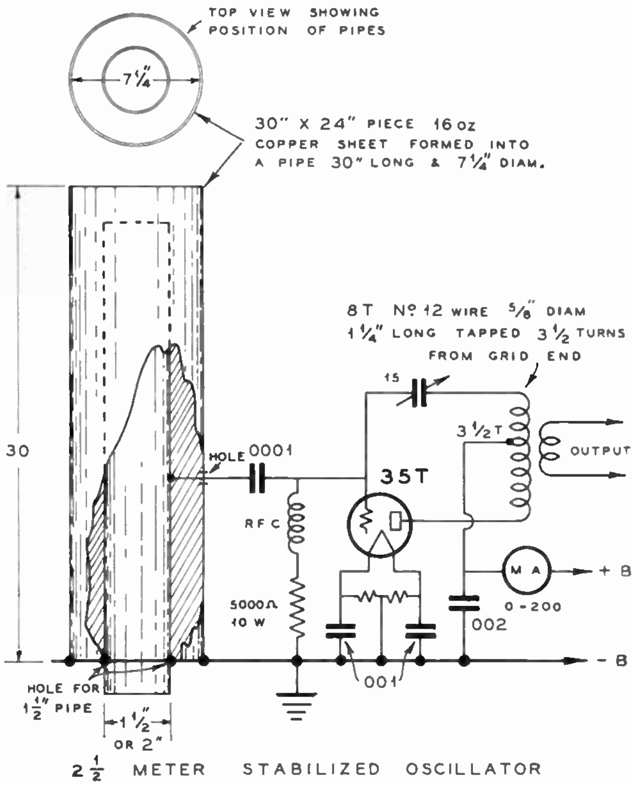
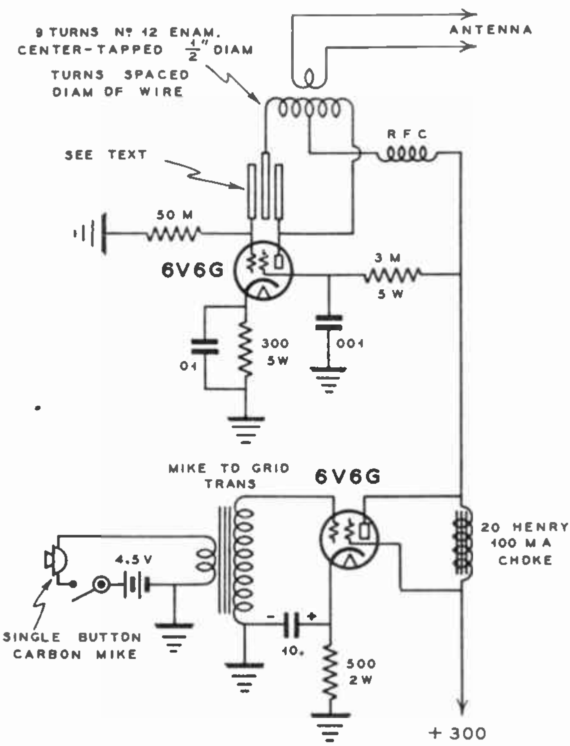


Figure 40

trol condenser results in an oscillator which has a frequency stability comparable to that of a high-Q parallel-rod oscillator. An increase in d.c. plate voltage of from 225 up to 350 volts caused a frequency change of less than 5,000 cycles when this oscillator was under test: the usual 5-meter oscillator has a frequency change of from 60 to 100 kc. under these test conditions. The tests were made by listening to the beat-note in a 5-meter c.w. superheterodyne receiver. A d.c. plate voltage drop of from the 225-volt value down to 100 volts caused a frequency change of approximately 7 kc.

The oscillator in the transmitter illustrated in figures 41 and 42 can be modulated up to 75 per cent without appreciable frequency

Figure 41—Stabilized U.H.F. Oscillator, diagrammed in figure 42. Note center plate between adjustable rotors of a standard, small size neutralizing-type condenser. It is of importance that the components be placed precisely as shown.



STABILIZED 5 METER TRANSMITTER

Figure 42

The heart of the transmitter is a special variable condenser made from a standard *Bud* neutralizing condenser, to which is added a small rectangular aluminum plate. One end of the coil connects to the fixed aluminum plate, which is fastened to the chassis by means of small, porcelain, standoff insulators at either end of the plate; the other end of the coil connects to one of the adjustable plates of the *Bud* condenser. This same lead is also connected to the plate terminal of the 6V6G tube. The grid of the tube connects to the remaining circular plate of the *Bud* condenser. A 50,000 ohm grid-leak connects from the grid to the chassis ground. The coil consists of 9 turns of no. 12 enameled wire, center-tapped; this coil is self-supporting and has an inside diameter of slightly more than ½-inch. The turns are spaced approximately one wire diameter.

The r.f. choke consists of 80 turns of no. 34 d.s.c. wire, close wound on a ⅜-inch diameter bakelite rod. This choke is mounted vertically under the coil, the lower end of the coil rod being supported to the chassis by means of a 6/32 machine screw. The .01-μfd. and .001-μfd. r.f. bypass condensers in the oscillator circuit are connected directly from the tube socket terminals to the chassis ground; these condensers are of the mica type. A combination of grid-leak and cathode bias provides better frequency stability than grid-leak bias alone. The screen and plate circuits of the oscillator are both modulated by the 6V6G modulator tube.

In operation, the circular condenser plate at the plate side of the coil is spaced approximately 1/16-inch from the fixed aluminum plate; the circular plate in the grid circuit should be spaced 1/16 to ⅛ inch from the center fixed plate, depending upon the degree of antenna loading. This plate must be close enough to the stator to supply just sufficient grid excitation for stable oscillation. The position of this condenser plate affects the frequency of operation, so that both con-

modulation. The signal can be received with excellent quality on a selective superheterodyne receiver.

This form of stabilized circuit was first shown in the 1936 edition of *"The 'RADIO' Handbook."* The new type-6V6G beam power tube replaces the type-45 used in the original model. A carrier output of 3 to 5 watts is obtained from this newer transmitter. Another 6V6G tube serves as a modulator, in conjunction with a single-button carbon microphone. A separate 4.5-volt microphone battery allows the use of either a.c. or d.c. heater supply and a.c. or dynamotor plate supply.

The heater drain of the 6V6G tubes is 0.9 amps. at 6 volts, for the two. The total plate current drain is approximately 70 ma. at 250 volts and approximately 85 ma. at 300 volts. The 6V6G tube is a small version of the 6L6G and is primarily designed for automobile receiver service. Its characteristics are similar to those of the 6L6G.

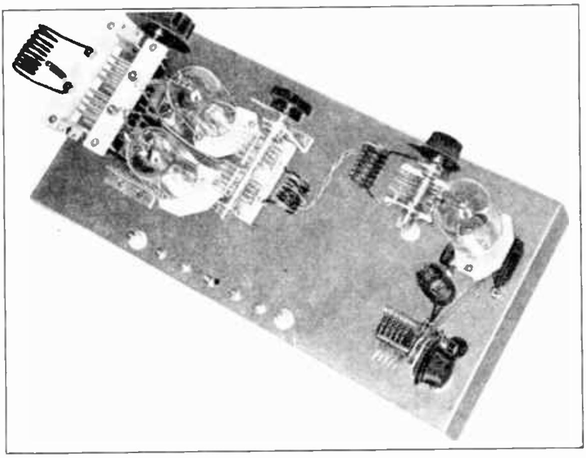


Figure 43—An ultra-efficient buffer-doubler and final r.f. amplifier for 5- and 10-meter operation. The illustration shows a complete group of 5-meter coils in their respective positions. The r.f. plate choke in the final stage is mounted closely to the center tap of the plate coil. Neutralizing condensers for the push-pull 35T stage are barely visible in the photograph; they are mounted directly under the final plate tuning condenser, close to the 35T's and the condenser terminals.

denser plates should be simultaneously adjusted in order to tune the circuit to the desired portion of the 5-meter band. The position of the grid coupling condenser plate is not critical.

High Power 5-Meter Transmitter

Occasionally, the 5-meter signals are reflected back to earth from the Heaviside layer and communications over a distance of several hundred or even several thousand miles can be accomplished. A high power c.w. or phone signal is desirable for these periods of unusual operation.

The amplifier and doubler shown in figures 43 and 44 are capable of furnishing a carrier output of 200 watts when driven by any 6L6G doubler which has a 10-meter output of 10 to 15 watts.

The requirements for satisfactory 5-meter operation demand very short r.f. leads and tubes with low interelectrode capacities. Type 35T tubes are very suitable for this purpose; the amplifier operates in the 5-meter band as easily as a normal amplifier will operate in the 40- or 80-meter bands. A 35T doubler drives the push-pull amplifier through a link-coupled circuit. The grid circuit of the doubler tube is tuned to 10 meters, the plate circuit to 5 meters. If this complete unit is to be used for 10-meter operation, the doubler should have its grid circuit tuned to 20 meters, or it may be used as a neutralized buffer. The plate coil must then be center-tapped and bypassed to ground and a neutralizing condenser connected from one end of the tuned circuit to the grid. Such a circuit can be used as a doubler as well as a buffer, whereas the one shown in figure 44 can be used only as a doubler. If a plate potential much higher than 1250 volts is applied to the doubler, the tuned plate circuit should be center-tapped for the usual neutralizing system in order to prevent excessive regeneration or oscillation in the doubler stage. This doubler is regenerative, even though the grid circuit is tuned to half the frequency of the plate circuit.

The complete unit is built on an 8 in. x 17 in. x 2 in. zinc-coated steel chassis. The doubler plate and grid-tuning condensers are mounted on small standoff insulators, the bypass condensers are soldered to the metal chassis and to the tube or variable condenser terminals. The 10-meter grid coil consists of 13 turns of no. 12 enameled wire, with a winding length of 2 inches. All coils have an inner diameter of ¾-inch. The 5-meter plate tuning coil has 8 turns of no. 12 enameled wire, 1¼ inches long. This coil is tuned by means of a midget variable condenser which has exceptionally wide plate spacing.

A one-turn link coupling circuit drives the grid circuit of the push-pull final amplifier. The grid coil of the final amplifier has 6 turns of no. 12 enameled wire, center-tapped, 1-inch long. The plate coil for the final amplifier has 9 turns of no. 8 enameled wire, 1¾-inches long, and center-tapped. All coils connect directly to the variable condenser terminals. The rotor of the plate tuning condenser remains "floating," and the condenser is mounted several inches above the chassis by means of two vertical panels of bakelite. The neutralizing condensers are mounted directly under the plate tuning condenser, on small standoff insulators; these neutralizing

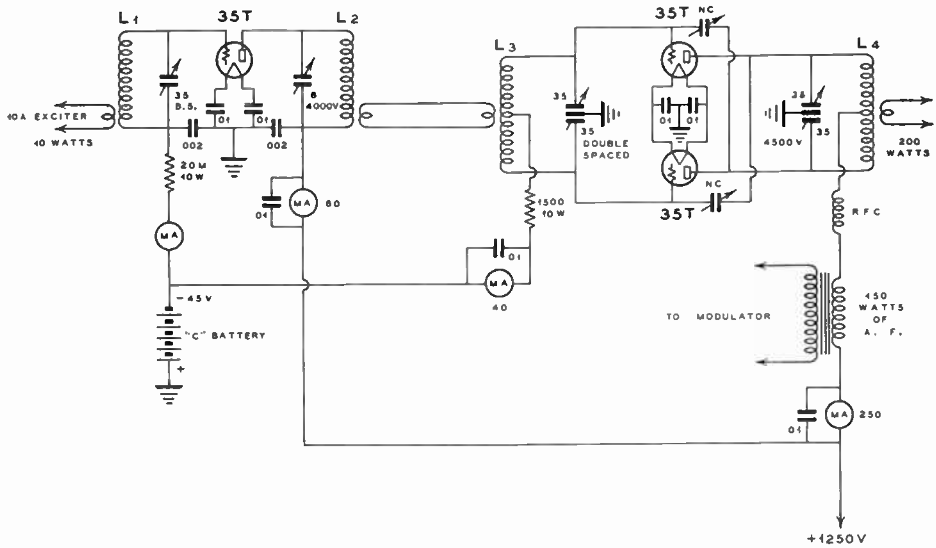


Figure 44—General Wiring Diagram of the 5 and 10 Meter 200 Watt Unit. It Can Be Driven by Any 10 Watt 10 Meter Exciter

condensers have 3 plates widely spaced. The 35T tubes are neutralized with the condensers enmeshed approximately 20 per cent.

If T-20 tubes are used in place of 35T's in the final amplifier, the neutralizing condensers will require a higher maximum capacity. Due to the higher interelectrode capacities of the T-20 tubes, the coil inductances must be reduced by greater spacing between turns. A type TZ-20 doubler tube can be used to drive a pair of T-20 tubes to a carrier output of 60 watts from a 700-volt plate supply.

The plate tuning condenser in the final amplifier must have sufficient spacing between plates to withstand the peak r.f. voltages developed when plate modulating the final amplifier. The new *Cardwell* u.h.f. split-stator condenser shown in the illustration has a 4,500-volt per section flashover rating.

Current readings in the various circuits, when 35T tubes are used with a 1,250-volt power supply, are as follows:

Doubler grid current..........10 to 15 ma.
Doubler plate current..........80 to 90 ma.
Final grid current....................40 ma.
Final plate current..................250 ma.

At this input to the final amplifier, 150 watts of audio power is required for 100 per cent modulation. This amount of power can be secured from a pair of 35T tubes in class-B.

A combination of grid-leak and battery-bias makes it possible to key the crystal oscillator for c.w. telegraphy.

The antenna should be inductively coupled to the final amplifier plate coil. The most desirable arrangement is by link coupling to an additional tuned circuit connected across the antenna feeders.

Scientific Progress in the U.H.F. Field

Individual experimentation and observations in the ultra high frequency field can result in little scientific accomplishment or progress unless correlated with the results and observations of others working for the advancement of u.h.f. communication.

Amateur radio has enjoyed the reputation of having been instrumental in pioneering and popularizing the wavelengths between 10 and 160 meters. We have another chance to contribute something to the advancement of the art. But nothing can be accomplished without correlation of observations and results.

When you have anything unusual to report in the way of circuits, antennas, sky-wave communication, weather or sunspot correlation, or anything else that will help in gathering useful data on the ultra high frequencies, mail it to:

Associate Editor of RADIO Magazine,
512 N. Main St., Wheaton, Ill.

Chapter 16

Power Supplies

Any device which incorporates vacuum tubes requires a power supply for the filament and plate circuits of the tube or tubes. The filaments of the tubes must be heated in order to produce a source of electrons within the vacuum tubes; direct-current voltages are needed for the other electrodes in order to obtain detection, amplification, oscillation, and rectification.

Either a.c. or d.c. voltage may be used for filament power supply in most applications; however, the a.c. power supply is the more economical, and can be used with most tubes without introduction of hum in the output of the vacuum tube device. The plate potential must be secured from a d.c. source, such as from batteries or a rectified and filtered a.c. power supply.

The a.c. current first must be converted into a uni-directional current; this is accomplished by means of vacuum tube *rectifiers*, of either the *full-* or *half-wave* type.

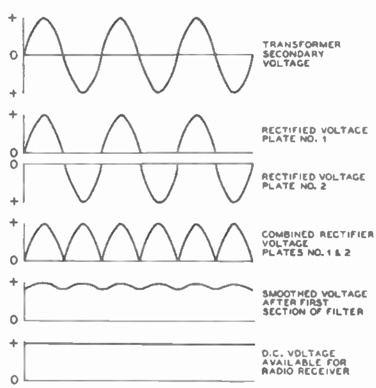


Figure 1—Showing effects of rectification and filtering of an AC current.

A half-wave rectifier passes one-half of the wave of each alternation of the a.c. current and blocks the other half. The output current is of a *pulsating* nature, which can be smoothed into pure, direct current by means of *filter* circuits. Half-wave rectifiers produce a pulsating current which has zero output during one-half of each a.c. cycle; this makes it difficult to filter the output properly into d.c. and also to secure good voltage regulation for varying loads.

A full-wave rectifier consists of two half-wave rectifiers working on opposite halves of the cycle, connected in such a manner that each half of the rectified a.c. wave is combined in the output as shown in figure 1. This pulsating uni-directional current can be filtered to any desired degree, depending upon the particular application for which the power supply is designed.

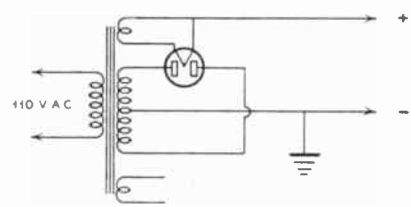


Figure 2

A full-wave rectifier consists of two plates and a filament, either in a single glass or metal envelope for low voltage rectification, or in the form of two separate tubes, each having a single plate and filament for high voltage rectification. The plates are connected across the high voltage a.c. power transformer winding, as shown in figure 2. The power transformer is for the purpose of transforming the 110-volt a.c. line supply to the desired secondary a.c. voltages for filament and plate supplies. The transformer delivers alternating current to the two plates of the rectifier tube; one of these plates is positive at any instant during which the other is negative. The center point of the high voltage transformer winding is usually grounded, and is, therefore, at zero voltage, thereby constituting the *negative "B" connection.*

When one plate of the rectifier tube is conducting, the other is inoperative, and vice-versa. The output voltages from the rectifier are connected together through a common rectifier filament circuit, and thus the plates alternately supply pulsating current to the output circuit. The rectifier tube filaments are always positive in polarity with respect to the output.

The output current pulsates 120 times per second for a full-wave rectifier connected to a 60-cycle a.c. line supply, and the output from the rectifier must connect to a *filter,* which will smooth the pulsations into direct current. Filters are designed to select or reject alternating currents; those most commonly used in a.c. power supplies are of the *low-pass* type. This means that pulsating currents which have a frequency below the cut-off frequency of the filter will pass through the filter to the load. Direct current can be considered as alternating current of zero frequency; this passes through the low-pass filter. The 120-cycle pulsations are similar to alternating current in characteristic, so that the filter must be designed to have a *cut-off* at a frequency *lower than* 120 *cycles.*

• Filter Circuits

A low-pass filter consists of combinations of inductance and capacitance. An inductance or *choke coil* offers an impedance to any change in the current that flows through it. A high inductance choke coil offers a relatively high resistance to the flow of pulsating current, with the result that the *a.c. component* or *ripple* passes from the rectifier tube through the load only with the greatest of difficulty. A capacitance has exactly the opposite action to that of an inductance. It offers a low impedance path to the flow of alternating or pulsating current, but represents practically infinite resistance to the flow of direct current. Inductance coils are usually connected in series with the rectifier outputs, while condensers are connected across the positive and negative leads of the output circuit. A simple filter circuit is shown in figure 3.

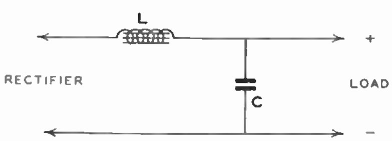


Figure 3

Electricity always follows the path of least resistance or impedance. The direct current will travel through the choke and back to the ground (negative B) connection through the *external load,* which normally consists of the plate circuits of vacuum tubes. The a.c. component, or ripple, tends to be impeded by the choke and short-circuited by the condensers across the filter, which offer a lower resistance to the pulsating voltage than that offered by the load. The *load impedance* across the output of most filter systems is generally high, usually from 5,000 to 10,000 ohms. This load resistance can be calculated by dividing the output voltage by the total load current, this value is necessary in making calculations for low-pass and resonant types of filter circuits.

A resonant type filter is shown in figure 4, in which a condenser C_1 tunes the choke coil inductance to series resonance at the ripple frequency. Series resonance provides a very low impedance to the resonant frequency limited only by the actual resistance of the choke coil (since the reactance of both the condenser C_1 and the choke coil cancel each other.)

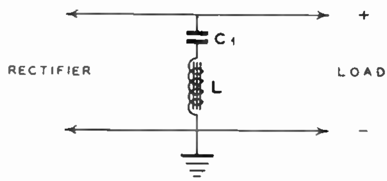


Figure 4

The filter circuit in figure 4 accomplishes the same purpose as a large shunt condenser at the ripple frequency, but is not effective in short-circuiting the higher harmonics in the output of the rectifier system. Additional low-pass filter circuits are needed to remove these harmonic components, which are of great enough magnitude to produce objectionable high-pitched hum in the vacuum tube amplifier circuits.

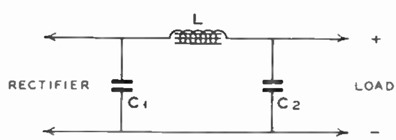


Figure 5

A typical *low-pass* filter is diagrammed in figure 5. The combination of C_1, C_2 and L should give a "cut-off" frequency below that of the rectified output pulsation frequency.

This type of filter is very effective because the circuit can be designed with *any* cut-off frequency, as long as the attenuation or rejection at the 120-cycle-and-higher harmonic frequencies is great. This type of filter is sometimes called a *"brute force filter,"* because large values of inductance and capacitance are normally used without much attention being paid to the actual cut-off frequency. Inductance values of 10 to 30 henrys are used for filter chokes, and shunt capacities of from 2 to 16 microfarads are used for C_1 and C_2 in figure 5.

A *resonant trap circuit,* such as shown in figure 6, is sometimes used to increase the impedance of the choke *L* at some particular frequency, such as 120 cycles per second.

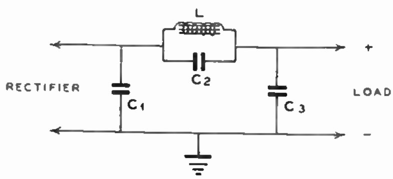


Figure 6

Parallel resonance of C_2 and L provides a very high impedance at the resonant frequency. The condenser C_3 tends to bypass the higher ripple harmonics that get through the trap circuit. This type of filter is often used in conjunction with an additional section of filter of the type shown in figure 3.

The single-section, low-pass filter in figure 5 is often combined with an additional choke coil is shown in figure 7. The additional choke coil L_1 is an aid in filtering and also provides better voltage regulation for varying d.c. loads, such as presented by a class-B audio amplifier.

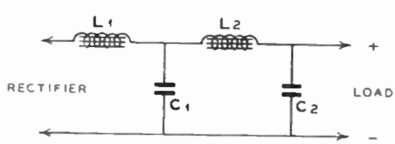


Figure 7

A two-section, low-pass filter with condenser input is shown in figure 8. In some cases, additional sections of choke coils and condensers are added for the purpose of obtaining very pure direct current.

Resistors may be used in place of inductances in circuits where the load current is of low value, or where the applied d.c. voltage must be reduced to some desired value.

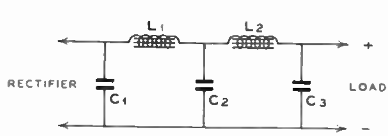


Figure 8

The ripple in the output of a filter circuit can be measured with an oscilloscope or by means of the simple circuit in figure 9. A high voltage condenser C_3, having a capacity of from ¼ to 1 μfd., and a high-resistance copper oxide a.c. voltmeter provides a method of measuring the actual *ripple voltage.*

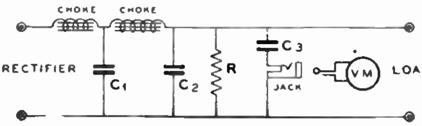


Figure 9—Circuit for Measuring A.C. Ripple

The voltmeter should be plugged into the measuring jack after the power supply and external load circuit are in *normal operating condition,* and the meter should be removed from the shorting type jack before turning off the power supply or removing the load. The charging current through condenser C_3 would tend to burn out the meter if it were left in the circuit at all times.

• Filter Circuit Considerations

The shunt condensers in a filter system serve a dual purpose: (1) a low impedance path for ripple, and (2) an energy storing system for maintaining constant power output from the power supply. The condensers are charged when the peak voltage is applied across them from the output of the rectifier; during the time in which the rectifier output decreases to zero, the filter condensers supply output current to the load. This action provides a constant output voltage.

In an a.c. circuit, the maximum peak voltage or current is the square-root of 2, or 1.41 times that indicated by the a.c. meters in the circuit. The meters read the *root-mean-square* (r.m.s.) values, which are the peak values divided by 1.41 for a sine wave.

If a potential of 1,000 r.m.s. volts is obtained from a high voltage secondary winding of a transformer, there will be 1,410 volts peak potential from the rectifier plate to ground. The rectifier tube has this voltage impressed on it, either positively when the current flows or *"inverse"* when the current is blocked on the other half-cycle. The *inverse peak voltage* which the tube will stand safely is used as a rating for rectifier tubes. At higher voltages the tube is liable to arc-back, thereby destroying it. The relations between peak inverse voltage, total transformer voltage, and filter output voltage depend upon the characteristics of the filter and rectifier circuits (whether full or half-wave, bridge, etc.).

Rectifier tubes are also rated in terms of *peak current load.* The actual d.c. load current which can be drawn from a given rectifier tube or tubes depends upon the type of filter circuit. A full-wave rectifier with condenser input may be called upon to deliver a peak current several times the d.c. load current.

In a filter with choke input, the peak plate current is not nearly so much greater than the load current, provided the inductance of the choke is fairly high.

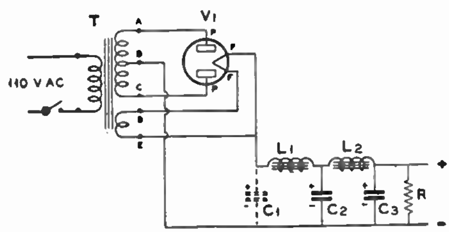


Figure 10—When "C1" is connected in the circuit, the filter is termed "Condenser Input." If "C1" is omitted, the filter is called "Choke Input."

A full-wave rectifier with two rectifier elements requires a transformer which delivers twice as much a.c. voltage as would be the case for a half-wave rectifier or bridge rectifier. The bridge rectifier is another type of full-wave circuit in which four rectifier elements or tubes are operated from a single high-voltage winding on the power transformer.

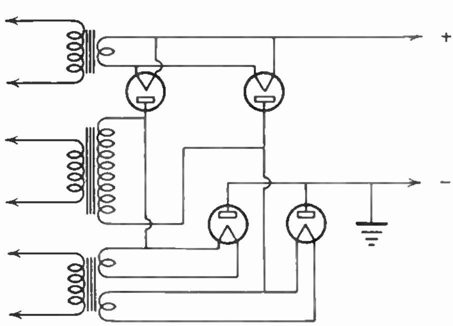


Figure 11—Bridge Rectifier Circuit

While twice as much output voltage can be obtained from a bridge rectifier as from a center-tapped circuit, the permissible output current, is only one-half as great for a given power transformer. In the bridge circuit, four rectifier and three filament heating transformer windings are needed, as against two rectifiers and one filament winding in the center-tap, full-wave circuit.

The output voltage across the filter circuit depends upon the design of the filter, resistance of rectifier, power transformer, and load resistance. A low resistance rectifier, such as the mercury-vapor type-83 or 866, has very low voltage drop in comparison to most *high-vacuum* (not mercury-filled) rectifiers. The filter circuit with *condenser input,* i.e., a condenser across the rectifier output, will deliver a higher d.c. voltage than one with *choke input,* but with a sacrifice both in voltage regulation and the amount of available load current.

The d.c. voltage across the load circuit of a condenser-input filter may be as high as 1.4 times the a.c. input voltage (r.m.s) across one of the rectifier tubes if the input condenser capacity is large and the current drain small. Low values of load resistance (heavy current drain) will cause this type of power supply to have a d.c. voltage output as low or even lower than the a.c. input to the rectifier. The maximum permissible load current in this same circuit is less for a given transformer-secondary wire size and rectifier tube peak current rating tnan would be the case for a choke-input filter.

A choke-input filter will reduce the d.c. voltage to a value of 0.9 the a.c., r.m.s. value, but the output voltage with choke input is fairly constant over a wide range of load resistances, and the allowable load current is greater than with condenser input for a given rectifier tube and power transformer.

• Types of Chokes

A *filter choke coil* consists of a coil of wire wound on a laminated iron or steel core. The size of wire is determined by the amount of d.c. current which is to flow through the choke coil. This direct current magnetizes the core and reduces the inductance of the choke coil; therefore, filter choke coils of the "smoothing" type are built with an airgap, a small fraction of an inch in the iron core, for the purpose of preventing saturation when maximum d.c. flows through the coil winding. This airgap is usually in the form of a piece of fiber inserted between the ends of the laminations. The airgap reduces the initial inductance of the choke coil, but keeps it at a higher value under maximum load conditions. The coil must have a great many more turns for the same initial inductance when an airgap is used.

As explained earlier in this chapter, choke input tends to keep the output voltage of the filter at approximately 0.9 of the r.m.s.

voltage impressed upon the filter from the rectifiers. However, this effect does not take place until the load current exceeds a certain minimum value. In other words, as the load current is decreased, at a certain critical point the output voltage begins to soar. This point is determined by the inductance of the input choke. If it has high inductance, the current can be reduced to a very low value before the output voltage begins to soar. Under these conditions, a low-drain bleeder resistor will keep the current in excess of the critical point and the voltage will not "soar" even if the external load is removed. For this purpose, chokes are made with little or no airgap in order to give them more inductance at low values of current. Their filtering effectiveness at maximum current is impaired somewhat, but it permits use of a smaller bleeder to keep the current in excess of the critical value. Such chokes are called *"swinging chokes"* because, while they have high initial inductance, the inductance rapidly falls to a comparatively low value as the current through the choke is increased.

The d.c. resistance of any filter choke should be as low as possible in conjunction with the desired value of inductance. Small filter chokes, such as those used in radio receivers, usually have an inductance of from 20 to 30 henrys, and a d.c. resistance of from 200 to 400 ohms. A high d.c. resistance will reduce the output voltage, due to the voltage drop across each choke coil. Filter choke coils for radio transmitters and class-B amplifiers usually have less than 100 ohms a.c. resistance.

• Types of Filter Condensers

There are two types of filter condensers: (1) Paper dielectric type; (2) Electrolytic type.

Paper condensers consist of two strips of metal foil, separated by several layers of waxed paper. Some types of paper condensers are wax-impregnated; others, especially the high voltage types, are oil-impregnated. High voltage filter condensers which are oil-impregnated will withstand a greater peak voltage than those impregnated with wax, but they are more expensive to manufacture. Condensers are rated both for *"flash"* test and normal operating voltages; the latter is the important rating and is the maximum voltage which the condenser should be required to withstand in service.

The condenser across the rectifier circuit in a condenser-input filter should have a working voltage rating equal to at least 1.41 times the r.m.s. voltage out of the rectifier. The remaining condensers may be rated more nearly in accordance with the d.c. voltage.

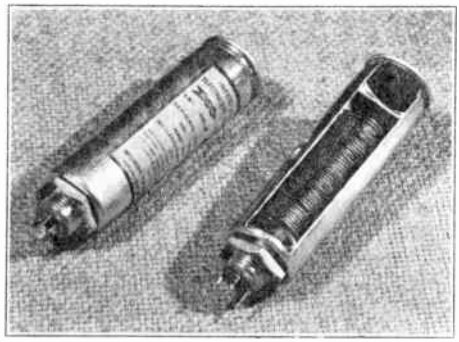


Figure 12—Newer Form of Electrolytic Condenser with a Bank of Electrodes, Rather Than a Foil-Coated Layer.

Electrolytic condensers are of two types: (1) Wet; (2) Dry. The wet electrolytic condenser consists of two aluminum electrodes immersed in a solution called *"electrolyte."* A very thin film of oxide is formed on the surface of the metal, and this acts as the dielectric. The electrolytic condenser must be correctly connected in the circuit because it has positive and negative electrodes, and a reversal of the polarity will ruin the condenser. The dry type of electrolytic condenser uses aluminum electrodes with an electrolyte in the form of paste. The dielectric in both kinds of electrolytic condensers is not perfect; these condensers have a much higher d.c. current leakage than the paper type. The leakage current is greater in the wet electrolytic than in the dry types.

The high capacitance of electrolytic condensers results from the very thin film which is formed on the plates. The maxi-

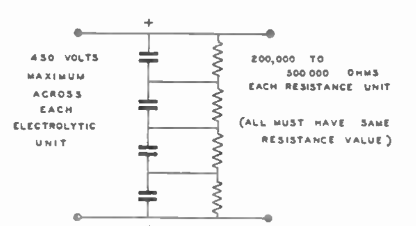


Figure 13—Electrolytic condensers connected in series plus to minus, with 500,000-ohm, 1-watt, resistor connected across each condenser in order to equalize the leakage and to prevent excessive strain on any one section of condenser.

mum voltage that can be safely impressed across the average electrolytic filter condenser is between 450 and 600 volts; the working voltage is usually rated at 450. When electrolytic condensers are used in filter circuits of high voltage supplies, the condensers should be connected in series, as shown in figure 13. The positive terminal of one condenser must connect to the negative terminal of the other, in the same manner as dry batteries are connected in series. Grid-leak resistors of equal value should be connected across each condenser in order to equalize the leakage and to provide a more uniform d.c. voltage drop across each condenser section.

The capacity of two condensers in series is only one-half that of a single condenser, but the voltage breakdown rating is doubled. Four condensers in series give only one-fourth as much capacity as a single condenser, but the voltage breakdown rating is approximately four times as high. There is very little economy in using electrolytic condensers in series in circuits where more than two of these condensers would be required to prevent voltage breakdown.

Bleeder Resistors

A heavy duty resistor should be connected across the output of a filter in order to draw some load current at all times. This resistor avoids "soaring" at no load when swinging choke input is used, and also provides a means for discharging the filter condensers when no external vacuum tube circuit load is connected to the filter. This *"bleeder"* resistor should normally draw approximately 10 per cent of the full load current. The power dissipated in the bleeder resistor can be calculated by dividing the square of the d.c. voltage by the resistance. This power is dissipated in the form of heat, and, if the resistor is not in a well ventilated position, the wattage rating should be higher than the actual wattage being dissipated. The following table gives suitable values of bleeder resistors for power supply systems with from 500 to 3,000 volts output.

Rectifier Circuits

The three types of rectifier circuits for single-phase a.c. line supply consist of a half-wave rectifier, as shown in figure 17, a full-wave rectifier as shown in figure 18, and a bridge rectifier circuit as shown in figure 19.

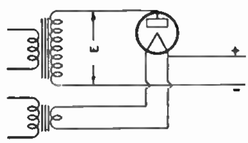


Figure 17

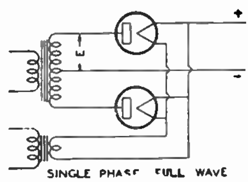


Figure 18

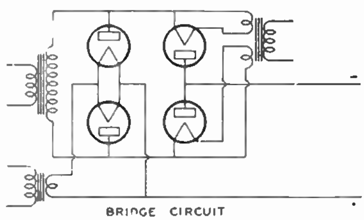


Figure 19

Three-phase circuits can be connected for half-wave rectification, as shown in figure 20, or for full-wave rectification as shown in figure 21.

The most popular circuits are those shown in figures 18 and 19. The maximum transformer voltage of the high voltage secondary, d.c. output voltage for choke-input filter, and maximum d.c. load current are shown in the accompanying table in terms

Output Voltage	Resistance In Ohms	Actual Dissipated Power In Watts	Recommended Resistor Wattage Rating
500	25,000	10	25
1,000	50,000	20	50
1,500	75,000	25	50
2,000	100,000	40	100
2,500	150,000	42	100
3,000	200,000	45	100

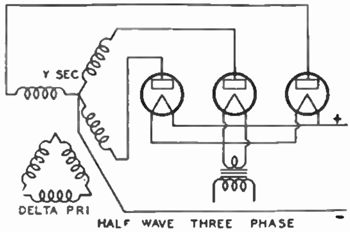


Figure 20

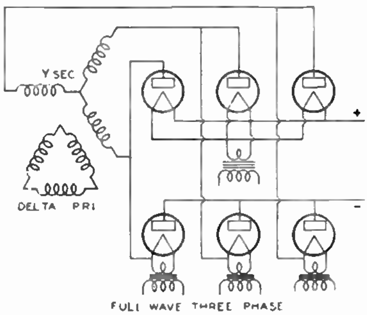


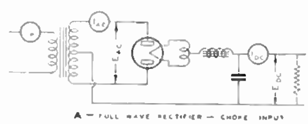
Figure 21

of rectifier tube peak ratings. These peak ratings are listed in a separate table for a few commonly used rectifier tubes.

An example for applying the figures in the table, if type-866A rectifier tubes are used as in figure 15, is given here: The maximum transformer voltage E across each side of the center-tap is 0.35 times 10,000 or 3,500 volts. The d.c. voltage at the input to the filter (choke input) is 3,500 times 0.9 or 3,150 volts. The maximum advisable d.c. output current is 0.66 times the peak plate current of 0.6 ampere or 396 milliamperes.

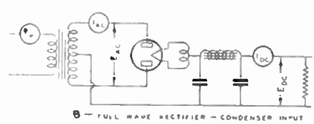
These are the maximum voltages and currents which can be used without exceeding the ratings of the rectifier tubes. The actual d.c. voltage at the output of the filter will depend upon the d.c. resistance of the filter, and can be found by subtracting the *IR* drop across the filter chokes from the value of 0.9 times the transformer voltage *E*. This does not take into consideration the voltage drop in the power transformer and rectifier tubes. The voltage drop across a mercury vapor rectifier tube is always between 10 and 15 volts. However,

Tube Type	Peak Inv. Volts	Peak Plate Current (amp.)
66 Jr.	2,500	.25
82	1,400	.40 } per sect.
83	1,400	.80 } per sect.
66	7,500	.6
66A	10,000	.6
72	7,500	2.5
72A	10,000	2.5
869	20,000	5.0



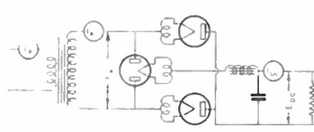
E_{DC}-435 V
I_{DC}-100 MA
E_{AC}-1100 V
I_{AC}-71 MA
I_{PRI}-.6 MA

Figure 22



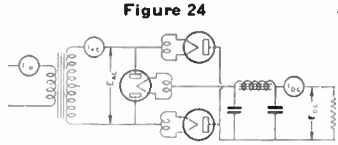
E_{DC}-675 V
I_{DC}-100 MA
E_{AC}-1100 V
I_{AC}-103 MA
I_{PRI}-.9 MA

Figure 23



E_{DC}-860 V
I_{DC}-100 MA
E_{AC}-1100 V
I_{AC}-96 MA
I_{PRI}-1.1 A

Figure 24



E_{DC}-1200 V
I_{DC}-100 MA
E_{AC}-1100 V
I_{AC}-148 MA
I_{PRI}-1.65 A

Figure 25

Typical voltage and current readings in various types of power supplies.

Figure No.	Transformer Volts Max. "E"	DC Output Volts at Input to Filter	DC Output Current In Amperes
18	.35 x Inv. Pk. Vtg.	.9 x E	.66 x Pk. Plate
19	.7 x Inv. Pk. Vtg.	.9 x E	.66 x Pk. Plate
20	.43 x Inv. Pk. Vtg.	1.12 x E	.83 x Pk. Plate
21	.43 x Inv. Pk. Vtg.	2.25 x E	1.0 x Pk. Plate

the voltage drop across high-vacuum rectifier tubes can be many times greater.

The power supply circuits illustrated in figures 22 to 25 represent commonly-used connections for power transformers. The values of d.c. output voltage are indicated in each case for a load current of 100 ma. The transformer secondary potential is 1,100 volts. The interesting figures in connection with each circuit are those of the primary winding current.

The circuit in figure 25 should never be used unless the load current is very low. Manufacturers generally rate their transformers in terms of secondary r.m.s. voltage and the maximum d.c. load current which can be taken *from a choke input filter* circuit such as shown in figure 22. In order to prevent overload of the power transformer, the load current must be reduced to less than one-third of the value which can be drawn from the circuit in figure 22. The load which can be drawn from the circuit in figure 24 without overload to the power transformer is approximately 50 per cent of that for the circuit in figure 22. The permissible d.c. load current in figure 23 would only be two-thirds as much as for figure 22, for a given transformer size.

• Mercury Vapor Rectifier Tubes

When new high voltage mercury vapor rectifier tubes are first placed in service, the filaments should be operated at normal temperature for approximately 20 minutes before plate voltage is applied, in order to remove all traces of mercury from the cathode. After this preliminary operation, plate voltage can be applied within 20 to 30 seconds of the time the filaments are turned on, each time the power supply is again used. If plate voltage is applied before the filament is brought to full temperature, active material may be knocked off the oxide-coated filament and the life of the tube will be greatly shortened.

Small r.f. chokes must sometimes be connected in series with the plate leads of mercury vapor rectifier tubes in order to prevent the generation of radio-frequency "hash." These r.f. chokes must have sufficiently heavy wire to carry the load current and enough inductance to attenuate the r.f. parasitic noise current from flowing into the filter supply leads and thereby radiating into nearby radio receivers.

Small resistors or small iron-core choke coils should be connected in series with each

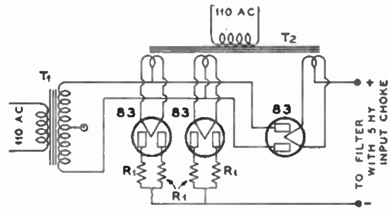


Figure 26

Bridge rectifier suitable for 1000-volt supply. Equalizing resistors are 100 ohms each, 10 w.

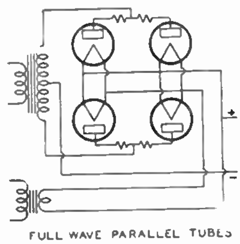


Figure 27

plate lead of a mercury vapor rectifier tube when used in circuits such as those shown in figures 26 and 27.

These resistors tend to prevent one plate from carrying the major portion of the current. *High-vacuum* type rectifiers which are connected in parallel do not require these resistors or chokes.

• Bias Voltage Power Supplies

Power supplies to supply negative grid voltage for radio or audio amplifiers differ from plate supplies only in that the positive and negative connections are reversed; the positive terminal of a C-bias supply is connected to ground. The filter chokes are usually connected in series with the "hot" lead, which in this case is the *negative* lead. A simple C-bias power supply for negative grid bias for a class-A audio amplifier is shown in figure 29.

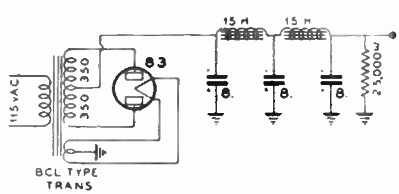
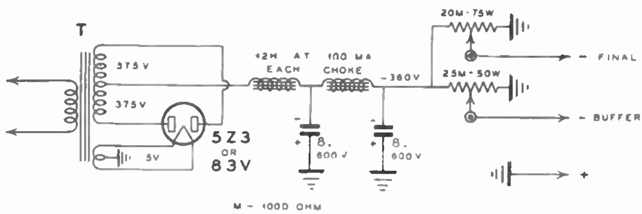


Figure 29—Here is a Bias Pack which uses a medium-to-high resistance bleeder. Voltage regulation is usually unimportant in biasing a class A modulator and very little bleeder is used.



ADJUST BIAS FOR ZERO PLATE CURRENT WHEN TUBE IS NOT BEING EXCITED

BIAS UNIT

Figure 30

The value of C-bias depends upon the secondary voltage of the transformer and whether condenser or choke input to the filter is used.

The bias voltage supply for a linear r.f. amplifier or class-B audio amplifier must have a very low resistance bleeder; a circuit such as the one in figure 31 is satisfactory. The power transformer must be rated to carry a d.c. load current of approximately 250 ma., which is dissipated in the low-resistance bleeder.

The exact required voltage for a class-B audio amplifier can be obtained by means of a slider on the bleeder resistor, provided the latter has a very low resistance, such as 800 to 2,000 ohms. The transformer secondary voltage should preferably be chosen in such a manner that the correct bias voltage is obtained at the output terminals of the filter.

A bias power supply for medium power radio transmitters is shown in figure 30.

Two bleeder resistors with slider adjustments provide any desired value of negative grid bias for the r.f. amplifiers. The location of the slider on the resistors should be determined experimentally with the amplifier in operation, since the d.c. grid current of the r.f. amplifier itself will affect the voltage across the bias supply taps. If the final r.f. amplifier or buffer-amplifier operates with high μ tubes, the values of bleeder resistance shown in figure 30 may have to be reduced as much as 50 per cent. The total resistance in series with the grid to ground acts as a grid-leak resistance. The circuit illustrated is practically free from reaction between buffer and final amplifier bias.

• Transmitter Power Input Control

The U. S. Government regulations require that only sufficient power input to a radio transmitter be used to maintain satisfactory communication. The power input to the final r.f. amplifier of a c.w. transmitter can be controlled over a very wide range by means of an *auto-transformer,* connected as shown in figure 32.

The a.c. voltage can be varied from a few volts up to 130 volts, by means of a relatively small auto-transformer. This a.c.

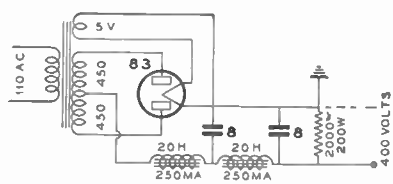


Figure 31—In the Bias Pack shown above, a low-resistance bleeder is used to provide a constant voltage output. A Bias Pack of this type is suitable for class B audio or class BC Linear Amplifier operation. The ungrounded side is the negative terminal.

voltage should be applied only to the high-voltage power transformer which supplies plate power to the final r.f. amplifier.

Convenient adjustment of input to a phone transmitter other than of the plate-modulated type is a more difficult problem. Input to a plate-modulated transmitter can be varied the same as for a c.w. transmitter without danger of overmodulating the reduced input if the primary voltage for the plate transformer that feeds the modulators

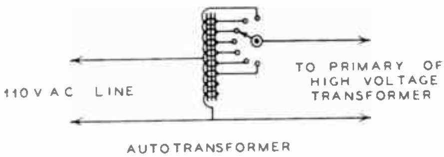


Figure 32

is fed from the same tap on the auto transformer as the plate transformer for the final amplifier. If one power supply is used for both, the problem is further simplified.

Reducing the power of a grid-modulated final amplifier is more of a problem. The best method for reducing power is to reduce the r.f. excitation *and* audio gain together,

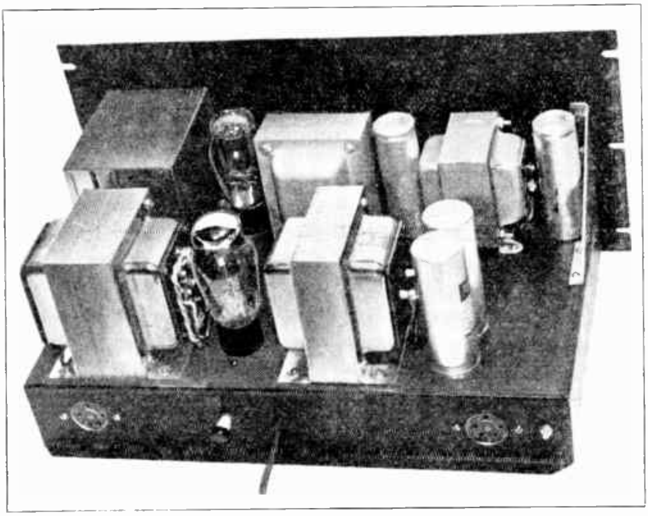


Figure 33—Dual-power supply for crystal oscillator, buffer-doubler and speech amplifier service. The unit closest to the front panel delivers from 350 to 400 volts, the other is a 600-volt supply for a buffer stage. Bleeder resistors are under the chassis. Wafer sockets are for plug-in terminals and cords.

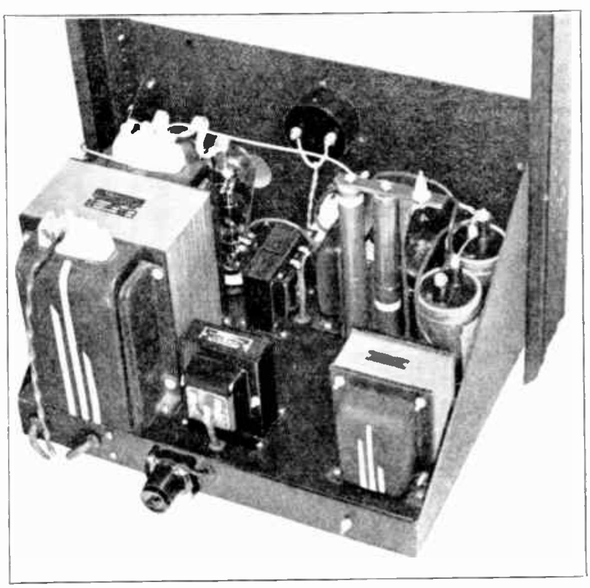


Figure 34—High-Voltage Power Supply with "Streamline" Transformer and Chokes. This unit delivers 1750 or 1500 volts for the medium-power phone transmitter described in the Chapter on Radiotelephone Transmitter Construction.

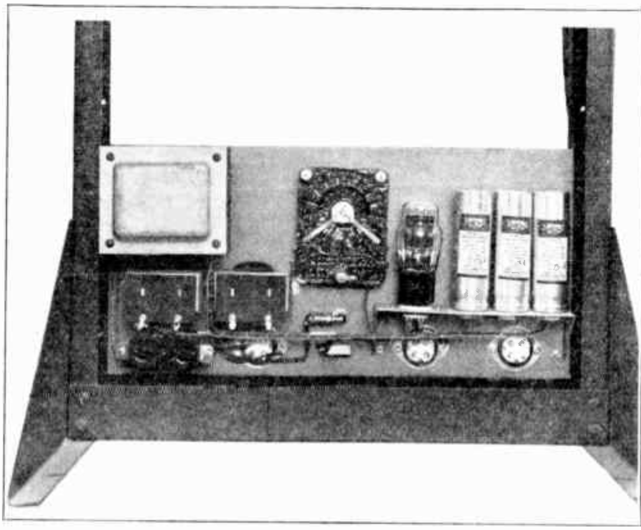


Figure 35—A laboratory type power supply which makes provision for various heater and plate voltages, with socket plugs for cable connections to any device under test. Some components are secured directly to the front panel, the others on a subdeck. A variable resistor allows line voltage adjustment over a wide range.

