Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

PRINCIPAL CONTENTS

The Generation and Amplification of Micro-Waves. Part I.

The "Wobbulator."

Ceramics in Valve Construction.

Review of Progress in Electronics. Part V.

The Technique of Receiver Measurements. Part I.

The Decibel: Does it need Clarification?

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Electronic Engineering

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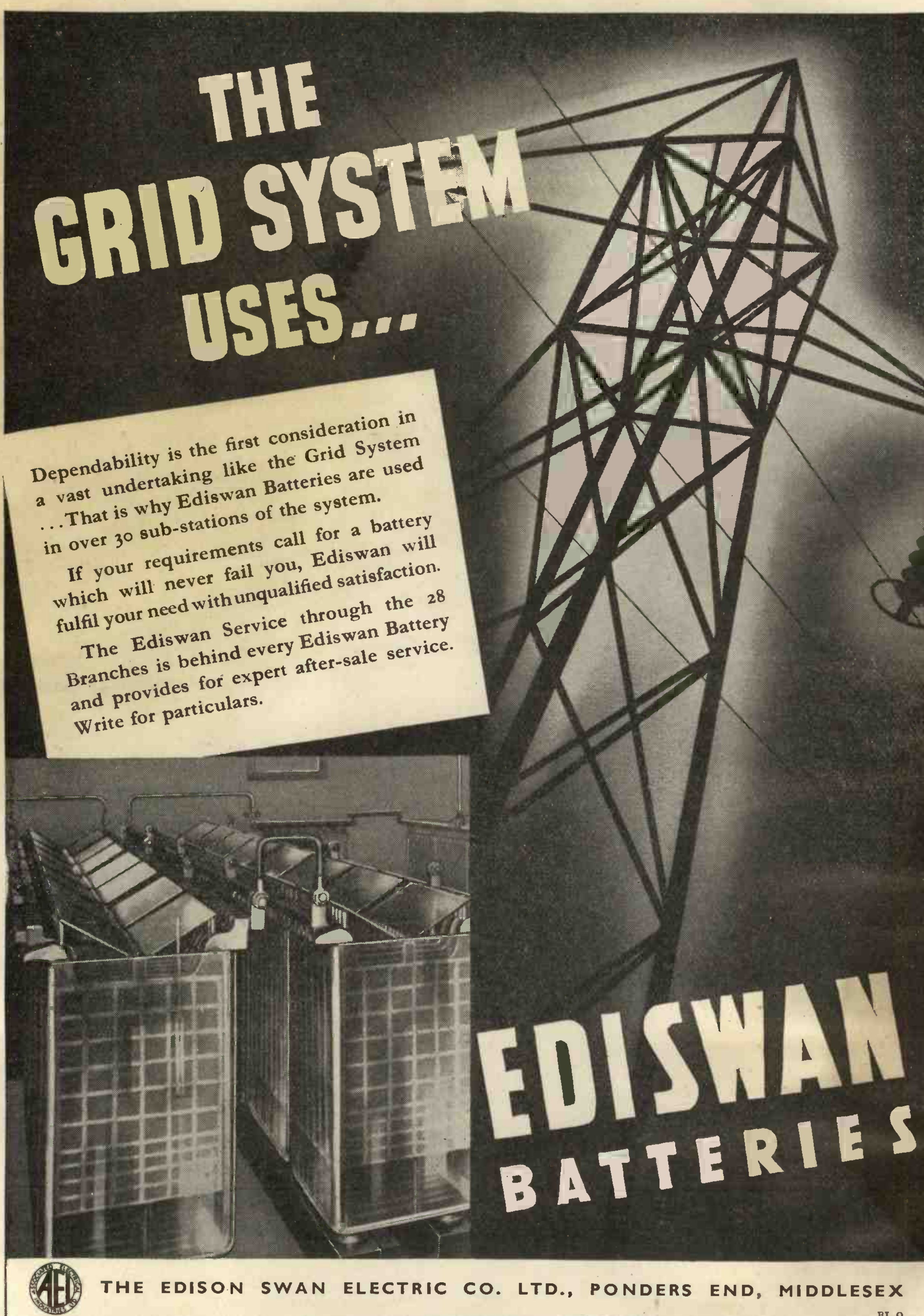
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Electronic Engineering

Encouragement

WITH the appearance of the third issue of this journal in its revised form we may perhaps be excused for making a few observations on its progress.