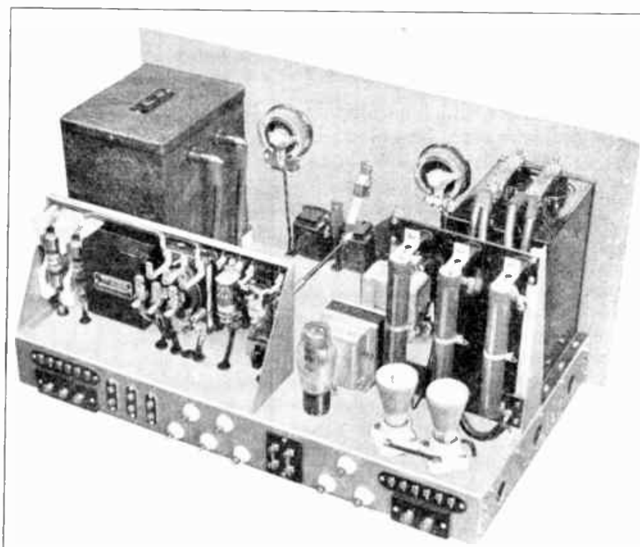


Figure 36—This unit, and the one illustrated in figure 37, are referred to in the W6LVS transmitter description in the radiotelephone construction chapter of this handbook. Figure 36 shows the relay-switching control unit, bias supply, bleeder resistors and filament supply transformers for a high power modulator. Figure 37 shows the high-power plate supply system for this same transmitter. A "pole pig" transformer, re-encased and re-impregnated, is shown at the far right in figure 37.

without disturbing the bias or plate voltage or antenna coupling adjustment.

Those using linear r.f. amplifiers can either incorporate a switching arrangement for throwing the antenna over to the low-level modulated stage and thus reduce power about 10 db, or else merely reduce excitation to the linear amplifier *without* disturbing the a.f. gain control.

Transformer Design

A common problem in radio and allied work is to determine how a transformer can be built to supply certain power requirements for a particular application, or how to calculate the windings needed to fit a certain

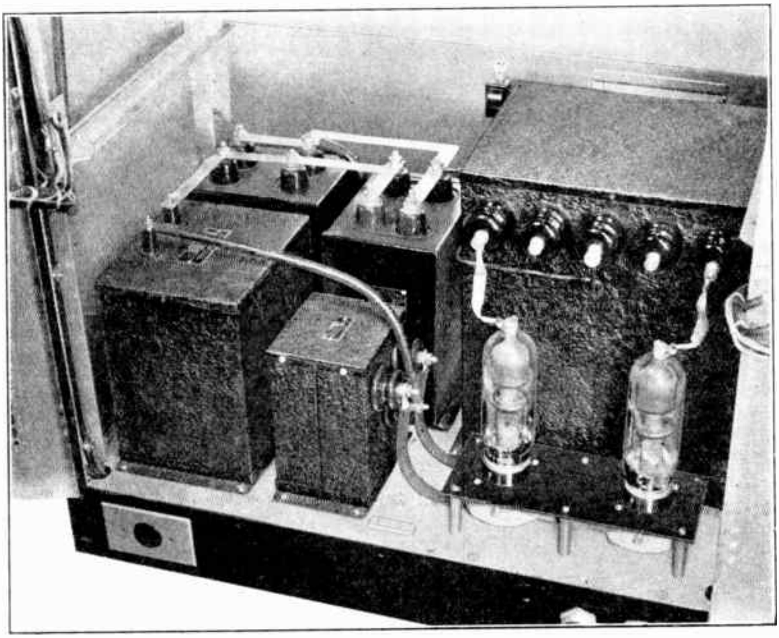


Figure 37—High voltage, high power plate supply referred to in figure 36.

transformer core which is already on hand. These problems can be solved by a small amount of calculation.

The most important factor in determining the size of any transformer is the amount of core material available. The electrical rating, as well as the physical size, is determined almost entirely by the size of the core. The core material is also important. The present practice is to use high-grade silicon-steel sheet. It will be assumed that this type of material is to be employed in all construction herein described. Soft sheet-iron or stovepipe iron is sometimes substituted, but transformers made from such materials will have about 50 to 60 per cent of the power rating, pound for pound of core, as those made from silicon-steel.

The core size determines the performance of a transformer because the entire energy circulating in the transformer (except small amounts of energy dissipated in resistance losses in the primary) must be transformed from electrical energy in the primary winding to magnetic energy in the core, and reconverted into electrical energy in the secondary. The amount of core material determines quite definitely the power that any transformer will handle.

Transformer cores are often designed so that if the losses per cubic inch of core material are determined, these losses can be used as a basis for calculating the rating of the transformer. These losses exist in watts, and are divided between the eddy current loss and the hysteresis loss. The eddy current loss is the loss due to the lines of force moving across the core, just as if it were a conductor, and setting up currents in it. Induced currents of this type are very undesirable and they are merely wasted in heating the core, which then tends to heat the windings, increase the resistance of the coils and reduce the overall power handling ability of the transformer. To reduce such losses, transformer cores are made of thin sheets, usually about no. 29 gauge. These sheets are insulated from each other by a coat of thin varnish, shellac or japan, or by the iron-oxide scale which forms on the sheets during the manufacturing process and which forms a good insulator between sheets.

"Hysteresis" means "to lag." and hysteresis in an iron-core means that the magnetic flux in the core lags behind the magnetizing force that produces it, which is, of course, the primary supply. Because all transformers operate on alternating current. the core is subjected to continuous magnetizing and demagnetizing force, due to the alternating effect of the a.c. field. This force heats the iron, due to molecular friction caused by the iron molecules re-orienting themselves as the direction of the magnetizing flux changes.

The higher the field strength, the greater the heat produced. A condition can be reached where a further increase in magnetizing flux does not produce a corresponding increase in the flux density. This is called "saturation" and is a condition which would cause considerable heat in a core. In practice, it has been found that all core material must be operated with the magnetic flux well below the limit of saturation.

Core losses manifest themselves as heat and these losses are the determining factor in transformer rating. They are spoken of as "total core loss," generally used as a single figure, and for common use a core loss of from .75 watts to 2.5 watts per pound of core material can be assumed for 60 cycles. The lower figure is for the better grades of thin sheet, while the higher loss is for heavier grades.

About 1 watt per pound is a very satisfactory rating for common grades of material. This rating is also dependent on the manner in which the transformer is built and mounted and in the ease with which the heat is radiated from the core. Transformers with higher losses may be used for intermittent service.

The transformer core loss can be assumed to be from 5 to 10 per cent of the total rating for small transformers. Thus, if the core loss is known, the rating of the transformer can be easily determined. If the figure of 1 watt per pound is assumed, the problem is further simplified. To determine the rating of the transformer, weigh the core. If, for example, the core weighs 10 pounds, the transformer will handle from 100 to 200 watts. Such a transformer core can be assumed to have about 150 watts nominal rating.

If the weighing of the core is inconvenient, the weight can be calculated from the cubic content or volume. Sheet-steel core laminae weigh approximately one-fourth pound per cubic inch.

Transformer cores are generally made of two types, shell and core. The shell-type has a center leg which accommodates the windings, and this is twice the cross-sectional areas of the side legs. The core-type is made from strips built-up into a hollow-like affair of uniform cross section. For the shell-type core, the area is taken as the square section of the center leg, in this case 2¼ in. x 4½ in. and in the core-type, this area is taken as the section of 1 leg, and is also 2¼ in. x 4½ in., or an actual core area in both cases of 10.1 square inches, which is large enough for a comparatively large transformer.

To determine the number of turns for a given voltage, apply the following formula:

$$E = \frac{4.44\ N\ B\ A\ T}{10^8}$$

Where E equals the volts of the circuit; N, the cycles of the circuit; B, the number of magnetic lines per square inch of the magnetic circuit; A, the number of square inches of the magnetic circuit, and T, the number of turns.

The proper value for B, for small transformers, and for ordinary grades of sheet-iron, such as are now being considered, is 75,000 for 25 cycles and 50,000 for 50 or 60 cycles.

Rewriting the above formula:

$$T = \frac{E \times 10^8}{4.44\ N\ B\ A\ T}$$

and since N and B are known

$$T = \frac{10^8}{4.44 \times 60 \times 50{,}000} \times \frac{E}{A}$$

from which

$$T = 7.5 \times \frac{E}{A}$$

That is, for a transformer to be used on a 60-cycle circuit, the proper number of turns for the primary coil is obtained by multiplying the line-voltage by 7.5 and dividing this product by the number of square inches cross-section of the magnetic circuit.

On a 25-cycle circuit, the 7.5 becomes 12, and on 50 cycles it becomes 9.

• Tentative Design

Assume a transformer core that is to be used on a 115-volt, 60-cycle circuit for supplying power to two rectifier tubes, each of which takes 1,000 volts on the plate. The rectifier is of the full-wave type. The core measures 2½ inches x 4½ inches; hence,

$$T = \frac{7.5 \times 115}{2.25 \times 4.5} = 85 \text{ (to the nearest turn).}$$

and the volts per turn equals

$$\frac{115}{85} = 1.353$$ which is the same for all coils.

Now, the secondary coil must have two windings in series, each to give 1,000 volts, and with a middle-tap. The secondary turns

Figure 39

WATTS	Section of Core (inches)	Area of Core (Square inches)	Primary Turns	Primary Wire Size	Turns per Volt	SECONDARY WINDINGS (Turns for Voltages Given)																	
											HIGH-VOLTAGE WINDING												
						2.5 volts	5.0 volts	6.3 volts	7.5 volts	10 volts	250 volts	300 volts	350 volts	400 volts	450 volts	500 volts	600 volts	700 volts	800 volts	900 volts	1000 volts	1250 volts	1500 volts
10	½ x ½	.25	3500	31	32	80	160	205	240	320													
10	½ x ⅝	.31	2800	31	24.2	61	122	147	182	242													
12	½ x ¾	.37	2300	30	20.0	50	100	126	150	200													
12	⅝ x ⅝	.38	2280	30	19.6	48	96	124	147	196													
15	⅝ x ¾	.46	1875	29	16.1	42	84	105	124	161													
22	⅝ x 1	.62	1400	28	12.2	31	61	77	92	122													
20	¾ x ¾	.55	1570	28	13.6	34	68	86	102	136													
25	¾ x 1	.75	1150	27	10.0	25	50	63	75	100	2620	3150	3700	4200	4750	5250							
30	¾ x 1¼	.93	930	26	8.1	21	42	52	62	81	2100	1500	3140	3400	3800	4200							
50	¾ x 1½	1.12	770	24	6.7	17	34	43	50	67	1860	2100	2500	2840	3150	3500	4200	5000					
50	1 x 1	1.0	860	21	7.5	19	38	48	57	75	1950	2400	2700	3150	3600	3900	4700	5500					
60	1 x 1¼	1.25	690	23	6.0	15	30	38	45	60	1600	1900	2200	2500	2800	3150	3800	4400					
65	1 x 1½	1.50	575	23	5.0	13	25	32	38	50	1300	1575	1850	2100	2400	2650	3150	3700					
75	1 x 1¾	1.75	490	22	4.2	11	21	27	31	42	1100	1320	1550	1750	2000	2200	2650	3150	3800	4000	4400		
110	1 x 2	2.0	430	21	3.7	9	18	23	28	37	980	1170	1370	1550	1750	1960	2300	2750	3100	3500	3900		
105	1¼ x 1¼	1.56	550	21	4.8	12	24	31	36	48	1260	1510	1770	2050	2240	2510	3050	3500	4100	4500	5020		
100	1¼ x 1½	1.87	460	21	3.8	9	19	25	29	38	1000	1200	1400	1600	1800	2000	2400	2720	3200	3560	4000		
120	1¼ x 1¾	2.18	400	20	3.5	9	18	21	26	35	920	1100	1315	1470	1650	1840	2200	2560	2940	3300	3700	4620	5500
140	1¼ x 2	2.5	350	19	3.2	8	16	20	24	32	840	1020	1180	1340	1510	1680	2050	2350	2680	3000	3380	4200	5050
125	1½ x 1½	2.25	380	20	3.3	8	16	21	25	33	870	1040	1210	1400	1560	1730	2100	2420	2800	3120	3500	4400	5250
150	1½ x 1¾	2.64	330	18	2.9	7	14	19	22	29	760	910	1130	1220	1360	1530	1840	2100	2450	2750	3050	3800	4650
200	1½ x 2	3.0	290	17	2.42	6	12	15	18	24	630	765	890	1020	1150	1265	1522	1780	2050	2380	2350	3200	3840
300	2 x 2	4.0	215	15	1.87	5	9	12	14	19	490	590	690	780	880	980	1180	1360	1570	1760	1950	2350	2940
400	2 x 2¼	5.0	175	14	1.52	4	8	10	12	15	395	470	550	640	710	790	950	1110	1265	1420	1590	1980	2400
500	2 x 3	6.0	145	13	1.26	3	6	8	9	12	330	395	455	530	595	660	790	920	1060	1200	1330	1650	2000

Gauge No B&S	Dia in Mils	Cross Sectional Area: Cir Mils	Cross Sectional Area: Sq. Inches	Turns per Linear Inch: DCC.	SCC.	DSC.	SSC.	Enam.	Enam. and SCC.	Enam. and SSC.	Turns per Square Inch: DCC.	SCC.	DSC.	SSC.	Enam.	Enam. and SCC.	Enam. and SSC.	Ft. per Pound: DCC	SCC.	Bare	Res per 1000 Ft. Copper	Carrying Capacity Copper: 1000 CM Per Amp.	1500 CM Per Amp.
0000	460.0	211600	.1662																	1.561	.0499	211.6	140.7
000	409.6	167800	.1318																	1.968	.0629	167.8	111.3
00	364.8	133100	.1045																	2.482	.0793	133.1	88.9
0	324.9	105500	.08289																	3.130	.1000	105.5	70.3
1	289.3	83690	.06573																	3.947	.1260	83.7	55.7
2	257.6	66370	.05213																	4.977	.1592	66.4	44.1
3	229.4	52640	.04134																	6.276	.2004	52.6	35.0
4	204.3	51740	.03278																	7.914	.2336	41.7	27.7
5	181.9	33100	.02600																	9.980	.3192	33.1	22.0
6	162.0	26250	.02062	5.44	5.60															12.58	.4028	26.3	17.5
7	144.3	20820	.01635	6.08	6.23															15.87	.5080	20.8	13.8
8	128.5	16510	.01297	6.80	6.94													19.6	19.9	20.01	.6405	16.5	11.0
9	114.4	13090	.01028	7.64	7.68													24.6	25.1	25.23	.8077	13.1	8.7
10	101.9	10380	.008155	8.51	8.55													30.9	31.6	31.82	1.018	10.4	6.9
11	90.74	8234	.006467	9.58	9.60													38.9	39.8	40.12	1.284	8.2	5.5
12	80.81	6530	.005129	10.62	10.80	11.8	12.1	12.1	11.4	11.8	121	136	139	146	146	130	139	48.9	50.2	50.59	1.619	6.5	4.4
13	71.96	5178	.004067	11.88	12.06	13.2	13.5	13.5	12.8	13.2	153	171	173	183	183	162	173	61.5	63.2	63.80	2.042	5.2	3.5
14	64.09	4107	.003225	13.10	13.45	14.7	15.1	15.2	14.2	14.7	187	213	216	229	239	201	216	77.3	79.6	80.44	2.575	4.1	2.7
15	57.07	3257	.002558	14.68	14.90	16.4	16.9	17.0	15.8	16.5	229	261	268	287	290	250	271	97.3	100	101.4	3.247	3.3	2.2
16	50.82	2583	.002028	16.40	17.20	18.2	18.9	18.7	17.6	18.4	280	327	333	358	350	309	338	119	126	127.9	4.094	2.6	1.7
17	45.26	2048	.001609	18.10	18.80	20.3	21.2	21.4	19.5	20.5	340	404	412	448	458	381	421	150	155	161.3	5.163	2.0	1.3
18	40.30	1624	.001276	20.00	21.00	22.6	23.6	24.0	21.7	22.9	412	498	510	559	575	469	524	188	196	203.4	6.510	1.6	1.1
19	35.89	1288	.001012	21.83	23.60	25.4	26.8	27.2	24.2	25.8	508	629	644	715	739	587	665	237	247	256.5	8.210	1.3	.86
20	31.96	1022	.0008023	23.91	26.40	27.8	29.5	30.1	26.5	28.4	596	752	773	867	904	701	805	298	311	323.4	10.35	1.0	.68
21	28.46	810.1	.0006363	26.20	29.70	30.8	32.8	33.6	29.6	31.5	752	949	949	1078	1129	878	991	370	389	407.8	13.05	.81	.54
22	25.35	612.4	.0005046	28.58	32.00	34.1	36.6	37.7	32.7	35.0	899	1161	1161	1337	1419	1071	1227	461	491	514.8	16.46	.64	.43
23	22.57	509.5	.0004002	31.12	34.30	37.6	40.7	42.3	36.1	39.0	1070	1416	1416	1656	1785	1306	1518	584	624	648.4	20.76	.51	.34
24	20.10	404.0	.0003173	33.60	37.70	41.5	45.3	47.2	39.7	43.1	1266	1722	1722	2048	2225	1575	1858	745	778	817.7	26.17	.41	.27
25	17.90	320.4	.0002517	36.20	41.50	45.7	50.3	52.9	43.7	47.9	1491	2085	2085	2525	2800	1907	2289	903	958	1031	33.00	.32	.21
26	15.94	254.1	.0001996	39.90	45.30	50.2	55.7	59.0	47.8	52.8	1715	2515	2515	3108	3484	2281	2788	1118	1188	1300	41.62	.25	.17
27	14.20	201.5	.0001583	42.60	49.40	55.0	61.7	65.8	52.1	58.1	2029	3019	3019	3811	4328	2713	3381	1422	1533	1639	52.48	.20	.13
28	12.64	159.8	.0001255	45.50	51.60	60.1	68.3	73.9	57.0	64.4	2317	3611	3611	4666	5156	3250	4141	1759	1903	2067	66.17	.16	.11
29	11.26	126.7	.00009953	48.00	58.80	65.5	75.4	82.2	61.9	70.6	2696	4294	4294	5688	6761	3830	4988	2207	2461	2607	83.44	.13	.084
30	10.03	100.5	.00007894	51.10	64.40	71.3	83.1	92.3	67.4	77.9	3076	5081	5081	6911	8527	4547	6075	2534	2893	3287	105.20	.10	.067
31	8.928	79.70	.00006260	56.80	69.00	77.3	91.6	103.0	72.8	85.3	3489	5981	5981	8389	10568	5305	7267	2768	3483	4145	132.70	.079	.053
32	7.950	63.21	.00004964	60.20	75.00	83.7	101.0	116.0	79.1	93.9	3931	7003	7003	10101	13363	6250	8818	3137	4414	5227	167.30	.063	.042
33	7.080	50.13	.00003937	61.30	81.00	90.3	110.0	130.0	85.6	103.0	4398	8143	8143	12130	16952	7326	10672	4697	5688	6591	211.00	.050	.033
34	6.305	39.75	.00003122	68.60	87.60	97.0	120.0	145.0	91.7	112.0	4883	9407	9407	14499	20967	8403	12610	6168	6400	8310	266.00	.039	.026
35	5.615	31.52	.00002476	73.00	91.20	101.0	131.0	161.0	98.8	123.0	5391	10817	10817	17247	26745	9766	15186	6737	8393	10480	335.00	.032	.021
36	5.000	25.00	.00001964	78.50	101.00	111.0	143.0	182.0	105.0	133.0	5917	12316	12316	20408	33051	11080	17777	7877	9846	13210	423.00	.025	.017
37	4.453	19.83	.00001557	84.00	108.00	118.0	155.0	206.0	113.0	146.0	6152	13996	13996	24015	40766	12758	21295	9309	11636	16660	533.40	.020	.013
38	3.965	15.72	.00001235	89.10	115.00	126.0	168.0	235.0	120.0	157.0	6978	15763	15763	28106	54990	14291	24685	10668	13848	21010	672.60	.016	.010
39	3.331	12.47	.000009793	95.00	122.50	133.0	181.0	261.0	128.0	172.0	7521	17630	17630	32690	68120	16308	29412	11907	18286	26500	848.10	.012	.008
40	3.134	9.888	.000007766	102.50	130.00	140.0	191.0	290.0	134.0	184.0	8015	19589	19589	37779	81244	18041	43727	14222	24381	33110	1069.00	.009	.006
41	2.800	7.841	.000006160	112.00	153.00													17920	30610	42130	1323.00	.008	.005
42	2.191	6.220	.000004885	124.00	168.00													22600	38700	53100	1667.00	.006	.004
43	2.221	4.933	.000003873	140.00	192.00													28410	48600	66970	2105.00	.005	.003
44	1.978	3.910	.000003073	153.00	210.00													35950	61400	84460	2655.00	.004	.0025

Figure 40—Copper Wire Table

will be $\frac{2000}{1.353} = 1478$ with a tap taken out at the 739th turn.

Allowing 1,500 cm. per ampere, the primary wire should be no. 12. The size of the wire on the plate coils may be no. 22 or 24 for a 400 to 300 ma. rating.

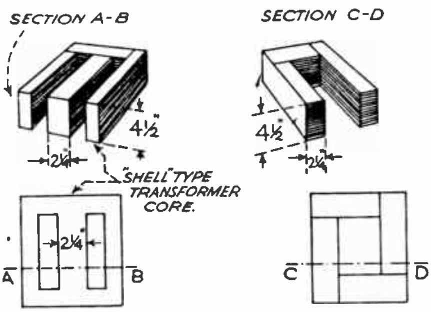


Figure 41—Types of Transformer Cores.

To determine the quantity of iron to pile up for a core, it is well to consider 1 to 1.5 volts per turn as a conservative range. For trial assume 1.25 volts. Then by transforming the first equation:

$A = 7.5 \times \frac{E}{T}$ or, the area required is 7.5 times the volts per turn; in this case, $7.5 \times 1.25 = 9.38$ sq. in.

The magnetic cross section must be measured at right angles to the laminations that are enclosed by the coil, the center leg when the core is built up around the coil, and either leg where the core is built up inside the coil, that is, between the arrows in the sketches shown above.

It should be kept in mind that there is a copper or resistance loss in all transformers. This is caused by the passage of the current through the windings and is commonly spoken of as the "IR" loss. It manifests itself directly as heat and varies as the load is varied; the heavier the load, the more heat is developed.

This heat, as well as other heat losses, must be removed, or the transformer will burn up. Most transformers are so arranged that both the core and windings can radiate heat into the surrounding air and thus cool themselves. Large transformers are mounted in oil for cooling and also for the purpose of increasing the insulation factors.

In any transformer, the voltage ratio is directly proportional to the turns ratio. This means that if the transformer is to have 110 volts input and 250 turns for the primary, and if the output is to be 1,100 volts, 2,500 turns will be needed. This may be expressed as:

$$\frac{E_p}{E_s} = \frac{T_p}{T_s}$$

It is often more convenient to take the figure obtained for the primary winding and, by dividing by the supply voltage, the number of turns per volt is calculated. This accomplished, the number of turns for any given voltage can be calculated by simple multiplication.

Radio transformers are generally of small size. The matter of power factor can therefore be disregarded, more especially because they work into an almost-purely resistive load. In the design of radio transformers, the power factor can be safely assumed as unity, in which case the apparent watts and the actual watts are the same. Admittedly, this is not always a correct assumption, but it will suffice for common applications.

The size of the wire to be used in any transformer depends upon the amperage to be carried. For a current of 1 ampere as a continuous load, at least 1,000 circular mils per ampere must be allowed. For transformers which have poor ventilation, or continuous heavy load service, or where price is not the first consideration, 1,500 circular mils per ampere is a preferable figure. If, for example, a transformer is rated at 100 watts primary load on 110 volts, the current will be

$$I = \frac{W}{V} = \frac{100}{110} = 0.90 \text{ amperes,}$$

and if the assumption is 1,000 circular mils per ampere, it will be found that this will require $1{,}000 \times .90$, or 900 circular mils. The wire table on page 381 shows that no. 20 wire for 1,200 mils, is entirely satisfactory. If it is desired to use 1,500 circular mils, instead of 1,000, this will require $1{,}500 \times .90$ or 1350 mils, which corresponds to approximately no. 19 wire. The difference seems to be small, yet it is large enough to reduce heating and to improve overall performance. Assume, for tentative design, a 600-volt, 100-ma. high-voltage secondary; a 3-ampere 5-volt secondary, and 2.5-volt 7.5-ampere secondary. Simple calculation will show a 60-watt load on the high-voltage secondary; 15 watts on the 5-volt winding, and 16 watts on the 2.5-volt winding, a total of 91 watts. The core and copper loss is 10 watts. The wire sizes for the secondaries will be for 100-ma. current, no. 30 wire; 3 amperes at 5 volts, No. 15 wire; No. 11 wire for the 7.5-ampere secondary.

For high voltage secondary windings, a small percentage of turns should be added to overcome the resistance of the small wire used, so that the output voltage will be as high as anticipated. The figures given in the table include this percentage which is added to the theoretical ratio of turns and, consequently, the number of turns shown in the table can be accepted as the actual number of turns to be wound on the core of any given transformer.

Allowance should always be made for the insulation and size of the windings. Good insulation should be provided between the core and the windings and also between each winding and between turns. Numerous materials are satisfactory for this purpose; varnished paper or cloth, called "empire," or paper is very satisfactory, although costly. Good bond paper will serve well as an insulating medium for small transformer windings.

Insulation between primary and secondary and to the core must be exceptionally good, as well as the insulation between windings. Thin mica or "micanite" sheet is very good. Thin fibre, commonly called "fish paper," is also a good insulator; bristol board, or strong, thin cardboard may also be used. In all cases, the completed coil should be impregnated with insulating varnish, and either dried in air or baked in an oven. Common varnishes or shellac are unsatisfactory on account of the moisture content of these materials. Air-drying insulating varnish is practical for all-around purposes; baking varnish may be substituted, but the fumes given off are inflammable and often explosive. Care must be exercised in the handling of this type of material. Collodion and banana oil lacquer are positively dangerous, and in the event of a short-circuit of transformer burn-out, a serious fire may result.

If it is desired to wind a transformer on a given core, it is much better to calculate the actual space required for the windings, then determine whether there is enough available space on the core. If this precaution is not observed, the designer may find that only about half the turns can actually be wound on the core, when the work is about three-fourths finished. From 15 to 40 per cent more space than is actually required must be allowed. The winding of transformers by hand is a space consuming process. Unless the builder is an experienced coil-winder, there is every chance that a sizable portion of the space will be used-up by insulation, etc., not sufficient space remaining for the winding. Calculate the cubical space needed for the total number of turns, and allow from 15 to 40 per cent additional space in the core "window." Thereby much time and labor will be saved.

• Filter Chokes

A choke is a coil of high inductance. It offers an extremely high impedance to alternating current, or to current which is substantially alternating, such as pulsating d.c. delivered at the output of a rectifier.

Choke coils are used in power supplies as part of the complete filter system in order

Choke Table for Transmitter Power Supply Units

Current M.A.	Wire Size	No. Turns	Lbs. Wire	Approx. Core (Area)	Air Gap	Wt. Core
200	No. 27	2000	1.5	1¼"x1¼"	3/32"	4 lbs.
250	No. 26	2000	1.75	1½"x2"	3/32"	5 lbs.
300	No. 25	2250	2	2"x2"	¼"	6 lbs.
400	No. 24	2250	3	2"x2½"	¼"	7 lbs.
500	No. 23	2500	4	2½"x2½"	⅛"	10 lbs.
750	No. 21	3000	6	2½"x3"	¼"	14 lbs.
1000	No. 20	3000	7.5	3"x3"	⅛"	18 lbs.

NOTES: These are approximately based on high-grade silicon steel cores, with total airgaps as given. Airgaps indicated are total of all gaps.

The use of standard "E" and "I" laminations is recommended. If strips are used, and if an ordinary square core is used, the number of turns should be increased about 25 %. Choke coils built as per the above table will have an approximate inductance of 10 to 15 henrys. Because considerable differences occur due to winding variations, allowable flux densities of cores, etc., the exact inductance cannot be stated; these chokes will, however, give satisfactory service in radio transmitter power supply systems.

The wire used is based on 1000 circular mils per ampere; this will cause some heating on long runs, and if the chokes are to be used continuously, as in a radio telephone station in continuous service, it is good practice to use the next size larger choke shown for such leads.

to produce an effectively-pure direct current from the pulsating current source, that is, from the rectifier. The wire size of the choke must be such that the current flowing through it does not cause an appreciable voltage drop due to the ohmic resistance of the choke; at the same time, sufficient inductance must be maintained to provide ample smoothing of the rectified current.

• Smoothing Chokes

The function of a smoothing choke is to discriminate as much as possible between the a.c. ripple which is present and the desired d.c. that is to be delivered to the output. Its air-gap should be large enough so that the inductance of the choke does not vary materially over the normal range of load current drawn from the power supply, but no larger than necessary to give maximum inductance at full current rating.

• Swinging Chokes

In certain radio circuits the power drawn by a vacuum tube amplifier can vary widely. Class B audio amplifiers are good examples of this type of amplifier. The plate current drawn by a class B audio amplifier can vary a thousand per cent or more. It is desirable to keep the d.c. output voltage applied to the plate of the amplifier as constant as possible, and the voltage should be independent of the current drawn from the power supply. The output voltage from a given power supply is always higher with a condenser input filter than with a choke-type input filter. When the input choke is of the *swinging* variety, it means that the inductance of the choke varies widely with the load current drawn from the power supply, due to the fact that high initial inductance is obtained by utilizing a "butt" gap, or none at all as in a transformer core.

• Choke Design and Construction

A choke is made up from a silicon-steel core which consists of a number of thin sheets of steel, similar to a transformer core, but wound with only a single winding. The size of the core and the number of turns of wire, together with the air-gap which must be provided to prevent the core from saturating, are factors which determine the inductance of a choke. The relative sizes of the core and coil determine the amount of d.c. which can flow through the choke without reducing the inductance to an undesirable low value due to magnetization.

The same core material which is used in ordinary radio power transformers or from those which are burned-out, is satisfactory for all general purposes.

In construction, the choke winding must be insulated from the core with a sufficient quantity of insulating material so that the highest peak voltages which are to be experienced in service will not rupture the insulation.

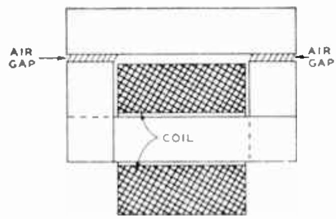


Figure 42—Two types of choke coil construction. The air-gap is approximately 1/32 inch.

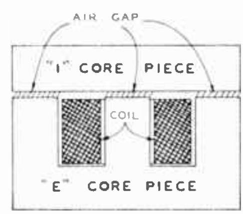


Figure 43—The air-gap can be filled with non-magnetic material, such as brass, bakelite, etc.

Chapter 17

Test Instruments

Certain pieces of test equipment should be part of every radio station and laboratory, in order to insure proper operation of radio receivers, transmitters, amplifiers, antenna systems, etc. Test equipment described in this chapter is suitable for practically every need of the average radio amateur. This equipment has been designed both from a standpoint of simplicity and economy.

● Field Strength Meter

The most practical method of tuning any antenna system, such as a half-wave antenna or a directional array, is by means of a field strength meter. This instrument gives a direct indication of the actual field strength of a transmitted signal in the vicinity of the antenna. The device consists of a tuned circuit and a diode rectifier which is connected in series with a 0-1 d.c. milliammeter or microammeter so that the meter will read the carrier signal strength.

The circuit is shown in figure 1 and a photograph of the instrument in figure 2.

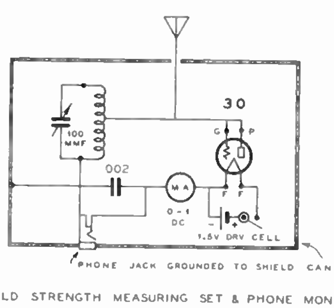


Figure 1—Simple Circuit of Field Strength Meter.

Three plug-in coils cover the six amateur bands from 5 to 160 meters, each coil being so designed that it will cover two separate bands by means of a midget tuning condenser having a maximum capacity of 100 $\mu\mu$fds. The coils are wound on 1½-in. diameter plug-in coil forms, with no. 24 d.s.c. wire. The 5- and 10-meter coil has two turns, spaced ½-in. apart, with a center-tap. The 20- and 40-meter coil has 12 turns, space wound to cover a winding length of ¾ in., with a tap taken at the fourth turn from the grounded end. The 80- and 160-meter coil has 60 turns close wound, with a tap at the 20th turn from the grounded end. The low capacity range of the tuning condenser covers the 5-, 20- and 80-meter bands, while the high capacity range covers the 10, 40- and 160-meter bands, with the three plug-in coils.

A type 30 tube is connected as a diode, with a single 1½-volt filament battery and an on-off switch. The diode is connected across a portion of the tuned circuit, rather than across the entire circuit, in order to obtain a selective tuning indication. The d.c. milliammeter reads the rectified current produced by the r.f. energy flowing through the diode. A telephone jack is connected in series with the meter in order to use the field strength set as a monitor. The complete instrument can be built into a small metal case, as shown in figure 2, with a

Figure 2

small rod-antenna, insulated from the metal case, for picking up r.f. energy. A longer antenna can be used for tuning low power transmitter antennas. The rod antenna illustrated has the advantage that the field strength meter can be calibrated as a wave-meter.

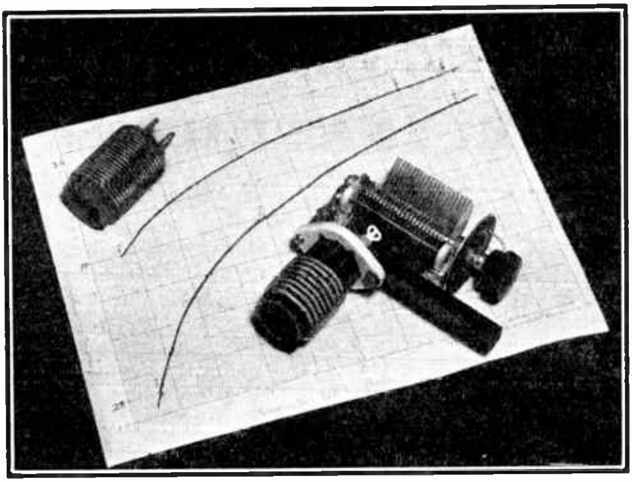


Figure 3—Simple Absorption Type Wavemeter, Useful for Identifying Harmonics

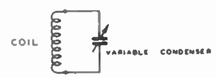
The field strength meter should be tuned to resonance and located in the vicinity of the antenna in order to secure a small deflection of the meter scale. As the antenna system becomes more efficiently tuned, greater indications will be obtained on the meter.

This device can also be used for checking key-clicks if it is coupled to the antenna and placed at least 10 feet from the c.w. key.

• Absorption-Type Wavemeter

The wavelength of any oscillator, doubler, or amplifier stage can be roughly determined with the aid of a simple absorption wavemeter. It is particularly useful for determining the correct harmonic from a harmonic crystal oscillator or frequency doubler or quadrupler. It consists of a simple tuned circuit which is coupled to the tank circuit under measurement. The wavemeter absorbs a small amount of energy from the transmitter tank circuit; this produces a change in reading of the milliammeter in the plate or grid circuit. A sharp rise or dip in milliammeter current reading will take place when the wavemeter is tuned to the same wavelength or frequency as that of the circuit under measurement. The wavemeter shown in figures 3 and 4 consists of a 220-$\mu\mu$fd. midget variable condenser and two plug-in coils which cover a range of from 8 to 80 meters; an additional coil can be wound for 160-meter operation, if desired.

The smaller coil consists of 8 turns of no. 16 pushback wire, space wound over a winding length of 1⅜ in. on a 1¼-in. form. The larger coil, which covers a range including



SIMPLE ABSORPTION WAVEMETER CIRCUIT

Figure 4

the 40- and 80-meter bands, is wound with 18 turns of pushback wire, spaced to cover a winding length of 1¾ in. on a 1¼-in. diameter form. A coil suitable for 160-meter measurements can be made by close-winding 40 turns of no. 24 d.c.c. on a similar coil form. The turns should be cemented in position with a liberal application of *Duco household cement.*

A four-prong coil socket is secured to one end of the tuning condenser by means of a machine screw; it is spaced from the condenser by means of a standard socket mounting bushing. An insulated handle is attached to the other end of the coil socket so that the wavemeter can be held in one hand while being tuned with the other. A small 180° dial is attached to the rotor frame of the condenser; the tuning knob is fitted with a sharply-pointed indicator. The coil socket terminals are soldered di-

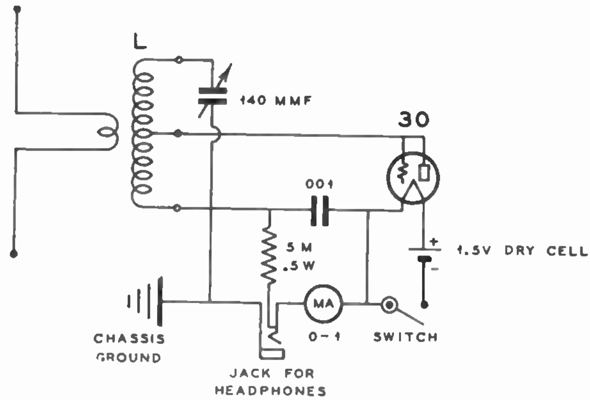


Figure 5—Phone Test Set Wiring Diagram.

rectly to rotor and stator of the variable tuning condenser.

The wavemeter can be calibrated by holding it near the secondary coil of an ordinary regenerative receiver which tunes to the known amateur bands. As the wavemeter condenser is rotated through its range, a point will be found where the receiver is pulled out of oscillation, as indicated by a sharp click in the headphones of the receiver. This point is then marked on the scale of the wavemeter dial. This calibration is sufficiently accurate to insure transmitter operation in the 10-meter band rather than 13-meter operation, which can be easily mistaken for 10-meter output when tuning a transmitter. The wavemeter can also be calibrated by holding it near the plate coil of a crystal oscillator. A change in oscillator plate current or even a cessation of oscillation will occur when the wavemeter is tuned to the same frequency as that of the oscillator.

The photograph shows a calibration chart for the two coils; this curve can be plotted by transferring the wavemeter dial scale readings for the various amateur bands to the graph paper, then drawing a curve through the plotted points.

• General Purpose Phone Test Set

A phone test set is quite similar to a field strength meter, yet it lends itself to making additional measurements. It can be used as an overmodulation indicator, phone monitor, field strength meter, neutralizing indicator and wavemeter. This test set enables the operator to check for overmodulation of a phone transmitter. When the tuned circuit of the test set is coupled to the modulated amplifier or antenna system in such a manner as to obtain half-scale deflection of the milliammeter, any flicker of the meter reading will then be an indication of overmodulation. A change in meter reading during modulation is an indication of *carrier shift,* which will produce illegal interference in adjacent radiophone channels. The phone test set consists of a diode rectifier connected across a tuned circuit, as shown in figure 5. A 0-1 d.c. milliammeter serves to check overmodulation, also serving for field strength measurements or neutralizing adjustments of a transmitter.

A phone jack provides a method for checking the voice quality of a radiophone transmitter. The audio volume with half to full scale meter indication is sufficient to give normal headphone response. A 5,000-ohm resistor is connected into the jack circuit so as to be in use when the test set functions as an overmodulation indicator. This resistor is in series with the diode and tends to produce linear rectification of the carrier wave.

For neutralizing or field strength measurements, a short-circuiting plug or brass rod should be plugged into the phone jack in order to short circuit the 5,000-ohm resistor and thereby increase the sensitivity of the meter. Neutralizing adjustments are made by coupling the test set's tuned circuit to the transmitter stage under test (without plate voltage applied to the stage). When the stage is completely neutralized,

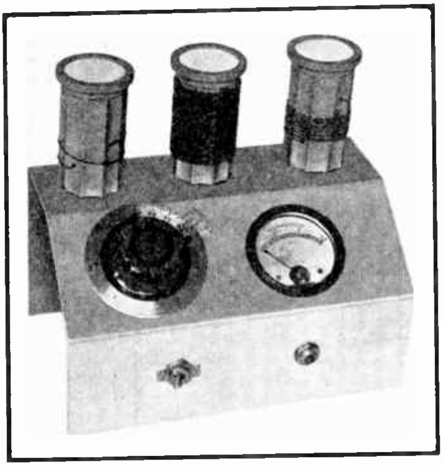


Figure 6—Phone Test Set for All Bands.

there will be either a minimum or zero deflection of the meter needle. The coil *L*, figure 5, can be coupled directly to the tank coil or loosely-coupled to it by means of a link circuit.

Antenna field strength measurements can be made by coupling an auxiliary antenna to coil *L* by merely wrapping one or two turns of this auxiliary antenna wire around

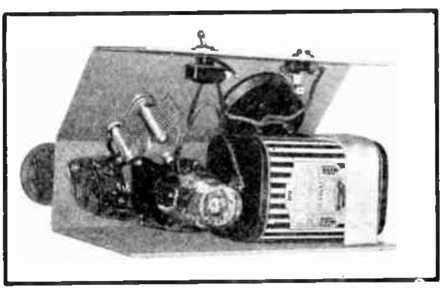


Figure 7—Under-Chassis View.

the field strength meter coil. This auxiliary antenna should be clear from the ground and parallel to the antenna under test. The degree of coupling to the coil can be varied in order to obtain a satisfactory preliminary reading on the scale of the milliammeter; the antenna feeder or coupling adjustments can be varied until maximum indication is obtained on the meter scale.

Three coils are needed to cover the six amateur bands. Only one coil is used at a time, the other two being mounted in spare sockets which have their terminals short circuited so as to prevent absorption effects in the unused coils.

COIL TABLE

Band In Meters	Coil Specifications
5-10	2 turns, no. 22 d.s.c., ¾-in. winding length, center-tapped.
20-40	10 turns, no. 22 d.s.c., ¾-in. winding length, tapped at 4th turn from ground end.
80-160	58 turns, no. 22 d.s.c., close wound, tapped at 21st turn from ground end.

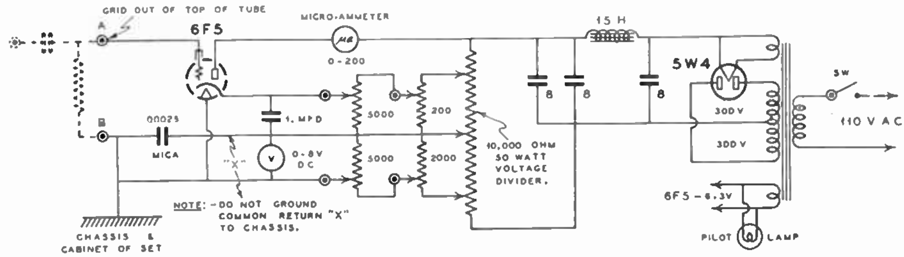
All coils are wound on standard 1½ in. dia. plug-in coil forms.

• Construction

The framework of this test set is made by bending an 8 in. x 12 in. piece of no. 12 gauge aluminum into an open-ended chassis, as shown in figures 6 and 7. The back side is 4¼ in. high, the top portion 2¼ in. wide, and the front consists of a 3-in. sloping portion and a 2-in. vertical portion. The sloping front panel has sufficient space for mounting a 2-inch meter, which can be easily read when tests are being made.

• A. C. Operated Peak Vacuum Tube Voltmeter

Peak values of radio- and audio-frequency voltages can be measured by means of a vacuum tube voltmeter. This device can be calibrated from a 60-cycle source, and the same calibration curve will be satisfactory for radio-frequency measurements. A vacuum tube voltmeter is also very useful for aligning circuits of a radio receiver. The device has nearly infinite input resistance. It consists of a vacuum tube, operated with high grid bias. The tube acts as a rectifier or detector, and the change in plate current produced by the application of an external grid voltage is indicated by means of a microammeter. There are many types of vacuum tube voltmeters, one of which is shown in figures 8, 9, 10, and 11. The outstanding features of this device are: (1) a.c. operation, (2) good calibration stability, very nearly independent of moderate changes in line voltage, (3) high-μ 6F5 tube can be plugged-into the side of the metal cabinet for voltage measurements on the workbench, or by plugging the tube into an extension cable for making r.f. tests where the length of grid and ground lengths are of extreme importance, such as lining-up r.f. amplifiers in radio receivers.



PEAK VACUUM TUBE VOLTMETER

Figure 8

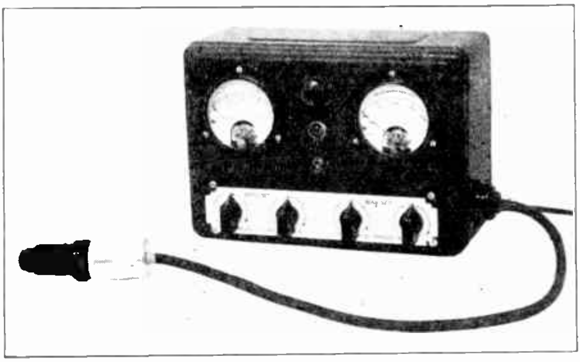


Figure 9—Front View of the Peak V. T. Voltmeter

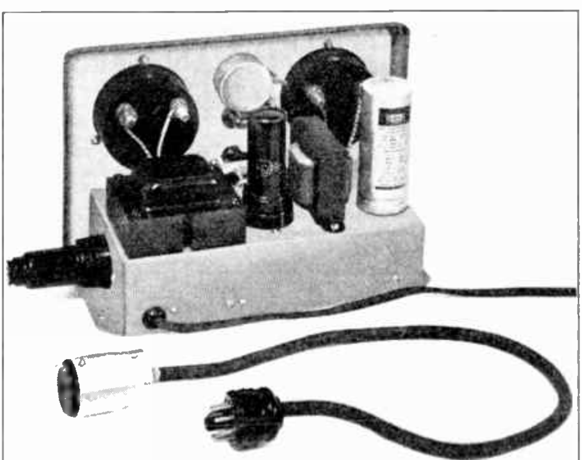


Figure 10—Showing Layout of Components

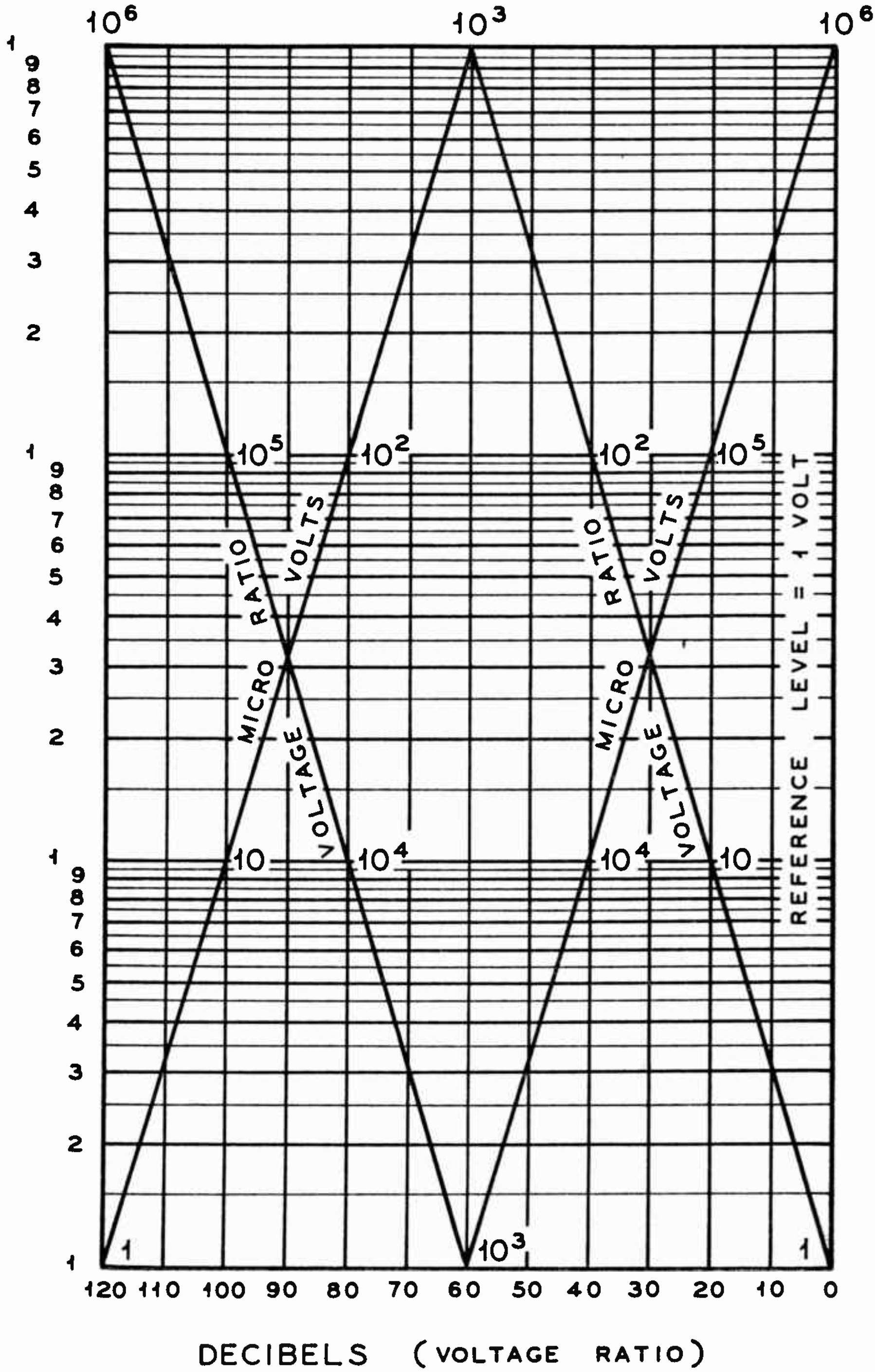
A 0-200 microammeter is operated at an initial deflection of approximately 10 microamperes or it can be used as a "slide-back" type of voltmeter with practically zero initial deflection. The input voltage should be balanced out by a change in the setting of the 6F5 grid-bias potentiometers. The d.c. voltmeter reading at this point is the actual peak input voltage. This type of measurement depends upon maintaining the microammeter reading at some fixed, low indication.

When this device is in operation, care must be taken to provide a d.c. path from the grid of the 6F5 to the chassis ground. Most circuits under measurement will complete this path, which can be as high as several megohms without damage to the microammeter. The complete test set is housed in a commercially - available metal cabinet of standard size.

A very simple battery-operated vacuum tube voltmeter is diagrammed in figure 12. This type of meter can be calibrated by means of a potentiometer and low-reading a.c. voltmeter connected across a transformer filament winding. The a.c. voltmeter reads r.m.s. values; consequently, 2.5 volts r.m.s. equals 3.53 volts peak. The maximum peak voltage which can be measured by this instrument is not over 4.5 volts, the useful range is from about 1 to 4 peak volts.

• Ohmmeter

One of the most useful instruments is a simple ohmmeter for making continuity



10^6
10^3
10^6
10^5
10^2
10^2
10^5
MICRO VOLTS
MICRO VOLTS
RATIO
RATIO
VOLTAGE
VOLTAGE
10
10^4
10^4
10
1
10^3
1
REFERENCE LEVEL = 1 VOLT
1 9 8 7 6 5 4 3 2
1 9 8 7 6 5 4 3 2
1 9 8 7 6 5 4 3 2 1
120 110 100 90 80 70 60 50 40 30 20 10 0
DECIBELS (VOLTAGE RATIO)

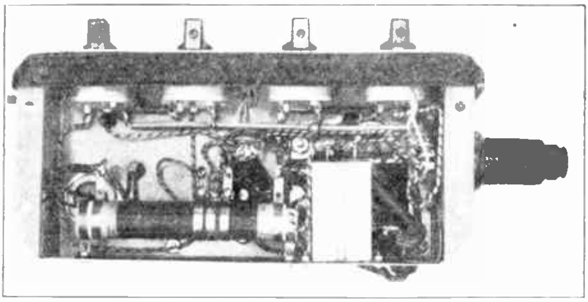


Figure 11—Subchassis View of Peak V. T. Voltmeter

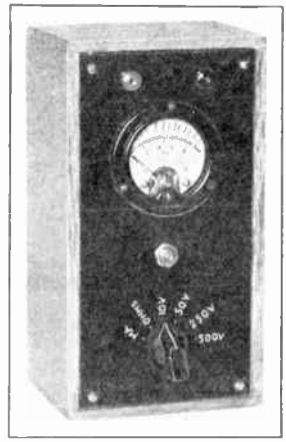
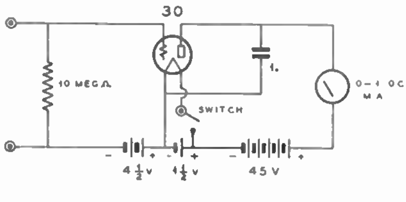
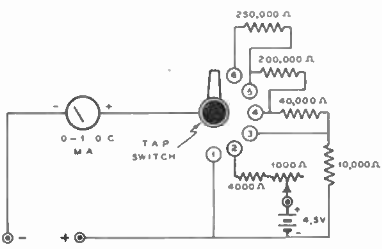


Figure 15



VACUUM TUBE VOLTMETER

Figure 12



OHMMETER — D C VOLTMETER

Figure 13

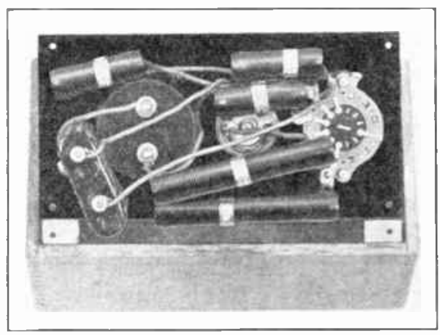


Figure 16—Interior View of Ohmmeter, Showing Battery, Rotary Switch and Ohmite Resistors.

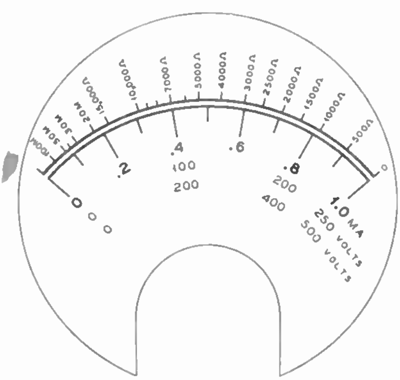


Figure 14

Position 1 of Switch	**0- 1 Ma.**
Position 2 of Switch	**0-100,000 Ohms**
Position 3 of Switch	**0- 10 Volts**
Position 4 of Switch	**0- 50 Volts**
Position 5 of Switch	**0-250 Volts**
Position 6 of Switch	**0-500 Volts**

tests and for measuring the values of resistors. The same instrument can be combined into a multi-range voltmeter by means of a rotary switch and a few resistors, as shown in the circuit, figure 13.

A 0-1 ma. d.c. milliammeter of the 2-inch size can be used in this test set by cutting out or reproducing the scale in figure 14 and pasting it over the existing meter scale.

The unit can be built into a small box, 4 in. x 8 in. x 3½ in., as shown in figures 15 and 16.

Continuity tests can be made by turning the switch to position *2;* the device then acts as an ohmmeter which has a range of from zero to approximately 100,000 ohms. The needle position should be adjusted to zero by means of the 1,000 ohm resistor, with the output leads short-circuited by means of pin jacks.

Resistance measurements are made by reading the values directly on the uppermost scale. The ohmmeter proper consists of only the 0-1 d.c. milliammeter, a 4,000-ohm fixed resistor, a 1,000-ohm variable resistor, and a 4.5-volt C-battery. The unknown resistance is connected in series with this combination. The additional components shown in the photograph and circuit diagram are necessary only when the meter is used as a multi-range voltmeter and 0-1 d.c. milliammeter.

● All-Wave Test Oscillator

A modulated test signal is required for lining-up a superheterodyne receiver in order to simply the procedure. The intermediate and tuned-radio-frequency circuits in the receiver must be properly aligned; an all-wave signal generator produces a signal similar to that of a weak radio signal, yet it is instantly available at any desired frequency.

A very simple modulated oscillator is shown in figure 17; interior and exterior views of the complete instrument are in figures 18 and 19. The entire instrument, batteries included, can be built into a 5 in. x 5 in. x 9 in. metal cabinet.

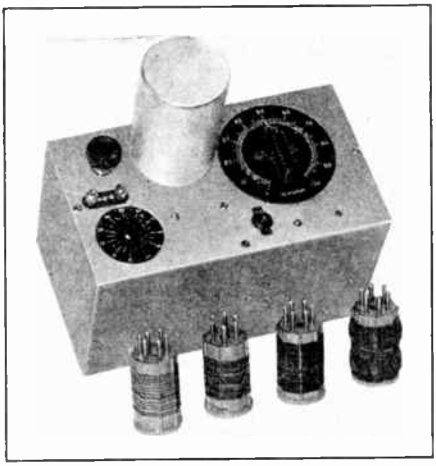
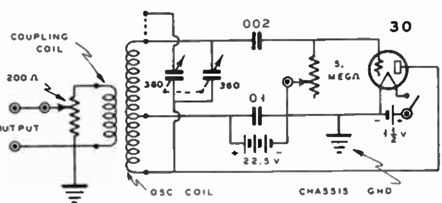


Figure 19—All-Wave Test Signal Generator in Aluminum Shield Can. The coil is also shielded with a large coil-shield can, as shown.



ALL WAVE TEST SIGNAL GENERATOR

Figure 17

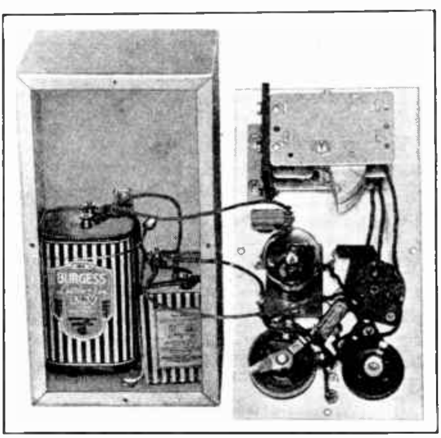


Figure 18—Interior View of All-Wave Test Signal Generator, Showing Type 30 Tube, Dry Cells, Condensers and Resistors.

The top panel is made of no. 12 gauge aluminum, 5 in. x 9 in. The plug-in coils are shielded by means of a removable aluminum can atop the oscillator cabinet.

The oscillator circuit is a standard *Hartley* with a type 30 tube. A variable gridleak is controlled from the front panel; this gives a means for obtaining either unmodulated or self-modulated carrier signals. High values of grid-leak cause a blocking grid action, and the result is a test r.f. signal modulated at some audio frequency of 500 or 1,000 cycles. This grid-leak resistor at low resistance values produces an unmodulated signal which simulates that of a c.w. signal.

A single 1.5-volt dry cell and a 22.5 C-battery furnish filament and plate potentials for the oscillator. A two-gang 360-$\mu\mu$fd. variable condenser has its sections in parallel when tuning the long-wave or low-frequency range, while only a single section of the condenser is used for the medium- and short-wave bands. The changeover is made by an additional link connection in the plug-in coil form. The output is controlled by a 200-ohm potentiometer. The condenser has a 2-to-1 reduction gear in order to spread the tuning range.

● Calibration

The instrument is calibrated by coupling it into a radio receiver which can be tuned to broadcast stations in the frequency range of from 550 to 1,500 kc. The oscillator is tuned to produce a heterodyne note with broadcast station signals of a known frequency.

The range of from 150 to 550 kc. can be calibrated in a similar manner by using the harmonics of the signal generator to produce the heterodyne note. When a calibration scale is to be plotted, the frequency can be divided by 2 or 3, depending on whether the second or third harmonic of the oscillator is being used in the long-wave calibration range.

The most satisfactory method of calibration in the short-wave range is to couple the device into an all-wave radio receiver in conjunction with another accurately calibrated all-wave test oscillator. Dial readings can be plotted in this manner to give a calibration curve for each set of coils, using the radio receiver as a means of detecting zero-beat between the two oscillators. Care must be exercised not to tune one oscillator to a harmonic of the other for this type of calibration.

• Operation

The long-wave ranges of this test oscillator are used to line-up the i.f. frequency circuits in superheterodyne receivers. The majority of receivers have an i.f. frequency of approximately 465 kc. The output terminals of the test oscillator can be connected to each stage of the i.f. amplifier in the radio receiver while that stage is being lined-up. The last i.f. stage should be lined-up first. The signal generator produces a steady tone modulated signal which can be heard in the output of the radio receiver. The shortwave ranges of the oscillator are useful for lining-up the first detector and r.f. stages, so as to make them track properly with the high-frequency tuned circuit in a superheterodyne receiver. More details are given in the chapter on *Receiver Theory*.

The frequency of a quartz crystal, such as that used in a single signal receiver, can be determined very closely by setting the quartz plate on, or leaning it against, the grid of the oscillator tube. The oscillator frequency will suddenly change at resonance with the crystal, as will be heard in a broadcast receiver tuned to the second harmonic of the oscillator. This test requires a manipulation of both oscillator and broadcast receiver, but once the crystal frequency is found, the i.f. amplifier in the shortwave receiver can be lined-up to this same frequency by means of the oscillator.

• A. C. Frequency Meter-Monitor

An accurate means for determining the frequency of a radio transmitter is essential when the circuit is of the self-excited oscillator type. The same device is also useful for checking quartz crystal transmitters in order to make certain that the crystal frequency falls within the desired amateur band. The frequency meter consists of a very stable electron-coupled oscillator which can be accurately calibrated. This same unit can serve as a c.w. *monitor* by adding an audio amplifier stage to the plate circuit of the electron-coupled oscillator. The oscillator can be designed to cover either the 80- or 160-meter amateur bands, and harmonics of these frequencies can then be used for measurements in the shorter-wave bands. The oscillator has a small tuning condenser shunted by a large band-setting condenser;

Test Signal Generator Coil Data

Approx. Freq. Range	Secondary 1¼" Diam.	Coupling Coil (over center of sec.)
13 to 4.2 mc. (One tuning condenser)	15 turns no. 24 d.s.c., c.t., 1½" long (space-wound)	1 turn
5100 to 1600 kc. (One tuning condenser)	38 turns no. 26 d.s.c., c.t., 1⅜" long (space-wound)	2 turns
1800 to 530 kc. (One tuning condenser)	110 turns no. 30 enam., c.t., Close-wound	5 turns
550 to 150 kc. (Two tuning condensers)	285 turns no. 26 d.s.c., c.t., Jumble-wound over 1½" of winding length	10 turns

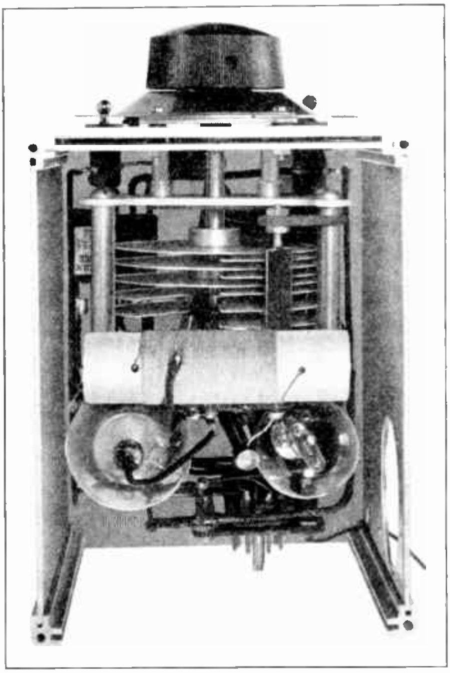


Figure 20—Frequency Meter-Monitor.

the latter is adjusted only when the frequency meter is calibrated by means of standard frequency transmissions or from broadcast station harmonics in conjunction with a calibration oscillator. A good, finely-graduated vernier dial is essential for reading the scale indication of the smaller condenser for accurate determination of frequency. The instrument must be housed in a metal cabinet or can in order to prevent excessive pickup between the frequency meter and the transmitter under test. The electron-coupled oscillator functions as a beat-note detector similar to that in a short-wave regenerative receiver.

Calibration

Standard frequency transmissions are sent on the amateur bands at regular intervals; schedules of these stations can be found in current issues of monthly amateur radio periodicals. These signals can be tuned-in on a shortwave receiver and the frequency meter can be tuned to the zero beat-note in the output of the radio receiver. A slight external coupling can be made from the frequency meter oscillator by connecting a short piece of wire to the grid circuit of the audio amplifier in the frequency meter; this wire can be run close to the radio receiver antenna lead-in in order to pick up a small amount of r.f. energy from the frequency meter.

If a superheterodyne is used for calibration purposes care must be taken to make certain that the frequency meter is *not tuned to the image frequency response* of the radio receiver, but to the same frequency as that of the standard signal transmission. A calibration chart can be plotted so that a frequency range of 3,500 to 4,000 kc. is obtained. Harmonics of the oscillator can be

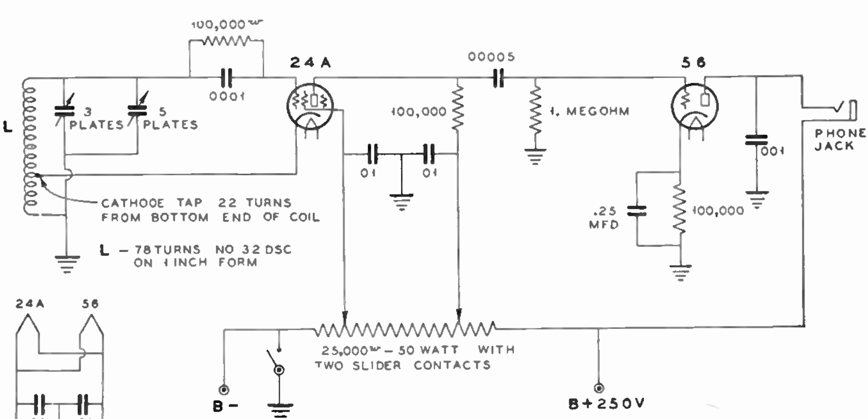


Figure 21—Complete Circuit Diagram of Frequency Meter-Monitor.

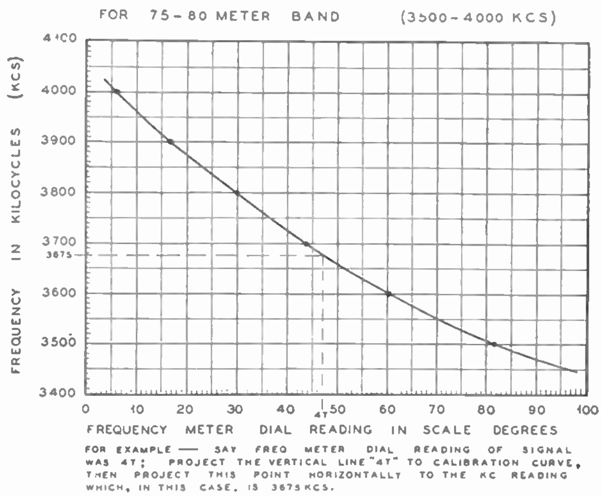


Figure 22—Frequency Meter Curve.

accurately set on the dial by multiplying the frequency readings from the chart by the number of the harmonic.

A typical calibration chart is shown in figure 22. On this chart the dial reading of 60 divisions shows frequency of 3600, 7200, 14,400 and 28,800 kc. If the frequency meter has a 160-meter coil, this same reading will also show a frequency of 1,800 kc. If the frequency meter is calibrated in the range of 3,500 to 4,000 kc., it does not matter whether a 160- or 80-meter coil is used in the electron-coupled oscillator circuit.

The frequency meter can be calibrated by means of a calibration oscillator and a broadcast receiver. The calibration oscillator is tuned to produce zero-beat in the broadcast receiver with carrier signals from broadcast stations of known frequency. The harmonics of the calibration oscillator are coupled into the frequency meter and the latter is tuned to zero-beat, as heard in the phone jack in the output of the monitor. An example would be where the local oscillator is tuned to zero-beat with a broadcast station signal of 880 kc.; the fourth harmonic of the local oscillator would be four times 880 or 3520 kc. This value can be used to obtain a calibration point on the frequency meter.

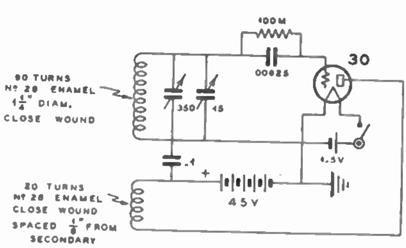


Figure 23—Calibration Oscillator for Battery Operation.

Suggested circuits for calibration oscillators are shown in figures 23 and 24. Calibration oscillators can be built on a small breadboard; they do not require shielding.

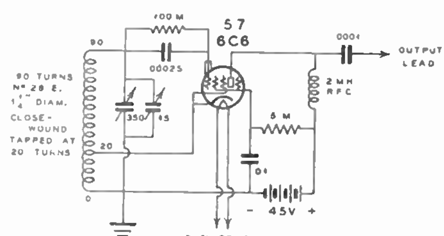
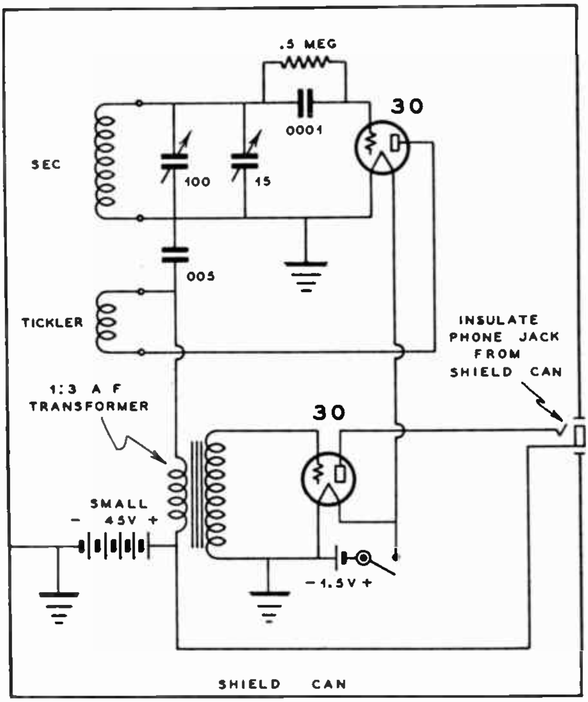


Figure 24—With Heater Type Tubes, Battery Plate Supply Is Still Used for Stability.

• C. W. Monitor

Most monitors for checking the characteristics of a c.w. signal from the radio station room are lacking in sufficient audio output. The c.w. monitor shown in figures 25 and 26 overcomes this defect by means of an additional tube and a stage of audio amplification. A c.w. monitor is used principally for determining the character of the emitted note and to check the keying characteristics of the dots and dashes, either from the standpoint of the apparatus or operator.



C W MONITOR

Figure 25

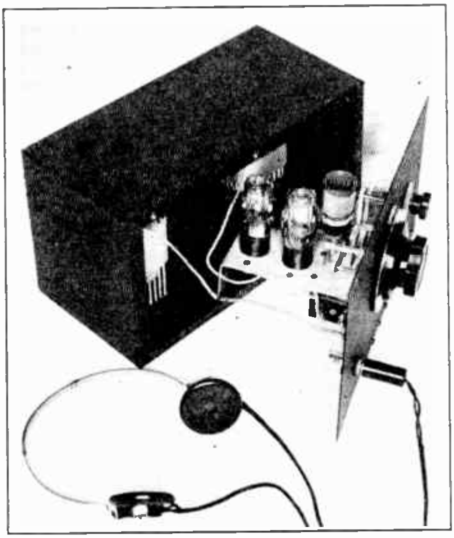


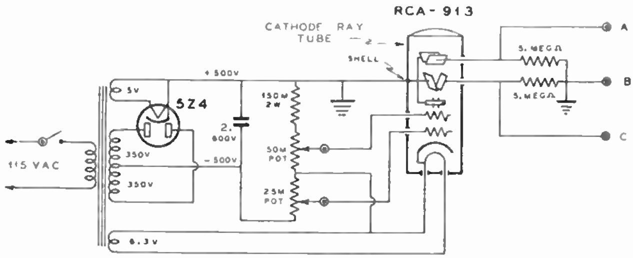
Figure 26—Illustrating Construction of the C. W. Monitor.

This monitor consists of a very simple oscillating receiver, built into a shielded container, which will only pick up enough r.f. energy from the transmitter to produce a beat-note in the output of the monitor. It employs two type 30 tubes, operated from a single 1½-volt dry cell, and a small 45-volt B-battery. These batteries should be located inside the shield can in order to prevent the leads from picking up r.f. energy from the antenna. The small amount of inherent leakage in the shielded container is sufficient to give a normal amount of pickup from the radio transmitter when the monitor is within a few feet of the transmitter.

Plug-in coils are used for covering the various amateur bands. The coil data are as follows:

80 Meters . .Secondary: 27 turns no. 22 d.s.c., close wound.
Tickler: 6 turns no. 22 d.s.c., close wound and spaced ⅛-inch from secondary.

Figure 27
Circuit for
Oscilloscope
Pictured in
Figures 28
and 29.



40 Meters. .Secondary: 14 turns no. 22 d.s.c., space-wound to cover a length of 1-inch.
Tickler: 4 turns no. 22 d.s.c., close-wound and spaced ⅛-inch from secondary.

20 Meters. .Secondary: 7 turns no. 22 d.s.c., space-wound to cover a length of 1-inch.
Tickler: 4 turns no. 22 d.s.c. close-wound, spaced ⅛-inch from secondary.

All of the above coils are wound on standard 1½-in. diameter forms.

● Cathode-Ray Oscilloscopes

Measurements of r.f. and a.f. voltage and wave form can be easily made with the aid of cathode-ray oscilloscopes. Such a device includes a vacuum tube which has two sets of deflecting plates for controlling a beam of electrons; this beam strikes a fluorescent screen on the face of the tube and traces a pattern of the signal applied to the control grid or deflection plates. The fluorescent screen in the tube produces a visual indication of the pattern of r.f. or audio voltages.

Cathode-ray oscilloscopes are extremely useful for measuring percentage modulation in a radiophone transmitter.

● Construction

A very simple oscilloscope, such as the one shown in figures 27, 28 and 29, is entirely satisfactory for amateur services. It consists of an *RCA*-913 cathode-ray tube which has a fluorescent screen approximately one inch in diameter. This tube, and a suitable power supply, can be built into a small metal cabinet approximately 6 in. long, 4 in. wide and 5 in. high. The tube screen is viewed through a 1⅛-in. diameter hole in the top of the container.

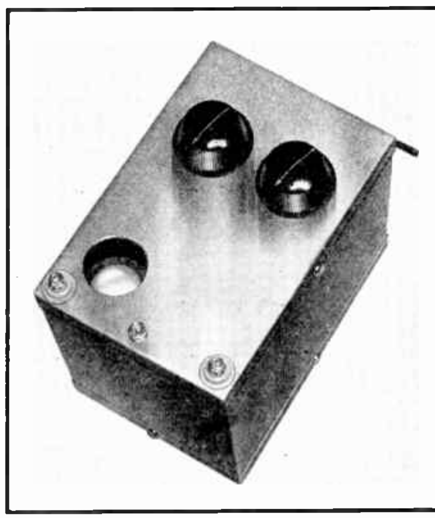


Figure 28—Exterior View of 913 Oscilloscope.

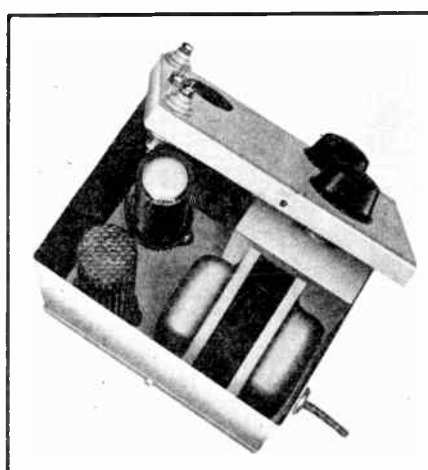
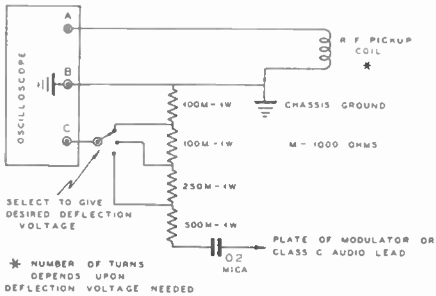


Figure 29—Looking Into the Oscilloscope.



CONNECTIONS FOR MODULATION MEASUREMENTS BY MEANS OF TRAPEZOIDAL FIGURES

Figure 30

The two deflecting plates which connect to the shell of the RCA-913 tube are connected to the center grounded output terminal, and the two remaining deflecting plates (horizontal and vertical) are brought through to a pair of push-through porcelain insulators. Either set of plates can be used for radio or audio measurements. When a voltage is applied to only one set of plates, a thin straight line is obtained on the face of the cathode-ray tube when the 50,000- and 25,000-ohm potentiometers are correctly adjusted.

When a modulated carrier voltage is applied to one set of plates, and the audio

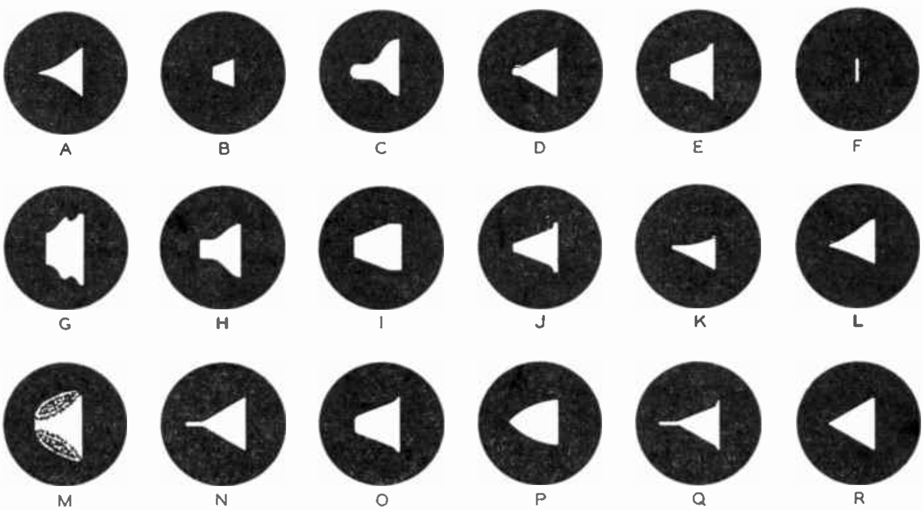


Figure 31

OSCILLOSCOPIC PATTERNS, PLATE AND GRID MODULATION

- **A:** Plate-Modulated. Excessive Bias or Regeneration.
- **B:** Undistorted Plate or Grid Modulation. Less Than 100%.
- **C:** Suppressor-Modulated 802 or RK-20 Phone with Crystal in Grid Circuit.
- **D:** Suppressor-Modulated Phone with Separate R. F. Driver Tube, Modulated Approximately 100%.
- **E:** Maximum Plate Modulation of 6L6, 865 or 860 Screen-Grid Tubes without Screen Modulation (or Insufficient Screen Modulation).
- **F:** Unmodulated Carrier Signal.
- **G:** Plate-Modulated, Regeneration and Modulator Overload or Mismatch.
- **H:** Plate Overmodulation with Bad Mismatch of Class-B Modulator Impedance.
- **I:** Plate Modulated, Insufficient R. F. Grid Drive to Allow Over 50% Modulation.
- **J:** Grid-Modulation. Excessive R. F .Grid Drive.
- **K:** Grid- or Plate-Modulated Phone with Improper Neutralization or Detuned Final Amplifier.
- **L:** 100% Grid Modulation, Normal Adjustments of 1½ Times Cut-Off Bias. Curvature Due to High Bias.
- **M:** Phase Shift Through Speech Amplifier. Approximately 60% Modulation. No Distortion in Output.
- **N:** Plate or Grid Overmodulation. Too Much Audio Input
- **O:** Class-B Mismatched or Underpowered. Corners on Pattern Indicate Overmodulation. May be due to Excessive Antenna Load for Transmitter.
- **P:** Insufficient R. F. Grid Drive with Plate Modulation.
- **Q:** Overmodulation. Too Much Audio Input (Audio Distortion) with Plate Modulation.
- **R:** 100% Modulation. Grid or Plate. No Distortion.

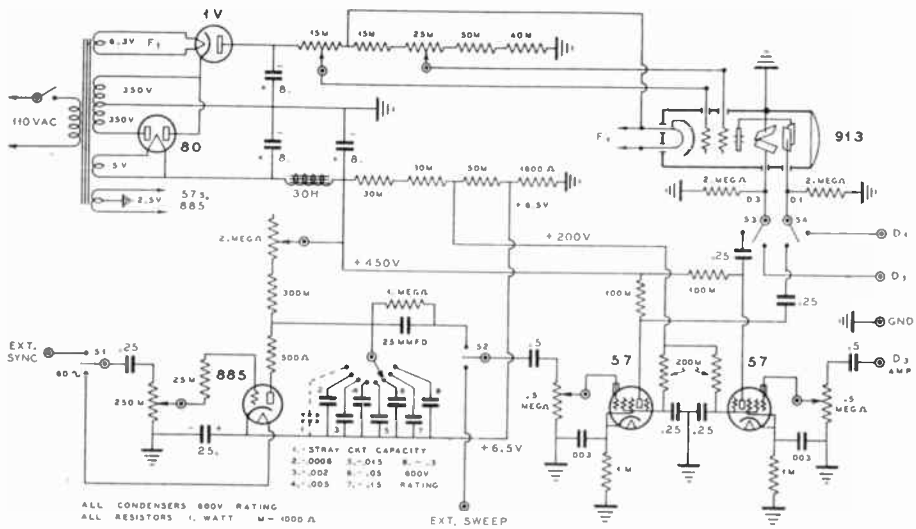


Figure 32—RCA Saw-Tooth-Wave Sweep Oscillator Circuit

modulating voltage applied to the other, a *trapezoidal figure* will be produced during modulation. This pattern should be a straight-sided triangle, sharply pointed when 100 per cent modulation is being obtained. Typical patterns are shown for plate and grid modulation in the accompanying sketches, figure 31.

The audio- or radio-frequency voltage should have an amplitude of from 50 to 100 volts in order to cause good deflection on the screen. The audio voltage should be obtained from the output of the modulator through a high resistance network, as shown in figure 30, when making modulation measurements in a radiophone transmitter. The r.f. voltage can be secured by coupling a few turns of wire to the center of the modulated amplifier tank coil or to the antenna tuning circuit. The amplitude should be sufficient to give a large pattern on the face of the tube. The 25,000- and 50,000-ohm potentiometers are adjusted to give sharp definition and a reasonable amount of illumination on the screen.

• Cathode-Ray Oscilloscope With Sweep Circuit

Most audio frequency measurements require a variable frequency sweep oscillator circuit which can be synchronized with the frequency of the audio voltage being tested. For this purpose, a saw-tooth wave form is desirable; it can be obtained from a condenser-charge-and-discharge-circuit. The condenser is slowly charged, then rapidly discharged by means of a gas-filled type 885 triode which ionizes at a certain peak voltage and short-circuits the condenser in the plate circuit. A sweep circuit of this type is shown in figure 32.

The sweep circuit oscillation can be synchronized with that of the audio frequency signal by applying a small portion of it to the grid circuit of the type 885 tube. The approximate frequency of the saw-tooth oscillator is adjusted by means of the capacity in the plate circuit of the type 885 tube and the value of the resistance in series with the positive-B lead from this tube. The output of this oscillator must be amplified by a high-gain audio stage, such as a type 57 tube, in order to provide sufficient voltage to produce a sweep across the screen of the RCA-913 cathode-ray tube. An additional type 57 pentode audio amplifier is shown in the circuit diagram; it can be used to amplify the test audio voltages if the latter are of low amplitude. The power supply consists of two rectifier and filter circuits which supply plate voltage to all of the tubes in the oscilloscope.

Emergency Work

In many of the larger cities, various individuals and clubs have prepared themselves for any emergency that might arise by constructing and keeping in readiness self-powered communication equipment, for use in case of power failure. Such foresightedness is to be commended.

On the other hand, disaster is bound to strike at times in localities where no such methodical preparation has been made. In such an event, amateurs with a reasonable amount of technical training and experience should be able to establish communication within a couple of hours with no other facilities than an automobile tool kit, two or three auto radio receivers, and a couple of auto batteries. The latter are universally available, and a high percentage of the newer cars are now equipped with auto radios. If the supply of auto batteries is limited, they can be recharged as necessary by one of the autos from which they were commandeered.

One receiver can be torn up to provide parts and a power source for the transmitter. The output tube will make a good oscillator, either crystal or "t.n.t."

Another set can be torn into and the coils cut down until with the condenser plates entirely unmeshed they "hit" around 70 meters. Both the 80 and 160 meter bands can then be covered in grand style if a good outside antenna and a ground connection are used.

By wrapping a piece of insulated wire around both plate and grid leads of an i.f. tube (assuming the set is a superheterodyne, as most are), the stage can be made to oscillate, thus providing makeshift yet satisfactory heterodyne reception of c.w. signals. If the a.v.c. action bothers on c.w., either use a very short antenna or else ground the a.v.c. bus; either will effect a cure, the latter being the better method.

A microphone can be temporarily borrowed for the emergency from the nearest telephone. Two output transformers, of the type designed to match a pentode tube to dynamic speaker voice coil, can be connected with their corresponding windings in series (primaries in series; secondaries in series) and used backwards as a single, microphone transformer to feed directly into a pentode tube used as a class A modulator (Heising). It will be necessary to talk loudly and directly into the microphone, which incidentally should be fed from a separate 6 volt battery in order to avoid vibrator hash in the speech.

Home stations often can be kept on the air after a power failure by utilizing an auto radio and battery, feeding plate voltage to either the oscillator or exciter of your regular transmitter from the vibrator pack and deriving heater voltage direct from the battery. The oscillator or exciter should be originally designed with this in mind.

Any amateurs in the vicinity possessing battery-powered or auto-installed 5 meter gear can locate their equipment at strategic points and take care of short-haul traffic.

Amateurs not in the immediate disaster area usually can be of most service by doing lots of listening, and little or no transmitting until called upon.

Chapter 18

Radio Therapy

SHORT-WAVE radio-frequency energy can be applied to the human body for the purpose of treating various ailments. This form of treatment is known as *radio therapy*, and the apparatus is called a *diathermy machine*.

Radio-frequency energy can be applied to various parts of the human anatomy in order to produce a localized fever or temperature. The increase in temperature is effective for increasing circulation and for destroying certain kinds of germ diseases. The radio-frequencies involved in radio therapy normally range from 6 to 16 meters in wavelength, although there has not yet been an accepted standard of frequencies for the treatment of any particular ailment. The muscular cartilage, fatty and bone tissues all respond differently to applied radio waves. Some of these tissues are dielectrics while others are conductors, yet most of them have an intermediate characteristic, that of a leaky dielectric shunted by a capacitance. The radio energy is dissipated in the form of a dielectric loss which increases the temperature of that portion of the anatomy under treatment.

The correct application of radio therapy depends upon the ailment and should, therefore, be under the supervision of a skilled physician. The diathermy machine usually has a means of controlling the power output and often has a frequency control in the form of plug-in coils. The radio energy is normally applied by means of a pair of rubber-covered metal electrodes which are placed on opposite sides of the portion of the body of the patient under treatment.

A diathermy machine consists of an oscillator with a normal output of from 100 to 200 watts. The load impedance connected across the oscillator varies greatly; this requires special design of the oscillator circuit. The variation in load impedance is caused by the variation in size and in spacing between the electrodes required for various forms of treatment.

Radio therapy is used to kill certain bacteria in the body, much in the same manner as artificially-induced typhoid fever. It must be emphasized that the ramifications of radio therapy are still highly problematical. The entire subject must be handled with discretion, because careless use of radio therapy can and has caused extremely serious damage. Self-treatment or treatment of friends by means of a home-built diathermy machine should never be attempted unless the operator is thoroughly familiar with this branch of physio-therapy.

Diathermy machines are essentially radio transmitters, and they can cause serious interference to radio reception. The diathermy machine should be housed in a shielded cabinet; the 110-volt line should include an r.f. filter in order to prevent the r.f. energy from feeding back into the line and thereby radiating into space. The output electrode pads and the patient proper act as an antenna system, and thus both machine and patient should be placed in a metallically-screened room. This room can be made of ordinary galvanized iron screen, provided that all seams are carefully soldered and especial care taken to prevent r.f. leakage around the doorway. This type of room construction is similar to that used for receiver testing in radio manufacturing plants.

A circuit for a typical diathermy machine is shown in figure 1. This circuit has certain features not found in most commercially-made machines. The oscillator circuit proper is a push-pull *Hartley* system in which the grid excitation is more constant than in most u.h.f. oscillator circuits for various load impedances. A full-wave rectifier system with sufficient filter capacity is of practical value for reducing radio interference which is caused by the more usual form of self-rectified power supply circuit.

The wave-form of the r.f. output power is not as sharply peaked when a full-wave rectifying system is used, with the result that there is less danger to body tissues. The ratio of peak-to-average r.f. voltage should be as low as possible in any diathermy machine. The only virtue of a self-rectified oscillator is its cheapness, and even though offered by many manufacturers, should not be given consideration.

A 6E5 electron-ray tube is used as a "ready" indicator by having its 6.3-volt heater connected across the 5-volt filament supply. The 866 rectifier tubes should be allowed to reach normal temperature before the high voltage power supply switch is thrown to the *on* position. By the time the 6E5 tube first glows at full brilliancy, the 866's will have reached operating temperature and plate voltage may be applied.

Many of the older machines, and some of the newer ones as well, do not use either a lumped or adjustable capacity across the output tank coil; the tank circuit therefore has insufficient *Q*, especially when a single-ended oscillator is used. The well-designed diathermy machine uses a pair of fixed condenser plates which act as a lumped capacity across the plate tank circuit. The pads are tuned to resonance by means of a variable condenser in the output circuit.

The system shown in the schematic diagram has many advantages over the aforementioned types in that the *oscillator* is tuned to the *output circuit*, instead of the pads being tuned to the frequency of the oscillator. When the plates of the tank condenser in figure 1 are entirely *out*, the "minimum" capacity of the condenser is high enough to offer sufficient *Q* for proper operation of a push-pull circuit below 16 meters; at the same time, it allows a frequency range of almost two-to-one to be covered by merely using pads that resonate at different frequencies. If a still greater frequency range is to be covered, this can be accomplished by means of plug-in coils. A five-connection plug and jack transmitter assembly is suitable for use with such coils, and by this means it will then be possible to cover a range of from approximately 5 to 19 meters. Pads with long leads sometimes can be resonated after a fashion at the higher frequencies (5 or 6 meters) by resonating them on the third harmonic.

The disadvantage of the customary fixed-tuned plate tank and series-tuned pad circuit lies in the high capacity series variable condenser which is required; also it is often difficult to resonate the pads when they are placed in some unusual position on the body of the patient. In addition to its high capacity, the series condenser must have wider spacing between plates than would ordinarily be assumed, because the pads will sometimes resonate when the condenser plates are almost entirely unmeshed. Under the latter condition, there is a high r.f. potential across the condenser.

The r.f. potential in a condenser which is placed across a plate tank is much more uniform under the varying conditions encountered with the pad circuit. In addition, the capacity of the condenser need be only a fraction of that ordinarily required where the condenser is used to resonate the pad circuit.

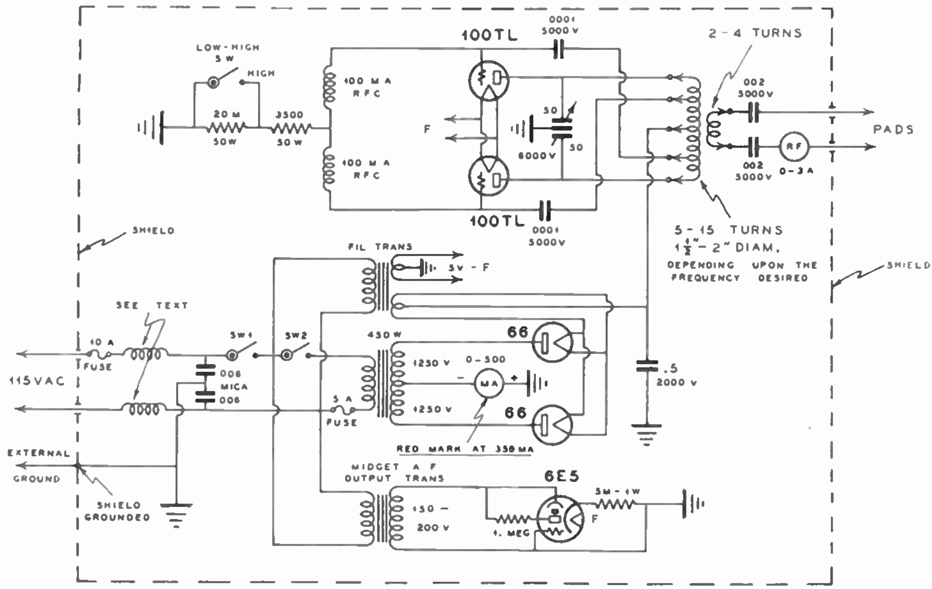
All insulation that is either in contact with r.f. leads or in an r.f. field should be of high-grade ceramic material. The tank and antenna coils can be wound with no. 8 wire, self-supported by end and center-tap connections.

A push-pull *Hartley* circuit is used in the machine described because its frequency can be varied by a single tuning condenser without affecting the excitation. In addition to being superior in this respect, the circuit performs equally well in all other respects; then, too, if plug-in coils are used, it is only necessary to change a single coil.

An approximate adjustment of the output is secured by means of a *Low-High* switch. The output decreases considerably when the switch is opened, thereby adding a 20,000-ohm grid-leak into the circuit. Minute adjustment of the output is obtained by simply detuning the tank condenser, a crude but entirely satisfactory method. This means that the operator need manipulate only one switch and one knob for adjustment of the output.

At the point where the 110-volt a.c. supply leads enter the cabinet which houses the diathermy machine, 20 turns of no. 12 wire are wound on a diameter of ¾-inch and connected in series with the transformer primaries and the two a.c. supply leads. These coils constitute an effective pair of line chokes, one in each lead of the 110-volt line. They are as effective as any commercially-made choke, the latter normally being designed to operate at lower frequencies than those at which the diathermy machine operates. These home-made u.h.f. chokes, in connection with the .006-μfd. condensers shown in the circuit diagram, constitute as effective a filter as it is possible to secure.

The grid taps on each tank coil are made exactly the same distance from each side of center. If one tube heats more than the other, it indicates that the taps are not symmetrically made. To adjust the taps to their proper position, disconnect the pads from the circuit, place a 0-150 or 0-250 ma. a.c. milliammeter across the 20,000-ohm grid-leak with the *Low-High* switch in the *Low* (open) position, and move the taps outwardly toward the ends of the coil until the meter gives an indication of 100 ma. This is greater than the maximum grid current



250 Watt Variable-High-Frequency Diathermy

rating of the tubes (35 ma. per tube), but with the pads connected to the circuit this value will decrease slightly, and when the pads are loaded (resonated) there will be another decrease. Under normal use, the grid current will be somewhat less than 70 ma. for the two tubes. When the grid meter is removed, and with the switch in the *Low* position (with the additional grid-leak in the circuit) the grid current will be still lower. A grid meter can be permanently incorporated in this diathermy machine, if desired, in which event it would be wired in *series* with the grid resistor. It is absolutely necessary, however, only for this initial adjustment.

A red ink "warning" marker should be drawn on the scale of the plate meter at the point of 350 ma., in order to make certain that this value of plate current will not be exceeded. The plate meter is the only essential meter in this machine, although some physicians insist upon a r.f. meter in the pad circuit. Neither plate current nor r.f. output are more than an approximate indication of the degree of heating; they are not relied upon except as a means for a relative check when the pads are in any *given position* on a *certain patient.* When the pads are placed in different positions, the r.f. meter may read either higher or lower for a given heating effect. The actual temperature of that portion of the body of the patient under treatment is the only safe barometer of the amount of heating effect being supplied.

The mica condensers in series with the pads have no effect on the performance of the circuit; they are used merely for the purpose of safeguarding the patient against high d.c. voltages in the event of breakdown of the ceramic material which supports the coils.

It is very difficult to stop oscillation by means of excessive output loading; nothing other than an abnormal value of plate current will result when the machine is too heavily loaded, as will be indicated by the meter when the needle passes the red ink "danger" mark. Should the circuit accidentally stop oscillating, a *very* high degree of plate current will flow just long enough to permit the 5-ampere primary fuse to blow. For this reason the fuses should be accessible at some point on the outer portion of the diathermy machine housing.

It is important that the center-tap connection of the rectifier filament winding be used, rather than one leg of the rectifier filaments, for the high voltage connection. This prevents r.f. from finding its way back into the tubes through the high voltage lead, because the capacity of the transformer to ground is sufficiently high to bypass practically all r.f.

to ground. The r.f. current in the high voltage lead is very small (theoretically zero at the fundamental frequency), but is sufficiently high to cause erratic operation of the rectifiers if this current finds its way back into the rectifier tubes. The 0.5 μfd. filter condenser is not very effective at radio frequencies and it is therefore possible to draw small sparks from the high voltage lead.

The small filter condenser (0.5 μfd.) provides sufficient filtering to prevent the oscillator tubes from going out of oscillation for an instantaneous period 120 times per second; it is the latter that results in "hash" on the lower frequencies, including the broadcast band. The ripple voltage will still be quite high, with the small filter, but interference on frequencies other than those of the operating frequency will be eliminated.

It is not advisable to use higher capacity values than those shown in figure 1; otherwise the plate voltage will rise to excessive values when the pads are not loaded and when the plate current is relatively low. This, in turn, results in excessive grid current. The grid current normally tends to rise badly anyway when an oscillator is not loaded.

If this diathermy machine causes interference to nearby amateurs on the 5, 10 and 20 meter bands, the cure lies in the installation of a heavy duty *choke-input filter,* consisting of a 30 henry 350 ma. swinging choke and a 4 μfd. 2,000 volt condenser. This permits a high degree of filtering without sacrificing voltage regulation. The interference will then be confined to a very narrow range of frequencies. If a choke input filter is used, a higher voltage plate transformer will be required (1500 v.).

In order to prolong the life of rectifier and oscillator tubes it is important that they be permitted to warm-up for a period of 20 or 30 seconds before plate voltage is applied. Switch *SW-2* should never be thrown to the *on* position, until switch *SW*-1 has first been turned on. This means that switch *SW-2* is turned on last, and turned off first. The 6E5 electron-ray indicator tube can be mounted directly above switch *SW-2* with the following inscribed on the panel: *"SW-2 Should Never Be Turned 'ON' Except When Green Light Shows."* By this means it will be necessary for the user to wait for about thirty seconds before the plate voltage is turned on. *SW-2,* however, must always be turned *off* before *SW*-1 is turned *on;* otherwise *SW-2* would remain *on* when the electron-ray indicator light is not glowing.

To avoid this possibility the following should also be inscribed conspicuously on the control panel: *"When Through with Machine, Be Sure All Switches Are Turned Off."* A red pilot light connected across the *primary* of one of the filament transformers will help the physician to remember to turn off switch *SW*-1.

If desired, a time delay relay may be used to protect the rectifiers, thus making a foolproof arrangement. However, besides being cheaper, the 6E5 indicator arrangement enhances the machine and impresses the patient. This last factor has been stressed by most physicians ordering this type of equipment, and cannot be ignored.

Information as to the availability of the heating pads may be obtained from the publishers by enclosing a stamped, self-addressed envelope.

Chapter 19

Radio Laws

Rules Governing Amateur Radio Stations and Operators in the United States

(As in effect November 1, 1937)

The following excerpts from the Federal Communications Commission's rules include all that deal solely with the amateur service and certain others that apply generally.

• Practice and Procedure

103.6. **Applications.**—Each application for an instrument of authorization shall be made in writing, under oath of the applicant, on a form prescribed and furnished by the Commission * * *. Separate application shall be filed for each instrument of authorization requested * * * The required forms may be obtained from the Commission or from any of its field offices. (For a list of such offices and related geographical districts, see rule 30.)

103.7. **Place of filing; number of copies.**—Each application for * * * station license, with respect to the number of copies and place of filing, shall be submitted as follows: * * *

g. Amateur. 1 copy to be sent as follows (*a*) To proper district office if it requires personal appearance for operator examination under direct supervision from that office; (*b*) Direct to Washington, D. C., in all other cases, including examinations for class C privileges.

103.8. **Amendments; withdrawals.**—Where other parties will not be aggrieved or adversely affected thereby, an applicant may amend or withdraw his application without prejudice, at any time up to the conclusion of a hearing thereon * * *.

103.14. **Modification of license.**—An application for modification of license may be filed for * * * change in location * * *. Except when filed to cover construction permit, each application for modification of license shall be filed at least 60 days prior to the contemplated modification of license; *Provided, however,* That in emergencies and for good cause shown, the Commission may waive the requirements hereof insofar as time for filing is concerned.

103.15. **Renewal of license.**—Unless otherwise directed by the Commission, each application for renewal of license shall be filed at least 60 days prior to the expiration date of the license sought to be renewed.

103.16. **Application called for by Commission.**—Whenever the Commission regards an application for a renewal of license as essential to the proper conduct of a hearing or investigation, and specifically directs that the same be filed by a date certain, such application shall be filed within the time thus specified. If the licensee fails to file such application within the prescribed time, the hearing or investigation shall proceed as if such renewal application had been received.

103.17. **Extension of station and operator licenses.**—Where there is pending before the Commission any application, investigation, or proceeding which, after hearing, might lead to or make necessary the modification of, revocation of, or the refusal to renew an existing license, or the suspension of an operator's license, the Commission may, in its discretion, grant a temporary extension of such license; *Provided, however,* That no such temporary extension shall be construed as a finding by the Commission that the operation of any radio station thereunder, or use of the operator's license, will serve public interest, convenience, and necessity beyond the express terms of such temporary extension of license, and *Provided further,* That such temporary extension of license will in no wise affect or limit the action of the Commission with respect to any pending application or proceeding.