That it fills a vacant place in the collection of technical literature in this country we have ample assurance from the many letters of encouragement and approval that have been received. It will continue to do so in the knowledge that the efforts of the Editorial staff have the support of the majority of readers.

Necessarily the first few months of progress are accompanied by experiments. New methods of presentation and new ideas are being tried. Some of these have already been commented on approvingly and some will be modified as experience shows that they are not welcomed.

Two criticisms that we have received deserve special mention. The first is a note of regret that many of the features which were familiar to readers of *Television and Short-Wave World* have disappeared and that the journal is tending to become " high-brow." This is a convenient epithet to apply as criticism of any journalistic or musical effort as it is so difficult to accurately define. If, for example, by " high-brow " is meant the use of more scientific terms and the avoidance of semi-technical jargon we plead guilty. A milliampere is a thousandth of an ampere and a mil is a thousandth of an inch, and no science is improved by slovenly use of terms which have a well-defined meaning attached to them. On the other hand, it is possible that a " high-brow " journal takes little account of the readers who are anxious to be up-to-date in what is going on in the technical world, but who are not so well up in the subject that they can follow highly technical articles written by engineers to whom the subject is second nature.

This brings us to the second criticism that has been made on behalf of the student and newcomer to electronics who feels that the journal would be of more use to him if some of the subjects could be dealt with in an introductory manner in addition to the more solid " meat " of a technical article. This is a very important point and one which will receive special attention in forthcoming issues.

Particularly at the present time, when the need for trained radio men is urgent, this journal will do everything in its power to encourage technical education and any suggestions as to how this may best be done will be welcomed.

It will, of course, be realised that we, in common with all technical journals, are working under the two handicaps of shortage of paper and restricted contributions. The first can only be mitigated by careful selection of matter and compressing it into the space available.

The restriction on the nature of contributions at the present time means that many of the most interesting developments in radio and allied sciences must remain unpublished until science is turned again into more peaceful channels.

A special word of thanks is due to the industry for its support and the confidence that it has shown in the future of this journal by advertising in its columns. The firms making use of these pages for advertising their products are all of sound standing and well established in the radio and electrical industry, and while at the present time it may be difficult for them to supply the ordinary requirements of the industry they are reminding us that they are ready to give the same service that was rendered in the past, and which we hope will not be long before they are able to render again.

Contributions

Original contributions to this journal are invited and will receive prompt consideration.

News items should reach the offices not later than the 15th day of the month for inclusion in the succeeding issue.

Manufacturers are invited to submit apparatus and components for review, which will be returned as soon as possible.

Drawings accompanying MS. need not be finished. Curves should be pencilled.

The recommendations of the British Standards Institution for symbols and graphical symbols should be followed as far as possible. Particulars of these can be obtained from the Institution at 28 Victoria Street, S.W.1.

The Generation and Amplification of Microwaves

By C. E. LOCKHART

Part I.

MICROWAVES have come to the forefront during recent years and are entering the stage of more rapid development. This is the usual phase of any new technique when it reaches the stage of finding industrial applications (such as aeroplane altimeters, remote pick-up television equipments, etc.[40 46])* One of the main advantages of microwaves is the ease and simplicity with which they may be concentrated into very sharp beams, and this feature is being applied on some American aerodromes to provide very satisfactory landing-beam systems[42].

The object of this series of articles is to provide a review of some of the different methods available for the generation and amplification of microwaves, and as there is no recognized definition for the upper wavelength limit of microwaves it is proposed to limit arbitrarily the majority of the discussion to valves operating at wavelengths below 150 cm. (200 Mc), though in the case of negative grid amplifiers, valves operating at somewhat longer wavelengths are included.

A number of alternative methods are available for generating or amplifying very short wavelengths. These are:

1. Negative grid triode or multi-electrode valves.
2. Inductive output valves (RCA-Haeff 825).
3. Klystron and G.E. velocity modulated valves.
4. Deflected beam valves.
5. Diode oscillators.
6. Magnetrons.
7. Barkhausen-Kurz.
8. Retarding or braking field valves.

The sequence of the above table should not, however, be taken to indicate any particular date precedence or virtue of a given system.

It is natural to start with the negative grid types, as these are so well known and are pre-eminent at the lower frequencies, and thus may be used as a standard of comparison. Recent developments, such as inductive output valves, Klystrons and velocity modulated valves, are of particular interest and will be treated later.

The requirements of an efficient wide-band amplifier for use at ultra-high frequencies are: (a) low input and output loading loss; (b) low input and output reactive loading; (c) low mutual couplings between input and output circuit; (d) low lead and electrode losses due to

* Figures refer to Bibliography to be given in concluding article.

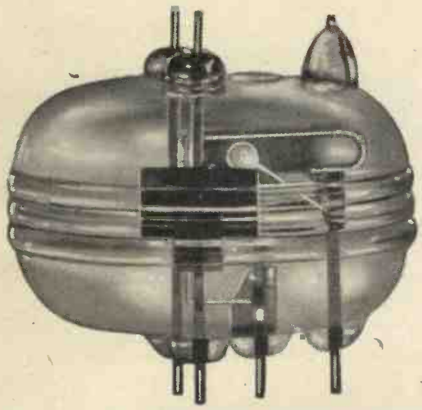


Fig. 6. Ultra-short-wave oscillator showing double lead-out from electrodes. Due to this construction, oscillations can be produced up to 1,800 Mc/sec. (Western Electric Co. D.156548.)

H.F. resistance and radiation. In the case of oscillators, the requirements are generally the same except that (c) is not so important, but on the other hand in the case of the negative grid oscillators a small transit time between cathode and anode (e) is very important, as it is necessary to provide a 180° phase relation between the grid and anode voltages and between anode voltage and anode current, in order to maintain efficiency with a normal type of oscillator circuit.

Negative Grid Triodes and Multi-Grid Valves as Amplifiers

These valves which are used exclusively for the lower frequencies fail to meet the above requirements to a varying degree as the frequency is increased.

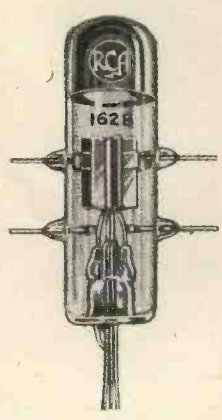


Fig. 7. R.C.A. ultra-short-wave valve type 1628, capable of delivering 34 W. at 500 Mc/sec.

(a) To understand the limitations of valves at high frequencies it is necessary to visualize the electrode currents from a different point of view from that normally employed at low frequencies. When an electron leaves the cathode it produces image charges on all the electrodes (cathode, grid, screen, anode). The redistribution of these charges as the electron moves is affected by currents flowing in the different electrodes. The component of current in a given electrode due to an electron, therefore, starts immediately it leaves the cathode and ceases to exist as soon as it is collected by another electrode (such as, for example, the screen or anode). From the foregoing it will be realized that currents of considerable magnitude may exist in the control grid even though no electrons are collected by it.

In the negative grid type valve the voltage applied to the grid affects the field at the cathode, and an alternating voltage applied to the grid will thus produce a variation in the charge density of the electrons leaving the cathode. The high-frequency variation in the convection current (v) is then large all the way from the cathode to the anode. Each electron approaching the grid will induce a current in it and each electron receding from the grid while travelling to the next electrode will similarly induce a current in the grid. The current induced is proportional to the product of the electron charge density of "ρ" and the electron velocity "v."