104.1. **Defective applications rejected.**—If an applicant, by specific request of the Commission, is required to file any documents or information not included in the prescribed application forms, a failure to comply therewith shall constitute a defect in the application, and the application will not be considered by the Commission. Any application which is not filed in accordance with the Commission's regulations with respect to the form used, manner of execution, and completeness of answer to questions therein required, will not be considered by the Commission. Each such application shall be returned to the applicant by the Secretary of the Commission, together with a brief statement of the respect in which it is defective.

105.23. **Answers to notice of violations.**—Any licensee receiving official notice of a violation of the terms of the Communications Act of 1934, any legislative act, Executive order, treaty to which the United States is a party or the rules and regulations of the Federal Communications Commission, which are binding upon licensee or the terms and conditions of a license, shall, within 3 days from such receipt, send a written reply direct to the Federal Communications Commission at Washington, D. C., and a copy thereof to the office of the Commission originating the official notice, when the originating office is other than the office of the Commission in Washington, D. C. The answer to each notice shall be complete in itself and shall not be abbreviated by reference to other communications or answers to other notices. If the notice relates to some violation that may be due to the physical or electrical characteristics of the transmitting apparatus, the answer shall state fully what steps, if any, are taken to prevent future violations, and if any new apparatus is to be installed, the date such apparatus was ordered, the name of the manufacturer, and promised date of delivery.

* * * * *

If the notice of violation relates to some lack of attention or improper operation of the transmitter, the name and license number of the operator in charge shall be given.

105.29. **Revocation proceedings under section 312 (a) of the act.**—Whenever the Commission shall institute a revocation proceeding against the holder of any radio station construction permit or license under section 312 (a), it shall initiate said proceeding by serving upon said licensee an order of revocation effective not less than 15 days after written notice thereof is given the licensee. The order of revocation shall contain a statement of the grounds and reasons for such proposed revocation and a notice of the licensee's right to be heard by filing with the Commission a written request for hearing within 15 days after receipt of said order. Upon the filing of such written request for hearing by said licensee the order of revocation shall stand suspended and the Commission will set a time and place for hearing and shall give the licensee and other interested parties notice thereof. If no request for hearing on any order of revocation is made by the licensee against whom such an order is directed within the time hereinabove set forth, the order of revocation shall become final and effective, without further action of the Commission.

* * * * *

105.31. **Suspension of operator license.**—Proceedings for the suspension of an operator license shall in all cases be initiated by the entry of an order of suspension, a copy of which shall be served upon or mailed to the holder of the license involved, to become effective on a day certain, in no event less than 40 days after date of serving or mailing such order. The order shall set forth the name of the operator, class and grade of license, the effective date of the order, the period of suspension, and a statement of the reasons for suspension, and shall contain a notice to the holder of such license of his right to be heard and contest the order, by filing with the Commission within 35 days from the receipt of said order, a written request for hearing with a statement executed by him under oath, denying or explaining specifically and in detail the charges set forth in the order of suspension. Upon receipt of such request and statement, the effective date of the suspension of such license will be extended; and the Commission, upon consideration of the licensee's statement, as herein provided, will either revoke its order of suspension, or fix a time and place for hearing, and notify the licensee thereof.

If no request for hearing on any order of suspension is made by the licensee against whom such order is directed within 35 days of receipt of such order of suspension, the same shall become final and effective.

Where any order of suspension has become final, the person whose license has been suspended shall forthwith send the operator's license in question to the office of the Commission in Washington, D. C.

Other General Rules

27. **Normal license periods.**—All station licenses will be issued so as to expire at the hour of 3 a. m., eastern standard time. * * *

e. The licenses for amateur stations will be issued for a normal license period of 3 years from the date of expiration of old license or the date of granting a new license or modification of a license.

28. **Designation of call signals.**—Insofar as practicable, call signals of radio stations will be designated in alphabetical order from groups available for assignment, depending upon the class of station to be licensed. Because of the large number of amateur stations, calls will be assigned thereto in regular order and requests for particular calls will not be considered except on formal application the Commission may reassign calls to the last holders of record.

29. **Deletion of call signals.**—Call signals of stations will be deleted in each of the following cases:

a. Where an existing instrument of authorization has expired and no application for renewal or extension thereof has been filed.

b. Where a license has been revoked.

c. Where a license is surrendered or cancelled.

d. Other cause, such as death, loss of citizenship, or adjudged insanity of the station licensee. Such occurrences coming to notice should be reported to the Commission, preferably accompanied by the station license for cancellation, if available.

30. **Radio districts.**—The following list of the radio districts [do not confuse with call areas—EDITOR] gives the address of each field office of the Federal Communications Commission and the territory embraced in each district: [See p. 408.]

a. **Examining cities.**—Examinations for all classes of radio operator licenses will be given frequently at Washington, D. C., and the District Offices of the Commission in accordance with announced schedules.

(1) Such examination will be held quarterly at:
Cincinnati, O.
Cleveland, O.
Columbus, O.
Des Moines, Iowa.
Nashville, Tenn.
Oklahoma City, Okla.
Pittsburgh, Pa.
St. Louis, Mo.
San Antonio, Texas.
Schenectady, N. Y.
Winston-Salem, N. C.

(2) Examinations will be held not more than twice annually at:
Albuquerque, N. Mex.
Billings, Mont.
Bismarck, N. Dak.
Boise, Idaho.
Butte, Mont.
Jacksonville, Fla.
Little Rock, Ark.
Phoenix, Ariz.
Salt Lake City, Utah.
Spokane, Wash.

Note.—Arrangements have also been made, including cooperation of other Federal agencies, for class A examinations in outlying areas as follows:

Alaska.—United States Signal Corps stations.

Guam.—District communications officer, United States naval station.

Hawaii.—At not exceeding one point on any island, by the inspector in charge (Honolulu).

Puerto Rico.—District communications officer, United States naval radio station, San Juan.

b. **Amateur call areas.**—The following is a list of the amateur call areas, showing the territory embraced in each area: [Omitted here for lack of space; refer to Radio Amateur Call Book or Government booklet from which this text is reprinted.—EDITOR.]

Services Other Than Broadcast

GENERAL REGULATIONS

182. **Scope.**—Whenever in these regulations the words "services other than broadcast" are used without specific restriction of further qualification, the words shall be taken to refer to all radio services, frequencies, etc., except broadcast serv-

ice in the band of frequencies between 550 and 1,500 kilocycles, inclusive.[1]

184. **Waves designated by frequency.**—In these regulations and instruments of authorization issued by the Commission a wave referred to is designated by its frequency in kilocycles per second.

185. **Total spectrum of waves.**—The total spectrum of waves shall be construed as extending in frequency from 10 to 500,000 kilocycles, inclusive. This provision, however, shall not be interpreted as precluding authority of the Commission over the use of waves having frequencies less than 10 kilocycles or more than 500,000 kilocycles if and when such waves, by reason of progress in the art, become availablee for radio communication either practically or experimentally, nor as precluding the Commission from issuing instruments of authorization with respect to the use of such waves.

186. **Division of total spectrum into major bands.**—The total spectrum of waves as hereinbefore defined is hereby divided into six major bands, as follows:

a. Low-frequency: 10 to 100 kilocycles.
b. Medium-frequency: 100 to 550 kilocycles.
c. Broadcast: 550 to 1,500 kilocycles.
d. Medium high-frequency: 1,500 to 6,000 kilocycles.
e. High-frequency: 6,000 to 30,000 kilocycles.
f. Very high-frequency: Above 30,000 kilocycles.

187. **Definitions.**—The following definitions shall apply generally to all services (see also International Telecommunication Convention).

188. **Station.**—The term "station" means all of the radio-transmitting apparatus used at a particular location for one class of service and operated under a single instrument of authorization. In the case of every station other than broadcast, the location of the station shall be considered as that of the radiating antenna.

189. **Mobile station.**—The term "mobile station" means a station that is capable of being moved and ordinarily does move.

190. **Fixed station.**—The term "fixed station" means a station, other than an amateur station, not capable of being moved, and communicating by radio with one or more stations similarly established.

191. **Land station.**—The term "land station" means a station not capable of being moved, carrying on a mobile service.

192. **Portable station.**—The term "portable station" means a station so constructed that it may conveniently be moved about from place to place for communication and that is in fact so moved about from time to time, but not used while in motion.

a. **Portable-mobile station.**—The term "portable-mobile station" means a station so constructed that it may conveniently be moved from one mobile unit to another for communication, and that is, in fact, so moved about from time to time and ordinarily used while in motion.

193. **Mobile service.**—The term "mobile service" means a radio-communication service carried on between mobile and land stations and by mobile stations, communicating among themselves, special services being excluded.

194. **Fixed service.**—The term "fixed service" means a service carrying on radio-communication of any kind between fixed points, excluding broadcasting services and special services.

195. **Special service.**—The term "special service" means a radio-communication service carried on especially for the needs of a specific service of general interest and not open to public correspondence, such as a service of radiobeacons, radio direction finding, time signals, regular meteorological bulletins, notices to navigators, press messages addressed to all, medical notices (medical consultation by radio), standard frequencies, emissions for scientific purposes, etc.

196. **International service.**—The term "international service" means a radio-communication service between offices or stations under the jurisdiction of different countries, or between stations of the mobile service except when the latter are of the same nationality and are within the limits of the country to which they belong. An internal or national radio-communication service which is likely to cause interference with services beyond the limits of the country in which it operates shall be considered as an international service from the standpoint of interference.

197. **General communication service.**—The term "general communication service" is used in these regulations only with respect to the service allocation of certain frequencies, and means that such frequencies have not been assigned to any specific service, and are available for future allocation to services which will be designated.

198. **Public service.**—The term "public service" means a service for the use of the public in general.

199. **Public correspondence.**—The term "public correspondence" means any radio-communication where the offices and stations, by reason of their being at the disposal of the public, must accept for transmission.

200. **Private service.**—The term "private service" means a radio-communication service which is not open to public correspondence and which may be used only by specified persons for either general or specific purposes.

201. **Private enterprise.**—The term "private enterprise" means any person, company, or corporation which operates one or more stations for radio communication.

202. **Limited service.**—The term "limited service" means a service which can be used only by specified persons or for special purposes.

203. **Radio operating signals.**—The term "radio operating signals" means a letter, figure, or combination of letters and figures, or both, designed to facilitate the conduct of communications; for example, the list of abbreviations to be used in Radio Transmission, appendix 9 to the General Radio Regulations annexed to the International Telecommunication Convention.

204. **Allocation of bands of frequencies to services.**—Allocations of bands of frequencies to services, such as mobile, fixed, broadcast, amateur, etc., are set forth in article 7 of the General Radio Regulations annexed to the International Telecommunication Convention and in the North American Radio Agreement. These allocations will be adhered to in all assignments to stations capable of causing international interference.

205. **Frequency standard.**—The national standard of radiofrequency maintained by the Bureau of Standards, Department of Commerce, shall be the basis for all frequency measurements, and assignments will be made on the basis of this standard.

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[1] *International conventions.*—In addition to the regulations herein contained licensees must observe the provisions of the following insofar as they apply:

a. The Telecommunication Convention and General Radio Regulations annexed thereto (State Department Treaty Series No. 867).

b. North American Radio Agreement of 1929 (State Department Treaty Series No. 777-A).

Copies may be obtained from the Superintendent of Documents, Washington, D. C. Treaty Series No. 867, price 20 cents, and Treaty Series No. 777-A, price 10 cents.

RADIO DISTRICTS

Territory embraced and address of inspector in charge. (Do not confuse with call areas.)

Radio District	Address of the Inspector in Charge	Territory Within District	
		States, Etc.	Counties
1	Customhouse, Boston, Mass.	Connecticut	All counties.
		Maine	Do.
		Massachusetts	Do.
		New Hampshire	Do.
		Rhode Island	Do.
		Vermont	Do.
2	Federal Building, New York, N. Y.	New Jersey	Bergen, Essex, Hudson, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Passaic Somerset, Sussex, Union, and Warren.
		New York	Albany, Bronx, Columbia, Delaware, Dutchess, Greene, Kings, Nassau, New York, Orange, Putnam, Queens, Rensselaer, Richmond, Rockland Schenectady, Suffolk, Sullivan, Ulster, and Westchester.
3	New United States Customhouse, Philadelphia, Pa.	Delaware	Newcastle.
		New Jersey	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Ocean, and Salem.
		Pennsylvania	Adams, Berks, Bucks, Carbon, Chester, Cumberland, Dauphin, Delaware, Lancaster, Lebanon, Lehigh, Monroe, Montgomery Northampton, Perry, Philadelphia, Schuylkill, and York.
4	Fort McHenry, Baltimore, Md.	Delaware	Kent and Sussex.
		District of Columbia	All counties.
		Maryland	Do.
		Virginia	Arlington, Clark, Fairfax, Fauquier, Frederick, Loudoun, Page, Prince William, Rappahannock, Shenandoah, and Warren.
5	New Post Office Building, Norfolk, Va.	North Carolina	All except district 6.
		Virginia	All except district 4.
6	New Post Office Building, Atlanta, Ga.	Alabama	All counties.
		Georgia	Do.
		North Carolina	Ashe, Avery, Buncombe, Burke, Caldwell, Cherokee, Clay, Cleveland, Graham, Haywood, Henderson, Jackson, McDowell, Macon, Madison, Mitchell, Polk, Rutherford, Swain, Transylvania, Watauga, and Yancey.
		South Carolina	All counties.
		Tennessee	Do.
7	Post Office Box 150, Miami, Fla.	Florida	Do.
		Puerto Rico	
		Virgin Islands	
8	Customhouse, New Orleans, La.	Arkansas	Do.
		Louisiana	Do.
		Mississippi	Do.
		Texas	City of Texarkana only.
9	Prudential Building, Galveston, Tex.	Texas	Aransas, Brazoria, Brooks, Calhoun, Cameron, Chambers, Fort Bend, Galveston, Goliad, Harris, Hidalgo, Jackson, Jefferson, Jim Wells, Kenedy, Kleberg, Matagorda, Nueces, Refugio, San Patricio, Victoria, Wharton, and Willacy.
10	Federal Building, Dallas, Tex.	New Mexico	All counties.
		Oklahoma	Do.
		Texas	All except district 9 and the city of Texarkana
11	Rives-Strong Building, Los Angeles, Calif.	Arizona	All counties.
		California	Imperial, Inyo, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, and Ventura.
		Nevada	Clarke.

Radio District	Address of the Inspector in Charge	Territory Within District: States, etc.	Territory Within District: Counties
12	Customhouse, San Francisco, Calif.	California	All except district 11.
		Nevada	All except Clarke.
		Guam	
		Midway	
		Wake	
		American Samoa	
13	New United States Courthouse, Portland, Oreg.	Idaho	All except district 14.
		Oregon	All counties.
14	Federal Office Building, Seattle, Wash.	Alaska	
		Idaho	Benewah, Bonner, Boundary, Clearwater, Idaho, Kootenai, Latah, Lewis, Nez Perce, and Shoshone.
		Montana	Beaverhead, Broadwater, Cascade, Deerlodge, Flathead, Gallatin, Glacier, Granite, Jefferson, Lake, Lewis and Clark, Lincoln, Madison, Meagher, Mineral, Missoula, Pondera, Powell, Ravalli, Sanders, Silver Bow, Teton, and Toole.
		Washington	All counties.
15	Customhouse, Denver, Colo.	Colorado	Do.
		Montana	Except district 14.
		Utah	All counties.
		Wyoming	Do.
16	New Main Post Office Building, St. Paul, Minn.	Minnesota	Do.
		Michigan	Alger, Baraga, Chippewa, Delta, Dickinson, Gogebic, Houghton, Iron, Keweenaw, Luce, Mackinac, Marquette, Menominee, Ontonagon, and Schoolcraft.
		North Dakota	All counties.
		South Dakota	Do.
		Wisconsin	All except dist 18.
17	Federal Building, Kansas City, Mo.	Iowa	Do.
		Kansas	All counties.
		Missouri	Do.
		Nebraska	Do.
18	Engineering Building, Chicago, Ill.	Illinois	All counties.
		Indiana	Do.
		Iowa	Allamakee, Buchanan, Cedar, Clayton, Clinton, Delaware, Des Moines, Dubuque, Fayette, Henry, Jackson, Johnson, Jones, Lee, Linn, Louisa, Muscatine, Scott, Washington, and Winneshiek.
		Wisconsin	Columbia, Crawford, Dane, Dodge, Grant, Green, Iowa, Jefferson, Kenosha, Lafayette, Milwaukee, Ozaukee, Racine, Richland, Rock, Sauk, Walworth, Washington, and Waukesha.
19	New Federal Building, Detroit, Mich.	Kentucky	All counties.
		Michigan	All except district 16.
		Ohio	All counties.
		West Virginia	Do.
20	Federal Building, Buffalo, N. Y.	New York	All except district 2
		Pennsylvania	All except district 3.
21	Aloha Tower, Honolulu, Territory of Hawaii.	Territory of Hawaii	

206. **Frequency checking.**—The licensee of each station, except amateur, shall provide for measurement of the station frequency and establish procedure for checking it regularly. These measurements of station frequency shall be made by means independent of the frequency control of the transmitter and shall be of such an accuracy that the limit of error is within the frequency tolerance allowed the station.

207. **Interference, prevention of.**—Licensees shall use radio transmitters the emissions of which do not cause interference, outside the authorized band, that is detrimental to traffic and programs of other authorized stations.

208. **Emissions.**—Except for amateur stations, each license and construction permit will specify the type or types of emission that the station is authorized to use, in conformity with the definitions given in article 7 of the General Radio Regulations annexed to the International Telecommunication Convention, but special types of emission not specifically defined therein will be designated in instruments of authorization with reference to the nature of service the station is authorized to render.

209. **Damped waves.**—Except for ship stations under the conditions hereinafter specified, no license will be issued for the operation of any station using, or proposing to use, transmitting apparatus employing damped wave emissions.

210. **Distress messages.**—Radio communications or signals relating to ships or aircraft in distress shall be given absolute priority. Upon notice from any station, government or commercial, all other transmission shall cease on such frequencies and for such time as may, in any way, interfere with the reception of distress signals or related traffic.

211. No station shall resume operation until the need for distress traffic no longer exists, or it is determined that said station will not interfere with distress traffic as it is then being routed and said station shall again discontinue if the routing of distress traffic is so changed that said station will interfere. The status of distress traffic may be ascertained by communication with Government and commercial stations.

212. The Commission may require at certain stations an effective, continuous watch on the distress frequency, 500 kilocycles (410 kilocycles in the Great Lakes area).

213. **Operators.**—One or more licensed operators of the grade specified by these regulations shall be on duty at the place where the transmitting apparatus of each station is located and whenever it is being operated; *Provided, however,* That for a station licensed for service other than broadcasting, and remote control is used, the Commission may modify the foregoing requirement, upon proper application and showing being made, so that such operator or operators may be on duty at the control station in lieu of the place where the transmitting apparatus is located. Such modification shall be subject to the following conditions:

a. The transmitter shall be capable of operation and shall be operated in accordance with the terms of the station license.

b. The transmitter shall be monitored from the control station with apparatus that will permit placing the transmitter in an inoperative condition in the event there is a deviation from the terms of the license, in which case the radiation of the transmitter shall be suspended immediately until corrective measures are effectively applied to place the transmitter in proper condition for operation in accordance with the terms of the station license.

c. The transmitter shall be so located or housed that it is not accessible to other than duly authorized persons.

214. **Licensed operator required.**—Only an operator holding a radiotelegraph class of operator's license may manipulate the transmitting key of a manually operated coastal telegraph or mobile telegraph station in the international service; and only a licensed amateur operator may manipulate the transmitting key at a manually operated amateur station. The licensees of other stations operated under the constant supervision of duly licensed operators may permit any person or persons, whether licensed or not, to transmit by voice or otherwise, in accordance with the types of emission specified by the respective licenses.[1]

220. **Maintenance tests.**—Licensees of stations other than broadcast stations are authorized to carry on such routine tests as may be required for the proper maintenance of the stations: *Provided, however,* That these tests shall be so conducted as not to cause interference with the service of other stations.

221. **Licenses, posting of.**—The original of each station license, except amateur, portable, and portable-mobile stations shall be posted by the licensee in a conspicuous place in the room in which the transmitter is located. In the case of amateur, portable, and portable-mobile stations the original license, or a photostat copy thereof, shall be similarly posted or kept in the personal possession of the operator on duty.

a. The original license of each station operator, except amateur and aircraft radio station operators, and operators of portable and portable-mobile stations, shall be posted in a conspicuous place in the room occupied by such operator while on duty. In the case of an amateur or aircraft radio operator, and operators of portable or portable-mobile stations, the original operator's license shall be similarly posted or kept in his personal possession and available for inspection at all times while the operator is on duty.

b. When an operator's license cannot be posted because it has been mailed to an office of the Federal Communications Commission for endorsement or other change, such operator may continue to operate stations in accordance with the class of license held for a period not to exceed 60 days, but in no case beyond the date of expiration of the license.

222. **Day frequencies.**—In all cases where the word "day" or "daylight" occurs in connection with a specific frequency, such use of the word shall be construed to mean that period of time included between 2 hours after local sunrise and 2 hours before local sunset.

Amateur Service

361. **Definitions, amateur service.** The term "amateur service" means a radio service carried on by amateur stations.

362. **Definition, amateur station.** — The term "amateur station" means a station used by an "amateur," that is, a duly authorized person interested in radio technique solely with a personal aim and without pecuniary interest.

363. Deleted. (See pars. 362 and 364.)

364. **Definition, amateur radio operator.**—The term "amateur radio operator" means a person holding a valid license issued by the Federal Communications Commission who is authorized under the regulations to operate amateur radio stations.

365. **Definition, amateur radio communication.**—The term "amateur radio communication" means radio communication between amateur radio stations solely with a personal aim and without pecuniary interest.

[1] With reference to rule 214 the expression "constant supervision of duly licensed operators" shall for the time being and until further notice, be construed to mean:

a. For stations licensed to use frequencies below 30,000 kilocycles an operator of the grade required under rules 403, 420, and 443 shall be on duty at the transmitter location, whenever the transmitter is being operated, or at the remote control point if authorized in accordance with rule 213.

b. For stations licensed to use frequencies above 30,000 kilocycles only, the operator shall be similarly employed as in (*a*) above, provided, however, in the case of two or more stations licensed in the name of the same individual or organization, except amateur, a licensed radio operator of any class except amateur and radiotelephone third class who has the stations within his effective control, may be on duty at any point within the communication range of such stations in lieu of the transmitter location or control point during the actual operation of the transmitting apparatus, and shall supervise the emissions of all such stations so as to insure proper operation in accordance with the station license(s).

366. **Station licenses.**—An amateur station license may be issued only to a licensed amateur radio operator who has made a satisfactory showing of ownership or control of proper transmitting apparatus: *Provided, however,* That in the case of a military or naval reserve radio station located in approved public quarters and established for training purposes, but not operated by the United States Government, a station license may be issued to the person in charge of such station who may not possess an amateur operator's license.

a. **Operator's license.**—An amateur operator's license may be granted to a person who does not desire an amateur station license, provided such applicant waives his right to apply for an amateur station license for 90 days subsequent to the date of application for operator's license.

367. **Eligibility for license.**—Amateur radio station licenses shall not be issued to corporations, associations, or other organizations: *Provided, however,* That in the case of a bona fide amateur radio society a station license may be issued to a licensed amateur radio operator as trustee for such society.

368. **Mobile stations.**—Licenses for mobile stations and portable mobile stations will not be granted to amateurs for operation on frequencies below 28,000 kilocycles. However, the licensee of a fixed amateur station may operate portable amateur stations (rule 192) in accordance with the provisions of rules 384, 386, and 387; and also portable and portable-mobile amateur stations (rules 192 and 192a) on authorized amateur frequencies above 28,000 kilocycles in accordance with rules 384 and 386, but without regard to rule 387.

369. Deleted. Paragraph 213 applies.

370. **Points of communication.**—Amateur stations shall be used only for amateur service, except that in emergencies or for testing purposes they may be used also for communication with commercial or Government radio stations. In addition, amateur stations may communicate with any mobile radio station which is licensed by the Commission to communicate with amateur stations, and with stations of expeditions which may also be authorized to communicate with amateur stations.

371. **Amateur stations not to be used for broadcasting.**—Amateur stations shall not be used for broadcasting any form of entertainment, nor for the simultaneous retransmission by automatic means of programs or signals emanating from any class of station other than amateur.

372. **Radiotelephone tests.**—Amateur stations may be used for the transmission of music for test purposes of short duration in connection with the development of experimental radiotelephone equipment.

373. **Amateur stations not for hire.**—Amateur radio stations shall not be used to transmit or receive messages for hire, nor for communication for material compensation, direct or indirect, paid or promised.

374. The following bands of frequencies are allocated exclusively for use by amateur stations:

1,715 to 2,000 kilocycles.
3,500 to 4,000 kilocycles.
7,000 to 7,300 kilocycles.
14,000 to 14,400 kilocycles.
28,000 to 30,000 kilocycles.
56,000 to 60,000 kilocycles.
400,000 to 401,000 kilocycles.

a. The licensee of an amateur station may, subject to change upon further order, operate amateur stations on any frequency above 110,000 kilocycles, without separate licenses therefor, provided:

(1) That such operation in every respect complies with the Commission's rules governing the operation of amateur stations in the amateur service.

(2) That records are maintained of all transmissions in accordance with the provisions of rule 386.

NOTE.—The use of frequencies above 110,000 kilocycles may be with any type of emission authorized for amateur stations.

375. **Types of emission.**—All bands of frequencies so assigned may be used for radiotelegraphy, type A-1 emission. Type A-2 emission may be used in the following bands of frequencies only:

56,000 to 60,000 kilocycles.
400,000 to 401,000 kilocycles.

376. **Frequency bands for telephony.**—The following bands of frequencies are allocated for use by amateur stations using radio-telephony, type A-3 emission:

1,800 to 2,000 kilocycles.
28,500 to 30,000 kilocycles.
56,000 to 60,000 kilocycles.
400,000 to 401,000 kilocycles.

377. **Additional bands for telephony.**—Provided the station shall be operated by a person who holds an amateur operator's license endorsed for class A privileges, an amateur radio station may use radiotelephony, type A-3 emission, in the following additional bands of frequencies:

3,900 to 4,000 kilocycles.
14,150 to 14,250 kilocycles.

378. **Amateur television, facsimile, and picture transmission.**—The following bands of frequencies are allocated for use by amateur stations for television, facsimile, and picture transmission:

1,715 to 2,000 kilocycles.
56,000 to 60,000 kilocycles.

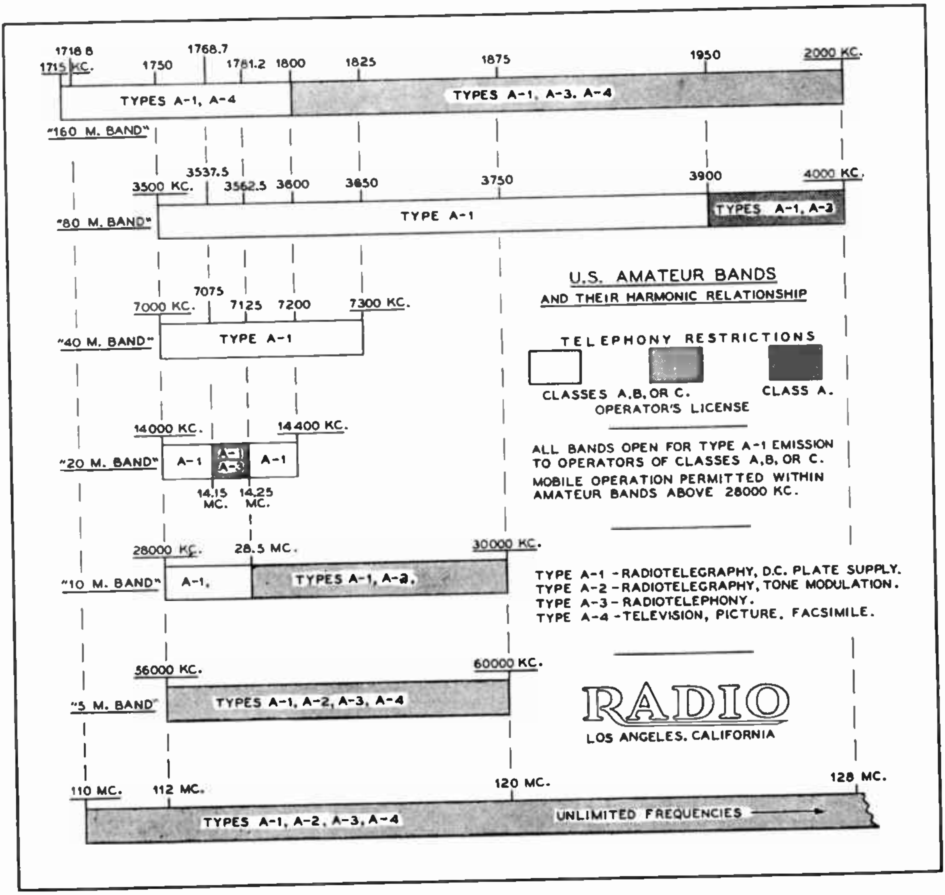
379. **Licenses will not specify individual frequencies.**—Transmissions by an amateur station may be on any frequency within an amateur band above assigned.

380. **Aliens.**—An amateur radio station shall not be located upon premises controlled by an alien.

381. **Prevention of interference.**—Spurious radiations from an amateur transmitter operating on a frequency below 30,000 kilocycles shall be reduced or eliminated in accordance with good engineering practice and shall not be of sufficient intensity to cause interference on receiving sets of modern design which are tuned outside the frequency band of emission normally required for the type of emission employed. In the case of A-3 emission, the transmitter shall not be modulated in excess of its modulation capability to the extent that interfering spurious radiations occur, and in no case shall the emitted carrier be amplitude-modulated in excess of 100 percent. Means shall be employed to insure that the transmitter is not modulated in excess of its modulation capability. A spurious radiation is any radiation from a transmitter which is outside the frequency band of emission normal for the type of transmission employed, including any component whose frequency is an integral multiple or submultiple of the carrier frequency (harmonics and subharmonics), spurious modulation products, key clicks and other transient effects, and parasitic oscillations.

382. **Power supply to transmitter.**—Licensees of amateur stations using frequencies below 30,000 kilocycles shall use adequately filtered direct-current power supply for the transmitting equipment to minimize frequency modulation and to prevent the emission of broad signals.

383. **Authorized power.**—Licensees of amateur stations are authorized to use a maximum power input of 1 kilowatt to the plate circuit of the final amplifier stage of an oscillator-amplifier transmitter or to the plate circuit of an oscillator transmitter.



384. **Transmission of call.**—An operator of an amateur station shall transmit its assigned call at least once during each 15 minutes of operation and at the end of each transmission. In addition, an operator of an amateur portable or portable-mobile radiotelegraph station shall transmit immediately after the call of the station the break sign (BT) followed by the number of the amateur call area in which the portable or portable-mobile amateur station is then operating, as for example:

Example 1. Portable or portable-mobile amateur station operating in the third amateur call area calls a fixed amateur station: W1ABC W1ABC W1ABC DE W2DEF BT3 W2DEF BT3 W2DEF BT3 AR.

Example 2. Fixed amateur station answers the portable or portable-mobile amateur station: W2DEF W2DEF W2DEF DE W1ABC W1ABC W1ABC K.

Example 3. Portable or portable-mobile amateur station calls a portable or portable-mobile amateur station: W3GHI W3GHI W3GHI DE W4JKL BT4 W4JKL BT4 W4JKL BT4 AR.

If telephony is used, the call sign of the station shall be followed by an announcement of the amateur call area in which the portable or portable-mobile station is operating.

a. In the case of an amateur licensee whose station is licensed to a regularly commissioned or enlisted member of the United States Naval Reserve, the commandant of the naval district in which such reservist resides may authorize in his discretion the use of the call-letter prefix N in lieu of the profix W or K, assigned in the license issued by the Commission, provided that such N prefix shall be used only when operating in the frequency bands 1,715-2,000 kilocycles, 3,500-4,000 kilocycles, 56,000 to 60,000 kilocycles, and 400,000 to 401,000 kilocycles in accordance with instruction to be issued by the Navy Department.

385. **Quiet hours.**—In the event that the operation of an amateur radio station causes general interference to the reception of broadcast programs with receivers of modern design, that amateur station shall not operate during the hours from 8 o'clock p. m. to 10:30 p. m., local time, and on Sunday from 10:30 a. m. until 1 p. m., local time, upon such frequency or frequencies as cause such interference.

386. **Logs.**—Each licensee of an amateur station shall keep an accurate log of station operation to be made available upon request by authorized Government representatives, as follows:

a. The date and time of each transmission. (The date need only be entered once for each day's operation. The expression "time of each transmission" means the time of making a call and need not be repeated during the sequence of communication which immediately follows; however, an entry shall be made in the log when "signing off" so as to show the period during which communication was carried on.)

*b.*The name of the person manipulating the transmitting key of a radiotelegraph transmitter or the name of the person operating a transmitter of any other type (type A-3 or A-4 emission) with statement as to type of emission. (The name need only be entered once in the log provided the log contains a statement to the effect that all transmissions were made by the person named except where otherwise stated. The name of any other person who operates the station shall be entered in the proper space for his transmissions.)

c. Call letters of the station called. (This entry need not be repeated for calls made to the same station during any sequence of communication, provided the time of "signing off" is given.)

d. The input power to the oscillator, or to the final amplifier stage where an oscillator-amplifier transmitter is employed. (This need be entered only once, provided the input power is not changed.)

e. The frequency band used. (This information need be entered only once in the log for all transmissions until there is a change in frequency to another amateur band.)

f. The location of a portable or portable-mobile station at the time of each transmission. (This need be entered only once, provided the location of the station is not changed. However, suitable entry shall be made in the log upon changing location, showing the type of vehicle or mobile unit in which the station is operated and the approximate geographical location of the station at the time of operation.)

g. The message traffic handled. (If record communications are handled in regular message form, a copy of each message sent and received shall be entered in the log or retained on file for at least 1 year.)

387. **Portable stations.**—Advance notice of all locations in which portable amateur stations will be operated shall be given by the licensee to the inspector in charge of the district in which the station is to be operated. Such notices shall be made by letter or other means prior to any operation contemplated and shall state the station call, name of licensee, the date of proposed operation, and the approximate locations, as by city, town, or county. An amateur station operating under this rule shall not be operated during any period exceeding 30 days without giving further notice to the inspector in charge of the radio-inspection district in which the station will be operated. This rule does not apply to the operation of portable or portable-mobile amateur stations on frequencies above 28,000 kilocycles authorized to be used by amateur stations. (See rule 368.)

• Radio Operators

AMATEUR OPERATORS

400. **Only amateur operators may operate amateur stations.**—An amateur station may be operated only by a person holding a valid amateur operator's license, and then only to the extent provided for by the class of privileges for which the operator's license is endorsed.

401. **Validity of operator's license.**—Amateur operators' licenses are valid only for the operation of licensed amateur stations, provided, however, any person holding a valid radio operator's license of any class may operate stations in the experimental service licensed for, and operating on, frequencies above 30,000 kilocycles.

402. **Proof of use.**—Amateur-station licenses and/or amateur-operator licenses may, upon proper application, be renewed provided: (1) The applicant has used his station to communicate by radio with at least three other amateur stations during the 3-month period prior to the date of submitting the application, or (2) in the case of an applicant possessing only an operator's license, that he has similarly communicated with amateur stations during the same period. Proof of such communication must be included in the application by stating the call letters of the stations with which communication was carried on and the time and date of each communication. Lacking such proof, the applicant will be ineligible for a license for a period of 90 days.

This rule shall not prevent renewal of an amateur-station license to an applicant who has recently qualified for license as an amateur operator.

403. **Class of operator and privileges.**—There shall be but one main class of amateur operator's license, to be known as "amateur class," but each such license shall be limited in scope by the signature of the examining officer opposite the particular class or classes of privileges which apply, as follows:

Class A.—Unlimited privileges.

Class B.—Unlimited radiotelegraph privileges. Limited in the operation of radiotelephone amateur stations to the following bands of frequencies: 1,800 to 2,000 kilocycles; 28,500 to 30,000 kilocycles; 56,000 to 60,000 kilocycles; 400,000 to 401,000 kilocycles.

Class C.—Same as class B privileges, except that the Commission may require the licensee to appear at an examining point for a supervisory written examination and practical code test during the license term. Failing to appear for examination when directed to do so, or failing to pass the supervisory examination, the license held will be canceled and the holder thereof will not be issued another license for the class C privileges.

404. **Scope and places of examinations.**—The scope of examinations for amateur operators' licenses shall be based on the class of privileges the applicant desires, as follows:

Class A.—To be eligible for the class A amateur operator's privileges the applicant must have been a licensed amateur operator for at least 1 year and must personally appear at one of the Commission's examining offices, and take the supervisory written examination and code test. (See pars. 2 h (1), 30, and 408.) Examinations will be conducted at Washington, D. C., on Thursday of each week, and at each radio district office of the Commission on the days designated by the inspector in charge of such office. In addition, examinations will be held quarterly in the examining cities listed in paragraph 30 on the dates to be designated by the inspector in charge of the radio district in which the examining city is situated. The examination will include the following:

a. Applicant's ability to send and receive in plain language messages in the Continental Morse Code (5 character to the word) at a speed of not less than 13 words per minute.

b. Technical knowledge of amateur radio apparatus, both telegraph and telephone.

c. Knowledge of the provisions of the Communications Act of 1934, subsequent acts, treaties, and rules and regulations of the Federal Communications Commission, affecting amateur licensees.

Class B.—The requirements for class B amateur operators' privileges are similar to those for the class A, except that no experience is required and the questions on radiotelephone apparatus are not so comprehensive in scope.

Class C.—The requirements for class C amateur operators' privileges shall be the same as for the class B except the examination will be given by mail. Applicants for class C privileges must reside more than 125 miles airline from the nearest office of the Commission and the nearest point named in Rule 30-a (1), or in a camp of the Civilian Conservation Corps, or be in the regular military or naval service of the United States at a military post or naval station; or be shown by physician's certificate to be unable to appear for examination due to protracted disability.

By arrangement with other Federal Agencies which cooperate with the Commission for the purpose of such examinations, the class B as well as the class A will similarly be given at Guam, at San Juan, Puerto Rico, and at various points in Alaska.

405. **Recognition of other classes of licenses.**—An applicant for any class of amateur operator's privileges who has held a radiotelephone second-class operator's license or higher, or an equivalent commercial grade license, or who has been accorded unlimited amateur radiotelephone privileges, within 5 years of the date of application may only be required to submit additional proof as to code ability and/or knowledge of the laws, treaties, and regulations affecting amateur licensees.

406. An applicant for the class B or C amateur operator's privileges who has held a radiotelegraph third-class operator's license or higher, or an equivalent commercial grade license, or who has held an amateur extra first-class license within 5 years of the date of application may be accorded a license by passing an examination in laws, treaties, and regulations affecting amateur licensees.

407. **Code ability to be certified by licensed operator.**—An applicant for the class C amateur operator's privileges must have his application signed in the presence of a person authorized to administer oaths by (1) a licensed radiotelegraph operator other than an amateur operator possessing only the class C privileges or former temporary amateur class license, or (2) by a person who can show evidence of employment as a radiotelegraph operator in the Government service of the United States. In either case the radiotelegraph code examiner shall attest to the applicant's ability to send and receive messages in plain language in the continental Morse code (5 characters to the word) at the speed of not less than 13 words per minute. The code certification may be omitted if the applicant can show proof of code ability in accordance with the preceding rule.

408. **Application forms.**—See Rule 103.6.

409. **Grading of examinations.**—The percentage that must be obtained as a passing mark in each examination is 75 out of a possible 100. No credit will be given in the grading of papers for experience or knowledge of the code. If an applicant answers only the questions relating to laws, treaties, and regulations by reason of his right to omit other subjects because of having held a recognized class of license, a percentage of 75 out of a possible 100 must be obtained on the questions answered.

410. **Operator's and station licenses to run concurrently.**—An amateur station license shall be issued so as to run concurrently with the amateur operator's license and both licenses shall run for 3 years from the date of issuance. If either the station license or the operator's license is modified during the license term, both licenses shall be reissued for the full 3-year term: *Provided, however*, if an operator's license is modified only with respect to the class of operator's privileges, the old license may be endorsed, in which case the expiration date will not change.

411. **Eligibility for reexamination.**—An applicant who fails examination for amateur privileges may not take another examination for such privileges within three months, except that this rule shall not apply to successive examinations at a point named in rule 30 *a*.

412. **Penalty.**—Any attempt to obtain an operator's license by fraudulent means, or by attempting to impersonate another, or copying or divulging questions used in examinations, or, if found unqualified or unfit, will constitute a violation of the regulations for which the licensee may suffer suspension of license or be refused a license and or debarment from further examination for a period not exceeding 2 years at the discretion of the licensing authority.

413. **Duplicate licenses.**—Any licensee applying for a duplicate license to replace an original which has been lost, mutilated, or destroyed, shall submit an affidavit to the Commission attesting to the facts regarding the manner in which the original was lost. Duplicates will be issued in exact conformity with the original, and will be marked "duplicate" on the face of the license.

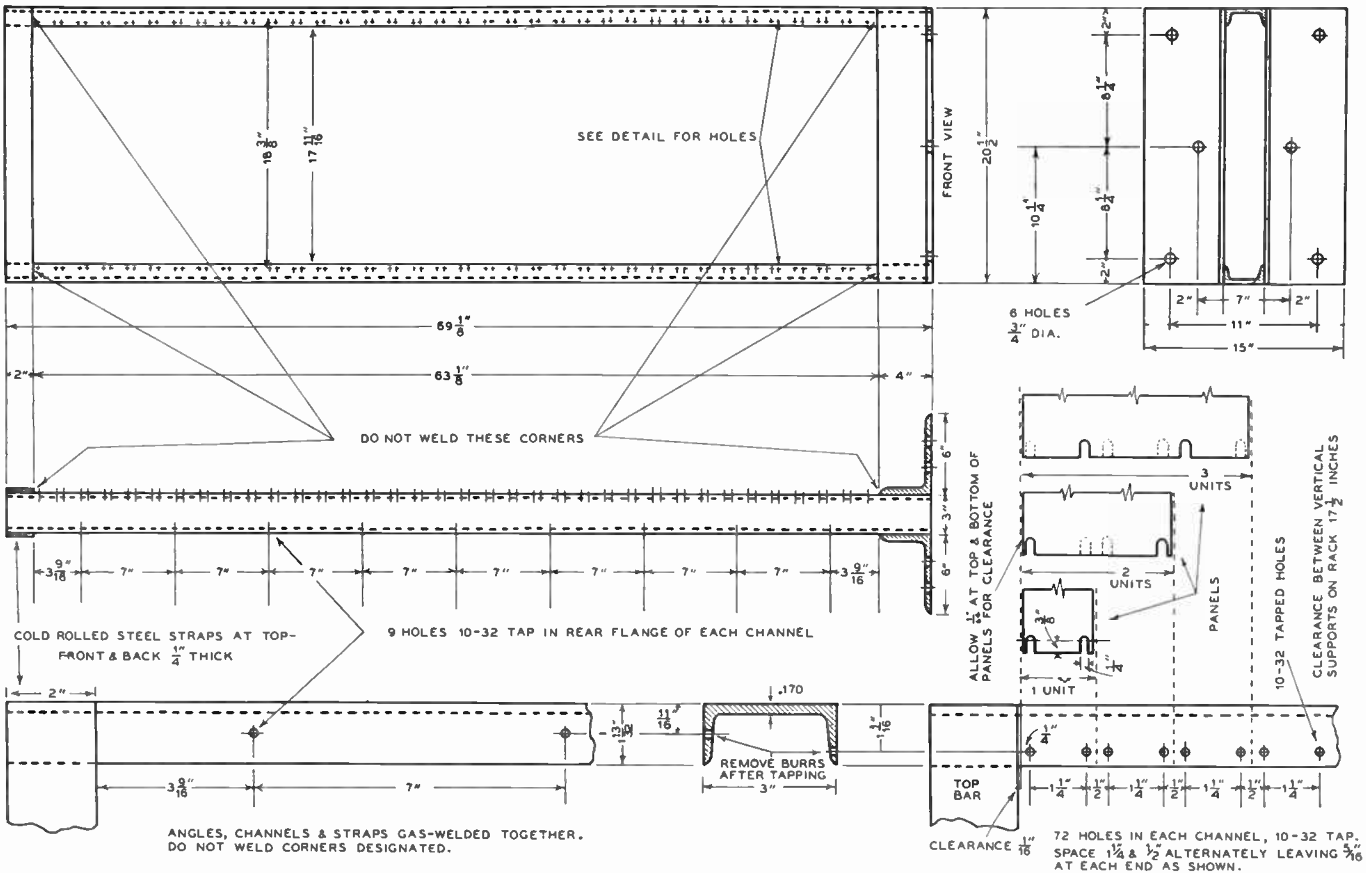
414. **Oath of secrecy.**—Licenses are not valid until the oath of secrecy has been executed and the signature of the licensee affixed thereto.

415. **Examination to be written in longhand.**—All examinations, including the code test, must be written in longhand by the applicant.

Chapter 20

Appendix

Handy tables, charts, formulas; useful data, short cuts and general information.



Construction Details of Standard Relay Rack

Relay Rack Construction

Rack and panel construction is a practice borrowed from a long established telephone practice. It offers many mechanical advantages, facilitates service and inspection, and lends itself to the increasing association of radio apparatus with telephone equipment, besides enhancing the appearance of the apparatus.

The relay rack type of construction offers many advantages not to be found in other styles. Its appearance is commercial, parts are quite accessible and alterations which change the physical size of one section of the transmitter can be made without requiring corresponding alterations in other sections, as would be the case with a frame-mounted or four-poster transmitter. The reason for this is that each section of the transmitter is provided with its own mounting unit, quickly removable after disconnecting supply wires. All the apparatus of the unit is supported by the panel.

The standard relay rack has two uprights made from three inch 4.1 pound channel iron. The base is made from two pieces of 6 inch by 4 inch, ⅜" angle, and the top straps are made from two pieces of ¼" by 2" cold-rolled iron. The diagram gives all the details as well as dimensions necessary.

Panels are usually of metal (either steel, dural or aluminum) though sometimes made from pressed wood products such as "Tempered Masonite." Masonite is the cheapest, with steel, aluminum and dural next in order. The usual thickness of the metal panels is 3/16", and sometimes ¼" is used. Metal panels of thinner dimensions are not satisfactory.

The versatility of the relay rack is due to the fact that dimensions have been completely standardized. A few manufacturers still use their own pet dimensions but they are quickly falling into line. Panels are 19" wide and of varying heights. The height is measured as a "rack unit," a rack unit being 1¾ inches. To allow for stacking and slight tolerance in cutting and fabrication, a relay-rack panel is always made to be a certain number of rack units high less 1/32 inch for clearance. This formula can be used:

$$\text{panel} = n(1\tfrac{3}{4}) - 1/32$$

Thus a panel four rack-units in height will measure 4 times 1¾ inches or 7 inches, less 1/32 inch, or an exact total height of 6 31/32 inches. The channel uprights are drilled to take 10-32 round head machine screws as can be noted in the drawing. A very light tapped thread is sufficient, the usual 75% tap being unnecessary. Most of the strain on the thread is at right angles to the axis, and since this is shear on the screw, very little thrust is placed on the threads. A light thread takes less time and effort and results in fewer broken taps. When panels are properly made, the edge of a panel always falls midway between two holes spaced one-half inch apart.

Now to start your rack, go to the local steel company and order the following:

- 2 pieces 3 inch, 4.1 pound channel, 5'9⅛" long
- 2 pieces 6 inch by 4 inch by ⅜ angle, 1'8½" long
- 2 pieces ¼ inch by 2 inch cold rolled, 1'8½" long

The total price on the above steel order including the cutting should be around $5.00. Make sure that the steel is cut square and exactly to the above lengths. It is just as easy for the steel man to cut the right length and your rack will come out square and save you lots of tough filing. Ordinary strap iron could have been used for the top straps, but the edges of this type of steel are not square and since this is such a small item, it is better to get the cold rolled for its square corners and finished appearance.

The steel will weigh within a pound or two of one hundred pounds. The next thing to do is to lay out the channels as shown in the drawing. Wipe off the steel and then chalk the front face of each channel. Use ordinary black-board chalk. Remember that one member is left handed and the other right-handed; *don't* make two right or left-handed members. Two tools are now needed: a center punch and one of the dime-store steel pushrules. Don't under any circumstances lay out the rack with an ordinary foot rule or yardstick. The cumulative error will show up and the rack will not be square. Note that the line of the holes is in 1 1/16 inch from the edge of the channel. Take a sharp pointed instrument and, using a scale set in a dividing head, mark this line (which will be the vertical line to the holes) carefully on the total length of the channel.

It can be seen that the top hole on each channel is 5/16 inch below the top strap, or a total of 2 5/16 inches below the top of the rack. Carefully mark this top hole on each channel, keeping in mind that there is a right and left hand member. Now take the steel tape and clamp it to the channel with an even half inch or inch mark exactly opposite the hole that has been center-punched 2 5/16 inches from the top. This first hole is the reference mark and all measurements are made from this point.

Now that the scale is clamped, go right down, first 1¼ inches and then one-half inch, alternating until 72 holes have been punched. If you have not made a mistake the last hole will be exactly 4 5/16 inches from the bottom end of the channel. While punching the holes, check back frequently. It is very easy to make an incorrect reading on the scale and a single "off hole" will throw all the rest in the wrong place. After all the holes are center-punched check back to see if the alternate ½ inch and 1¼ inch spacings are correct. You cannot be too careful, as it is very easy to make a mistake here.

Now that all the holes are center-punched, do the same on the back if desired. The frequent spacings are not necessary, but a few holes may prove handy. In any case two holes should be drilled and tapped about 5 inches above the bottom so that grounding and bonding wires can be fastened.

The next operation is to pilot-drill all the center-punches. It is suggested that a small drill, number 28 or so, be used for this purpose. This operation consists of drilling the punch marks slightly so as to preserve the spacing and to give the tap drill a good bearing surface. The pilot holes need be drilled only until the maximum diameter of the drill is reached which is about 1/16 inch deep.

After all the pilot holes are drilled, select the tap drill that will give the correct percentage of thread desired. For 10-32 thread of 75% clearance thread, a number 19 drill is correct. However, 75% thread is really unnecessary and several sizes larger can easily be used as explained before. For a drill press one can use a small mail-order house type which, with motor, costs about $20.00. A good, high speed drill and a little oil make the drilling operation quite simple. Remember to set the channel so as to get the holes at right angles to the channel axis.

After all the holes are drilled, tapping is next in order. Use a small hand tap-wrench, and above all things remember to get a *taper tap*. This type of tap is tapered and will easily go through without very much effort. Use plenty of thread cutting oil and take it easy. If you feel that you are getting tired, stop and come back to the job later. The least side twist on the wrench will break the tap.