At the lower frequencies these two currents are sensibly equal and opposite so that no current flows in the grid, but as the frequency is increased the net induced current in the grid rises owing to the finite transit times altering the proportion of electrons approaching the grid to those receding from the grid.

The resulting induced grid current may be resolved into two components, one in phase with the applied grid voltage and the other in quadrature. It is the component in phase with the applied grid voltage which loads the input circuit and can be expressed as an input resistance[1-19].

This energy abstracted from the input grid circuit will be transferred to the electron stream in the form of increased kinetic energy. The electrons will, therefore, on an average arrive at the anode with velocities equivalent to a potential greater than the potential of the anode at the instant of impact.

The excess energy delivered by the grid circuit to the electron stream is thus dissipated at the anode in the form of heat, which in turn reduces the available output from the valve.

It has been shown ([7 and 16]) that the input loading (for the case where the input signal is small compared with the applied D.C. voltages and the transit times are comparatively small) may be expressed as an admittance equal to

$$\frac{1}{Ri} = \frac{g\omega^2(\tau_1)^2}{20} K \quad \ldots \quad \ldots \ (1)$$

where

$$K = \left\{ 1 + \frac{2}{3} \cdot \frac{d_2}{d_1} \frac{1}{n+1} \cdot \left[\frac{44}{9} + \frac{1}{n+1}\left(\frac{10}{3} \cdot \frac{d_2}{d_1} - \frac{34}{9} \right) - \frac{140}{27} \cdot \frac{d_2}{d_1} \frac{1}{(n+1)^2} + \frac{40}{3} \frac{d_2}{d_1} \frac{1}{(n+1)^3} \right] \right\} \quad (2)$$

where τ_1 = transit time between cathode and grid.

d_1 = grid to cathode spacing.

d_2 = grid to anode or screen spacing.

$$n = \sqrt{E_a/V_{eff}} \ldots \quad \ldots \quad \ldots \quad \ldots \ (3)$$

E_a = anode or screen voltage.

V_{eff} = lumped voltage, defined later in this article.

The factor K is a correction for the loading effect of the grid-anode or grid-screen space, and this factor reduces to unity as the dimensions of this space, or more correctly the transit time in this space, is reduced to zero.

A long transit time in the grid-anode space will also reduce the effective mutual conductance, though in general this effect is usually small compared with the limitation due to loading of the input circuit.

The limiting wavelength at which an amplifier ceases to be useful may be defined as either the wavelength at which the input power is equal to the output power or the wavelength at which it ceases to provide an improvement in the signal-to-noise ratio. In the case of receivers, the latter definition is preferable.

As was shown recently in this journal[46] the figure of merit of a wide-band H.F. amplifier is proportional to

$$g/\sqrt{C_w C_0} \quad \ldots \ (4)$$

where g is the Mutual Conductance and C_w and C_0 are the input and output capacities respectively. At ultra-high frequencies we are faced with the further problem that both C_w and C_0 have to be kept small in order to enable reasonably efficient tuned circuits to be provided.