RELAY-RACK PANELS

1. Make panel height a multiple of 1¾ inches less ⅛ inch for clearances.

2. Both top and bottom edges of a properly mounted panel will, neglecting clearances, always fall half way between a pair of holes spaced ½ inch apart on the rack.

3. It is seldom necessary to cut all the possible mounting-screw slots in a panel, but it can be done if desired.

4. Any panel laid out to fit the rack will also fit if the panel is turned end-for-end or back-for-front.

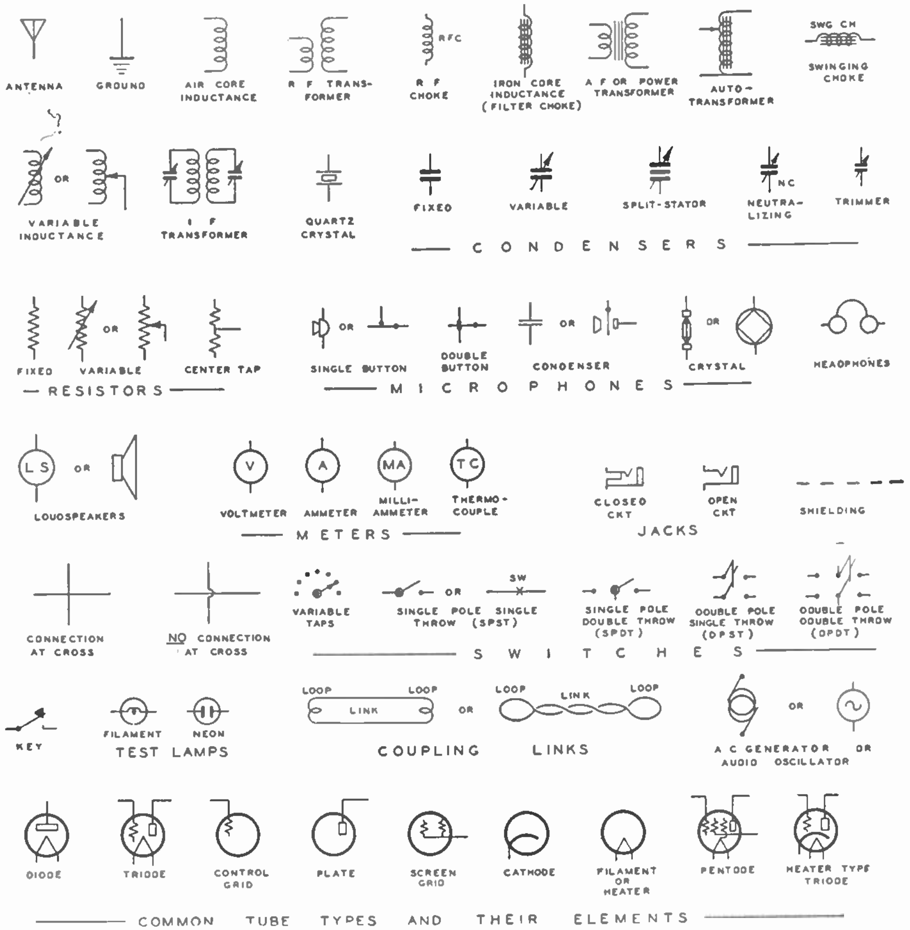
When all the tapping is done, clean the burrs off the holes on the inside of the channel. This can easily be done with the head of a file.

The only other holes required are the base holes in the bottom angles. These are desirable, but not necessary. The racks are self-supporting with most amateur radio equipment and do not need to be bolted to the floor. However, if it is felt the bottom holes are desirable, have some machine shop drill or punch the holes. The job is too tough for a small drill press.

The next operation is welding. This is a difficult job and can best be done by an experienced welder. Take the pieces to him together with the drawing and show him just where the welding is to be done. There are eight welds altogether, and make sure that the welding is *not done where the panels will mount*. The rack should be set up on a welding table and checked several times for squareness. Before the welding "tacks" are made, check again the distance from the center of the bottom and top holes to the strap and the base. This must be exactly 5/16 inch. If it is less the panels will jam, and if it is more, an open space will show through. A welder should not charge over $4.00 for this welding job. Make the welder keep in mind that you want a "finished" job; it won't cost you any more provided you get him to set the price first!

After welding, the steel should be well cleaned and given a good coat of paint. Black is usually used, although black panels set against a rack painted with aluminum lacquer is quite striking.

Radio Symbols Used in Circuit Diagrams



R. M. A. COLOR CODE

For Fixed Condensers, Unit: Micro-Microfarads

First Dot		Second Dot		Third Dot	
Black	0	Black	0		
Brown	1	Brown	1	Brown	0
Red	2	Red	2	Red	00
Orange	3	Orange	3	Orange	000
Yellow	4	Yellow	4	Yellow	0000
Green	5	Green	5	Green	00000
Blue	6	Blue	6	Blue	000000
Purple	7	Purple	7	Purple	0000000
Gray	8	Gray	8	Gray	00000000
White	9	White	9	White	000000000

For Resistors, Unit: Ohms

Body Color		End Color		Dot Color	
Black	0	Black	0		
Brown	1	Brown	1	Brown	0
Red	2	Red	2	Red	00
Orange	3	Orange	3	Orange	000
Yellow	4	Yellow	4	Yellow	0000
Green	5	Green	5	Green	00000
Blue	6	Blue	6	Blue	000000
Purple	7	Purple	7	Purple	0000000
Gray	8	Gray	8	Gray	00000000
White	9	White	9	White	000000000

THE "Q SIGNALS"

Abbreviation	*Question*	*Answer*
QRA	What is the name of your station?	The name of my station is ....
QRB	How far approximately are you from my station?	The approximate distance between our stations is .... nautical miles (or .... kilometres).
QRC	What company (or Government Administration) settles the accounts for your station?	The accounts for my station are settled by the .... company (or by the Government Administration of ....).
QRD	Where are you bound and where are you from?	I am bound for .... from ....
QRG	Will you tell me my exact frequency (wave-length) in kc/s (or m)?	Your exact frequency (wave-length) is .... kc/s (or .... m).
QRH	Does my frequency (wave-length) vary?	Your frequency (wave-length) varies.
QRI	Is my note good?	Your note varies.
QRJ	Do you receive me badly? Are my signals weak?	I cannot receive you. Your signals are too weak.
QRK	Do you receive me well? Are my signals good?	I receive you well. Your signals are good.
QRL	Are you busy?	I am busy (or I am busy with ....). Please do not interfere.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are you troubled by atmospherics?	I am troubled by atmospherics.
QRO	Shall I increase power?	Increase power.
QRP	Shall I decrease power?	Decrease power.
QRQ	Shall I send faster?	Send faster (........ words per minute).
QRR		*Amateur "SOS" or distress call (U.S.A.). Use only in serious emergency.*
QRS	Shall I send more slowly?	Send more slowly (.......... words per minute).
QRT	Shall I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.
QRV	Are you ready?	I am ready.
QRW	Shall I tell .... that you are calling him on .... kc/s (or .... m)?	Please tell .... that I am calling him on .... kc/s (or .... m).
QRX	Shall I wait? When will you call me again?	Wait (or wait until I have finished communicating with ....) I will call you at .... o'clock (or immediately).
QRY	What is my turn?	Your turn is No. .... (or according to any other method of arranging it).
QRZ	Who is calling me?	You are being called by ....
QSA	What is the strength of my signals (1 to 5)?	The strength of your signals is .... (1 to 5).
QSB	Does the strength of my signals vary?	The strength of your signals varies.
QSD	Is my keying correct; are my signals distinct?	Your keying is incorrect; your signals are bad.
QSG	Shall I send .... telegrams (or one telegram) at a time?	Send .... telegrams (or one telegram) at a time.
QSJ	What is the charge per word .... including your internal telegraph charge?	The charge per word for .... is .... francs, including my internal telegraph charge.
QSK	Shall I continue with the transmission of all my traffic, I can hear you through my signals?	Continue with the transmission of all your traffic, I will interrupt you if necessary.
QSL	Can you give me acknowledgment of receipt?	I give you acknowledgment of receipt.
QSM	Shall I repeat the last telegram I sent you?	Repeat the last telegram you have sent me.
QSO	Can you communicate with .... direct (or through the medium of ....)?	I can communicate with .... direct (or through the medium of ....).
QSP	Will you retransmit to .... free of charge?	I will retransmit to .... free of charge.
QSR	Has the distress call received from....... been cleared?	The distress call received from .... has been cleared by ....
QSU	Shall I send (or reply) on .... kc/s (or m) and/or on waves of Type A1, A2, A3, or B?	Send (or reply) on .... kc/s (or ....m) and/or on waves of Type A1, A2, A3, or B.
QSV	Shall I send a series of VVV ....?	Send a series of VVV ....

Abbreviation	*Question*	*Answer*
QSW	Will you send on .... kc/s (or .... m) and/or on waves of Type A1, A2, A3 or B?	I am going to send (or I will send) on .... kc/s (or ....m) and or on waves of Type A1, A2, A3 or B.
QSX	Will you listen for .... (call sign) on .... kc/s (or .... m)?	I am listening for .... (call sign) on .... kc/s (or ....m).
QSY	Shall I change to transmission on .... kc/s (or .... m) without changing the type of wave? or	Change to transmission on .... kc/s (or .... m) without changing the type of wave.
	Shall I change to transmission on another wave?	Change to transmission on another wave.
QSZ	Shall I send each word or group twice?	Send each word or group twice.
QTA	Shall I cancel telegram No. .... as if it had not been sent?	Cancel telegram No. .... as if it had not been sent.
QTB	Do you agree with my number of words?	I do not agree with your number of words; I will repeat the first letter of each word and the first figure of each number.
QTC	How many telegrams have you to send?	I have .... telegrams for you (or for ....).
QTE	What is my true bearing in relation to you? or	Your true bearing in relation to me is .... degrees or
	What is my true bearing in relation to .... (call sign)? or	Your true bearing in relation to .... (call sign) is .... degrees at .... (time) or
	What is the true bearing of .... (call sign) in relation to .... (call sign)?	The true bearing of .... (call sign) in relation to .... (call sign) is .... degrees at .... (time).
QTF	Will you give me the position of my station according to the bearings taken by the direction-finding stations which you control?	The position of your station according to the bearings taken by the direction-finding stations which I control is....... latitude .... longitude.
QTG	Will you send your call sign for fifty seconds followed by a dash of ten seconds on .... kc/s (or .... m) in order that I may take your bearing?	I will send my call sign for fifty seconds followed by a dash of ten seconds on .... kc/s (or .... m) in order that you may take my bearing.
QTH	What is your position in latitude and longitude (or by any other way of showing it)?	My position is .... latitude .... longitude (or by any other way of showing it).
QTI	What is your true course?	My true course is .... degrees.
QTJ	What is your speed?	My speed is .... knots (or .... kilometers) per hour.
QTM	Send radioelectric signals and submarine sound signals to enable me to fix my bearing and my distance.	I will send radioelectric signals and submarine sound signals to enable you to fix your bearing and your distance.
QTO	Have you left dock (or port)?	I have just left dock (or port).
QTP	Are you going to enter dock (or port)?	I am going to enter dock (or port).
QTQ	Can you communicate with my station by means of the International Code of Signals?	I am going to communicate with your station by means of the International Code of Signals.
QTR	What is the exact time?	The exact time is ....
QTU	What are the hours during which your station is open?	My station is open from .... to ....
QUA	Have you news of .... (call sign of the mobile station)?	Here is news of .... (call sign of the mobile station).
QUB	Can you give me in this order, information concerning: visibility, height of clouds, ground wind for .... (place of observation)?	Here is the information requested ....
QUC	What is the last message received by you from .... (call sign of the mobile station)?	The last message received by me from .... (call sign of the mobile station) is ....
QUD	Have you received the urgency signal sent by .... (call sign of the mobile station)?	I have received the urgency signal sent by .... (call sign of the mobile station) at .... (time).
QUF	Have you received the distress signal sent by .... (call sign of the mobile station)?	I have received the distress signal sent by .... (call sign of the mobile station) at .... (time).
QUG	Are you being forced to alight in the sea (or to land)?	I am forced to alight (or land) at .... (place).
QUH	Will you indicate the present barometric pressure at sea level?	The present barometric pressure at sea level is .... (units).
QUJ	Will you indicate the true course for me to follow, with no wind, to make for you?	The true course for you to follow, with no wind, to make for me is .... degrees at .... (time).

Conversion Table

Factors for conversion, alphabetically arranged

MULTIPLY	BY	TO GET
Amperes	×1,000,000,000,000	micromicroamperes
Amperes	×1,000,000	microamperes
Amperes	×1,000	milliamperes
Cycles	×1,000,000	megacycles
Cycles	×.001	kilocycles
Farads	×1,000,000,000,000	micromicrofarads
Farads	×1,000,000	microfarads
Henrys	×1,000,000	microhenrys
Henrys	×1,000	millihenrys
Kilocycles	×1,000	cycles
Kilovolts	×1,000	volts
Kilowatts	×1,000	watts
Megacycles	×1,000,000	cycles
Mhos	×1,000,000	micromhos
Microamperes	×.000,001	amperes
Microfarads	×.000,001	farads
Microhenrys	×.000,001	henrys
Micromhos	×.000,001	mhos
Micro-ohms	×.000,001	ohms
Microvolts	×.000,001	volts
Microwatts	×.000,001	watts
Micromicrofarads	×.000,000,000,001	farads
Milliamperes	×.001	amperes
Millihenrys	×.001	henrys
Millimhos	×.001	mhos
Milliohms	×.001	ohms
Millivolts	×.001	volts
Milliwatts	×.001	watts
Ohms	×1,000,000,000,000	micromicro-ohms
Ohms	×1,000,000	micro-ohms
Volts	×1,000,000	microvolts
Volts	×1,000	millivolts
Watts	×1,000,000	microwatts
Watts	×1,000	milliwatts
Watts	×.001	kilowatts

Radio Symbols

The following symbols are commonly used in radio work and many of these symbols are used in the pages of this book:

E_F .... Filament (or heater) terminal voltage
E_B .... Average plate voltage (DC)
I_B .... Average plate current (DC)
E_P .... AC component of plate voltage (effective value)
I_P .... AC component of plate current (effective value)
E_C .... Average grid voltage (DC)
I_C .... Average grid current (DC)
E_G .... AC component of grid voltage (effective value)
I_G .... AC component of grid current (effective value)
E_{FF} .... Filament (or heater) supply voltage
E_{BB} .... Plate supply voltage (DC)
E_{CC} .... Grid supply voltage (DC)
Mu .... Amplification factor
r_P .... Plate resistance
s_M .... Grid plate transconductance (also mutual conductance, gm)
R_P .... Plate load resistance
Z_P .... Plate load impedance
DC .... Direct Current (as adjective)
AC .... Alternating Current (as adjective)
RMS .... Root Mean Square
U.P.O. .... Undistorted power output
C_{GK} .... Grid-cathode (or filament) capacitance
C_{PK} .... Plate-cathode (or filament) capacitance
C_{GIP} .... Effective grid-plate capacitance in a tetrode (cathode [or filament] and screen grounded)
$C_{G1}(k+g_2)$ ...... Direct interelectrode capacitance of grid to cathode (or filament) and screen
$C_P(k+g_2)$ ...... Direct interelectrode capacitance of plate to cathode (or filament) and screen

R-S-T REPORTING SYSTEM

READABILITY

1—UNREADABLE.
2—BARELY READABLE — OCCASIONAL WORDS DISTINGUISHABLE.
3—READABLE WITH CONSIDERABLE DIFFICULTY.
4—READABLE WITH PRACTICALLY NO DIFFICULTY.
5—PERFECTLY READABLE.

SIGNAL STRENGTH

1—FAINT—SIGNALS BARELY PERCEPTIBLE.
2—VERY WEAK SIGNALS.
3—WEAK SIGNALS.
4—FAIR SIGNALS.
5—FAIRLY GOOD SIGNALS.
6—GOOD SIGNALS.
7—MODERATELY STRONG SIGNALS.
8—STRONG SIGNALS.
9—EXTREMELY STRONG SIGNALS.

TONE

1—EXTREMELY ROUGH, HISSING NOTE.
2—VERY ROUGH A.C. NOTE—NO TRACE OF MUSICALITY.
3—ROUGH, LOW-PITCHED A.C. NOTE—SLIGHTLY MUSICAL.
4—RATHER ROUGH A.C. NOTE—MODERATELY MUSICAL.
5—MUSICALLY MODULATED NOTE.
6—MODULATED NOTE — SLIGHT TRACE OF WHISTLE.
7—NEAR D.C. NOTE—SMOOTH RIPPLE.
8—GOOD D.C. NOTE—JUST TRACE OF RIPPLE.
9—PUREST D.C. NOTE.

IF THE NOTE APPEARS TO BE CRYSTAL CONTROLLED, SIMPLY ADD AN X AFTER THE APPROPRIATE NUMBER.

U. S. POSTAL RATES ON CARDS AND LETTERS

LETTERS 3c each ounce or fraction to United States, U. S. Possessions, Canada, Labrador and Newfoundland, 2c each ounce or fraction if for delivery in the town in U. S. where letter was mailed. AIRMAIL to U. S. and Canada: 6c each ounce or fraction.

LETTERS, 3c each ounce or fraction, CARDS 2c, to: Argentina, Balearic Islands, Bolivia, Brazil, Canary Islands, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Eucador, Guatemala, Haiti, Honduras, Mexico, Morocco (Spanish), Nicaragua, Panama, Paraguay, Peru, Salvador, Spain and its Colonies, Uruguay, Venezuela.

Letters 3c each ounce or fraction to CANADA, LABRADOR, and NEWFOUNDLAND. Letters 5c each ounce or fraction to GREAT BRITAIN (England, Scotland, Wales), NORTHERN IRELAND, and IRISH FREE STATE.

LETTERS 5c first ounce and 3c for each additional ounce or fraction to: All other countries not in the above lists.

Registration Fee—In addition to postage, **15 cents to all countries.**

POST CARDS (Government and Private)

CARDS 1c each in United States and Possessions, and 2c to countries taking 3c letter rate.

Cards 2c each to CANADA, LABRADOR, and NEWFOUNDLAND.

Cards 3c each to all other foreign countries.

International Prefixes

AC4	TIBET
AR	SYRIA
CE	CHILE
CM	CUBA
CN	MOROCCO
CO	CUBA (fones)
CP	BOLIVIA
CR4	CAPE VERDE
CR5	PORTUGUESE GUINEA
CR6	ANGOLA
CR7	MOZAMBIQUE
CR8	PORTUGUESE INDIA
CR9	MACAO
CR10	TIMOR
CT1	PORTUGAL
CT2	AZORES
CT3	MADERIA
CX	URUGUAY
D	GERMANY
EA	SPAIN
EA8	CANARY ISLANDS
EI	IRISH FREE STATE
EL	LIBERIA
EP, EQ	IRAN (ex-Persia)
ES	ESTONIA
F3	FRANCE
F8	FRANCE
FA	ALGERIA
FB8	MADAGASCAR
FD8	TOGOLAND (French)
FE8	CAMEROONS (French)
FF8	FRENCH WEST AFRICA
FG8	GUADELOUPE
FI8	FRENCH INDO-CHINA
FK8	NEW CALEDONIA
FL8	SOMALI COAST
FM8	MARTINIQUE
FN8	FRENCH INDIA
FO8	FRENCH OCEANIA, TAHITI
FP8	ST. PIERRE & MIQUELON
FQ8	FRENCH EQUATORIAL AFRICA
FR8	REUNION
FT4	TUNIS
FU8	NEW HEBRIDES
FY8	FRENCH GUIANA
G	GREAT BRITAIN
GI (see G)	NORTHERN IRELAND
GM (see G)	SCOTLAND
GW (see G)	WALES
HA	HUNGARY
HB	SWITZERLAND
HC	EDUCATOR
HH	HAITI
HI	DOMINICAN REPUBLIC
HJ, HK	COLOMBIAN REPUBLIC
HP	PANAMA
HR	HONDURAS
HS	SIAM
HZ	HEDJAZ
I	ITALY
J	JAPAN
K4	PORTO RICO, VIRGIN ISLANDS
K5	CANAL ZONE
K6	GUAM, HAWAII, MIDWAY ISLAND, SAMOA (U. S.), WAKE ISLAND
K7	ALASKA
KA	PHILIPPINE ISLANDS
LA	NORWAY
LU	ARGENTINA
LX	LUXEMBOURG
LY	LITHUANIA
LZ	BULGARIA
MX	MANCHUKUO
N.	U. S. NAVAL COMMUNICATION RESERVE STATIONS
NY	CANAL ZONE
OA	PERU
OE	AUSTRIA
OH	FINLAND
OK	CZECHOSLOVAKIA
OM	GUAM
ON	BELGIUM
OQ5	BELGIAN CONGO
OX	GREENLAND
OY	FAROE ISLANDS
OZ	DENMARK
PA	NETHERLANDS
PI	NETHERLANDS (schools)
PJ	CURACAO
PK	NETH. INDIES
PX	ANDORRA
PY	BRAZIL
PZ	SURINAM
SM	SWEDEN
SP	POLAND
ST	SUDAN

MASTER RESISTOR CHART

STANDARD RESISTANCE VALUES WITH CORRESPONDING PART NUMBERS AND COLOR CODE

20% TOL PART NO	10% TOL PART NO	5% TOL PART NO	OHMS RESIST-ANCE	COLOR CODE A	B	C
1	38	111	10	BROWN	BLACK	BLACK
		112	11	BROWN	BROWN	BLACK
	39	113	12	BROWN	RED	BLACK
		114	13	BROWN	ORANGE	BLACK
2	40	115	15	BROWN	GREEN	BLACK
		116	16	BROWN	BLUE	BLACK
	41	117	18	BROWN	GRAY	BLACK
		118	20	RED	BLACK	BLACK
3	42	119	22	RED	RED	BLACK
		120	24	RED	YELLOW	BLACK
	43	121	27	RED	VIOLET	BLACK
		122	30	ORANGE	BLACK	BLACK
4	44	123	33	ORANGE	ORANGE	BLACK
		124	36	ORANGE	BLUE	BLACK
	45	125	39	ORANGE	WHITE	BLACK
		126	43	YELLOW	ORANGE	BLACK
5	46	127	47	YELLOW	VIOLET	BLACK
		128	51	GREEN	BROWN	BLACK
	47	129	56	GREEN	BLUE	BLACK
		130	62	BLUE	RED	BLACK
6	48	131	68	BLUE	GRAY	BLACK
		132	75	VIOLET	GREEN	BLACK
	49	133	82	GRAY	RED	BLACK
		134	91	WHITE	BROWN	BLACK
7	50	135	100	BROWN	BLACK	BROWN
		136	110	BROWN	BROWN	BROWN
	51	137	120	BROWN	RED	BROWN
		138	130	BROWN	ORANGE	BROWN
8	52	139	150	BROWN	GREEN	BROWN
		140	160	BROWN	BLUE	BROWN
	53	141	180	BROWN	GRAY	BROWN
		142	200	RED	BLACK	BROWN
9	54	143	220	RED	RED	BROWN
		144	240	RED	YELLOW	BROWN
	55	145	270	RED	VIOLET	BROWN
		146	300	ORANGE	BLACK	BROWN
10	56	147	330	ORANGE	ORANGE	BROWN
		148	360	ORANGE	BLUE	BROWN
	57	149	390	ORANGE	WHITE	BROWN
		150	430	YELLOW	ORANGE	BROWN
11	58	151	470	YELLOW	VIOLET	BROWN
		152	510	GREEN	BROWN	BROWN
	59	153	560	GREEN	BLUE	BROWN
		154	620	BLUE	RED	BROWN
12	60	155	680	BLUE	GRAY	BROWN
		156	750	VIOLET	GREEN	BROWN
	61	157	820	GRAY	RED	BROWN
		158	910	WHITE	BROWN	BROWN

20% TOL PART NO	10% TOL PART NO	5% TOL PART NO	OHMS RESIST-ANCE	COLOR CODE A	B	C
13	62	159	1,000	BROWN	BLACK	RED
		160	1,100	BROWN	BROWN	RED
	63	161	1,200	BROWN	RED	RED
		162	1,300	BROWN	ORANGE	RED
14	64	163	1,500	BROWN	GREEN	RED
		164	1,600	BROWN	BLUE	RED
	65	165	1,800	BROWN	GRAY	RED
		166	2,000	RED	BLACK	RED
15	66	167	2,200	RED	RED	RED
		168	2,400	RED	YELLOW	RED
	67	169	2,700	RED	VIOLET	RED
		170	3,000	ORANGE	BLACK	RED
16	68	171	3,300	ORANGE	ORANGE	RED
		172	3,600	ORANGE	BLUE	RED
	69	173	3,900	ORANGE	WHITE	RED
		174	4,300	YELLOW	ORANGE	RED
17	70	175	4,700	YELLOW	VIOLET	RED
		176	5,100	GREEN	BROWN	RED
	71	177	5,600	GREEN	BLUE	RED
		178	6,200	BLUE	RED	RED
18	72	179	6,800	BLUE	GRAY	RED
		180	7,500	VIOLET	GREEN	RED
	73	181	8,200	GRAY	RED	RED
		182	9,100	WHITE	BROWN	RED
19	74	183	10,000	BROWN	BLACK	ORANGE
		184	11,000	BROWN	BROWN	ORANGE
	75	185	12,000	BROWN	RED	ORANGE
		186	13,000	BROWN	ORANGE	ORANGE
20	76	187	15,000	BROWN	GREEN	ORANGE
		188	16,000	BROWN	BLUE	ORANGE
	77	189	18,000	BROWN	GRAY	ORANGE
		190	20,000	RED	BLACK	ORANGE
21	78	191	22,000	RED	RED	ORANGE
		192	24,000	RED	YELLOW	ORANGE
	79	193	27,000	RED	VIOLET	ORANGE
		194	30,000	ORANGE	BLACK	ORANGE
22	80	195	33,000	ORANGE	ORANGE	ORANGE
		196	36,000	ORANGE	BLUE	ORANGE
	81	197	39,000	ORANGE	WHITE	ORANGE
		198	43,000	YELLOW	ORANGE	ORANGE
23	82	199	47,000	YELLOW	VIOLET	ORANGE
		200	51,000	GREEN	BROWN	ORANGE
	83	201	56,000	GREEN	BLUE	ORANGE
		202	62,000	BLUE	RED	ORANGE
24	84	203	68,000	BLUE	GRAY	ORANGE
		204	75,000	VIOLET	GREEN	ORANGE
	85	205	82,000	GRAY	RED	ORANGE
		206	91,000	WHITE	BROWN	ORANGE

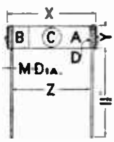
20% TOL PART NO	10% TOL PART NO	5% TOL PART NO	OHMS RESISTANCE	COLOR CODE A	B	C
25	86	207	100,000	BROWN	BLACK	YELLOW
		208	110,000	BROWN	BROWN	YELLOW
	87	209	120,000	BROWN	RED	YELLOW
		210	130,000	BROWN	ORANGE	YELLOW
26	88	211	150,000	BROWN	GREEN	YELLOW
		212	160,000	BROWN	BLUE	YELLOW
	89	213	180,000	BROWN	GRAY	YELLOW
		214	200,000	RED	BLACK	YELLOW
27	90	215	220,000	RED	RED	YELLOW
		216	240,000	RED	YELLOW	YELLOW
	91	217	270,000	RED	VIOLET	YELLOW
		218	300,000	ORANGE	BLACK	YELLOW
28	92	219	330,000	ORANGE	ORANGE	YELLOW
		220	360,000	ORANGE	BLUE	YELLOW
	93	221	390,000	ORANGE	WHITE	YELLOW
		222	430,000	YELLOW	ORANGE	YELLOW
29	94	223	470,000	YELLOW	VIOLET	YELLOW
		224	510,000	GREEN	BROWN	YELLOW
	95	225	560,000	GREEN	BLUE	YELLOW
		226	620,000	BLUE	RED	YELLOW
30	96	227	680,000	BLUE	GRAY	YELLOW
		228	750,000	VIOLET	GREEN	YELLOW
	97	229	820,000	GRAY	RED	YELLOW
		230	910,000	WHITE	BROWN	YELLOW
31	98	231	1.0 Meg.	BROWN	BLACK	GREEN
		232	1.1 Meg.	BROWN	BROWN	GREEN
	99	233	1.2 Meg.	BROWN	RED	GREEN
		234	1.3 Meg	BROWN	ORANGE	GREEN
32	100	235	1.5 Meg	BROWN	GREEN	GREEN
		236	1.6 Meg	BROWN	BLUE	GREEN
	101	237	1.8 Meg	BROWN	GRAY	GREEN
		238	2.0 Meg.	RED	BLACK	GREEN
33	102	239	2.2 Meg.	RED	RED	GREEN
		240	2.4 Meg.	RED	YELLOW	GREEN
	103	241	2.7 Meg	RED	VIOLET	GREEN
		242	3.0 Meg.	ORANGE	BLACK	GREEN
34	104	243	3.3 Meg	ORANGE	ORANGE	GREEN
		244	3.6 Meg	ORANGE	BLUE	GREEN
	105	245	3.9 Meg	ORANGE	WHITE	GREEN
		246	4.3 Meg	YELLOW	ORANGE	GREEN
35	106	247	4.7 Meg	YELLOW	VIOLET	GREEN
		248	5.1 Meg	GREEN	BROWN	GREEN
	107	249	5.6 Meg	GREEN	BLUE	GREEN
		250	6.2 Meg	BLUE	RED	GREEN
36	108	251	6.8 Meg	BLUE	GRAY	GREEN
		252	7.5 Meg.	VIOLET	GREEN	GREEN
	109	253	8.2 Meg	GRAY	RED	GREEN
		254	9.1 Meg	WHITE	BROWN	GREEN
37	110	255	10.0 Meg	BROWN	BLACK	BLUE

A (Body Color)—The first digit of the number representing the resistance value

B (End Color)—The second digit of the number representing the resistance value

C (Dot or Band on Body)—The number of ciphers following the first two digits (A & B). For example, if C = O (Black) nothing follows A and B, hence the resistance value is represented by a two digit number of which A is the first and B the second digit. If C = 1, one cipher (not No. 1) follows A and B, and the value is a three digit number. If C = 2, two ciphers (not No. 2) follows A and B, the value is a four digit number, etc.

D (End Color)—Resistance Tolerance Identification.



The above illustration shows the relative positions of A, B, C, and D

Table of Color Values

Value	Color
0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Gray
9	White
5% Tolerance	Gold
10% Tolerance	Silver
20% Tolerance	None

GLOBAR TYPE NUMBER	WATT RATING	PHYSICAL DIMENSIONS X	Y	Z	M	COLOR CODE SPECIFICATIONS	
763A	1/3	1/2"	[illegible]	[illegible]	.025"	A	Body Color
759A	1/2	3/4"	[illegible]	[illegible]	.032"	B	End Color
766A	1	1"	[illegible]	[illegible]	.032"	C	Dot or Band Color
792A	3	1 3/4"	[illegible]	1 [illegible]"	.040"	D	Tolerance Color
774A	5	2 1/2"	[illegible]	2 [illegible]"	.040"		

Examples

763A-184 Globar Type 763A, 1/3 watt, 11,000 Ohms, 5% Tolerance

759A-81 Globar Type 759A, 1/2 watt, 39,000 Ohms, 10% Tolerance

792A-5 Globar Type 792A, 3 watt, 47 Ohms 20% Tolerance

Chart courtesy The Carborundum Co., Globar Division

SU ....EGYPT
SV ....GREECE
TA ....TURKEY
TF ....ICELAND
TG ....GUATEMALA
TI ....COSTA RICA
U, UE, UK, UX ....................................U.S.S.R.
VE ....CANADA
VK ....AUSTRALIA
VO ....................................NEWFOUNDLAND
VP1 ....BRITISH HONDURAS
VP2 ....DOMINICA, GRENADA, ST. LUCIA, ANTIGUA, ST. KITTS-NEVIS
VP3 ....BRITISH GUIANA
VP4 ....TRINIDAD & TOBAGO
VP5 ....CAYMAN ISLANDS, JAMAICA, TURKS & CAICOS ISLANDS
VP6 ....BARBADOS
VP7 ....BAHAMAS
VP8 ....FALKLAND ISLANDS SOUTH GEORGIA
VP9 ....BERMUDA
VQ1 (*VR3) ....FANNING ISLAND
VQ2 ....NORTHERN RHODESIA
VQ3 ....TANGANYIKA
VQ4 ....KENYA
VQ5 ....UGANDA
VQ6 ....BRITISH SOMALILAND
VQ8 ....MAURITIUS
VQ9 ....SEYCHELLES
VR1 ....GILBERT & ELLICE ISLANDS
VR2 ....FIJI ISLANDS
VR3 ....FANNING ISLAND
VR4 ....BR. SOLOMON ISLANDS
VR5 ....TONGA ISLANDS
VR6 ....PITCAIRN ISLAND
VS1, VS2, VS3 ....MALAYA
VS4 ....BORNEO
VS5 ....SARAWAK
VS6 ....HONG KONG
VS7 ....CEYLON
VS8 ....BAHRAIN ISLAND
VS9 ....MALDIVE ISLANDS
VU ....INDIA
W ....UNITED STATES
XE ....MEXICO
XT, XU ....CHINA
XZ ....BURMA

YA	AFGHANISTAN
YI	IRAQ
YJ (**FU8)	NEW HEBRIDES
YL	LATAVIA
YM	DANZIG
YN	NICARAGUA
YR	ROUMANIA
YS	SALVADOR
YT, YU	JUGOSLAVIA
YV	VENEZUELA
ZA	ALBANIA
ZB1	MALTA
ZB2	GIBRALTAR
ZC1	TRANSJORDANIA
ZC2	COCOS ISLANDS
ZC3	CHRISTMAS ISLAND
ZC4	CYPRUS
ZC5	PALESTINE
ZD1	SIERRA LEONE
ZD2	NIGERIA, CAMEROONS (British)
ZD3	GAMBIA
ZD4	GOLD COAST, TOGOLAND (British)
ZD6	NYASALAND
ZD7	SAINT HELENA
ZD8	ASCENSION
ZE1	SOUTHERN RHODESIA
ZK1	COOK ISLANDS
ZK2	NIUE
ZL	NEW ZEALAND
ZM	WESTERN SAMOA
ZP	PARAGUAY
ZS, ZT, ZU	SOUTH AFRICA
*ZU9	TRISTAN DA CUNHA

*Suggested by the British Empire Radio Union.
**Official, by French Govt.

Prefixes by Countries

AFGHANISTAN (A)	YA
ALASKA (NA)	K7
ALBANIA (E)	ZA
ALGERIA (AF)	FA
ANDORRA (E)	PX
ANGOLA (AF)	CR6
ANTIGUA (NA)	VP2
ARGENTINA (SA)	LU
ASCENSION (AF)	ZD8
AUSTRALIA (O)	VK
AUSTRIA (E)	OE
AZORES (AF)	CT2
BAHAMAS (NA)	VP7
BAHRAIN ISLAND (A)	VS8
BARBADOS (NA)	VP6
BELGIAN CONGO (AF)	OQ5
BELGIUM (E)	ON
BERMUDA (NA)	VP9
BOLIVIA (SA)	CP
BORNEO (O)	VS4
BRAZIL (SA)	PY
BRITISH GUIANA (SA)	VP3
BRITISH HONDURAS (NA)	VP1
BR. SOLOMON ISLANDS (O)	VR4
BRITISH SOMALILAND (AF)	VQ6
BULGARIA (E)	LZ
BURMA (A)	XZ
CAMEROONS (British) (AF)	ZD2
CAMEROONS (French) (AF)	FE8
CANADA (NA)	VE
CANAL ZONE (NA)	K5, NY
CANARY ISLANDS (AF)	EA8
CAPE VERDE (AF)	CR4
CAYMAN ISLANDS (N)	VP5
CEYLON (A)	VS7
CHILE (SA)	CE
CHINA (A)	XT, XU
CHRISTMAS ISLAND (O)	ZC3
COCOS ISLANDS (O)	ZC2
COLOMBIAN REPUBLIC (SA)	HJ, HK
COOK ISLANDS (O)	ZK1
COSTA RICA (NA)	TI
CUBA (NA)	CM, CO
CURACAO (SA)	PJ
CYPRUS (E)	ZC4
CZECHOSLOVAKIA (E)	OK
DANZIG (E)	YM
DENMARK (E)	OZ
DOMINICA (NA)	VP2
DOMINICAN REPUBLIC (NA)	HI
DUTCH EAST INDIES (see Neth. Indies)	
ECUADOR (SA)	HC
EGYPT (AF)	SU
ELLICE ISLANDS (see Gilbert)	
ESTONIA (E)	ES
FALKLAND ISLANDS (SA)	VP8
FANNING ISLAND (O)	VR3
FAROE ISLANDS (E)	OY
FIJI ISLANDS (O)	VR2
FINLAND (E)	OH
FRANCE (E)	F3, F8
FRENCH EQUATORIAL AFRICA	FQ8
FRENCH GUIANA (SA)	FY8
FRENCH INDIA (A)	FN8
FRENCH INDO-CHINA (A)	FI8
FRENCH WEST AFRICA	FF8
GAMBIA (AF)	ZD3
GERMANY (E)	D
GIBRALTAR (E)	ZB2
GILBERT & ELLICE ISLANDS (O)	VR1
GREAT BRITAIN (E)	G
GREECE (E)	SV
GREENLAND (NA)	OX
GRENADA (NA)	VP2
GUADELOUPE (NA)	FG8
GUAM (O)	K6, OM
GUATEMALA (NA)	TG
HAITI (NA)	HH
HAWAII (O)	K6
HEDJAZ (A)	HZ
HONDURAS (NA)	HR
HONG KONG (A)	VS6
HUNGARY (E)	HA
ICELAND (E)	TF
INDIA (A)	VU
IRAN (EX-PERSIA) (A)	EP, EQ
IRAQ (A)	YI
IRISH FREE STATE (E)	EI
ITALY (E)	I
JAMAICA (NA)	VP5
JAPAN (A)	J
JUGOSLAVIA (E)	YT, YU
KENYA (AF)	VQ4
LATVIA (E)	YL
LIBERIA (AF)	EL
LITHUANIA (E)	LY
LUXEMBOURG (E)	LX
MACAO (A)	CR9
MADAGASCAR (AF)	FB8
MADEIRA (AF)	CT3
MALAYA (A)	VS1, VS2, VS3
MALDIVE ISLANDS (A)	VS9
MALTA (E)	ZB1
MANCHUKUO (A)	MX
MARTINIQUE (NA)	FM8
MAURITIUS (AF)	VQ8
MEXICO (NA)	XE
MIDWAY ISLAND (O)	K6
MOROCCO (AF)	CN
MOZAMBIQUE (AF)	CR7
NETHERLANDS (E)	PA, PI
NETHERLANDS INDIES (O)	PK
NEW CALEDONIA (O)	FK8
NEWFOUNDLAND (NA)	VO
NEW HEBRIDES (O)	YJ (**FU8)
NEW ZEALAND (O)	ZL
NICARAGUA (NA)	YN
NIGERIA (AF)	ZD2
NIUE (O)	ZK2
NORTHERN IRELAND (E)	GI
NORTHERN RHODESIA (AF)	VQ2
NORWAY (E)	LA
NYASALAND (AF)	ZD6
OCEAN ISLAND (see Gilbert)	
PALESTINE (A)	ZC6
PANAMA (NA)	HP
PARAGUAY (SA)	ZP
PERSIA (see Iran)	
PERU (SA)	OA
PHILIPPINES (O)	KA

PITCAIRN ISLAND (O)	VR6
POLAND (E)	SP
PORTO RICO (NA)	K4
PORTUGAL (E)	CT1
REUNION (AF)	FR8
ROUMANIA (E)	YR
SAINT HELENA (A)	ZD7
ST. KITTS-NEVIS (NA)	VP2
ST. LUCIA	VP2
ST. PIERRE & MIQUELON (NA)	FP8
SALVADOR (NA)	YS
SAMOA (O) (U.S.)	K6
SARAWAK (O)	VS5
SCOTLAND (E)	GM
SEYCHELLES (AF)	VQ9
SIAM (A)	HS
SIBERIA (see U.S.S.R.)	
SIERRA LEONE (AF)	ZD1
SOMALI COAST	FL8
SOUTH AFRICA	ZS, ZT, ZU
SOUTH GEORGIA (SA)	VP8
SOUTHERN RHODESIA (AF)	ZE1
SPAIN (E)	EA
STRAITS SETTLEMENTS (see Malaya)	
SUDAN (AF)	ST
SURINAM (SA)	PZ
SWEDEN (E)	SM
SWITZERLAND (E)	HB
SYRIA (A)	AR
TAHITI (O)	F3 (**FO8)
TANGANYIKA (AF)	VQ3
TIBET (A)	AC4
TOGOLAND (British) (AF)	ZD4
TOGOLAND (French) (AF)	FD8
TONGA ISLANDS (O)	VR5
TRANSJORDANIA (A)	ZC1
TRINIDAD & TOBAGO (SA)	VP4
TRISTAN DA CUNHA (AF)	ZU9
TUNIS (AF)	FT4
TURKEY (E&A)	TA
UGANDA (AF)	VQ5
UNITED STATES (NA)	W
U. S. NAVAL COMMUNICATION RESERVE STATIONS (NA)	N
URUGUAY (SA)	CX
U.S.S.R. (E&A)	U, UE, UK, UX
VENEZUELA (SA)	YV
VIRGIN ISLANDS (NA)	K4
WALES (E)	GW
WESTERN SAMOA (O) (British)	ZM
ZANZIBAR (AF)	VP1

*Suggested by the British Empire Radio Union.
**Official, by French Govt.

Abbreviations Commonly Used by Amateurs

Short	*Full*
A B T	About
A G N	Again
A H D	Ahead
A H R	Another
A N I	Any
A P R X	Approximate-Approximately
B C	Broadcast
B D	Bad
B 4	Before
B I	By
B K	Break
B N	Been
B T	But
B C U Z	Because
B T W N	Between
B I Z	Business
C	See
C L R	Clear
C N	Can
C N T	Can't
C K	Check
C K T	Circuit
C M G	Coming
C U D	Could
C W	Continuous Wave
C U L	See You Later
C U A G N	See You Again
D E	From
D A	Day
D N T	Don't
D I N T	Did Not
D H	Deadhead
D C	Direct Current
D X	Long Distance
E S	And
E Z	Easy
F B	Fine Business
F M	From
F R	For
F R Q	Frequency
G A	Go Ahead
G B	Good-Bye
G M	Good Morning
G N	Good Night
G G	Going
G T	Got—Get
G N D	Ground
H A (H I)	Laughter
H M	Him
H R	Here—Hear
H V	Have
H W	How
I	OK
I C	I See
I C W	Interrupted Continuous Wave
K	Go Ahead
L I D	Poor Operator
L I L	Little
L F T	Left
L S T	Last—Listen
L T R	Letter
M A	Milliampere
M C	Megacycle
M G	Motor Generator
M I	My
M K	Make
M O	More
M S G	Message
M T	Empty
N D	Nothing Doing
N G	No Good
N I L	Nothing

N M	No More	T K S	Thanks
N R	Number	T N K	Think
N W	Now	T N X	Thanks
O B	Old Boy	U	You
O L	Old Lady	U D	You Would
O M	Old Man	U L	You Will
O P	Operator	U R	Your
O T	Old Top—Timer	V B	Very Bad
O W	Old Woman	V T	Vacuum Tube
P L S	Please	V Y	Very
P S E	Please	W A	Word After
P X	Press	W B	Word Before
R	O K	W D	Would
R C D	Received	W F	Word Following
R C V R	Receiver	W K	Work
R I	Radio Inspector	W L	Will—Would
S A	Say	W N	When
S E Z	Says	W T	What
S M	Some	W X	Weather
S W	Short-Wave	X	Interference
S I G	Signal	X M T R	Transmitter
S K E D	Schedule	Y F	Wife
T F C	Traffic	Y L	Young Lady
T M W	Tomorrow	Y R	Your
T R	There	30	Finish—End
T T	That	73	Best Regards
T K	Take	88	Love and Kisses

Pertinent Excerpts from the Radio Laws Affecting Radio Amateurs

Any licensee receiving notice of violation of radio laws shall reply to said notice in writing to the F.C.C. at Washington.

Requests for special call-letters will not be considered.

The person manipulating the telegraph key of an amateur station must be a duly licensed operator.

The original license shall be posted in the station or kept in the personal possession of the operator on duty, except when it has been mailed to an office of the F.C.C. for endorsement or change before date of its expiration.

Amateur stations must not be used to handle messages for pecuniary interests, direct or indirect, paid or promised.

Amateur transmissions must be free from harmonics. Loosely-coupled circuits must be used, or devices that will result in giving equivalent effects to minimize keying impacts, clicks, harmonics and parasitics.

Phone transmitters must not be modulated in excess of their modulation capability, and means must be incorporated to insure against such overmodulation.

One kw. power input to the stage which feeds the antenna is the maximum permissible power for amateur operation.

Amateur operators must transmit their assigned call letters at the end of each transmission, or at least once during each 15 minutes of operation. If an amateur transmitter causes general interference with reception of broadcast signals in receivers of modern design, that amateur station shall not operate during the hours from 8 p. m. to 10:30 p. m., local time, and on Sundays from 10:30 a. m. until 1 p. m., local time, in addition to the evening silent period, upon such frequency or frequencies as cause such interference.

Each licensee of an amateur station must keep *an accurate log* of station operation, name of person operating the transmitter, with statement as to the nature of transmission. The call letters of the station, the input power to the stage which feeds the antenna, the frequency band used, the location of the station if portable operation is used, must all be entered in the station *log*.

A copy of each message sent and received must be kept on file for at least one year.

This information must be available on request by authorized representatives of the Government of the United States.

• Distress Signals

The International Distress Signal is . . . — — — . . . (three dots, three dashes, three dots). The distress signal is *not* SOS; it is an easily recognized group of *characters* of three dots, three dashes, three dots. For radiotelephony distress calls the signal is *MAYDAY*. All communication must cease when a distress call is heard. Communication must not be resumed until it has been definitely determined that all is clear again. When you hear a distress call, notify the nearest source from which aid can be secured.

It is unlawful to send fraudulent signals of distress or communications relating thereto; to maliciously interfere with any other radio communication. Distress calls have precedence over all others. Minimum power must be used to effect reliable communication. The use of profane language is prohibited. The contents or meaning of a message must be kept secret, except to an authorized agency which takes part in the forwarding of the message, or to the addressee or his agent, or upon the demand of a court of competent jurisdiction or authority.

Secrecy provisions do not apply to broadcasts for public use, or to distress calls. In the event of a national emergency the station can be ordered closed.

In the event of an emergency an amateur station is permitted to communicate with stations other than amateur.

The penalty for violation of the provisions of the Communications Act of 1934 is $10,000, or imprisonment not to exceed 2 years, or both, for each offense. The operator's license is liable to suspension for 2 years if a conviction is secured. The station license can also be revoked.

For violation of any of the regulations of the Federal Communications Commission a fine not to exceed $500 can be imposed for each day of such offense. If the convicted person is a licensed operator his license can be suspended for a period not to exceed two years. The station license can also be revoked. The penalty for not keeping a station log is the same as related above. For malicious intereference with distress communications the maximum penalty of $10,000 and 2 years can be imposed. For malicious interference with other than distress communications the license can be suspended for up to 2 years. An amateur who accepts material compensation for any services rendered by his station is subject to a fine of not more than $500 for each day of such offense. His license can also be suspended for as long as 2 years.

Rules of the Board of Underwriters

• Receiving Stations

Owners of insured residences and buildings are compelled to comply with the following Underwriter's rules:

a—Outdoor antenna and counterpoise conductor sizes shall not be less than no. 14 if copper or no. 17 if of bronze or copper-clad steel. Antenna and counterpoise conductors outside of buildings shall be kept well away from all electric light and power wires or any circuit of more than 600 volts, and from railway, trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions.

b—Antenna and counterpoise where placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be so located and provided with suitable clearances to prevent accidental contact with such wires by sagging or swinging.

c—Splices and joints in the antenna span shall be soldered unless made with approved splicing devices.

d—The preceding paragraphs a, b, and c, shall not apply to power circuits used as receiving antenna, but the devices used to connect the light and power wires to radio receiving sets shall be of approved type.

e—Lead-in conductors, that is, conductors from outdoor antennas to protective devices, shall be of copper, approved copper-clad steel or other metal which will not corrode excessively and in no case shall they be smaller than No. 14, except that bronze or copper-clad steel not less than No. 17 may be used.

f—Lead-in conductors from the antenna to the first building attachment shall conform to the requirements for antennas similarly located. Lead-in conductors from the first building attachment to the building entrance shall, except as specified in the following paragraph, be installed and maintained so that they cannot swing closer to open supply conductors than the following distances:

Supply wires 0 to 600 volts......2 feet

Supply wires exceeding 600 volts..10 feet

Where all conductors involved are supported so as to secure a permanent separation and the supply wires do not exceed 150 volts to ground, the clearance may be reduced to not less than 4 inches. Lead-in conductors on the outside of buildings shall not come nearer than the clearances specified above to electric light and power wires unless separated therefrom by a continuous and firmly fixed non-conductor which will maintain permanent separation. The non-conductor shall be in addition to any insulating covering on the wire.

g—Each lead-in conductor from an outdoor antenna shall be provided with an approved protective device (lightning arrester) which will operate at a voltage of 500 volts or less, properly constructed and located either inside the building at some point between the entrance and the set which is convenient to a ground, or outside the building as near as practicable to the point of entrance. The protector shall not be placed in the immediate vicinity of easily ignitable material, or where exposed to inflammable gases or dust or flyings of combustible materials.

h—The grounding conductor from the protective device may be bare and shall be of copper, bronze or approved copper-clad steel, and if entirely outdoors shall not be smaller than No. 14 if of copper nor smaller than No. 17 if of bronze or copper-clad steel. If wholly indoors or with not more than ten feet outdoors it need not be larger than No. 18. The protective grounding conductor shall be run in as straight a line as possible from the protective device to a good permanent ground. The ground connections shall be made to a cold-water pipe where such pipe is available and is in service connected to the street mains. An outlet pipe from a water tank fed from a street main or a well may be used, providing such outlet pipe is adequately bonded to the inlet pipe connected to the street water main or well. If water pipes are not available, ground connections may be made to a grounded steel frame of a building or to a grounding electrode, such as a galvanized pipe or rod driven into permanently damp earth or to a metal plate or other body of

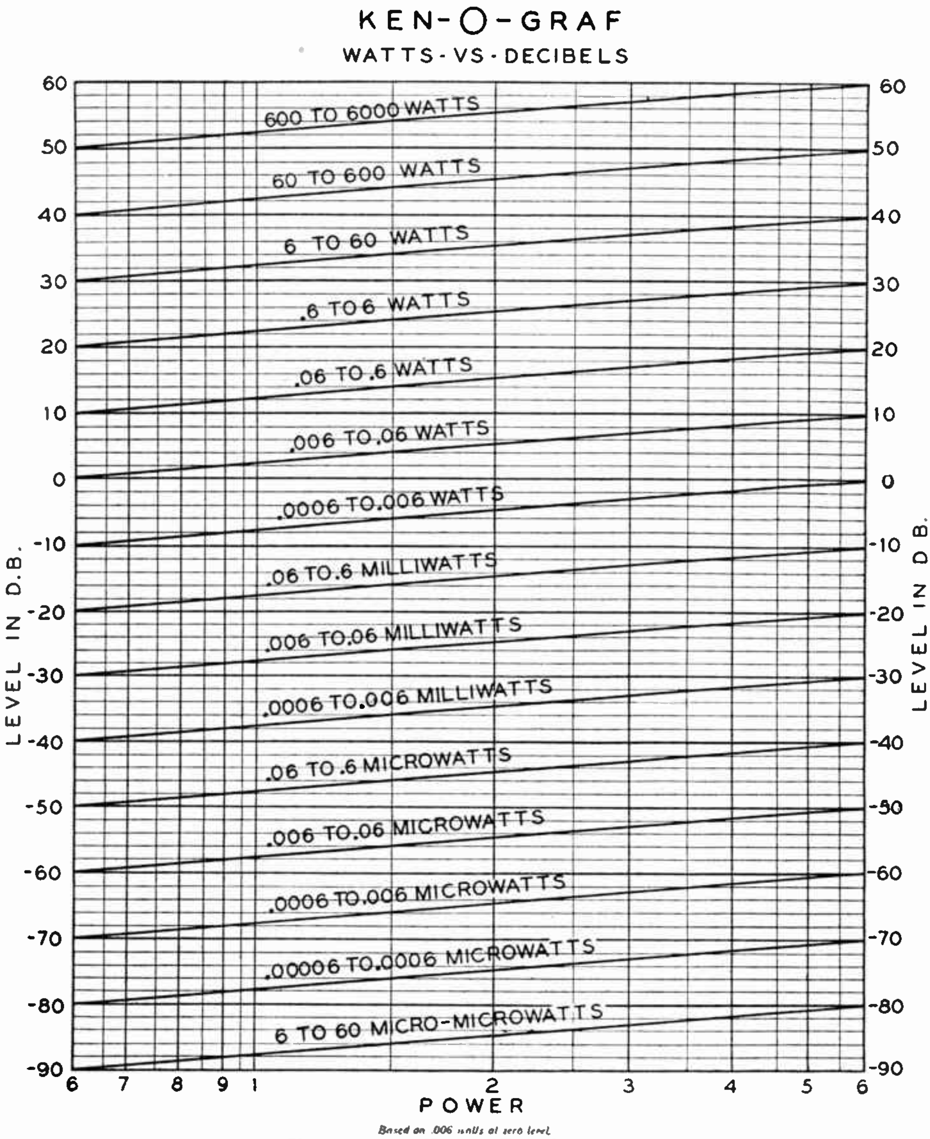


Chart courtesy Kenyon Transformer Co.

metal buried similarly. Gas piping shall not be used for the ground.

i—The protective grounding conductor shall be guarded where exposed to mechanical injury.

An approved ground clamp shall be used where the protective grounding conductor is connected to pipes or piping.

j—The protective grounding conductor may be run either inside or outside the building. The protective grounding conductor and ground, installed as prescribed in the preceding paragraphs h and i may be used as the operating ground.

It is recommended that in this case the operating grounding conductor may be connected to the ground terminal of the protective device.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If desired, a separate operating grounding connection and ground may be used. This operating grounding conductor may be either bare or provided with an insulated covering.

k—Wires inside buildings shall be securely fastened in a workman-like manner and except as provided in paragraph *m* of this section shall not come nearer than two inches to any electric light or power wire not in conduit unless separated therefrom by some continuous and firmly fixed non-conductor, such as porcelain tubes or approved flexible tubing, making a permanent separation. This non-conductor shall be in addition to any regular insulating covering on the wire.

l—Storage battery leads shall consist of conductors having approved rubber insulation. The circuit from a filament "A," storage battery of more than 20 ampere-hours capacity, NEMA rating, shall be properly protected by a fuse or circuit-breaker rated at not more than 5 amperes. The circuit from a plate, "B," storage battery or power supply shall be properly protected by a fuse.

Transmitting Stations

The following paragraphs apply to amateur stations only:

a—Antenna and counterpoise conductors outside buildings shall be kept well away from all electric light or power wires or any circuit of more than 600 volts, and from railway, trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions. Antenna and counterpoise conductors when placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be so located and provided with suitable clearances as to prevent accidental contact with such wires by sagging or swinging.

b—Antenna conductor sizes shall not be less than given in the following table:

c—Splices and joints in the antenna and counterpoise span shall be soldered joints unless made with approved splicing devices.

d—Lead-in conductors shall be of copper, bronze, approved copper-clad steel or other metal which will not corrode excessively and in no case shall be smaller than No. 14.

e—Antenna and counterpoise conductors and wires leading therefrom to ground switch, where attached to buildings, shall be firmly mounted five inches clear of the surface of the building, on a non-absorptive insulating support, such as treated pins or brackets, equipped with insulators having not less than five inches creepage and air-gap distance to inflammable or conducting material, except that the creepage and air-gap for continuous wave sets of 1,000 watts and less input to the transmitter shall not be less than 3 inches.

f—In passing the antenna or counterpoise lead-in into the building, a tube slanting upward toward the inside or a bushing of non-absorptive insulating material shall be used, and shall be so insulated as to have a creepage and air-gap distance in the case of continuous wave sets of 1,000 watts and less input to the transmitter, not less than three inches, and in other cases not less than five inches. Fragile insulators shall be protected where exposed to mechanical injury. A drilled window pane may be used in place of a bushing, provided the creepage and air-gap distance, as specified above. are maintained.

g—Adequate lightning protection either in the form of a grounding switch or suitable lightning arrester shall be provided. The grounding conductor for such protection shall be at least as large as the lead-in and in no case smaller than no. 14 copper, bronze, or approved copper-clad steel. The protective grounding conductor need not have an insulating covering or be mounted on insulating supports. The protective grounding conductor shall be run in as straight a line as possible to a good, permanent ground suitable for the purpose. The protective grounding conductor shall be

Material	Stations to which power supplied is less than 100 watts and voltage of power is less than 400 v.	Stations to which power supplied is more than 100 watts or voltage of power is more than 400 volts
Soft copper	No. 14	No. 7
Medium drawn copper	No. 14	No. 8
Hard drawn copper...........	No. 14	No. 10
Bronze or copper-clad steel....	No. 14	No. 12

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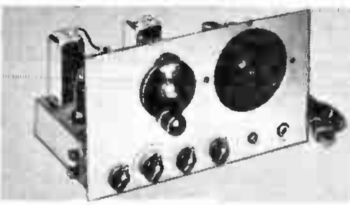

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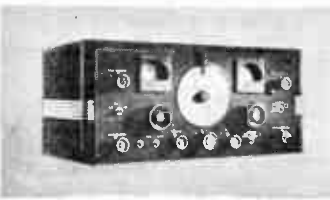

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protected where exposed to mechanical injury.

h—The operating grounding conductor where used shall be of copper strip not less than 3/8 inch wide by 1/32 inch thick, or of copper, bronze or approved copper-clad steel having a periphery, or girth, of at least 3/4 inch, such as no. 2 wire, and shall be firmly secured in place throughout its length.

i—The operating grounding conductor shall be bonded to a good, permanent ground. Preference shall be given to water piping. Other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building, and artificial grounding devices such as driven pipes, rods, plates, cones, etc. Gas piping shall not be used for the ground.

j—The transmitter shall be enclosed in a metal frame, or grill, or separated from operating space by a barrier or other equivalent means, all metallic parts of which are effectually connected to ground.

k—All external metallic handles and controls accessible to the operating personnel shall be effectually grounded.

No circuit in excess of 150 volts should have any parts exposed to direct contact. A complete dead-front type of switchboard is preferred.

l—All access doors shall be provided with interlocks which will disconnect all voltages in excess of 750 volts when any access door is opened.

m—Under the conditions noted in paragraphs 1 and 2, below, wiring may be grouped in the same conduit armored cable, electrical metallic tubing, metal raceway, pull-box, junction box or cabinet.

1. When power-supply wires are introduced solely for supplying power to the equipment to which the other wires are connected.

2. Wires other than power-supply wires run in conduit, armored cable, electrical metallic tubing, metal raceways, pull-box, junction box or cabinet with power supply wires are insulated individually or collectively in groups by insulation at least equivalent to that on the power-supply wires or the power and other wires are separated by a lead sheath or other continuous metallic sheathing.

An alphabetical glossary of words and phrases commonly used to describe the operation of television equipment.

(Courtesy, *Electronics* and Farnsworth Television, Inc., of Penna.)

Aperture distortion:
A loss of image definition due to the finite width of the scanning aperture, the height of the aperture being equivalent to the height of one scanning line.

Aspect Ratio:
The numerical ratio of the width to the height of the picture frame area.

Automatic Background Control:
A method of automatically adjusting the background illumination of the cathode-ray reproducer by modulating the cathode-ray intensity with the d.c. component of the video signal.

Black Control:
A name sometimes used for Automatic Background Control.

Composite Television Signal (R.M.A.):
By a composite television signal is meant a signal in which the combined video, blanking, and synchronizing signals are present.

Consecutive Scanning:
A method of television image scanning in which the field-frequency and the frame-frequency are identical.

D.C. Video Component:
The part of the video signal due to the average steady back-ground illumination of the scene being transmitted is called the d.c. Component of the video signal.

Direct Pickup:
The process of televising scenes or objects directly from life as contrasted with the transmission of film subjects.

Electron Multiplier:
A video amplifier tube in which amplification of the original electron emission (either photo-electric or thermionic) is obtained by bombarding the emitted electrons against one or more secondary-emissive surfaces.

Even-line Interlace:
An interlaced scanning field in which the number of lines scanned during each frame is an even integer.

Field Frequency (R.M.A.):
The field frequency is the number of times per second the field area is fractionally scanned in interlaced scanning.

Field Frequency Blanking Impulse:
A square topped impulse transmitted at the end of each vertical scansion of the picture field for the purpose of erasing the re-

trace path of the cathode ray spot at the television receiver.

Field Distortion:
Distortion of the shape or proportions of objects in the television image due to non-uniform velocity of the scanning spot, or departure from a rectilinear shape of scanning field.

Field Frequency Synchronizing Impulse:
A square topped impulse transmitted at the end of each vertical scansion of the picture field for the purpose of keeping the vertical scanning generator at the receiver in step with the transmitter.

Frame Frequency (R.M.A.):
The frame frequency is the number of times per second the frame area is completely scanned in interlaced scanning.

Frame:
A single complete picture.

Horizontal Scanning Frequency:
Synonym for "Line Frequency."

Horizontal Blanking Impulse:
Synonym for "Line Frequency Blanking Impulse."

Ghost Image:
A spurious image usually displaced in phase from the main image and having the same or opposite polarity as the main image. (E.g. The signals generated during the retrace time of the television camera scanning produce a ghost image signal which is subsequently erased by the blanking signals.)

Iconoscope:
An electronic television camera tube in which an insulated photo-electric mosaic plate is scanned with a cathode ray beam so that the positive charges thereon are neutralized and the resulting discharge currents constitute a video signal.

Image Dissector:
A television camera tube in which an electron image which corresponds to the optical image of the scene being televised is made to move with respect to a fixed scanning aperture in such a way that the electrons so collected constitute a video signal current.

Interlaced Scanning Field:
A unidirectional rectilinear scanning field in which the field frequency is an integral multiple of the frame frequency and in which the lines traced on each fractional scansion of the picture area are made to fall evenly between those of each previous fractional scansion so as to completely scan each picture frame.

Interlace Ratio:
The numerical ratio of the field frequency to the frame frequency is called the interlace ratio.

Keystone Distortion:
An optical or electrical distortion whereby the picture field assumes a trapezoidal rather than rectangular shape.

Kinescope:
An electrostatically focused cathode ray television receiver tube.

Line Frequency (R.M.A.):
The line frequency is the frequency of the saw tooth wave used for scanning in the horizontal direction and is numerically equal to the number of lines scanned per second.

Line Frequency Synchronizing Impulse:
A square topped impulse transmitted at the end of each scanning line to keep the horizontal scanning generator at the receiver in step with the horizontal generator at the transmitter.

Line Frequency Blanking Impulse:
A square-topped impulse transmitted at the end of each scanning line for the purpose of erasing the return trace of the cathode-ray spot on the television receiver tube.

Master Pulse Generator:
A central unit used at the television studio to provide all blanking and synchronizing signals both for the transmitter and the receiver.

Magnetic Deflection:
The method of imparting lateral or vertical motion to the cathode-ray spot by means of the field produced by a coil through which the sawtooth scanning current is made to flow.

Magnetic Focus Coil:
A D.C. solenoid placed over the neck of an oscillight tube for the purpose of concentrating the stream of electrons emitted by the cathode-ray gun into a fine spot on the cathode-ray screen.

Multipactor:
A cold-cathode secondary-emission multiplier tube.

Negative Polarity of Transmission:
The polarity of transmission is said to be negative when a decrease in initial light intensity results in an increase in the radiated r.f. power.

Negative Picture:
The image produced when a video signal

of reversed polarity is applied to the grid of the cathode-ray receiver tube.

Odd-Line Interlace:
An interlaced scanning field in which an odd number of lines is scanned during each picture frame.

Optical Focus:
The focussing of the optical image on the light sensitive cathode of an image dissector as distinguished from the electrical focussing of the electron image produced within the tube.

Oscillight:
A magnetically-focused cathode-ray television reproducer tube.

"Pairing-Off":
Expression used to describe the condition of an interlaced scanning field when the lines traced on succeeding fractional scansions are not evenly spaced but are distributed in pairs.

Positive Polarity of Transmission:
The polarity of transmission is said to be positive when an increase in initial light intensity results in an increase in the radiated r.f. power.

Picture Element:
A picture element is the smallest subdivision of the picture area defined in the process of scanning.

"Rain":
Expression used to describe the effect on the television image of a poor signal-to-noise-ratio. Under such conditions thermal agitation and shot-noise produce on effect similar to the appearance of "rain" on the television image.

Retrace Time:
The time which elapses between the end of one vertical scansion of the picture field and the start of the next vertical scansion or the time elapsing between the ending of one scanning line and the starting of the next consecutive line.

R. F. Television Signal:
The signal resulting from modulation of the r.f. picture carrier by the composite television signal.

Scanning:
The process of analyzing in a predetermined manner an optical image having the dimensions width, height, and intensity for the purpose of obtaining an electrical amplitude-time function representative of the illumination intensity of each elementary area of the original image. The amplitude-time function thus obtained constitutes a video signal.

Scanning Interference:
The effect produced on the television image by cross-talk between the video and scanning circuits.

Scanning Field:
The area traversed by the scanning spot either in dissecting or reproducing the television image.

Synchronization:
The process of keeping the scanning generators at the receiver in step with the scanning generators feeding the television camera.

Scanning Generator:
A vacuum tube circuit used to generate the sawtooth waves used for the electrical scanning of a television camera tube or a cathode-ray reproducer tube.

Telecine Transmission:
The process of transmitting motion-picture film subjects by television.

Vertical Blanking Impulse:
Synonym for "Field Frequency Synchronizing Impulse."

Vertical Synchronizing Impulse:
Synonym for "Field Frequency Synchronizing Impulse."

Vertical Scanning Generator:
Synonym for "Field Frequency Scanning Generator."

Video Signal:
The video signal is the signal generated by the television camera in the process of scanning the image being transmitted.

Handy Workshop Kinks

• To Resharpen Old Files

Wash the files in warm potash water to remove the grease and dirt, then wash in warm water and dry by heat. Put one and one-half pints warm water in a wooden vessel, put in the files, add three ounces blue vitriol finely powdered, three ounces borax. Mix well and turn the files so that every one may come in contact with the mixture. Add ten and one-half ounces sulphuric acid and one-half ounce cider vinegar. Remove the files after a short time, dry, rub with olive oil, wrap in porous paper. Coarse files should be kept in the mixture for a longer time than fine ones.

• File Lubricant

When filing aluminum, dural, etc., the file should be oiled or rubbed in chalk, but will cut slower than with no lubricant. However, the file will last much longer.

• Screw Lubricant

Put hard soap on lag screws, wood screws, or any screw for wood. It will surprise you how much easier they will turn in, and prevent or at least reduce splitting.

• Drilling Glass

This is done very readily with a common drill by using a mixture of turpentine and camphor. When the point of the drill has come through it should be taken out and the hole worked through with the point of a three cornered file, having the edges ground sharp. Use the corners of the file, scraping the glass rather than using the file as a reamer. Great care must be taken not to crack the glass or flake off parts of it in finishing the hole after the point of the drill has come through. Use the mixture freely during the drilling and scraping. The above mixture will be found very useful in drilling hard cast iron.

• Etching Solution

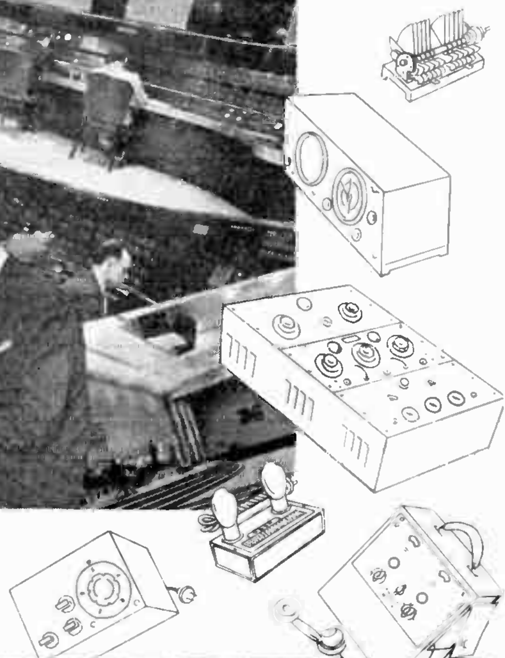
Add three parts nitric acid to one part muriatic acid. Cover the piece to be etched with beeswax. This can be done by heating the piece in a gas or alcohol flame and rubbing the wax over the surface. Use a sharp steel point or hard lead pencil point as a stylus. A pointed glass dropper can be used to put the solution at the place needed. After the solution foams for two or three minutes, remove with blotting paper and put oil in the piece and then heat and remove the wax.

• Annealing Brass or Copper

In working brass or copper, it will become hard and if hammered to any great extent will split. To prevent cracking or splitting, the piece must be heated to a dull red heat and plunged into cold water; this will soften it so it can be worked easily. Be careful not to heat brass too hot, or it will fall to pieces.

• To Clean Copper

Prepare a strong soda or potash lye solution by adding about a pound of lye to a pail



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of boiling water. Dip the metal or apply this solution with a brush, scrubbing well. Then rinse or wash with plain hot water and finally with cold water.

• To Protect Brass from Tarnish

Thoroughly cleanse and remove the last trace of grease, by the use of potash and water. The brass must be carefully rinsed with water and dried; but in doing it, care must be taken not to handle any portion with the bare hands nor anything else that is greasy. The preservative varnish is made by mixing two parts of shellac to nine parts of alcohol. Put on with a brush as thin and smooth as possible.

• To Color Brass a Steel Blue

Dissolve three drams antimony sulphite and four ounces calcined soda in one and one-half pints water. To this add five and one-half drams Kermes. Filter and mix this solution with five and one-half drams tartar, eleven drams sodium hyposulphate, and one and one-half pints water. Polished sheet brass placed in the warm mixture will assume a steel blue color.

• To Give Brass a Dull Finish

Mix one part (by weight) of iron rust, one part white arsenic, and twelve parts hydrochloric acid. Clean the brass thoroughly and apply with a brush until the desired color is obtained, after which it should be oiled, dried, and lacquered.

• Polish for Bakelite and Crackle Finish

Mix two parts benzine with one part mineral oil and apply with cloth. Wipe with dry cloth. This is not a messy polish and does not leave an oily surface.

• Inverted Tubes

Surprisingly few amateurs have thought of the possibility and desirability of mounting tubes upside down in their ultra-high frequency rigs. An inverted tube may not look as well but in most cases shorter leads are the result. A solid mounting can be had by fastening the tube socket face downward on two pieces of ⅜" wooden dowling. By having the tube socket at the same level as the tuning condenser and the tank inductance, much shorter leads can be obtained.

NUMBERED DRILL SIZES

Drill Number	*Diameter (in.)*	*Clears Screw*	*Correct for Tapping Steel or Brass**
1	.228	—	—
2	.221	12–24	—
3	.213	—	14–24
4	.209	12–20	—
5	.205	—	—
6	.204	—	—
7	.201	—	—
8	.199	—	—
9	.196	—	—
10	.193	10–32	—
11	.191	10–24	—
12	.189	—	—
13	.185	—	—
14	.182	—	—
15	.180	—	—
16	.177	—	12–24
17	.173	—	—
18	.169	8–32	—
19	.166	—	12–20
20	.161	—	—
21	.159	—	10–32
22	.157	—	—
23	.154	—	—
24	.152	—	—
25	.149	—	10–24
26	.147	—	—
27	.144	—	—
28	.140	6–32	—
29	.136	—	8–32
30	.128	—	—
31	.120	—	—
32	.116	—	—
33	.113	4–36 4–40	—
34	.111	—	—
35	.110	—	6–32
36	.106	—	—
37	.104	—	—
38	.102	—	—
39	.100	3–48	—
40	.098	—	—
41	.096	—	—
42	.093	—	4–36 4–40
43	.089	2–56	—
44	.086	—	—
45	.082	—	3–48

*Use next size larger drill for tapping bakelite and similar composition materials (plastics, etc.).

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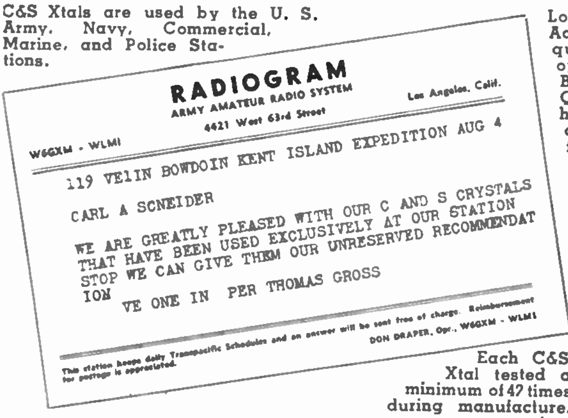
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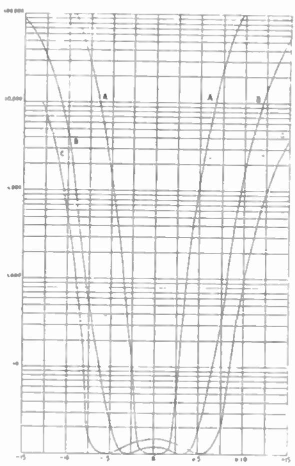
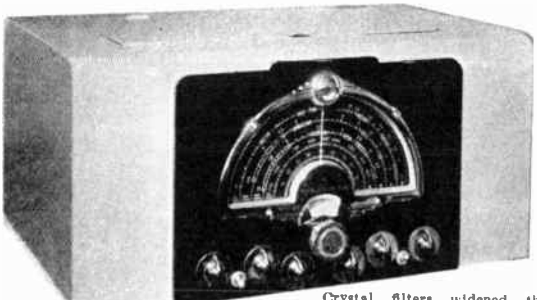


Three choices of selectivity at the flick of a knob. Curve A spells clear, intelligible speech coupled with QRM and QRN rejection in phone reception which is amazing. Curve C is "broad as a barn" standby, or for modulated 10 meter transmitters. Curve B is in between—actually better selectivity than that of most non-crystal amateur phone receivers.



Crystal filters widened the c.w. bands, but after many years the phone selectivity problem seems to have gone from bad to worse. For phone reception the crystal is only a half-way help, with its serious loss of both volume and intelligibility as the price of some increase in selectivity.

The center curve at the left is the answer to phone QRM. It is the ideal of 3kc. (1500 cycle a.f.) intelligence-conveying admittance band coupled with ideally steep cutoff just outside this band. Not only is it the ideal, it is here today in the new McMURDO SILVER "14-15," the variable selectivity of which goes from the extremes of single signal c.w. code without a crystal to as broad as you'll ever need for standby or 10 meters.

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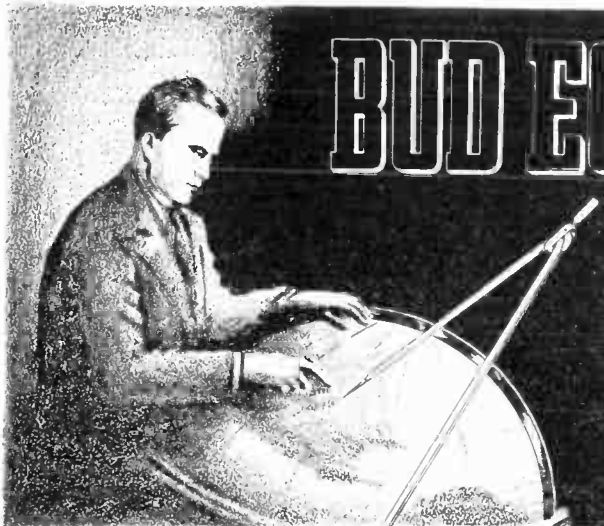
ACOUSTICAL LEVELS

Various Noises and Orchestral Effects	Sound Pressure — Dynes per Sq. Cm.	Particle Velocity — Cm. per Sec.	Movement of Air — Millimeters at 1,000 Cycles	Sound Intensities — Microwatts per Sq. Cm.	Power Level — Decibels
Threshold	0.000204	0.0000050	2.22×10^{-8}	10^{-10}	0
	0.000363	0.0000089	3.95×10^{-8}	3.165×10^{-10}	5
	0.000645	0.0000158	7.00×10^{-8}	10^{-9}	10
	0.001146	0.0000281	1.25×10^{-7}	3.165×10^{-9}	15
Whisper 4′ from source	0.00204	0.000050	2.22×10^{-7}	10^{-8}	20
	0.00363	0.000089	3.95×10^{-7}	3.165×10^{-8}	25
Soft Violin 12′ from source	0.00645	0.000158	7.00×10^{-7}	10^{-7}	30
	0.01146	0.000281	1.25×10^{-6}	3.165×10^{-7}	35
	0.0204	0.0005	2.22×10^{-6}	10^{-6}	40
	0.036	0.00089	3.95×10^{-6}	3.165×10^{-6}	45
Bell F4 160′ from source	0.0645	0.00158	7.00×10^{-6}	10^{-5}	50
Ordinary Conversation 3′ from source	0.1146	0.00281	1.25×10^{-5}	3.165×10^{-5}	55
	0.204	0.0050	2.22×10^{-5}	10^{-4}	60
	0.363	0.0089	3.95×10^{-5}	3.165×10^{-4}	65
Bell F2 160′ from source	0.645	0.0158	7.00×10^{-5}	10^{-3}	70
	1.146	0.281	1.25×10^{-4}	3.165×10^{-3}	75
Full Orchestra					
Bell F4 6′ from source	2.04	0.15	2.22×10^{-4}	10^{-2}	80
	3.63	0.089	3.95×10^{-4}	3.165×10^{-2}	85
	6.45	0.158	7.00×10^{-4}	10^{-1}	90
	11.46	0.281	1.25×10^{-3}	0.3165	95
	20.4	0.5	2.22×10^{-3}	1.0	100
Bell F2 6′ from source					
	36.3	0.89	3.95×10^{-3}	3.165	105
Thunder	64.5	1.58	7.00×10^{-3}	10.0	110
Hammer 2′ from source	114.6	2.81	1.25×10^{-2}	31.65	115
	204	5.0	2.22×10^{-2}	100.00	120
	363	8.9	3.95×10^{-2}	316.5	125
Threshold of pain	645	15.8	7.00×10^{-2}	1000.0	130

Courtesy, Brush Development Co.



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IN 'most every ham "shack"—in the far-flung corners of the world—BUD PRODUCTS will be found. These amateurs, like their fellow operators in America, **know** that with BUD PRODUCTS, they are sure of Precision, Accuracy and **lasting Durability.**

Every BUD PRODUCT before being approved by the engineering department, is put through a "torture" test calling for thousands of hours of laboratory-simulated operating conditions. BUD PRODUCTS are designed and tested to perform under the *most adverse operating conditions*. This is your assurance that complete satisfaction will be obtained from BUD laboratory-tested products.

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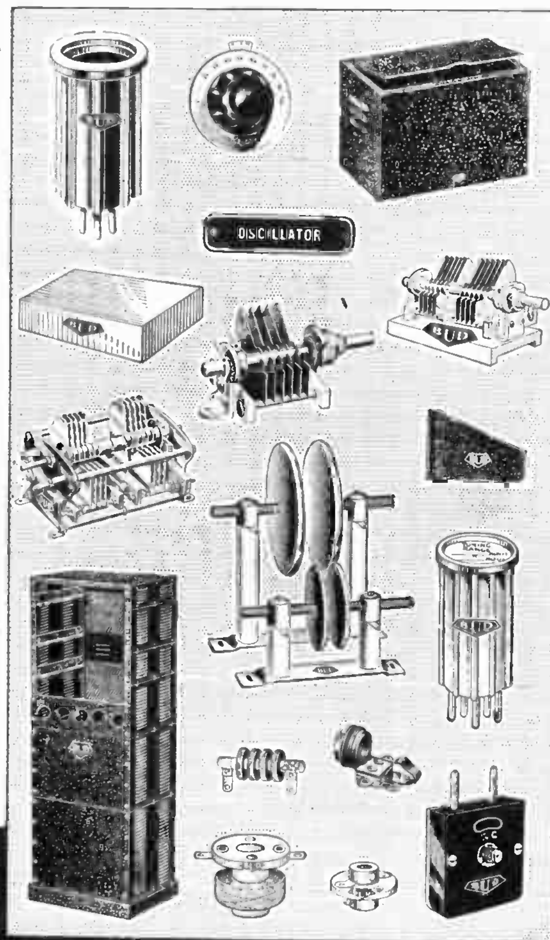
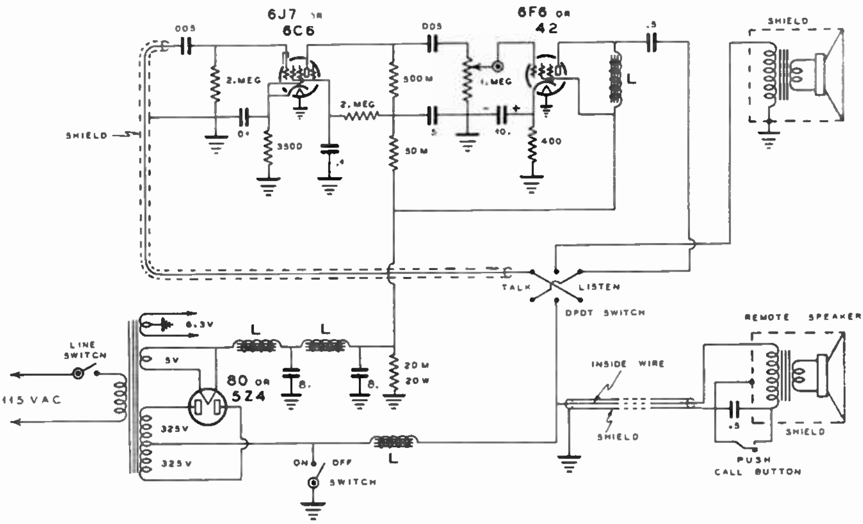


BUD

RADIO INC. 5205 CEDAR AVE., CLEVELAND, O.

"Talk Back" Intercommunication System



Simple, "Talk Back" Amplifier System

The accompanying diagram shows an audio amplifier circuit suitable for "talk back" interoffice, kitchen call, and other such communication.

Small permanent magnet type dynamic loudspeakers are used both as receiving loudspeakers and microphones by means of a "talk-listen" switch located in the amplifier circuit, connected in such a manner that when one is in the input circuit the other is in the output circuit and vice versa.

The speakers and amplifier have enough gain when used as microphones that it is not necessary to talk directly into the unit. The amplifier has sufficient power output to drive one of the speakers hard enough to be heard considerable distance if desired. Quite good quality is obtained from the units when used as microphones, due to the equalizing circuit used.

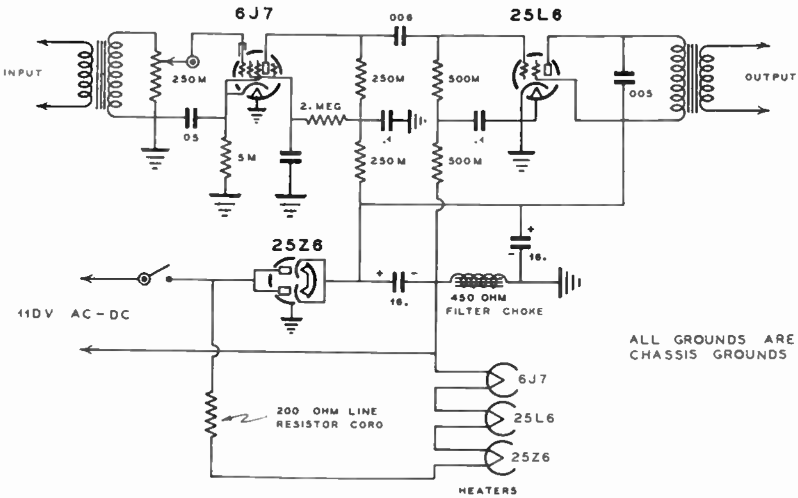
The amplifier proper "on-off" switch, "talk-listen" switch, and the speaker unit shown as the upper one in the diagram are *all located at the "main" station.* The "remote" speaker and "push-call" button are the only components located at the other station. The lead from the grid of the input tube to the "talk-listen" switch should be shielded for the entire length, as should be the wire from the remote speaker. If the lead to the remote speaker is not shielded right up to the "talk-listen" switch, there may be some hum pickup. If the "local" speaker unit is located more than a short distance from the amplifier, the lead to it too should be shielded.

The remote speaker-microphone unit and associated "push-call" button can be located up to several hundred feet from the main station. Two remote speakers instead of one can be used if desired, the second unit being connected in parallel with the remote unit shown in the diagram. The voice quality and gain will suffer slightly, but not enough to be serious. The two remote stations cannot talk to each other in this case; they can only talk with the main station. Connecting more than two remote speakers in the circuit shown is not recommended.

In the "standby" condition, the filaments are left lit and the "talk-listen" switch left on "listen." The "on-off" switch is left on "off." If the operator wishes to talk to the remote station, he turns the switch "on" and the "talk-listen" switch to "talk." When through talking he turns it to "listen" to hear the remarks of the remote station. He always turns the switch to "listen" when not actually talking. When through with the conversation he turns the "on-off" switch "off" and the "talk-listen" to "listen."

To call the main station to start a con-


TYPE 4
TYPE 9
TYPE 59
The World's
most complete
line of
APACITORS
for the
Amateur
TYPE TJ-U
TYPE DT
TYPE JR



A.c.-d.c. amplifier circuit suitable for any intercommunicating system, either the simple "talk-back" type or the more elaborate, multi-station selective type system.

versation, the remote station pushes the "push-call' button and calls the main station, holding the button down until the operator at the main station has a chance to turn the "on-off" switch to the "on" position. It is then no longer necessary for the remote operator to hold the "push-call" button while talking.

With the above arrangement, there is no plate voltage applied to the tubes during the standby periods, and the tubes will last a long time. At night or when the system is not in use, the line switch should be turned off, thus saving the tube filaments.

The chokes L should be 20 to 30 hy. 50 ma. or more.

Radio Data Charts

Radio data charts provide designers of amateur radio equipment with a ready and convenient means of solving problems without having recourse to complicated formula and mathematics.

To use the chart properly and to prevent disfiguring the page, simply place a piece of tracing paper, celluloid, or waxed paper over the scales, then, the index line which intercepts the scales may be drawn with a hard pencil and a straight edge.

The first chart, which is a *logarithmic alignment nomogram*, will solve many problems encountered in ordinary practice.

• Voltage Drop Calculation in Resistors

To find the voltage drop for a certain bias for a self-biased tube, add three ciphers to the value desired, seek this value on scale A; next, search for the value which corresponds to the plate current (cathode current) on the B scale. Now, drawing a line between these two points will intersect a point on C; this corresponds to the ohmage. Hence, a resistance required to produce 9 volts bias for a triode which operates at 3 ma. plate current is: on the A scale, 9 plus three ciphers equals 9000; on the B scale 3 ma. The ohmage 3000, is found on C.

• Wattage or Heat Capacity in Resistors

To find the power in watts dissipated by a certain resistor when ohmage and voltage is known, proceed as follows: On C find the voltage, on A, the resistance; draw a line connecting these two points over to the B scale. Next, find the voltage (for the second time) on the A scale and draw a line

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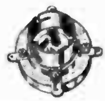
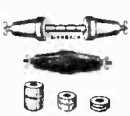


Featuring side wiping contacts. Brass, nickel plated shell. Highly vitrified, low absorption base. All brass hardware. Low prices.
No. **434.** 50 Watt, List ea......$1.25
No. **435.** 10 Watt, List ea...... .90

X'MTR LEAD IN INSULATORS

Made of highly vitrified glazed porcelain. Feature low absorption.



Cat. No.		List Price
4235	10 inch rod	$0.90
4236	15 inch rod	1.00
4237	10 inch rod with bushings	1.20
4238	15 inch rod with bushings	1.50
4240	Bushing 1" long ¾" dia.	.05
4241	Bushing ½" long ¾" dia.	.05
4242	Bushing ¼" long ¾" dia.	.05

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Feature large contact area.

Cat. No.	Description	List Price
395	Giant Jack ⅜" Mtg. Hole	$0.25
396	Giant Plug 10/32 threaded hole	.25
397	Giant Plug ¼-20 threaded hole	.25
398	Giant Plug ½-28 threaded shank	.25
399	Giant Jack ½" mounting hole	.25
400	Plug 6/32 threaded shank ½" long	.06
401	Plug 6/32 threaded hole	.07
403	Jack ¼" mounting hole	.06

COPPERWELD ANTENNA WIRE

Stretchless! Has steel core covered with copper and heavily enameled. Low R.F. resistance.

Gauge		
10	List per 100 ft.	$2.60
12	List per 100 ft.	1.80
14	List per 100 ft.	1.25

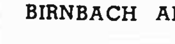
Special prices in 250, 500, 1000, 2500 ft. lengths.

E01 TRANSMISSION CABLE

Surge impedance 72 ohms. Can use up to 1000 ft. with negligible loss. Immune to the elements.

No. 953 1000 ft. coil......List $100.00
No. 955 250 ft. reel......List 25.00
Also available in 100 and 500 ft. lengths.

BIRNBACH ANTENNA INSULATOR



Unusually strong. Long leakage path.

Cat. No. 470 Length 7"..........List Price Ea. $0.50
Cat. No. 471 Length 12"..........List Price Ea. .70

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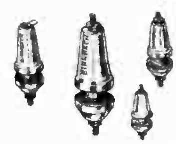
Of improved physical and electrical qualities. Complete range of heights.

Cat. No.	Height	List Price
430	⅝"	$0.10
431	1"	.15
431J	1"	.20
432	1¼"	.20½
432J	1¼"	.25
433	2¾"	.25
433J	2¾"	.50

FEEDTHRU STANDOFF INSULATORS

An original Birnbach development. Two pieces. Designed and proportioned for maximum strength. Brass nickel plated hardware supplied.

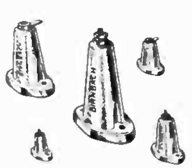
Cat. No.	Height	List Price
458	⅝"	$0.12
478	1"	.20
478J	1"	.25
4125	1¼"	.25
4125J	1¼"	.30
4234	2¾"	.55
4234J	2¾"	.80



BIRNBACH STANDOFF INSULATORS

Come in fine, properly graduated heights to cover every need. Highly vitrified, low absorption porcelain used throughout.

Cat. No.	Height	List Price
405	⅝"	$0.065
966	1"	.075
966J	1"	.10
866	1½"	.12
866J	1½"	.15
866SJ	1½"	.35
4275	2¾"	.30
4275J	2¾"	.55
4450	4½"	.50
4450J	4½"	.75



INSULATED SCRULOCK PIN TIP

Phenolic resin handle, 1" long x 5/6" dia. Designed for easy insertion of wire. Compact. Colors: black, red, green, yellow.

No.		List
412	Insulated Scrulock Phone Tip	$0.12
407	Insulated Phone Tip Jack	.10
406	Insulated Banana Plug Jack	.10
409	Insulated Solderless Pin Tip (sr.)	.12
415	Insulated Solderless Pin Tip (jr.)	.12

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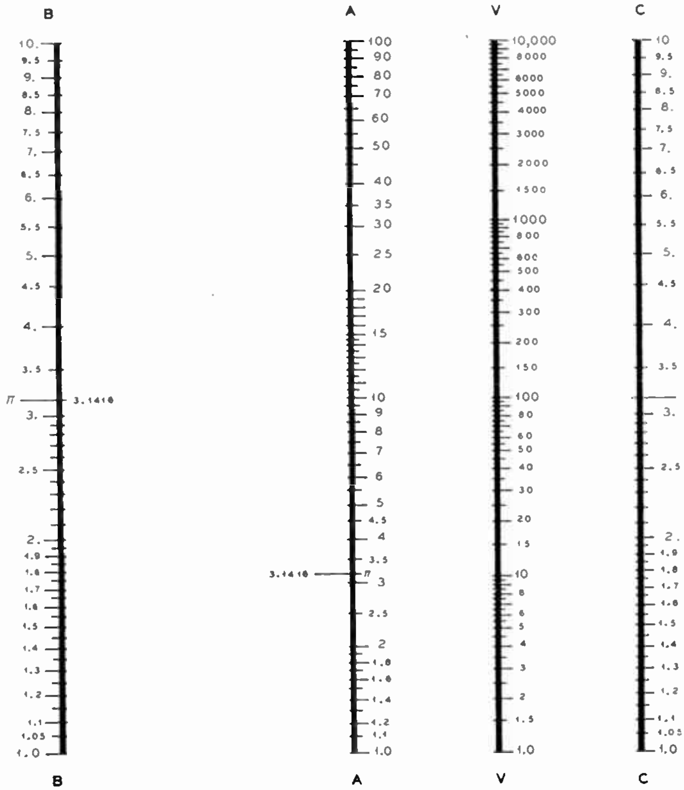


Radio Handbook Logarithmic Alignment Nomogram.

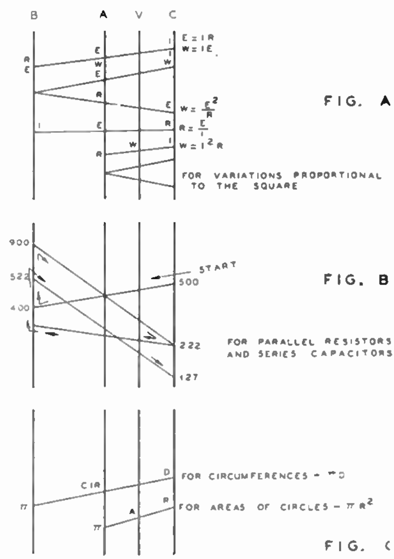
from point B through A. The wattage will be given on C. See the auxiliary Figure for an example.

If the current instead of the voltage is known in the above procedure, the technique is as follows: On C find the value of current; on A, the resistance. A line drawn connecting these points will intercept the wattage rating on V.

• Series Capacity Calculations

To determine the value of any *two* series-capacities, find one of the values on C and the other on B; draw a line to connect these two points; next, *add* the values of the capacities on B, then from this new point, draw a line to intersect A. The series value will be read on C.

If three series capacities are to be employed, the value of any two of them is found as above, and then this is treated as a single capacity and its value combined with the



Auxiliary Chart.

third by repeating the process, which can be carried on indefinitely.

An example illustrating the method is shown in auxiliary figure (b).

NOTE: Raise the A scale the distance from 1 to 10 when the reading is beyond the bottom, or by taking a piece of tracing paper and tracing the A scale so as to extend it another length of 1 to 10.

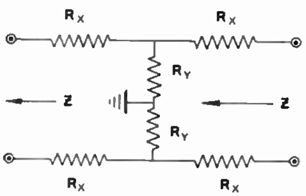
• Parallel Resistor Calculations

These are treated exactly as series capacities, and the above explanation will solve all values.

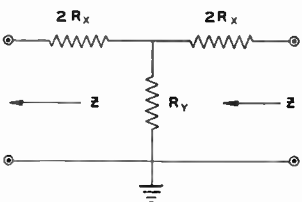
Fixed Networks

• "T" and "H" Pads

The "T" section, which is an unsymmetrical network (unbalanced) is most frequently used where small unbalances in the line or to ground are of little importance. Fixed type networks are chiefly employed in circuits where it is desired to limit the



"H" Pad.



"T" Pad

amount of input voltage available to excite amplifiers, thus precluding the possibilities of overloading certain components in the amplifying system. A resistive network which functions as an absorption device loses its identity as a "pad" and is most often referred to as an "insertion loss," because the section has been inserted to attenuate a known and definite quantity.

To design a fixed "T" or "H" type section for some predetermined loss in db., the following equations are given. These equations only hold good when the line impedances terminating each end of the network are equal; therefore where

$$R_x = \frac{Z}{2}\,\frac{(K-1)}{(K+1)}$$

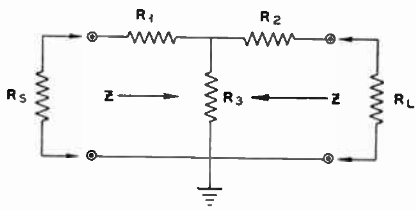
$$R_y = 2Z\,\frac{K}{(K^2-1)}$$

$$K = \text{antilog}\,\frac{N_{db}}{20}$$

equals the series resistor (this value must be multiplied by 2 for "T" sections); R_y, the shunt resistor; Z, the line impedance; and K, a constant derived by taking the inserted attenuation in db. and dividing by 20, then extracting the antilog.

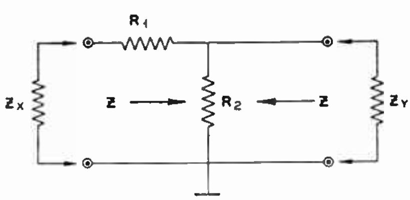
• Impedance Matching Networks

At audio frequencies an impedance matching network comprised of resistive impedances can be substituted for an impedance matching transformer or like device. Unfortunately, this type of network introduces a small loss; however, this loss is of little consequence because it can be counteracted by simply working the input or output circuits at a higher level.



Impedance Matching Network.

In the above figure it is very important that the resistors R_1 and R_2 be placed correctly in the configuration, otherwise impedances will be mismatched.



"L"-Type Network

In the above figure, resistor R_1 must face the highest terminal impedance.

To design an impedance matching network

of the "T" type requires the use of the following equations:

$$R_1 = \frac{(R_S + R_L)\ K_1 + (R_S - R_L)}{2}$$

$$R_2 = \frac{(R_S + R_L)\ K_1 + (R_S - R_L)}{2}$$

$$R_3 = \frac{(R_S + R_L)}{2K_2}$$

Where R_S is the input impedance; R_L, the output impedance; and K_1 and K_2 are constants taken from the following table. These constants appear directly opposite the amount of attenuation in the N_{db} column:

N_{db}	K_1	K_2
1	.057	0.115
2	.114	0.232
3	.171	0.352
4	.226	0.477
5	.280	0.609
6	.331	0.747
7	.382	0.897
8	.430	1.055
9	.476	1.233
10	.519	1.422
11	.560	1.634
12	.598	1.863
13	.634	2.122
14	.667	2.404
15	.697	2.720
16	.726	3.075
17	.752	3.468
18	.776	3.907
19	.798	4.398
20	.818	4.952
21	.835	5.555
22	.852	6.262
23	.867	7.013
24	.880	7.868
25	.893	8.870
26	.904	9.977
27	.914	11.188
28	.923	12.484
29	.931	14.091
30	.938	15.734
31	.945	17.744
32	.950	19.810
33	.956	22.339
34	.960	24.939
35	.965	27.121
36	.968	31.393
37	.972	35.397
38	.975	39.515
39	.978	44.555
40	.980	50.237
41	.982	56.079
42	.984	63.230
43	.985	70.583
44	.987	78.792
45	.988	88.836
46	.990	100.165
47	.991	111.813
48	.992	126.070
49	.993	140.729
50	.994	158.672

To design an impedance matching network of the "L" type requires this set of equations:

$$R_1 = Z_x(Z_x - Z_y)$$

$$R_2 = \frac{Z_x Z_y}{\sqrt{Z_x(Z_x - Z_y)}}$$

Since the insertion loss is a function of the impedances terminating the network it can be calculated as follows:

$$K = \sqrt{\frac{Z_x}{Z_y}} + \sqrt{\frac{Z_x}{Z_y} - 1}$$

Where loss in db. = 20 Log_{10} K.

Calculation of Inductance

The calculation of inductance values for coils in radio transmitter and receiver circuits is not difficult when certain basic considerations are taken into account. There are a number of formulas for such inductance calculations, some laying claim to greater accuracy than others. It must be remembered that most of such formulas give only approximate solutions to practical problems; few claim absolute accuracy. There is lacking an absolutely accurate means of inductance calculations at the frequency at which the inductance is to be used. The following discussion is confined to calculations for single-layer solenoids.

If it is desired to find the value of inductance to tune a receiver circuit to 3,500 kc. with a 50-$\mu\mu$fd. maximum capacity variable condenser, the formula is:

$$L = \frac{25{,}330}{f^2 \times C}$$

For ease of calculation, assume that *C* was to be approximately 41 $\mu\mu$fds., and *f* was 3.5 megacycles; these values would then give a value of *L* equal to 50 microhenries.