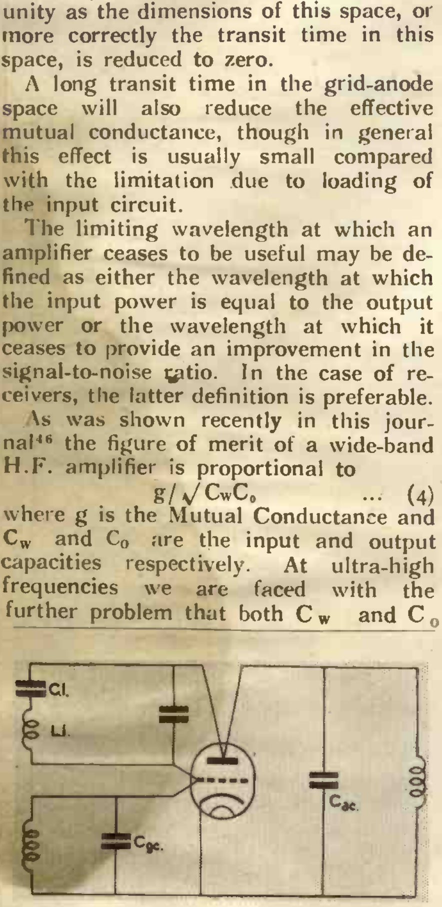


Fig. 1. "Coil-neutralized" circuit in which the grid-anode capacity is converted into a high resistance by resonating with the inductance L1.

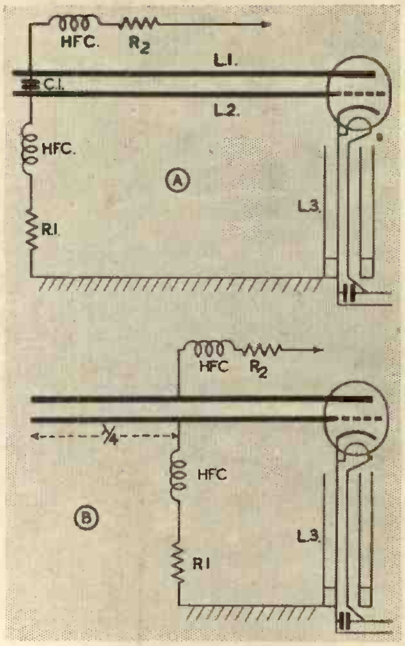


Fig. 2. (A) the Colpitts circuit for a single valve oscillator. (B) Similar circuit employing a half-wave open-circuited line.

With the increase of frequency the provision of neutralization becomes more and more difficult. By the use of specially designed triodes having two separate connections to the grid and anode such as the Western Electric D156548, Standard 3B/250 and RCA1628, it is possible to separate the output circuit currents from the neutralizing network and thus achieve neutralization at frequencies as high as 350 Mc.[26 27 45]

At very high frequencies the usual form of bridge neutralizing circuits fails and it is preferable to employ the "coil-neutralized" type of circuit shown in Fig. 1.

In this method of neutralization the low feed-back impedance provided by the grid-to-anode capacity C_{ga} is converted into a high resistance by resonating it with the inductance L_1. The condenser C_1 acts only as a blocking condenser for the H.T. voltage.

The provision of screened valves to greatly extend the frequency range has not met with much success, as in addition to the increase in the capacities due to screening, it is very difficult to reduce the mutual reactances between electrode leads and the self-reactance of the screening electrode lead to a sufficiently low order.[13 17]

Screened valves for use at wavelengths up to the order of 100-150 cms., however, do exist and are commercially available.[20 24 25 27 30 31]

In order to obtain a reasonable dynamic resistance for the tuned circuits at U.H. frequencies, it is necessary to reduce both the radiation and dissipation losses of the tuned circuit and connecting leads.

In the case of the tuned circuits this is best achieved by the use of low-loss resonant chambers (preferably closed) made of good conducting material. An example of this is the concentric line; other arrangements will be discussed later.

As the radiation resistance of a length of wire "l" short compared to a ¼ wavelength is proportional to$(l/\lambda)^2$ (where λ is the wavelength) it is essential to keep the electrode connecting leads exceedingly short. This, together with the fact that a stage is soon reached when the valve electrodes themselves have to be considered as having distributed rather than lumped constants implies that the valve should be designed as part of the tuned circuits, or vice versa.