From the formula:

$$N = \sqrt{\frac{L}{df}}$$

where

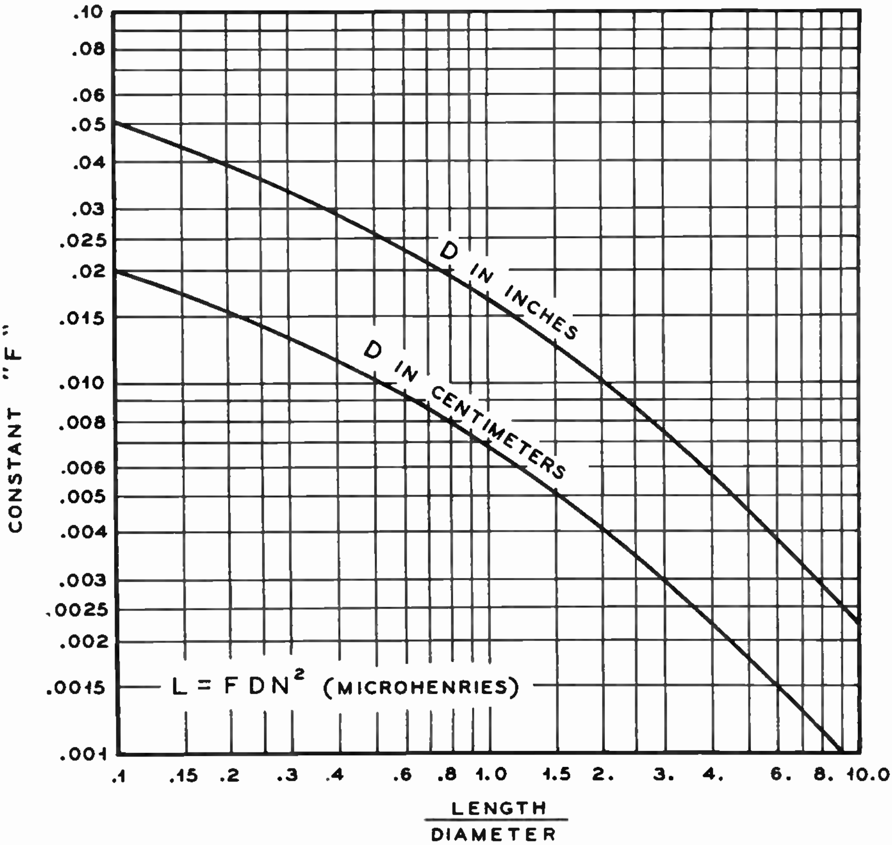
N = number of turns,
L = inductance in microhenries,
d = diameter of coil measured to center of wire,
f = a factor dependent upon the ratio of length of winding to coil diameter.

The value of L is known; the diameter d will be dependent upon the coil form which has been selected. Once the ratio of length to diameter is known, the value of f (constant) can readily be found from the accompanying graph. If the coil diameter is one-inch, and if it is assumed that the winding will be one inch long, the ratio of the two will be unity. From the graph, a ratio of 1 corresponds to factor f of .0175. This graph is published by courtesy of Professor F. E. Terman of Stanford University, in whose textbook, *Radio Engineering*, the original presentation was made.

Continuing with the coil calculations, the values are now substituted in an equation, as follows:

$$N = \sqrt{\frac{50}{1 \times .0175}} = 53.5 \text{ turns.}$$

Referring to the *copper wire table* in the *Power Supply* chapter, it is found that a wire size which will wind approximately 53



Coil Inductance Calculation Chart

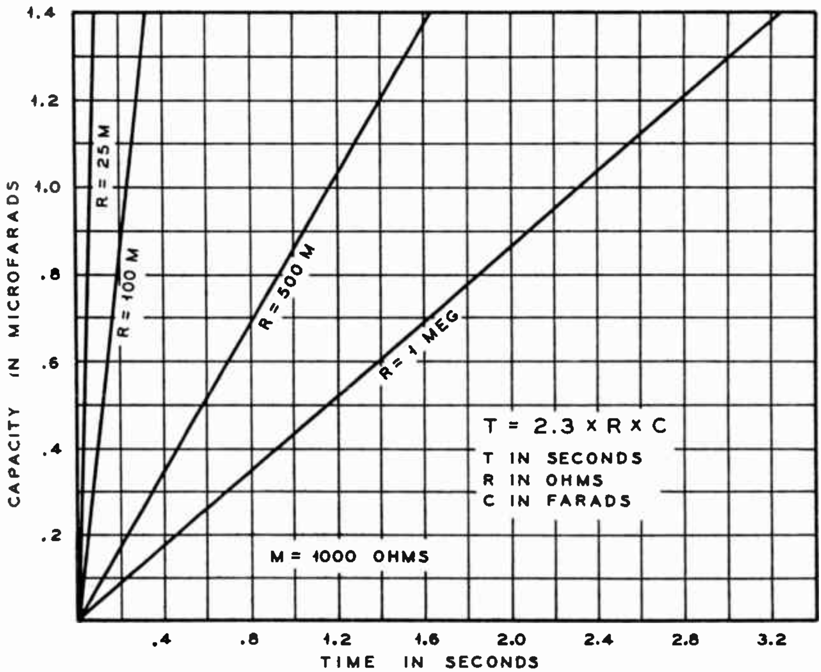
turns per inch will be size No. 28, double cotton covered (DCC). This wire size will actually wind 54.6 turns per inch, yet it comes closest to what is here desired, and consequently must be used. The actual difference between 53 turns per inch and 54.6 turns is neglible.

The chart will require a bit of practice when used with the foregoing formula; it is suggested that several ratios of length to diameter be experimented with, insofar as the calculations are concerned, before a coil is actually to be wound. If the wire size is very small as compared with the diameter of the coil, the stipulation that the diameter be regarded as that measured from the center of the wire can be neglected. If greater accuracy is required, the formula should be converted into centimeters insofar as units of length and diameter are concerned.

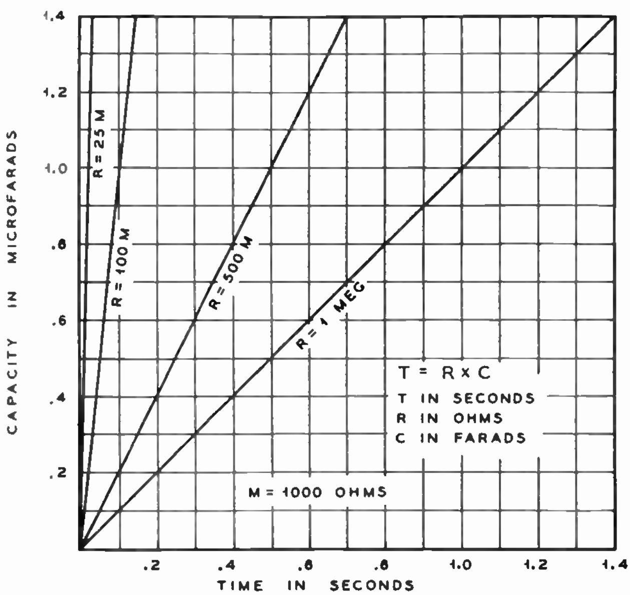
WIRE TABLE

Winding Turns Per Inch

B & S Gauge No.	D.C.C.	S.C.C.	En-amel	B & S Gauge No.	D.C.C.	S. C. C.	En-amel
6	5.44	5.60		26	39.90	45.30	57.00
7	6.08	6.23		27	42.60	49.40	64.00
8	6.80	6.94		28	45.50	54.00	71.00
9	7.64	7.68		29	48.00	58.80	81.00
10	8.51	8.55		30	51.10	64.40	88.00
11	9.58	9.60		31	56.80	69.00	104.00
12	10.62	10.80		32	60.20	75.00	120.00
13	11.88	12.06		33	64.30	81.00	130.00
14	13.10	13.45	14.00	34	68.60	87.60	140.00
15	14.68	14.90	16.00	35	73.00	94.20	160.00
16	16.40	17.20	18.00	36	78.50	101.00	190.00
17	18.10	18.80	21.00	37	84.00	108.00	195.00
18	20.00	21.00	23.00	38	89.10	115.00	205.00
19	21.83	23.60	27.00	39	95.00	122.50	215.00
20	23.91	26.40	29.00	40	102.50	130.00	230.00
21	26.20	29.70	32.00	41	112.00	153.00	240.00
22	28.58	32.00	36.00	42	124.00	168.00	253.00
23	31.12	34.30	40.00	43	140.00	192.00	265.00
24	33.60	37.70	45.00	44	153.00	210.00	275 00
25	36.20	41.50	50.00				

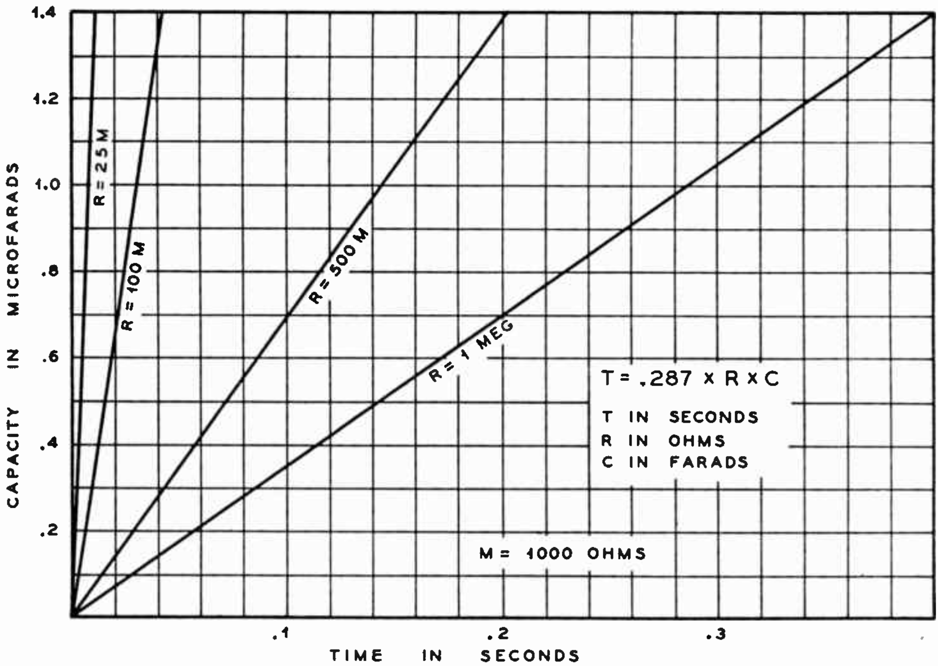


TIME REQUIRED FOR A 90% DROP OF VOLTAGE ACROSS C



TIME REQUIRED FOR A 63% DROP OF VOLTAGE ACROSS C

HANDY R-C TIME CONSTANT CHARTS



TIME REQUIRED FOR A 25% DROP IN VOLTAGE ACROSS C

It is sometimes desirable to know how much time will be taken for a condenser to discharge its stored energy through a resistance. The voltage across the condenser diminishes, or dies away, according to an exponential curve. For this voltage to drop to absolute zero would require an indefinite length of time, but for practical purpose the voltage is at a negligible value a few seconds after the condenser is discharged.

This information is of value for calculating *R-C* filters of the type used in feeding automatic volume control voltage to the control grid of a tube. Values of *R* and *C* are chosen to give as rapid or slow an a.v.c. action as may be desired.

Three graphs are reproduced, giving the time required for the voltage to fall to either 75%, 37% or 10% for various *R-C* combinations.

Oscillator Tracking Calculations for Superheterodynes

Practically all of the present-day superheterodyne receivers use a single two or three-gang tuning condenser, depending upon whether or not a tuned r.f. stage is incorporated in the receiver circuit, and consideration must therefore be given to the oscillator circuit so that it will maintain a constant frequency difference from the r.f. and detector stages.

If the tuning ratio (frequency to be covered at the high-frequency end divided by the frequency at the low-frequency end) is greater than 1.5-to-1, it will be impossible to make the oscillator and r.f. stages *track*, unless certain precautions are observed.

Since all three of the condenser sections are mounted on a common shaft, they all have identically the same capacity change for a given degree of rotation. It should not be difficult to understand that since the oscillator must operate at a higher frequency than the r.f. stages (differing from the r.f. stages by an amount equal to the i.f. frequency), it will not cover the same tuning ratio as the latter. For example, if the band

to be covered is from 2,000 to 4,000 kc, the r.f. tuning ratio will be 2-to-1. For this same coverage the oscillator will tune from 2,460 to 4,460 (if the intermediate frequency is 460 kc.) This corresponds to a tuning ratio of 1.81-to-1. Obviously the two tuning ratios are not the same. The oscillator tuning condenser must therefore be decreased in capacity in order to make its ratio the same as for the r.f. stages.

This is accomplished by adding a fixed condenser in series with the oscillator condenser and the inductance. The proper value of this condenser can be obtained by calculation. There are three points in the tuning range where the tracking will be correct (although slight departures from these optimum points will not be at all serious) if the calculations are accurately made. These three points are known as the *cross-over points*.

In order to make use of the formulas shown for calculation of oscillator series condenser and inductance, it will be neces-

Formulas for Calculation of Superheterodyne Oscillator Constants

Frequencies expressed in megacycles
Inductances expressed in microhenries
Capacitances expressed in micromicrofarads

Basic Consideration and Relations

f_0 = Intermediate frequency

F_1, F_2, F_3 = Frequencies at which exact tracking is to be obtained.

$a = F_1 + F_2 + F_3$ .... (3)

$b^2 = F_1F_2 + F_1F_3 + F_2F_3$ .... (4)

$c^3 = F_1F_2F_3$ .... (5)

$d = a + 2f_0$ .... (6)

$l^2 = (b^2d - c^3)/2f_0$ .... (7)

$m^2 = l^2 + f_0^2 + ad - b^2$ .... (8)

$n^2 = (c^3d + f_0^2l^2)/m^2$ .... (9)

C_0 = Tuning capacitance at frequency F_0 ....

$L = 25330/C_0F_0^2$, or if L is known, then $C_0F_0^2 = 25330/L$ .... (1)

$A = C_0F_0^2(1/n^2 - 1/l^2)$ Required only for Case 3 .... (16)

$B = (C_0F_0^2/l^2) - C^3$ Required only for Case 4 .... (20)

Case 1: When $C_4 = 0$, or $C_4 \ll C_2$ (the usual case).

$C_2 = C_0F_0^2(1/n^2 - 1/l^2)$ .... (10)

$C_3 = C_0F_0^2/l^2$ .... (11)

$L_1 = L(l^2/m^2)(C_2 + C_3)/C_2$ .... (12)

Case 2: When $C_3 = 0$.

$C_2 = C_0F_0^2/n^2$ .... (13)

$C_4 = C_0F_0^2/(l^2 - n^2)$ .... (14)

$L_1 = L(l^2/m^2)C_2/(C_2 + C_4)$ .... (15)

Case 3: When C_4 is known.

$C_2 = A\left(1/2 + \sqrt{1/4 + C_4/A}\right)$ .... (17)

$C^3 = (C_0F_0^2/l^2) - C_2C_4/(C_2 + C_4)$ .... (18)

$L_1 = L(l^2/m^2)(C_2 + C_3)/(C_2 + C_4)$ .... (19)

Case 4: When C_3 is known.

$C_2 = (C_0F_0^2/n^2) - C_3$ .... (21)

$C_4 = C_2B/(C_2 - B)$ .... (22)

$L_1 = L(l^2/m^2)(C_2 + C_3)/(C_2 + C_4)$ .... (23)

Check Formulas

Equation for oscillator frequency:

$f_1 = m\sqrt{(f^2 + n^2)/(f^2 + l^2)}$ .... (24)

Equations for l^2, m^2, and n^2, in terms of oscillator constants:

$$l^2 = C_0F_0^2/\left(C_3 + \frac{C_2C_4}{C_2 + C_4}\right) \quad (25)$$

$$m^2 = C_0F_0^2/(L_1/L)\left(C_4 + \frac{C_2C_3}{C_2 + C_3}\right) \quad (26)$$

$$n^2 = C_0F_0^2/(C_2 + C_3) \quad (27)$$

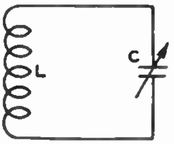
EL "RADIO" HANDBOOK

Edición Español

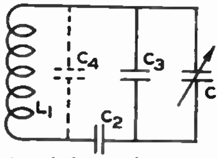
As in former years, this edition of the "RADIO" HANDBOOK is available in English or Spanish. The Spanish edition is published under license by Editorial Pan America, Perú 677, Buenos Aires, Argentina, to whom all inquiries and orders should be directed. The list price is $5.00, Buenos Aires funds.* Copies may be obtained at retail ($1.65, postpaid) from Radio, Ltd., 7460 Beverly Boulevard, Los Angeles.

*Money orders, checks, and banknotes for the current equivalent of $5.00 Argentine funds will be accepted drawn in local funds on New York, La Paz, Rio de Janeiro, Santiago de Chile, Lima, Lisbon, and Montevideo.

R-F CIRCUIT



OSCILLATOR CIRCUIT



sary to have the following information:

(1) Capacity of variable condenser at maximum and at minimum values.

(2) Capacity must include that which is introduced by grid-cathode capacity of the tubes, and approximately 10 $\mu\mu$fds. of miscellaneous stray capacities, due to wiring, etc.

(3) Frequency range to be covered. Minimum and maximum capacity of the tuning condenser will limit the range. Knowing the frequency and capacity the inductance can be readily determined from:

$$L = \frac{25{,}330}{f^2 C}$$

(4) Tracking frequencies. These are notated F_1, F_2 and F_3 in the formula, and two are usually selected at points close to the extreme ends of the band to be covered, with the third point being approximately at the mid-point on the dial.

(5) The term F_0 is arbitrarily chosen at some frequency close to the center of the band. Since the inductance is already known, the values of capacity for this frequency can be readily determined:

$$C = \frac{25{,}330}{f^2 L}$$

(6) Case (1) should be used for oscillator constants, because this is the most general case.

It may appear on first inspection that the formulas are quite complicated; actually they involve nothing more than ordinary arithmetic. For accuracy where the frequencies to be covered are high, divisions should be carried out to at least three places, and preferably four. Slide-rule calculations are very apt to be in error, unless the rule is capable of being read to the above stipulations.

At the ultra-high frequencies, the percentage of oscillator variance from the tuning ratio of the r.f. stages will be small. In such cases, the series padder condenser may usually be omitted, and a slight adjustment on the oscillator inductance will suffice to give reasonably good tracking.

In many cases the capacity of the oscillator section of the tuning condenser can be decreased by bending-out the plates; in this manner some measure of tracking can be obtained. The foregoing formulas for calculation of superheterodyne oscillator constants are by courtesy of the RCA Mfg. Co., from whose bulletin the reprint is made by permission

The Experimental License

Where Required and How Obtained

Any licensed amateur who chooses to conduct experiments at his station, whether he plans honest-to-goodness scientific investigation or only wishes to test a new rig, is within his right as long as the experiments are non-commercial in character and he confines his transmissions to amateur frequencies. The amateur station license, however, does not authorize any type of experimenting where money-making features are involved, whether stated or implied; the use of frequencies other than those allocated for amateur communication; or the use of types of emission not permitted to amateur stations.

For all special experimental work, the Federal Communications Commission issues an experimental class station license, and this ticket *must* be obtained whenever anticipated experiments cannot be covered by the accepted definition of *amateur* radio communication. The experimental license is not a ham ticket, though the call letters are made up with the district numeral in the conventional amateur fashion. The one distinguishing feature of the call is the initial letter, X (such as W1XYZ) which has given rise to the slang terms, X-license and X-station.

Special frequencies are set aside for use by X-stations, and the particular ones chosen by an applicant should best suit the conditions under which he plans to operate. An applicant for an experimental license is required to request one or more of these definite frequencies, as the Commission neither assigns frequencies individually nor advises applicants which would be the best ones for their particular experiments. Whatever the frequencies chosen, the applicant must satisfy the Commission that his equipment will enable him to maintain those

frequencies within three-hundredths of one per cent, plus or minus. And he must show that he has precision monitoring equipment which will indicate this small tolerance.

The Experimental Service includes (1) General Experimental Stations, (2) Special Experimental Stations, (3) Experimental Broadcast Stations, and (4) Experimental Visual Broadcast (television) Stations. It is assumed that the average amateur of experimental bent will be interested only in the first two classifications, hence this discussion will be confined to general and special stations.

Rules 303 and 304 (Rules and Regulations of the Federal Communications Commission) define these two classes of experimentals as follows: "The term 'general experimental station' means a station equipped to carry on research or development in the radio art requiring the transmission of radio-frequency power and operating on frequencies designated by the Commission for general experimental service. The term 'special experimental station' means a station used to carry on special research or development in the radio art which because of the nature of the experiments, requires frequencies other than those designated for general experimental stations."

The following frequencies are allocated for general experimental service: 1614, 2398, 3492.5, 4797.5, 6425, 8655, 12862.5, 17310, 23100, 25700, 26000, 27100, 31600, 35600, 38600, 41000, 86000 to 400,000 and 401,000 kilocycles and above. An applicant may request any or all of these frequencies, but he *must* be equipped to maintain the 0.03% tolerance on each one requested.

None of the frequencies is assigned exclusively to any one applicant; they are shared by similar stations throughout the country, and when interference results, the license holders are required to arrange a division of time.

• Special Experimental Frequencies

Special X-stations may ask for definite frequencies other than those in the above list when the proposed owners can show that the general experimental frequencies are unsuitable for their research. Where the frequency requested is already in use by some other radio service, the applicant must make arrangements with those services beforehand in order that interference may be prevented and in many cases must file with his application statements from the other services that experimental use of the frequency is agreeable.

• Special Operators License Necessary

Experimental Stations may be operated only by individuals who hold commercial operator licenses of the radiotelegraph third class or higher, except in the case of stations employing frequencies higher than 30,000 kc. where an amateur operator license is acceptable.

• Emissions Permitted

A1 (c.w. telegraphy), A2 (i.c.w. telegraphy), A3 (radiotelephony), and "special" types of emission are authorized under the experimental license, and the applicant may request permission to use any or all. Under the heading of *special* are included all types of keying, modulation, etc., which cannot be classified as A1, A2, or A3.

Experimental applicants may ask for definite operating hours or may request unlimited time.

• Application Procedure

The prospective experimental's first job will be to apply to the Commission for a construction permit. The application, Form 401, is an eight-page document containing thirty-four questions. Herein, the applicant requests the frequency desired, hours of operation, operating output power, and emission. He must state the proposed location of the station to the nearest degree, minute, and second, north latitude and west longitude, and must list the airways and airports within ten miles of the location. He must also state the number of persons residing within one mile and within five miles of the proposed transmitter.

The type of experimental research to be carried on must be described in detail, and the applicant's own technical qualifications, or the qualifications of those he will engage to carry on the work, must be outlined. A *bona fide* statement must be made of the applicant's financial responsibility to see the work through.

Most difficult of all, the applicant must satisfy the Commission that his proposed researches will be in the public interest, convenience, and necessity. A large number of applicants are refused the construction permit because they fall down on this last requirement.

Before filling out an application for station

construction permit, a study should be made of *Rules and Regulations of the Federal Communications Commission,* with particular attention to the section on Experimental Services. The booklet may be obtained for thirty-five cents from the Superintendent of Documents, Government Printing Office, Washington, D. C.

• Station License

The construction permit bears the call-letters of the station, frequency (s), power output of transmitter, emission (s), and hours of operation, and authorizes the building and testing of the equipment described in detail in the application. Six months are allowed for completion of the station; and if at the expiration of that period the station has not been completed, the applicant may file an application for an extension of time.

On completion of the construction and testing, application for station license is made on Form 403. This application merely certifies that the station has been completed and corresponds to the description in the application for construction permit. Should changes have been made in the original plan, these changes are detailed in the station license application. The applicant also reaffirms all statements regarding ownership, operation, control, and so forth, made by him in the application for construction permit.

Both the application for construction permit and the one for station license are filed in duplicate.

Experimental station licenses are issued for a period of one year.

Every station is required to keep an accurate log and to file with each application for renewal a report showing:

A. Ultimate objective to be reached by experiments.

B. General results accomplished during period of report, including references to published reports of experimental work.

C. Technical studies in progress at time of filing report.

D. Any major changes in equipment.

E. Total hours of operation.

FRACTIONAL—DECIMAL EQUIVALENTS

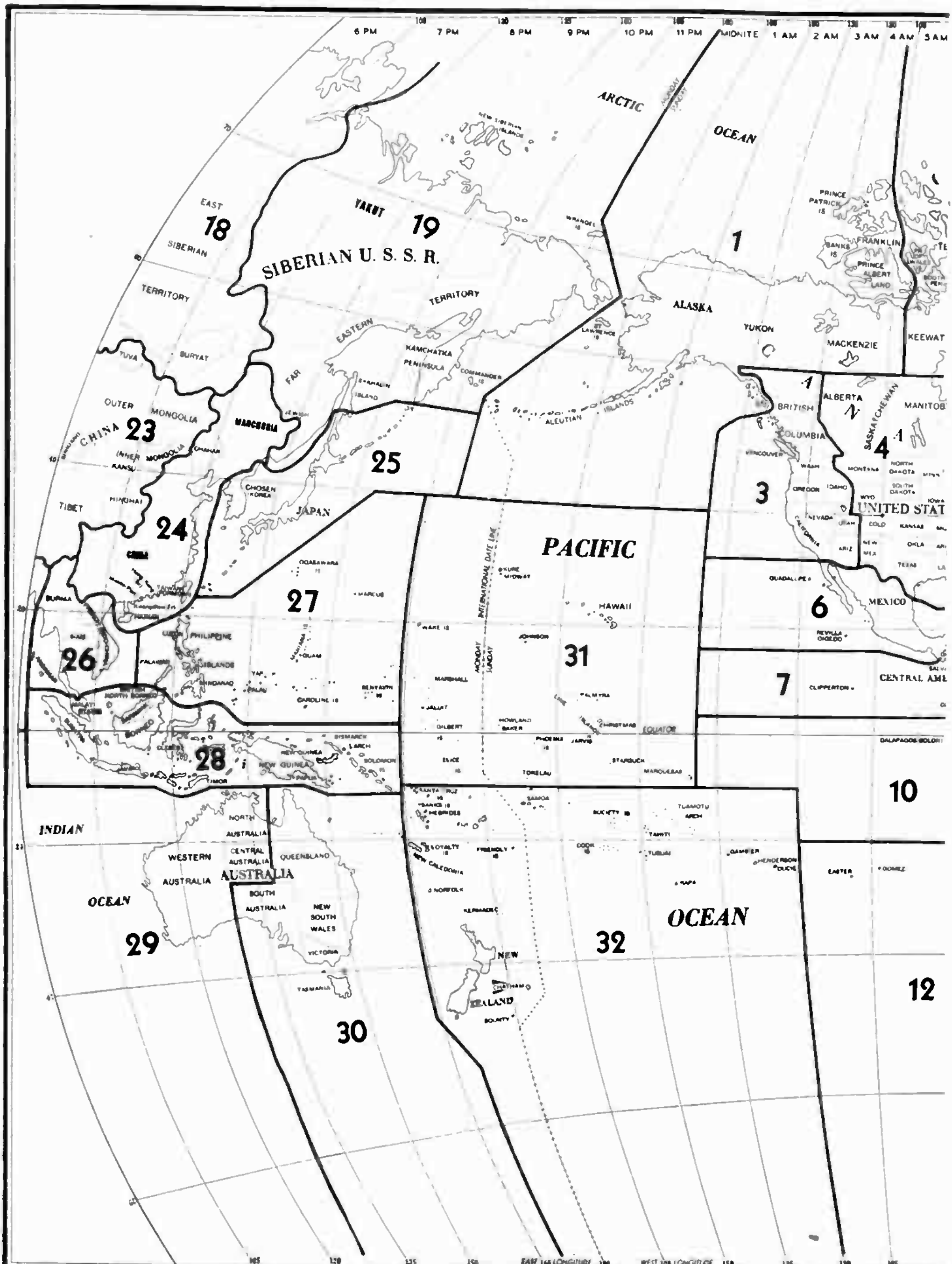
A time-saving table is given for fractional-decimal conversion. Many of the commonly used fractions and their decimal equivalents are shown. Others can be calculated by dividing the numerator by the denominator.

$\frac{1}{64}$ = .0165	$\frac{7}{16}$ = .4375
$\frac{1}{32}$ = .0312	$\frac{1}{2}$ = .500
$\frac{3}{64}$ = .0468	$\frac{9}{16}$ = .5625
$\frac{1}{16}$ = .0625	$\frac{5}{8}$ = .625
$\frac{3}{32}$ = .0936	$\frac{11}{16}$ = .6825
$\frac{1}{8}$ = .125	$\frac{3}{4}$ = .750
$\frac{3}{16}$ = .1875	$\frac{13}{16}$ = .8125
$\frac{1}{4}$ = .250	$\frac{7}{8}$ = .875
$\frac{5}{16}$ = .3125	$\frac{15}{16}$ = .9375
$\frac{3}{8}$ = .3750	

Simplified Trigonometric Tables

Angles of Every 3 Degrees

Angle in Degrees	SINE Side Opp. / Hypotenuse	COSINE Side Adj. / Hypotenuse	TANGENT Side Opp. / Side Adjacent
0	0.0000	1.0000	0.0000
3	.0523	.9986	.0524
6	.1045	.9945	.1051
9	.1564	.9877	.1584
12	.2079	.9782	.2126
15	.2588	.9659	.2679
18	.3090	.9511	.3249
21	.3584	.9336	.3839
24	.4067	.9136	.4452
27	.4540	.8910	.5096
30	.5000	.8660	.5774
33	.5446	.8387	.6494
36	.5878	.8090	.7265
39	.6293	.7772	.8098
42	.6691	.7431	.9004
45	.7071	.7071	1.0000
48	.7431	.6691	1.1106
51	.7772	.6293	1.2349
54	.8090	.5736	1.4281
57	.8387	.5446	1.5399
60	.8660	.5000	1.7321
63	.8910	.4540	1.9626
66	.9136	.4067	2.2460
69	.9336	.3584	2.6051
72	.9511	.3090	3.0777
75	.9659	.2588	3.7321
78	.9782	.2079	4.7046
81	.9877	.1564	6.3138
84	.9945	.1045	9.5144
87	.9986	.0523	19.0813
90	1.0000	.0000	


6 PM
7 PM
8 PM
9 PM
10 PM
11 PM
MIDNITE
1 AM
2 AM
3 AM
4 AM
5 AM
ARCTIC
OCEAN
EAST
18
SIBERIAN
TERRITORY
YAKUT
19
SIBERIAN U. S. S. R.
TERRITORY
EASTERN
FAR
KAMCHATKA
PENINSULA
1
PRINCE PATRICK IS
BANKS IS
FRANKLIN
PRINCE ALBERT LAND
ALASKA
YUKON
MACKENZIE
KEEWAT
TUVA
BURYAT
OUTER
MONGOLIA
CHINA
23
INNER MONGOLIA
KANSU
TIBET
24
CHOSEN
JAPAN
25
ALEUTIAN
ISLANDS
BRITISH
COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
4
3
OREGON
IDAHO
NEVADA
CALIFORNIA
UNITED STAT
PACIFIC
INTERNATIONAL DATE LINE
27
HAWAII
6
MEXICO
26
PHILIPPINE ISLANDS
31
7
CENTRAL AME
MARSHALL
CAROLINE IS
EQUATOR
28
NEW GUINEA
TIMOR
10
INDIAN
NORTH
AUSTRALIA
WESTERN
AUSTRALIA
CENTRAL
AUSTRALIA
QUEENSLAND
AUSTRALIA
SOUTH
AUSTRALIA
NEW
SOUTH
WALES
VICTORIA
TASMANIA
OCEAN
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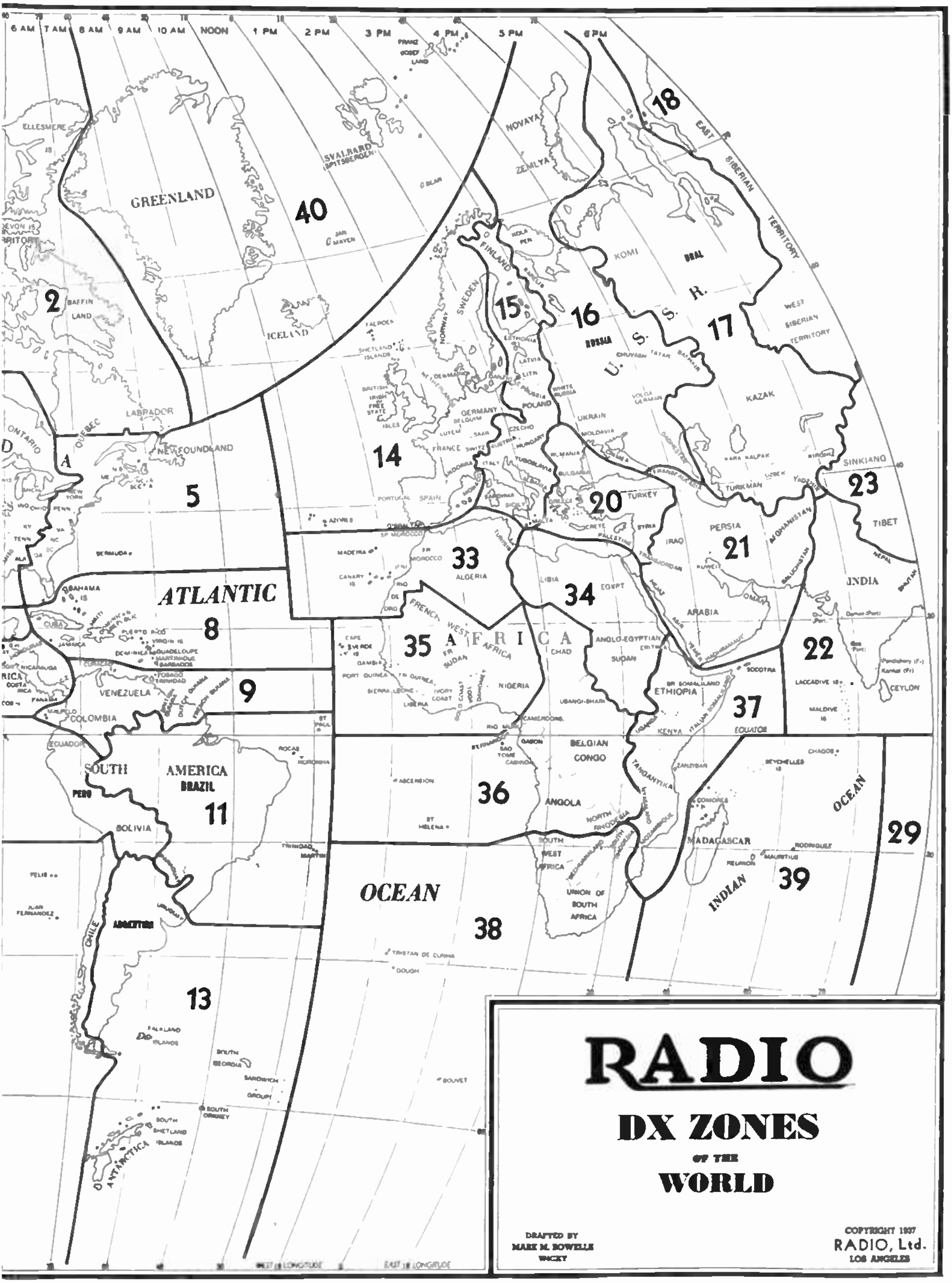
NEW
ZEALAND
32
OCEAN
12
EAST 165 LONGITUDE
WEST 165 LONGITUDE


6 AM
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10 AM
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2 PM
3 PM
4 PM
5 PM
6 PM
GREENLAND
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2
ICELAND
LABRADOR
NEWFOUNDLAND
QUEBEC
5
14
15
16
17
18
FINLAND
SWEDEN
NORWAY
NOVAYA
ZEMLYA
U. S. S. R.
RUSSIA
KOMI
KAZAK
EAST SIBERIAN TERRITORY
WEST SIBERIAN TERRITORY
GERMANY
POLAND
FRANCE
SPAIN
PORTUGAL
ITALY
UKRAIN
TURKEY
20
23
SINKIANG
TIBET
PERSIA
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ARABIA
INDIA
22
CEYLON
ATLANTIC
8
9
VENEZUELA
COLOMBIA
ECUADOR
SOUTH AMERICA
BRAZIL
11
BOLIVIA
CHILE
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ALGERIA
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EGYPT
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FRENCH WEST AFRICA
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LOS ANGELES

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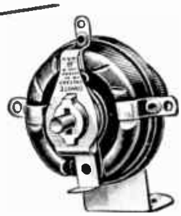
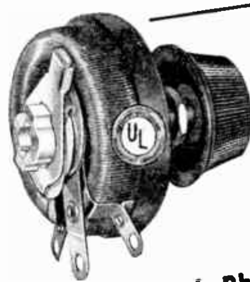
OHMITE PRODUCTS



Band-Change Switch

Here's the unit you've heard 'em all talking about. Substitutes turn of a knob for the bothersome plug-in coil method of changing transmitter frequency. Get one and bring your rig up to date.



Vitreous Enameled Rheostats

These famous power rheostats are in a class by themselves. Get them for your rig if you want that close control that means long tube life. Made in 25, 50, and 100 watt sizes and up to 1 K.W.

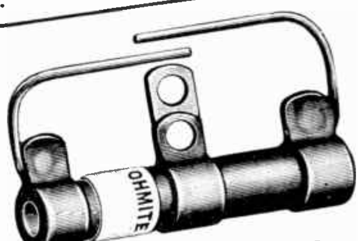
Fixed Resistors

If you use Ohmite Vitreous Enameled Fixed Resistors you can rest assured you have the best that money can buy. Now made in 25, 50, 100, 160 and 200 watt sizes in resistance ranges from 5 to 250,000 ohms.

Tap-Switches

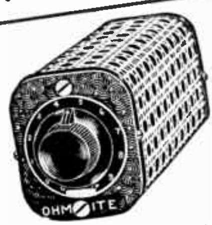
Ohmite tap-switches are rugged units which are used to switch one circuit to any of several other circuits. Can be furnished with any number of taps up to twelve, inclusive, and in either the shorting or non-shorting type.

Send for your free copy of this new catalog describing the complete line of Ohmite products.



Center-Tap Resistors

Ohmite Wirewatt and Brown Devil center-tapped resistors are most frequently used across transmitter tube filaments, to provide an electrical center for the grid and plate returns. Center tap is accurate to plus or minus 1%.



T-Pad and L-Pad Attenuators

These attenuators afford stepless control of the volume of loudspeakers used in high-power P.A. systems. They are inserted between the amplifier and loudspeakers to permit the controlled speakers to be varied in volume without changing the impedance of the total connected load.

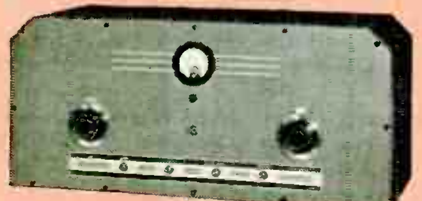
OHMITE MANUFACTURING COMPANY

4849 W. Flournoy St., Chicago, Ill.

Quality Equipment by RCA

RCA COMMUNICATION RECEIVER AR-67

9 tubes. Receives phone and C-W signals between 75 and 1500 kilocycles. May be operated from A-C or batteries. Complete with tubes but less other accessories, $275.00.



RCA AMATEUR TRANSMITTER ACT-20

This crystal-controlled transmitter offers easy tuning, "broadcast quality" and excellent performance. 20 watts C-W, 16-watt phone output 10-160 meter bands.

RF Stage: RCA-807 — RCA-802 — RCA-807

Audio Stage: RCA-6F5 — RCA-6F6 — RCA-6L6 / RCA-6L6

$129.50 with one set of coils but less tubes and accessories.

RCA MODEL ACT-150 TRANSMITTER

150 watts output CW and phone. 10 to 160 meter amateur bands.

RF Stages:
RCA-807 — RCA-802
RCA-807 — RCA-808
RCA-807 — RCA-808

Audio Stages: RCA-6J7
RCA-6C6 — RCA-6C6
RCA-2A3 — RCA-808
RCA-2A3 — RCA-808

with one set of coils but less Tubes and Accessories, $625.00. *f.o.b. Camden, New Jersey*

See our distributor or write us for complete details of equipment illustrated.

All prices are amateur's net, f. o. b. factory and subject to change or withdrawal.

RCA AMATEUR RECEIVER ACR-155

A 9-tube communication receiver covering from 520 to 22,000 kilocycles. 100-1 ratio tuning drive and large knob for bandspread. R-F stage, air-dielectric trimmers and magnetite core I-F transformers. Complete with built-in speaker and tubes at $74.50.

RCA AMATEUR RECEIVER ACR-111

The last word in modern design! Features of particular importance are constant-percentage electrical bandspread system, noise suppressor, two r-f and i-f stages, crystal filter, exceptional sensitivity and signal-to-noise ratio. Rack-mounting or table style. Complete with speaker and 16 tubes, $189.50.

for Amateur Radio

AMATEUR RADIO SECTION

RCA MANUFACTURING COMPANY, INC. • CAMDEN, NEW JERSEY

TRANSMITTING AND A TYPE FOR *Every*

RCA-801

A rugged, carbon-anode triode, having wide application in buffer/doubler and final stages. Rated at 20 watts max. plate dissipation, 600 max. plate volts, 70 max. plate m.a. Full rated input up to 60 m.c.

RCA-802

The favorite pentode for crystal oscillator or buffer/doubler. Well-shielded construction eliminates neutralization in most applications. The stability and reliability of this type makes it particularly suitable for exciter stages. Rated at 500 max. plate volts, 60 max. plate m.a.

RCA-803

The outstanding high-power pentode. Nominal output is 53 watts when suppressor modulated, 210 watts as Class C amplifier. The low driving-power requirements, large power gain, and elimination of neutralization in well-shielded circuits, make this husky type ideal for many applications.

RCA-804

A medium power-pentode of popular design. Particularly useful as a suppressor-modulated amplifier or driver for higher-power stage. Requires no neutralization in most cases. Rated at 120 watts input for Class C telegraph service.

RCA-805

The popular triode for all-around amateur use. Easy to drive; will deliver over 200 watts r-f output at 1500 volts. High-mu design provides zero-bias operation in Class B modulator service. Two tubes deliver 370 watts of audio power. Excellent as a high-power frequency doubler.

RCA-806

A heavy-duty tantalum plate triode for the high powered final or modulator. A pair take a kilowatt input easily and another pair will modulate a kilowatt input with plenty to spare. The most economical tubes to use for the kilowatt final r-f stage.

RCA-807

The sensational beam-power tube Rated at 60 watts Class C input, the RCA-807 is widely useful as crystal oscillator, buffer/doubler or final stage. Requires no neutralization in most applications.

RCA-808

For the medium power stage this tantalum-plate type offers the unusual advantages of high power output (150 watts) at moderate plate voltage (1500 volts), high-mu, low driving power, rugged construction, heavy-duty filament, yet the price is surprisingly low.

RCA-866—For the power supply system, the logical choice is

the rugged, reliable RCA-866 now at an amazingly low price.

In addition to these types, we call your particular attention to RCA Acorn Tubes for the ultra-high frequency receiver, RCA Cathode-Ray Tubes, and RCA Receiving Tubes. Go RCA Tubes all the Way for better performance.

SPECIAL PURPOSE TUBES—*Requirement!*

CATALOGUE OF POPULAR RCA TRANSMITTING AND SPECIAL PURPOSE TYPES

TRANSMITTING TYPES

Type	Net Price	TRIODES	Max. Plate Dissipation Watts	Cathode Type	Cathode Volts
203-A	$15.00	R-F Power Amplifier, Oscillator, Class B Modulator	100	Filament	10.0
204-A	97.50	Oscillator, R-F Power Amplifier, Class B Modulator	250	Filament	11.0
211	15.00	R-F and A-F Power Amplifier, Oscillator, Modulator	100	Filament	10.0
800	10.00	R-F Power Amplifier, Oscillator, Class B Modulator	35	Filament	7.5
801	3.45	R-F and A-F Power Amplifier, Oscillator, Modulator	20	Filament	7.5
805	13.50	R-F Power Amplifier, Oscillator, Class B Modulator	125	Filament	10.0
806	22.00	R-F Power Amplifier, Oscillator, Class B Modulator	150	Filament	5.0
808	7.75	R-F Power Amplifier, Oscillator, Class B Modulator	50	Filament	7.5
830-B	10.00	Class B Modulator, R-F Power Amplifier, Oscillator	60	Filament	10.0
831	265.00	Oscillator, R-F Power Amplifier	400	Filament	11.0
834	12.50	Ultra-High Frequency R-F Power Amplifier, Oscillator	50	Filament	7.5
838	16.00	Class B Modulator, R-F Power Amplifier, Oscillator	100	Filament	10.0
841	3.25	R-F Power Amplifier, Oscillator, A-F Voltage Amplifier	15	Filament	7.5
842	3.25	A-F Power Amplifier, Modulator	12	Filament	7.5
843	12.50	Power Amplifier, Oscillator	15	Heater	2.5
845	15.00	Modulator, A-F Power Amplifier	75	Filament	10.0
849	160.00	Modulator, A-F and R-F Power Amplifier, Oscillator	400	Filament	11.0
851	350.00	Modulator, A-F and R-F Power Amplifier, Oscillator	750	Filament	11.0
852	16.40	Oscillator, R-F Power Amplifier	100	Filament	10.0

TETRODES

Type	Net Price	TETRODES	Max. Plate Dissipation Watts	Cathode Type	Cathode Volts
807	$3.50	Transmitting Beam-Power Amplifier	21	Heater	6.3
844	18.00	Screen-Grid R-F Power Amplifier	15	Heater	2.5
850	37.50	Screen-Grid R-F Power Amplifier	100	Filament	10.0
860	32.50	Screen-Grid R-F Power Amplifier	100	Filament	10.0
861	295.00	Screen-Grid R-F Power Amplifier	400	Filament	11.0
865	12.75	Screen-Grid R-F Power Amplifier	15	Filament	7.5

PENTODES

Type	Net Price	PENTODES	Max. Plate Dissipation Watts	Cathode Type	Cathode Volts
802	$3.50	R-F Power Amplifier Pentode	10	Heater	6.3
803	34.50	R-F Power Amplifier Pentode	125	Filament	10.0
804	15.00	R-F Power Amplifier Pentode	40	Filament	7.5
837	8.50	R-F Power Amplifier Pentode	12	Heater	12.6

RECTIFIERS

Type	Net Price		Electrodes	Max Peak Inverse Volts	Cathode Type	Cathode Volts
217-A	$20.00	Half-Wave, High Vacuum	2	3,500	Filament	10.0
217-C	20.00	Half-Wave, High Vacuum	2	7,500	Filament	10.0
836	11.50	Half-Wave, High Vacuum	2	5,000	Heater	2.5
866	1.50	Half-Wave, Mercury-Vapor	2	7,500	Filament	2.5
866-A	4.00	Half-Wave, Mercury-Vapor	2	10,000	Filament	2.5
872	14.00	Half-Wave, Mercury-Vapor	2	7,500	Filament	5.0
872-A	16.50	Half-Wave, Mercury-Vapor	2	10,000	Filament	5.0
878	11.00	Half-Wave, High-Vacuum for Cathode-Ray Tubes	2	20,000	Filament	2.5
879	3.00	Half-Wave, High-Vacuum for Cathode-Ray Tubes	2	7,500	Filament	2.5
885	2.00	Gas-Triode for Cathode-Ray Sweep-Circuit Control	3	300	Heater	2.5

PHOTOTUBES

Type	Net Price		Electrodes	Max. Anode Volts
868	$3.70	Phototube (Gaseous Type)	2	90
917	4.75	Phototube (Vacuum Type)	2	500
918	4.50	Phototube (High Sensitivity)	2	90
919	4.75	Phototube (Vacuum Type)	2	500
920	5.25	Twin Phototube (Gaseous Type)	4	90
921	2.00	Cartridge Phototube (Gaseous Type)	2	90
922	2.00	Cartridge Phototube (High-Vacuum Type)	2	250
923	2.60	Phototube (High Sensitivity)	2	90

HIGH-VACUUM CATHODE-RAY TUBES

Type	Net Price		Electrodes	Max. Anode No. 2 Volts	Cathode Type	Cathode Volts
903	$86.00	9 in. Electromagnetic Deflection (Medium Persistence Screen)	5	7,000	Heater	2.5
904	52.50	5 in. Electrostatic-Magnetic Deflection (Medium Persistence Screen)	5	4,600	Heater	2.5
905	45.00	5 in. Electrostatic Deflection (Medium Persistence Screen)	4	2,000	Heater	2.5
906	13.50	3 in. Electrostatic Deflection (Medium Persistence Screen)	4	1,200	Heater	2.5
907	48.75	5 in. Electrostatic Deflection (Short Persistence Screen)	4	2,000	Heater	2.5
908	18.00	3 in. Electrostatic Deflection (Short Persistence Screen)	4	1,200	Heater	2.5
909	49.00	5 in. Electrostatic Deflection (Long Persistence Screen)	4	2,000	Heater	2.5
910	21.25	3 in. Electrostatic Deflection (Long Persistence Screen)	4	1,200	Heater	2.5
911	22.50	3 in. Electrostatic Deflection (With Non-Magnetic Gun)	4	1,200	Heater	2.5
912	163.40	5 in. Electrostatic Deflection (High Voltage Type)	5	15,000	Heater	2.5
913	4.00	1 in. Electrostatic Deflection (Medium Persistence Screen)	4	500	Heater	6.3

MISCELLANEOUS TYPES

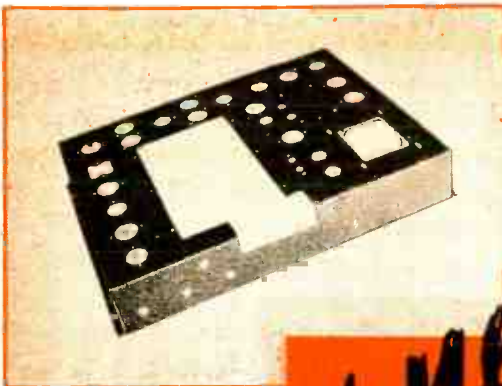
Type	Net Price		Electrodes	Max. Plate Dissipation Watts	Cathode Type	Cathode Volts
840	$6.00	R-F Pentode	5	....	Filament	2.0
864	1.00	Amplifier (Low Microphonic Design)	3	....	Filament	1.1
954	5.00	Detector, Amplifier Pentode (Acorn Type)	5	....	Heater	6.3
955	3.00	Amplifier, Detector, Oscillator (Acorn Type)	3	....	Heater	6.3
956	5.00	Super-Control R-F Amplifier Pentode (Acorn Type)	5	....	Heater	6.3
991	.90	Voltage Regulator	2	....	......	..
1602	2.75	Amplifier, Triode (Low Microphonic Type)	3	15	Filament	7.5
1603	4.75	Triple-Grid Amplifier (Low Microphonic Type)	5	....	Heater	6.3
1608	4.00	Power Amplifier, Oscillator	3	20	Filament	2.5
1609	1.60	Amplifier Pentode (Low Microphonic Design)	5	....	Filament	1.1
1610	2.00	Crystal-Oscillator Pentode	5	6	Filament	2.5
1612	3.25	Pentagrid Amplifier, (Low Microphonic Design)	7	....	Heater	6.3

Prices effective Sept. 7, 1937—Prices subject to change or withdrawal without notice.