Oscillators

The majority of the remarks on amplifiers apply equally to oscillators. The most usual circuit employed for a single valve oscillator is the Colpitts, shown diagrammatically in Fig. 2a, where the tuned circuit consists of a parallel wire line L_1 L_2 forming a quarter-wave anti-resonant line and tuned by means of a sliding shorting condenser C1. The equivalent circuit in terms of lumped constants is shown in Fig. 2c, in which the line is, for convenience, represented as two adjustable inductances L_5 and L_6. The condenser potentiometer of the Colpitts circuit is provided by the valve anode-to-cathode (C_{ac}) and grid-to-cathode (C_{gc}) inter-electrode capacities. The line length for a given wavelength is determined by the effective loading capacity C_{eff}

$$C_{eff} = C_{ag} + \frac{C_{ac}\,C_{gc}}{C_{ac} + C_{gc}} \quad \ldots \ (5)$$

Actually the working grid-cathode capacity C_w should be used in the equation instead of C_{gc} with a class C oscillator. C_w is very nearly equal to C_{gc} [17].

The grid leak resistance R_1 and the anode feed resistance R_2 are connected to the nodal points of the line through small H.F. chokes. With parallel wire lines it is essential to operate the line under proper balanced conditions if the radiation losses are to be kept at a

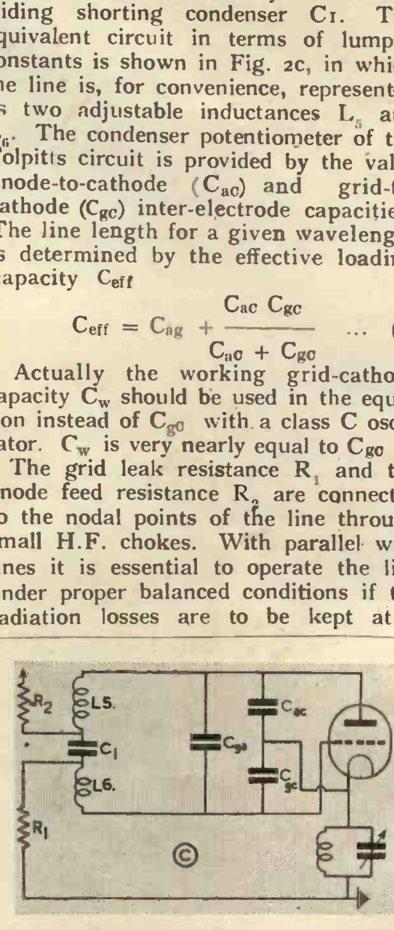


Fig. 2 (C). Equivalent circuit of the Colpitts oscillator of Fig. 2 (A).

minimum. Equivalently, this implies that the currents in the two wires at any portion of the line must be equal and opposite.

Unless the capacities C_{ao} and C_{go} are equal, earthing the cathode would upset the line balance and appreciably increase its loss. As these capacities have usually somewhat different values it is necessary to connect the cathode to earth through a high impedance.

In Figs. 2a and 2b this high impedance takes the form of an anti-resonant quarter-wave concentric line L_3, though any other form of high impedance, such as self-resonant chokes, would do.

Instead of employing a quarter-wave shorted anti-resonant line tuned by a sliding condenser, a half-wave open circuited line could be used (Fig. 2b), which has the advantage of eliminating problems of the sliding condenser C_1, or alternatively other forms of low-loss resonant circuits, such as concentric lines or resonant chambers can be used.[33 39]

The electrical length of the line and,

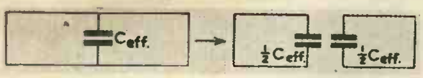


Fig. 3. Line with valve capacity and its equivalent circuit.

therefore, its dynamic resistance, are reduced owing to the loading effect of the reactance of C_{eff}.* While the reactive loading has less effect on lines of low characteristics impedance, it still presents a serious limitation on the size of valve that may be employed at a given wavelength, or the shortest wavelength for which a valve can be built.