RCA *for Amateur Radio*

AMATEUR RADIO SECTION

RCA MANUFACTURING CO., INC., Camden, N. J. • A Service of the Radio Corporation of America



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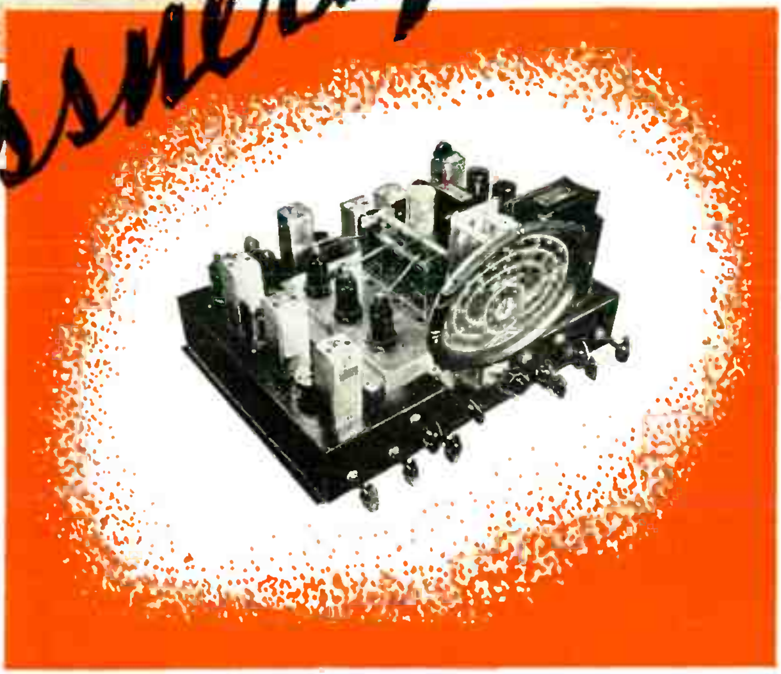
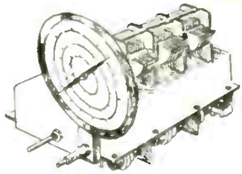


PEAK PERFORMANCE WITH *Meissner* COILS AND R. F. COMPONENTS



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The entire "front end" of the radio receiver. Each unit is completely wired and accurately balanced and aligned. READY FOR USE. Only six wires to be connected to any 456 I.F. channel. FIVE BANDS—540Kc to 60Mc (5 to 555 meters) no skip. AIR TUNED.

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112 PAGE INSTRUCTION BOOK

Containing complete detailed wiring instructions, diagrams, schematics, pictorial diagrams, chassis layouts, alignment data and operating instructions for:

16 MODERN CIRCUITS

Ranging from the latest 4 tube circuit to the ultra-modern 14 tube Communications receiver using B.F.O., Crystal Filter, Noise Silencer, Band Expansion, etc., etc., and:

4 ADAPTER UNITS

Consisting of Beat Frequency Osc., Noise Silencer, Phonograph Osc., and Remote Control. All self-powered.

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LINEAR STANDARD TRANSFORMERS

UTC Linear Standard components are ideal high fidelity units for broadcast and recording service. The frequency response is guaranteed uniform from 30 to 20,000 cycles and hum pick-up and insertion loss is maintained at extremely low values. These units are unequalled for studio and speech input equipment.

ULTRA COMPACT HIGH FIDELITY AUDIO UNITS

The UTC ultra compact audio units are extremely small and weigh only 5½ ounces. The fidelity however, is excellent, the frequency response being uniform ±2 DB from 30 to 20,000 cycles. These units are ideal for remote pickup equipment and similar applications where both weight and size are paramount factors.

HIPERM ALLOY COMPONENTS

UTC Hiperm Alloy Components are similar to the Linear Standard units but of a more compact design and employ a light-weight high conductivity case so that these units can be employed for portable and compact service. They are used extensively in recording and remote pickup equipment.

UTC VARITRAN VOLTAGE CONTROL UNITS

The UTC VARITRAN makes possible continuously variable output voltage using a sliding contact riding over the turns of an auto-transformer. Standard units are designed for 115 volt input, 0-130 volts continuously variable output.

APPLICATIONS

- Line voltage control
- Rectifier control
- Motor control
- Heat control
- Light control

FEATURES

- Smooth control
- High efficiency
- Excellent regulation
- Low cost

Model V-1 570 Watts—5 amp. maximum rating, complete with cord, plug and switch, net $10.00

Model V-2 Same as V-1, but uncased, with terminal strip for rack or panel mounting, net $9.00

Model V-3 850 Watts maximum rating 7.5 amps., uncased, with terminal board and provisions for mounting, net $14.00

Model V-4 1250 Watts — 11 amps. maximum rating, uncased, net $20.00

Model V-5 2000 Watts maximum rating, 17.5 amps., uncased, net $32.00

Automatic VARITRANS are available to maintain line voltage constant. Details and prices on request.

UTC VARIMATCH Input and Output Transformers will match ANY Modulator Tubes to ANY RF Load . . .

See for yourself

The Varimatch Transformer is a unique unit developed and pioneered by UTC which will not only match PRESENT available modulator tubes, but any tube that may be released at a FUTURE date. All you have to decide is the DC input to your RF stage. Then just pick the VARIMATCH output transformer that will handle the maximum audio power required. The secondaries of all Varimatch transformers are designed to carry the Class C plate current.

VARIMATCH TRANSFORMERS NEVER BECOME OBSOLETE

Tubes in Push Pull	Plate Voltage	P to P Load	Approximate Audio Power in Watts	Driver Tubes	UTC Input	UTC Output
RK-30, 800	1000	12500	100	45	PA 52 AX	VM-3
35-T	1000	10000	115	2A3	" 53 AX	VM-3
35-T	1250	12800	130	2A3	" 53 AX	VM-3
RK-18	1000	12000	100	2A3	" 53 AX	VM-3
RK-31	1000	13600	110	2A3	" 53 AX	VM-3
845	1250	8800	105	45	" 52 AX	VM-3
825	850	8000	80	45	" 52 AX	VM-3
756	850	6750	100	45	" 52 AX	VM-3
50-T	1250	10000	135	2A3	" 53 AX	VM-3
203-A	1000	6900	200	2A3	" 53 AX	VM-4
242, 211						
838	1000	7600	200	2A3	" 53 AX	VM-4
830-B	1000	7600	175	2A3	" 53 AX	VM-4
805	1250	6700	300	2A3	" 53 AX	VM-4
50-T	1500	15000	175	2A3	" 53 AX	VM-4
50-T	2000	20000	250	2A3	" 53 AX	VM-4
203-A, 242, 211	1250	9000	260	2A3	" 53 AX	VM-4
808	1500	18300	200	2A3	" 53 AX	VM-4
T-55	1000	10000	175	2A3	" 53 AX	VM-4
T-55	1250	12000	250	2A3	" 53 AX	VM-4
HF-100	1000	7000	200	2A3	" 53 AX	VM-4
HF-100	1250	8800	250	2A3	" 53 AX	VM-4
HF-100	1500	12000	300	2A3	" 53 AX	VM-4
HF-100	1750	16000	350	2A3	" 53 AX	VM-5
805	1500	8200	370	2A3	" 53 AX	VM-5
204-A	2000	8800	600	845 or 4-2A3's	" 238 AX	VM-5
HK-354	2000	15000	400	2A3	" 53 AX	VM-5
HK-354	3000	25000	650	4-2A3's	" 238 AX	VM-5
150-T	1500	8000	350	4-2A3's, 845	" 238 AX	VM-5
150-T	2000	10400	500	4-2A3's, 845	" 238 AX	VM-5
150-T	2500	14000	650	4-2A3's, 845	" 238 AX	VM-5
HD-203-A	1750	9000	500	4-2A3's	" 238 AX	VM-5
822	2000	9000	500	4-2A3's	" 238 AX	VM-5
HF-200	2000	11200	500	4-2A3's	" 238 AX	VM-5
HF-200	2500	16000	600	4-2A3's	" 238 AX	VM-5
HF-300	2000	9600	650	4-2A3's	" 238 AX	VM-5
ZB-120	750	4800	150	45	" 52 AX	VM-4
ZB-120	1000	6900	200	2A3	" 53 AX	VM-4
ZB-120	1250	9000	245	2A3	" 53 AX	VM-4
ZB-120	1500	11200	300	2A3	" 53 AX	VM-4
100-TH	1000	5200	200	2A3	" 53 AX	VM-4
100-TH	1250	7200	250	2A3	" 53 AX	VM-4
100-TH	1500	9600	300	2A3	" 53 AX	VM-4
100-TH	2000	16000	380	2A3	" 53 AX	VM-5
100-TH	2500	22000	460	2A3	" 53 AX	VM-5
250-TH	1000	2360	350	2A3	" 53 AX	VM-5
250-TH	1250	3280	540	4-2A3's	" 238 AX	VM-5
250-TH	1500	4200	630	4-2A3's	" 238 AX	VM-5

- **VM-0** Will handle any power tubes to modulate a 10 to 25 watt Class C stage. Net to Hams..........................$3.0(
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- **VM-5** Will handle any power tubes to modulat a 450 watt to 1 KW plus, Class C stage. Maximum audio output 600 watts. Net to Hams........................$42.0
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- **PA-53AX** Push pull 42, 45, 50, 59, 2A3 or 6L plates to two 210, 801, RK-18, 35T, 50T, HF-10 or 800 Class B grids. Push pull 2A3 plates t two 838, 203A, 50T, 35T, 211A, 242A, 830B, 80 RK-18, 801 or 210 Class B grids. Net to Hams..........................$4.5
- **PA-238AX** Push pull parallel 2A3, 45, 50, 59 6L6 to four 805, 838, or 203A Class B grid Push pull parallel 2A3, 45, 50, 59, 6L6 or tw 211A, 845 plates to Class B 204A. HF300 849 grids. Push pull parallel 2A3, 45, 50 or tw 50T, 211A, 845 plates to Class B 150T, HD 203 or HF200 Class B grids. Net to Hams...$10.

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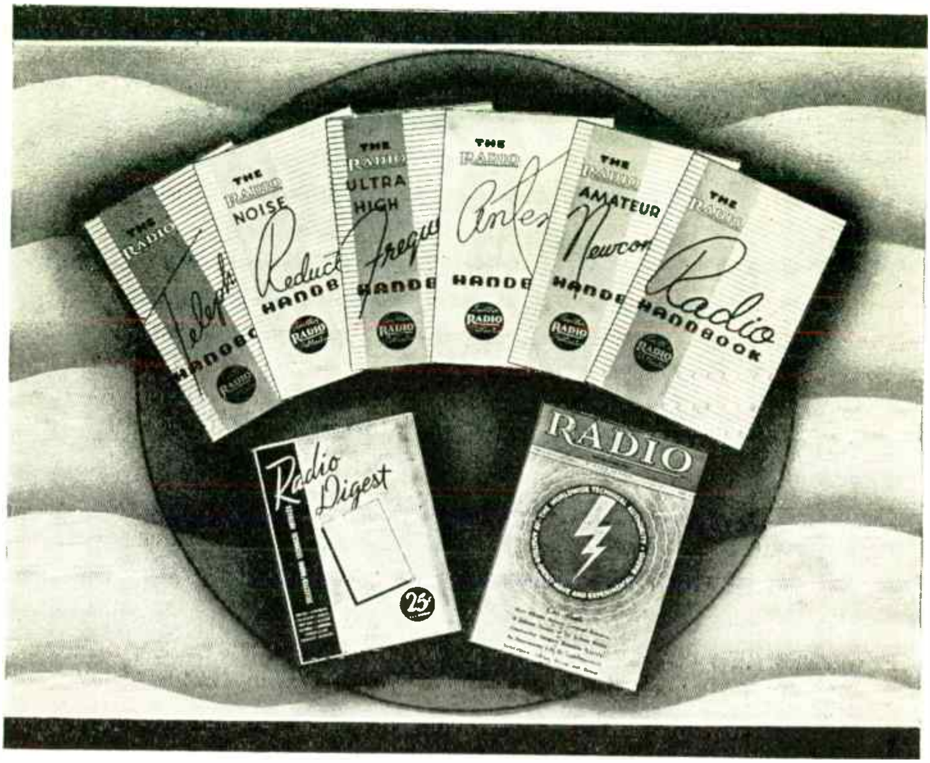

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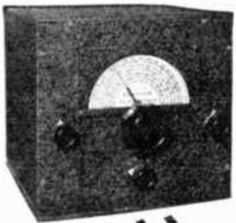
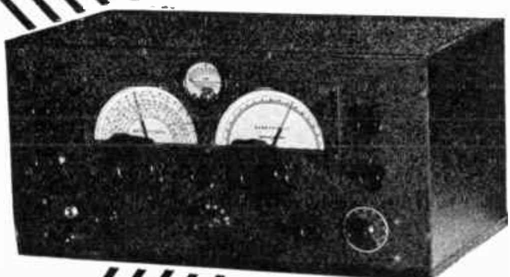


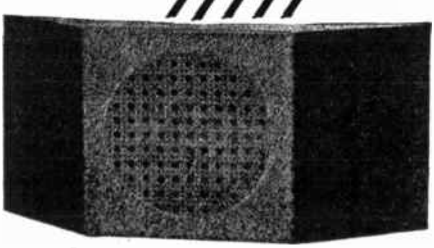
DB-20
Pre-Selector and
Image Rejector

RME

RECEIVERS—
PRE-SELECTORS—
TRANSMITTERS—



RME-69 SSS
Receiver with built-in
noise suppressor



There is only one way of knowing whether the radio equipment you desire to purchase will satisfy—

TRY IT.

Thousands have done this and are enthusiastic users of RME Receivers. The latest DX contest winners and high scorers will verify our contention that RME users are pleased. They must be or we should know the reason why.

Note the completeness in the RME line: Standard with built-in crystal filter, range from 550 KC to 32,000 KC, electrical band-spread, built-in continuous reading decibel-R meter, monitor circuit, and the optional choice of a relay rack model, combination battery and AC, special 6 Volt B pack model, noise suppressor when desired, special band coverage receivers for aircraft, weather bureau, or police frequencies, and a finish in either gray or black crinkle. Do not forget the DB-20 pre-selector—the best obtainable today. It will function with practically any receiver and add tremendously to the present signal intensity and tuning capabilities of your receiver.

Literature on request.

RADIO MFG. ENGINEERS, Inc.

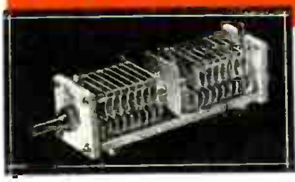
306 FIRST AVE. PEORIA, ILLINOIS, U. S. A.

CARDWELL Quality

No flamboyant hyperboles, no exaggerated descriptive adjectives, are needed to bring home a known truth. Most of you *know* Cardwell Quality—You have *used* Cardwell products—they have spoken for themselves.

This is no catalog—Every dealer has our new No. 40 and our handy reference sheets for easy comparison of characteristics of the most popular units in the Cardwell complete line. Representative types are shown—with characteristics applying to that particular class or size. See your dealer or jobber, for complete information.

TRIM-AIR MIDGET CONDENSERS



★ ET-30-AD

A 30 Mmfd. per section 2500 V. dual—.070" airgap. 1 13/32" square ends; single hole mounting or regular Trim-air mounting brackets or mounting studs and 4 mounting screws in tie rods provide flexible mounting facilities. Duals of all single units available.
Net.................. **$2.16**

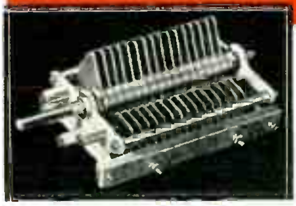
★ ZT-15-AS

3-15 Mmfds., low power neutralizer, 2500 V. single, .070" airgap. Detachable shaft, screw driver slot for screw driver adjustment; shaft locking nut. Net............ **$ .93**

★ ES-4-SDI

Dual Midget ganged neutralizer. 1.5-4 Mmfds. each section; 4500 V. peak flash over; new type ES-9-SDI—$3.00 net. ES-4-SDI—
Net.................. **$2.46**

MIDWAY FEATHERWEIGHT CONDENSERS



★ MT-150-GS

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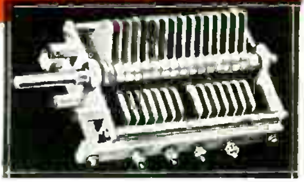

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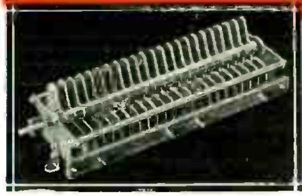

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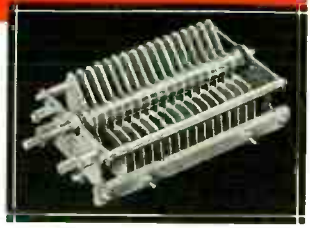

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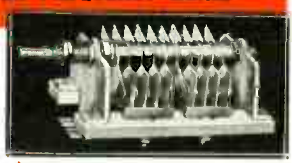

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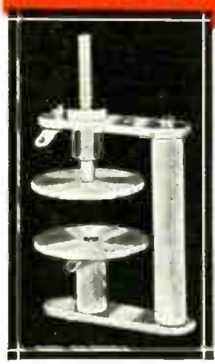

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INDEX OF ADVERTISERS

Questions and Answers

The questions which an applicant for Class-A Amateur License should be able to answer are of the general type here shown. A careful study of the theoretical text of the pages of this book will further enhance the knowledge required for answering correctly any of the examination questions.

1. Explain the operation of a simple microphone.

A carbon microphone converts sound into electrical energy by means of a diaphragm which vibrates in accordance with the sound waves impressed upon it. This vibration changes the resistance of the carbon particles to the flow of current which is supplied from an external battery. The variation in current across a transformer winding causes a voltage change which can be applied to a vacuum tube amplifier.

2. Describe the operation of a Class-A Amplifier or Modulator.

The output of a Class-A Audio Amplifier is an undistorted replica of the grid signal. The grid is biased for operation over the linear portion of the grid voltage-plate current curve, and the input signal is never great enough in amplitude to exceed the fixed bias. The result is a constant D.C. plate current.

3. Describe the Operation of a Class-B Amplifier or Modulator.

Two tubes are connected in push-pull, with grid bias equal approximately to cut-off. Each tube operates during half of the audio cycle, and the distorted output is combined in an output transformer in order to provide a replica of the input signal. The grids may be swung positive, and a power driver stage should therefore be used.

4. What adjustments are required for a Class-A Amplifier if the plate current increases during operation?

This is an indication of excessive grid bias or excitation. The negative grid bias should be reduced, or less audio excitation should be applied.

5. What adjustments are required for a Class-A Amplifier if the plate current decreases during operation?

More negative grid bias, or less audio input is required.

6. What causes distortion in a Speech Amplifier and what is the cure?

(1) Incorrect grid bias. (2) Excessive excitation. (3) Audio frequency regeneration or degeneration. (4) R.F. feed-back. (5) Defective tubes or incorrect type of tubes. The corresponding adjustments to overcome these difficulties are: (1) Adjust grid bias to the correct operating point. (2) Reduce excitation by means of gain control. (3) Installation of decoupling filter circuits. (4) Installation of R.F. chokes and shielding. (5) Use tubes which are capable of supplying the required signal voltage.

7. If the plate current in a Class-A Amplifier or Modulator fluctuates with speech input, when all voltages are at their proper values, what adjustments should be made?

Turn down the gain control, or do not talk so loudly into the microphone.

8. What are the effects of excessive Audio Amplification?

Distortion of speech, and overmodulation in some cases.

9. What is the function of a Gain Control?

It is usually a potentiometer which controls the amount of audio frequency input to a speech amplifier.

10. What is a Modulator?

A modulator is a device for varying the radio-frequency carrier amplitude in accordance with the audio-frequency signal.

11. What is a Speech Amplifier?

A speech amplifier consists of one or more stages of audio frequency amplification for the purpose of increasing the microphone output to a value required for actuating the modulator.

12. How is a plate modulated Class-C Amplifier properly adjusted?

The Class-C amplifier is operated with normal plate voltage, normal grid current, and grid bias of at least twice cut-off. It is neutralized, unless a screen-grid tube is used. The antenna loading is adjusted until normal plate current loads the modulator tube to the proper value for correct impedance matching. All circuits are tuned to exact resonance. The audio gain control should be set below the point where sound input to the microphone causes fluctuation of the Class-C amplifier plate current, or where overmodulation is shown by an overmodulation indicator.

13. How is a grid-modulated transmitter adjusted?

The modulated stage is operated with fixed bias equal to from 1½ to 2 times cutoff. Considerably less r.f. driving power and grid current are utilized than with an equivalent Class-C stage. However, the r.f. driver must have good regulation. This can be secured by dissipating approximately half the driver output in a load resistor connected across a portion of the driver tank. The modulated stage is loaded somewhat heavier than would be the case for a Class-C amplifier, by using tighter antenna coupling. The excitation to the modulated stage is increased in small steps until the modulation capability of the amplifier is around 90%. More excitation will reduce the modulation capability, giving less sideband power even though the carrier may be greater. If the tubes run too hot, the antenna coupling should be reduced and the process repeated. If they are running at less than rated dissipation, the antenna coupling may be increased and the excitation adjustment repeated.

14. What is the indication of correct modulation?

With plate modulation, the D.C. plate current of the modulated stage should be constant during modulation. Unsymmetrical modulation takes place when this plate current varies. A pure audio-frequency sine wave from the modulator will cause the antenna R.F. current to increase 22½ percent at 100 percent modulation, grid current and plate current remaining constant.

15. What is a Class-C Amplifier?

The power output of a Class-C amplifier is proportional to the square of the plate voltage. The grid-bias is usually twice that required for cut-off of plate current with no R.F. excitation. High grid excitation is required, and the amplifier is more efficient than a Class-A or Class-B amplifier.

16. What is the principle of operation of the Class-B Linear Amplifier?

The plate power output in a Class-B R.F. amplifier is proportional to the square of the grid excitation voltage, and thus it can be used as a linear amplifier of modulated R.F. power. The grid-bias is adjusted to cut-off, and in the case of a single-ended stage, the output becomes sinusoidal by means of the "fly-wheel" effect of the tuned plate circuit.

17. Describe the effects of overmodulation. What is the cure?

Overmodulation causes the radiation of a broad interfering wave. Another effect is audio distortion at the receiving end. Overmodulation can be eliminated by using the correct value of grid excitation, correct D.C. grid bias, well-regulated power supplies, correct amount of audio-frequency output from the modulator, and proper degree of antenna coupling.

18. What is the most likely cause of overmodulation?

Excessive audio power output from the modulator. The gain control in the speech amplifier should be turned down.

19. How is overmodulation observed in a transmitter?

Overmodulation is observed by checking continuously with an approved type of overmodulation indicator. When any tuning adjustments are made, an initial check should preferably be made with a monitor and oscilloscope, to check the modulation capability of the transmitter.

The plate current should remain absolutely constant in a Class-A amplifier or modulator, a Class-B linear amplifier, and in a modulated Class-C amplifier. It should not vary over 10% in a grid bias modulated transmitter, and any change should be upward.

20. What causes radiotelephone interference with broadcast reception and how is it eliminated?

Overmodulation or frequency modulation will cause interference with broadcast reception. Insufficient selectivity in the broadcast receiver, or a lack of shielding, or transmitting and receiving antennas too close together, are other causes of interference. A tuned wavetrap in series with the receiving antenna and a change in the relative position of the antennas will relieve interference, except in the case of overmodulation or frequency modulation. The cure for the latter is covered in another question.

21. Name three causes of frequency modulation.

(1) Variation in oscillator plate voltage. (2) Vibration of the oscillator. (3) Reaction of the modulated stage upon the oscillator due to lack of a buffer amplifier. (4) Im-

proper neutralization of an amplifier. (5) Modulated R.F. feed-back to the oscillator.

22. Why is frequency modulation undesirable?

Spurious side-band frequencies are generated by frequency modulation and these side-bands may extend far into other phone channels, causing unnecessary interference.

23. How can frequency modulation be eliminated?

By the use of a well-regulated power supply for the oscillator and separate power supplies for the remainder of the transmitter. A buffer amplifier or doubler and a stable oscillator should also be used. The R.F. amplifier should be correctly neutralized, and the crystal oscillator should be shielded from the remainder of the set.

24. What is a test for frequency modulation?

Monitor the output of the transmitter by means of a heterodyne meter tuned to zero beat with the carrier frequency. The presence of frequency modulation will cause the signal quality to be distorted, or "mushy."

25. Why is a buffer amplifier used in a phone transmitter?

To isolate the oscillator from the modulated amplifier, in order to prevent frequency modulation. The input resistance of a modulated tube varies during modulation, which places a varying load upon the R.F. driver stage.

26. Why should a crystal oscillator be operated with light load and moderate plate voltage?

Changes of load conditions will have minimum effect when the crystal is lightly loaded. Moderate plate voltage is desirable in order to prevent frequency drift due to overload of the quartz crystal. High plate voltage may cause excessive vibration of the quartz crystal at radio-frequencies.

27. How should the oscillator be isolated from the modulated amplifier?

By means of one or more buffer or doubler stages.

28. What is the proper adjustment for a frequency-doubler-amplifier?

High R.F. grid excitation is necessary, and the grid bias should be from 3 to 6 times cut-off. High L-to-C ratio is also desirable.

29. What is the proper indication of resonance in the R.F. amplifier tuning circuit?

Resonance is indicated by setting the plate tuning condenser to the point where minimum plate current is indicated. In the case of a tuned grid circuit, resonance occurs at the point of maximum D.C. grid current, as read by a milliammeter.

30. What method is used to determine the correct harmonic frequency of operation of a doubler stage?

An absorption wavemeter or frequency meter should be used for this purpose.

31. What method is used to ascertain whether or not the crystal oscillator is operating on only the desired frequency?

The output is checked with an oscillating c.w. monitor while tuning the oscillator plate circuit over the range of the tuning condenser.

32. What radio-frequencies are produced during the process of amplitude modulation?

Upper and lower sideband frequencies equal to the carrier frequency plus and minus the various audio frequencies applied.

33. What is meant by Percentage of Modulation?

It is the ratio of one-half the difference between the maximum and minimum amplitudes of a modulated wave to the average or unmodulated amplitude (expressed in percentage).

34. How much audio power output is required for a given plate modulated Class-C input for 100% modulation?

50% of the D.C. power input to the Class-C stage.

35. What is the ratio of peak power output to carrier power at 100 percent modulation?

The peak power output is 4 times the unmodulated carrier power.

36. What is the ratio of average power output to carrier power at 100 percent modulation?

One-and-one-half to one, with pure tone input.

37. How close to the edge of the amateur bands can the carrier frequency be operated?

The carrier should be far enough from

the edge of the band so that the side-band frequencies which are radiated will fall within the assigned phone bands.

38. What determines the above limits?

The highest modulation frequency determines the outermost side-band frequency. The carrier frequency must be inside of the band by the amount of the highest audio frequency used.

39. What is meant by Modulation?

Modulation is the process of combining the audio-and-radio-frequency signals into a radio-frequency wave for the purpose of transmitting intelligence. The a.f. signal is superimposed on the r.f. signal.

40. What is a Carrier Wave?

A carrier wave is the unmodulated component of the R.F. wave.

41. Why should self-excited oscillators not be modulated?

Because frequency modulation as well as amplitude modulation takes place. This causes radiation of an extremely broad wave.

42. What should be done to reduce harmonic radiation?

The remedies consist of: (a) Increasing the capacity-to-inductance ratio in the tank circuit of the final amplifier. (b) The use of additional tuned antenna circuits by means of link or inductive coupling. (c) By means of low-pass "pi" antenna couplers.

43. Draw a complete circuit diagram of a radiotelephone transmitter, and explain the operation of all parts.

The reader is referred to the theoretical section of this book for complete information on the theory, operation and circuit design of any type of radiotelephone transmitter.

44. Describe three means of indicating Audio volume level.

(1) By means of a volume indicator consisting of a vacuum-tube voltmeter, (2) By means of an oxide rectifier type voltmeter or volume indicator, (3) By noting the readings of a D.C. milliammeter in the plate supply lead of a Class-B audio amplifier.

45. Explain why a transmitter should not be modulated in excess of its modulation capability.

Because it will cause interference with adjacent radiophone channels.

46. Why are two tubes necessary in a Class-B audio output circuit, whereas only one tube is necessary in a Class-B linear radio frequency amplifier?

Two tubes are needed in a Class-B audio circuit in order to supply the complete audio cycle to the output transformer, since each tube functions during only half the audio cycle. The output transformer is not resonant and therefore cannot complete the cycle in a manner similar to that of the tank circuit of a Class-B R.F. linear amplifier.

In the r.f. amplifier the tank circuit provides a "fly-wheel" effect which completes the R.F. cycle, even though the tank circuit is only driven during half of the R.F. cycle.

47. Explain the action of a quartz crystal oscillator. Why is its use desirable?

The quartz crystal acts as a tuned circuit, due to its piezo-electric properties, and it has an extremely high degree of stability since it is mechanically resonant to the electrical frequency of oscillation. Feed-back causes oscillation at a frequency determined by the physical dimensions of the quartz crystal, and power can be taken from the plate circuit.

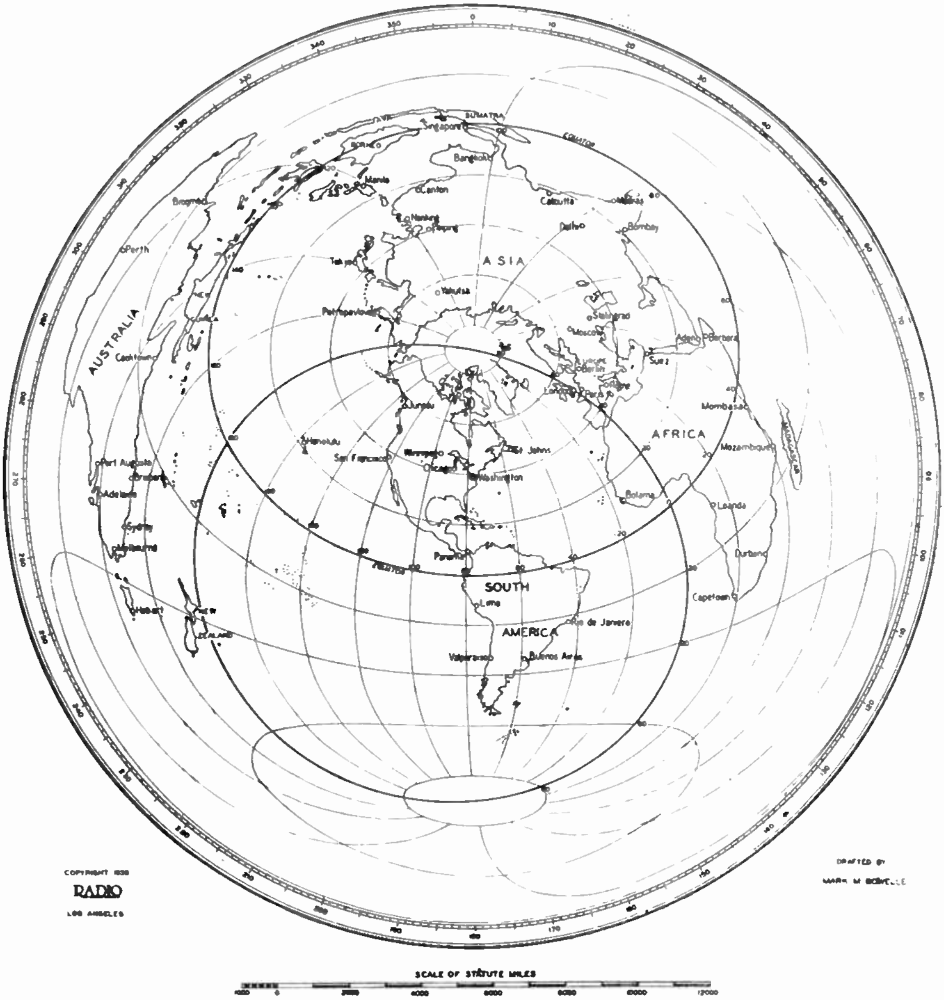
The quartz crystal is mechanically resistant to changes in physical dimensions, with the result that the frequency of oscillation is very constant.

48. Explain how a plate modulated transmitter is correctly operated with reduced power.

The D.C. plate voltage in the final plate-modulated R.F. amplifier can be lowered by reducing the 110 volt A.C. line voltage by means of an auto-transformer or a primary line resistor. The audio power output from the modulator should be reduced by turning down the gain control to a point which prevents overmodulation, as indicated by an oscilloscope or overmodulation indicator. If the plate voltage to the Class-B audio modulator is reduced, the C bias must be proportionately reduced in order to maintain good voice quality. The modulator output impedance will usually remain the same at reduced power, since a reduction of plate voltage generally causes a reduction of plate current in the R.F. amplifier.

49. Under what circumstances is it necessary to reduce the power of a radio transmitter?

Only sufficient power should be used to



GREAT CIRCLE MAP OF THE WORLD

Centered on Washington, D. C.

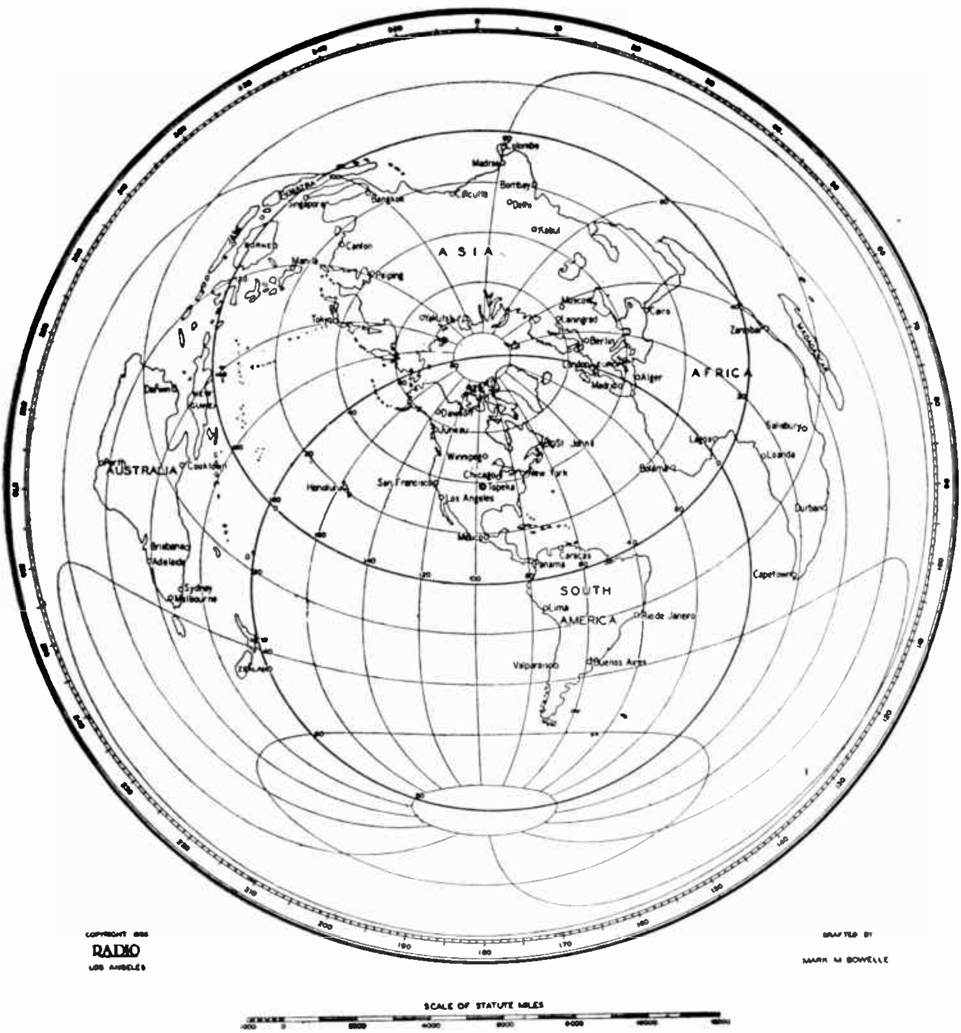
For Use in Orienting Directive Antennas

enable reliable communication with the desired station.

50. Explain how to eliminate parasitic oscillations from the various stages of a radio transmitter.

Use shorter leads in the grid and neutralizing circuits, or use small parasitic chokes, shunted by a 200 ohm resistor, in the grid circuits adjacent to the grid terminals. Low-frequency parasitics can be prevented by eliminating the grid R.F. choke, or by using one with very much less inductance than that used in the plate circuit.

Parasitics in a Class-B audio amplifier can be eliminated by shunting .0005 mfd. or .001 mfd. condensers from grid to filament,



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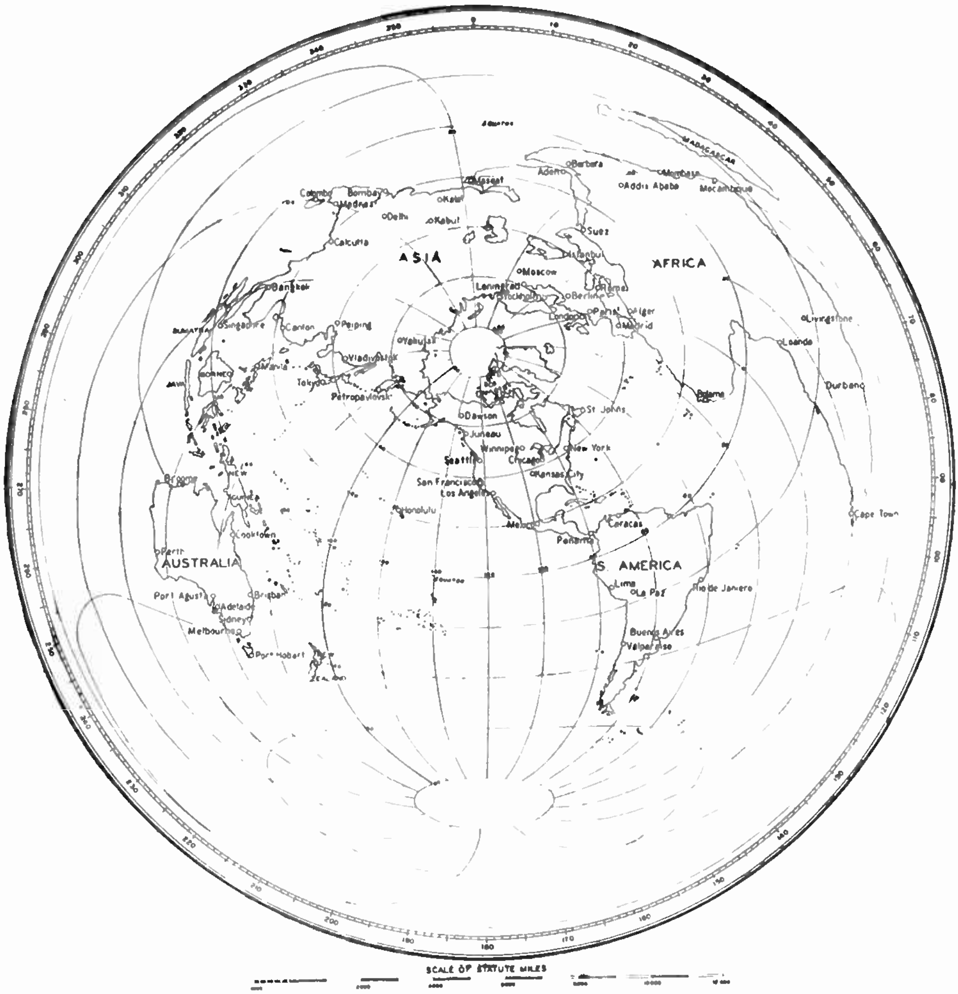
and by inserting 40 ohm resistors in the plate leads to the output transformer.

Parasitics are undesirable because they will introduce distortion in Class-B audio circuits. In R.F. circuits, parasitics will cause excessive tube heating, radiation of undesired frequencies, and instability in neutralized R.F. amplifiers.

51. What is meant by "Cross Modulation" in a receiver, and how is it eliminated?

"Cross Modulation" is the effect of an undesired signal superimposed upon the signal to which the receiver is tuned. It is usually due to lack of selective R.F. circuits ahead of the first tube, incorrect bias on the first tube, or lack of a variable-mu charac-



GREAT CIRCLE MAP OF THE WORLD

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teristic in the first tube of a radio receiver. A wavetrap tuned to the undesired signal will help reduce Cross Modulation.

52. What is "Image Interference" in a receiver, and how is it eliminated?

In a superheterodyne receiver, the oscillator supplies a heterodyne signal which differs from the frequency of the desired signal by the value of the intermediate frequency. Image interference may take place from an undesired signal which differs from the desired signal by twice the I.F. frequency, since the oscillator will also heterodyne this signal into the I.F. amplifier. The cure lies in the use of sufficient pre-selection to eliminate the undesired signal.

Every reader of this handbook will find "Radio Digest" of interest and value. But because the magazine is so new, perhaps you have not seen a copy. The following pages will give you a general idea as to the aims, purpose, and content of this new and different technical radio magazine.

If, after perusal of these typical "Digest" pages you are interested, and we know you will be, turn to page 2 of this handbook for prices, size, frequency, and other pertinent data. In the U. S. A. you can subscribe to "Radio Digest" for two years for $2.50. Foreign rates are correspondingly low.

The Editors

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HIGHLIGHTS FROM THIS ISSUE

NOVEMBER, 1937

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● NUMBER 2 SEPTEMBER, 1937 ●

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From Bell Laboratories Record, Oct., 1937

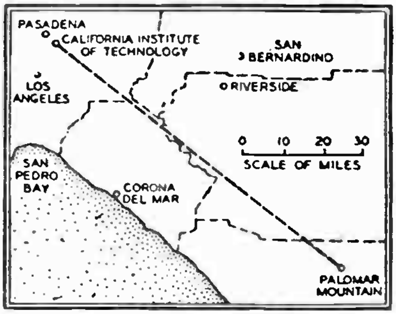
An Ultra Short Wave Circuit for Mt. Palomar Observatory

BY AUSTIN BAILEY

THERE is under construction on the top of Palomar Mountain, in Southern California, a new astronomical observatory in which the world's largest telescope is to be installed. The establishment of the observatory represents a major construction project, for which a telephone "order wire" is required between the mountain top and the headquarters in the California Institute of Technology, situated about ninety miles away.

Members of the staff of the California Institute proposed establishing the desired telephone connection by means of an ultra-short wave radio link. As this seemed to be a favorable opportunity to try out ultra-short waves for telephone purposes over an unusual and difficult transmission path, the engineers of the Laboratories became interested in it, and the project was undertaken on a coöperative basis.

The transmission path is characterized by its considerable length, ninety miles, and the fact that the peaks of an intervening range of mountains protrude into it. The situation is illustrated by the profile chart, figure 2, where the solid line indicates the shortest path and



the dashed one represents the mean path which the ultra-short waves would be expected to take under average conditions, were no barriers present. The curvature is due to atmospheric refraction which is caused primarily by water vapor in the air. It is difficult to predict results on a theoretical basis, but preliminary studies indicated that the obstruction of the mountains might insert a transmission loss of about eighteen db. The indications were that five-watt transmitters might serve if the local noise conditions were not too severe and if antennas of reasonable gain were employed.

The circuit has now been established and is used thirty or forty times on each work day. The transmission to Palomar Mountain

From Successful Servicing
June-July, 1937

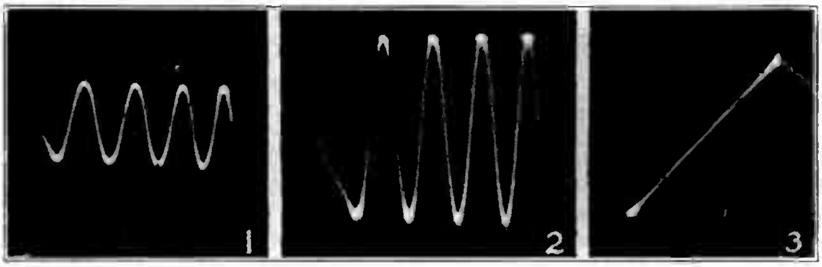
AUDIO AMPLIFIER CHECKING
with the Oscillograph

BY JOHN F. RIDER

WITH the introduction of the new small screen cathode-ray tubes and the resulting economies which they make possible. an ever increasing number of servicemen are becoming owners of cathode-ray oscillographs. Now, more than ever before, many servicemen are surveying these shiny new instruments with their array of knobs and wondering just how the new instruments will help them speed up their service work.

Those using the cathode-ray oscillograph for the first time will probably be disappointed. It is going to take a considerable amount of experience and study before one will be able to save time in service operations through the use of the oscillograph. At the beginning, if one is an average serviceman, he will attempt to do things with the oscillograph that it was never meant to do. He will find the large number of controls confusing; and he will run across all sorts of puzzling effects. But with experience and study, an understanding of just what the instrument is capable of will come, and then he will find himself amply repaid for all the effort expended.

The peculiar adaptability and usefulness of the cathode-ray oscillograph over all other types of measuring instruments is that it permits the visual observation of waveforms. Whereas the ordinary type of instrument can tell us only the magnitude or the size of a given voltage or current, the oscillograph can tell us not only the magnitude but its waveform. As such it is to



Normal Amplifier Operation

from RCA Review,
July, 1937

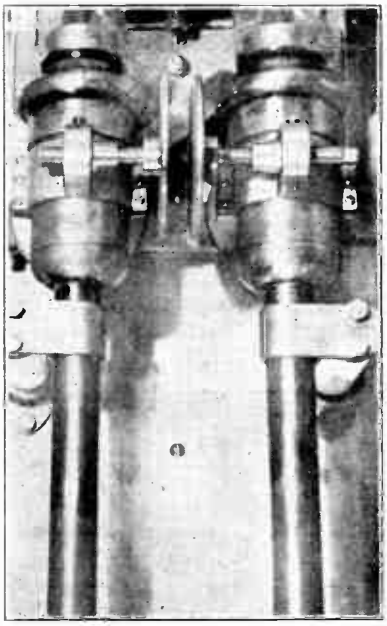
TELEVISION TRANSMITTERS

BY J. W. CONKLIN AND H. E. GIHRING

THE advent of high-definition television, involving modulation frequencies up to several million cycles, has necessitated the development of high-power, ultra-high frequency transmitters. The unique tube and circuit problems encountered and the practicability of line sections as circuit elements has resulted in radical departures from conventions in transmitter design as may be seen from the accompanying illustrations, showing features of high-power, ultra-high-frequency television transmitters.

• *Vacuum Tube Problems*

In ultra-high-frequency development the vacuum tubes have always been one of the major sources of difficulty. Vacuum tubes developed for lower frequencies have a number of limitations rendering them unsuitable for u-h-f applications. For low-power u-h-f transmitters and receivers, special tubes having low internal capacities, short leads, and other features are available, permitting conventional designs insofar as tubes are concerned. Television transmitters with carrier powers between five and ten kilowatts require tubes with dissipation capabilities of the order of thirty kilowatts. The Type 899 is one of the tubes now used in these applications. Some of the problems of high-power u-h-f transmitters are due to the large physical size of tubes now available.



A 50-megacycle amplifier. Tank circuit is of the parallel-line type using a small disc condenser for fine tuning adjustment.

From All-Wave Radio
August, 1937

ADVANCED 10-20 SUPERHET

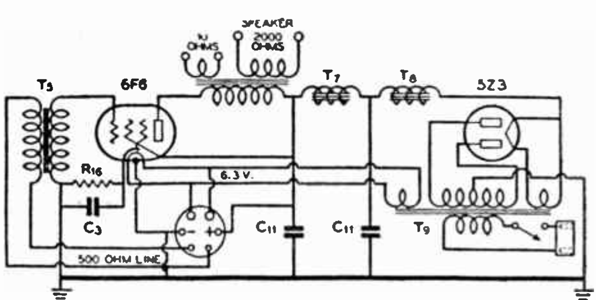
BY H. G. MUSTERMANN

IN THIS article is described a receiver built specifically for 10-meter work. Nevertheless 20-meter coils are also provided, as a receiver that performs well on 10 always works a little better on 20. A set of 5-meter coils is contemplated for the near future. This will permit the reception of crystal controlled transmitters on this band.

High gain in the r.f. stages is of most importance for a 10-meter receiver and is most difficult of attainment. High-inductance coils and small tuning capacities are imperative if this high gain is to be realized. For this reason the somewhat odd construction shown in the high-frequency section is used. Four 20-μμfd. midget tuning condensers are ganged to a PW-O type drive unit. The 500-degree scale of this unit provides adequate mechanical band spread. The coil sockets are placed as close as possible to the condensers in a raised position. This gives shortest tank leads. APC air trimmers are mounted right in the coils. The first r.f. stage is trimmed with a panel mounted condenser (C_9). This takes care of antenna variations.

A shelf of ⅛ in. thick aluminum is mounted an inch above the chassis, and supports the entire high-frequency section with the exception of the drive unit. This is bolted direct to the chassis, being raised a half inch. Both the drive unit and the shelf are fastened to the chassis by means of long 6/32 bolts and Cardwell half-inch spacers. Two of the latter make up the inch height for the shelf. This shelf should be fastened in about a dozen places to the chassis to keep it rigid.

Another set of half-inch spacers raises the tuning condensers to the proper height above the shelf for ganging to the drive unit. Great



SCHEMATIC DIAGRAM OF POWER AMPLIFIER AND POWER-SUPPLY UNIT

More Uses of the Electric Eye

Astronomy: When finally established in the next three or four years, the 200-inch Mount Palomar telescope will be used in conjunction with a photocell detector for registering the presence of extremely faint illuminations.

General research: The color reflection and transmission properties of any material can be analyzed by a machine which employs polarized light along with a single photocell and plots the complete spectral response in three minutes.

Telegraph delivery: Automatic indications of trouble in connection with the conveyor belt system of one of the larger Western Union offices is made available by strategically-placed photocells.

Silk manufacture: Photocells are now responsible for the smoothness and hence the sheen of women's silk hose.

Cotton making: A new weft straightening control, which has phototubes to detect skew in cotton cloth, has been developed by G. E.

Burglar alarm: Successful in its every test, a phototube burglar alarm, which has an infra-red beam and automatically notifies the police by a spoken alarm played from a record, should prove effective in the apprehending of certain "master" criminals.

Ship guidance: Photocell controlled, motor-operated rudder-control devices are being increasingly used as robot pilots for motorship guidance.

Refining industry: The "compensating calorimeter," a phototube device, measures the color of anything transparent or translucent, and is thus being used for color measurements which control various industrial processes such as sugar or oil refining, heat treatments in the metal industry, and so forth.

Spark plug manufacturing: The proper gap in spark plugs can be obtained very accurately by controlling with a phototube the vibrating hammer used to bend one of the electrodes.