A method of reducing the reactive loading of an electrode structure on a line is to bring out two sets of leads to the grid and anode electrodes and to arrange these in such a manner that the valve may form the centre portion of a half-wave line shorted at both ends or a whole wavelength line open at both ends.[26 27]

The line with the valve capacity is shown diagrammatically in Fig. 3, in which the half-wave line shorted at both ends has been resolved into two separate quarter-wave lines. Each of these quarter-wave lines is now loaded with only one half of C_{eff}. In practice, improvements in the maximum frequency of operation up to 40 per cent. by the use of this system have been reported.[26]

Western Electric D156548 and Standard 3B/250 valves have been designed for this form of operation, and Fig. 4 illustrates the circuit recommended for the latter valve which has an upper frequency limit of oscillation of the order of 17 cm. (1800 Mc). The tuned circuit consists of a shielded pair line working

* *See* ELECTRONIC ENGINEERING Data Sheets in this issue, p. 351.—Ed.

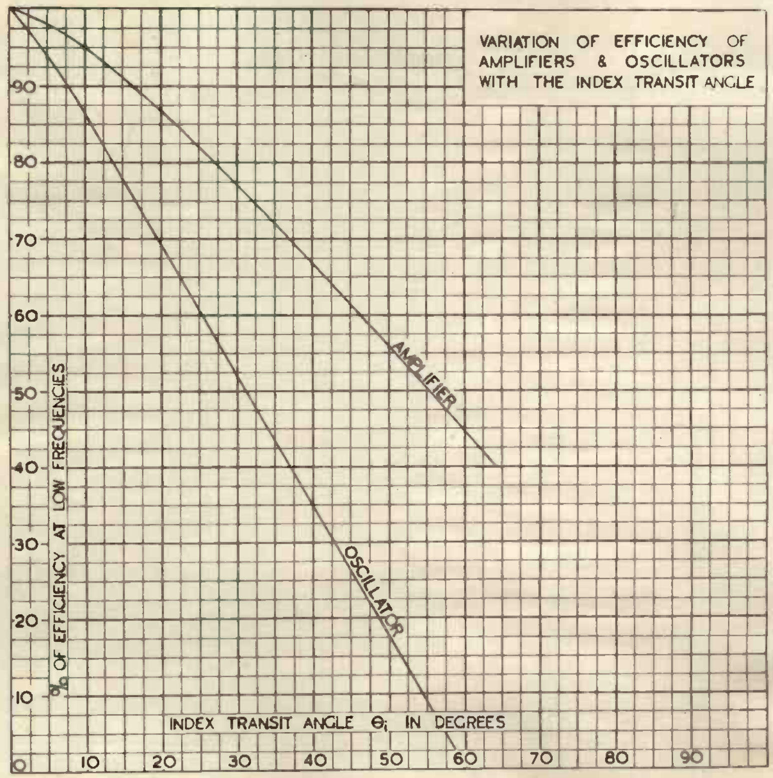


Fig. 5. Efficiency of Amplifiers and Oscillators at U.H.F.
$\theta_i = \omega T_t = (T_t/T_p) \times 360°$.
T_t = **Transit Time F-G, calculated on peak grid volts.**
T_p = **Period of R.F. wave.**

as a capacity loaded open-circuited whole wavelength anti-resonant circuit. The valve is directly heated and a quarter-wave concentric line is connected in each filament lead.

The anode and grid feeds are connected to the nodal points of one of the half-wave lines. For the line recommended by the manufacturers the characteristic impedance Z is 113.8 ohms and the required length of line on each side of the valve may be calculated from the relation

$$Z_s = j\ 113.8 \cot \frac{2\pi}{\lambda}\left(\frac{\lambda}{1.67} - 6\right) \text{ohms}$$

or

$$l = \left(\frac{\lambda}{1.67} - 6\right) \text{cms.}$$

where

λ = the operating wavelength in centimetres.

l = line length in centimetres.

In addition to the increased small signal input loss of an amplifier with increase of frequency, in the case of Class B or Class C amplifiers the anode circuit efficiency will also drop owing to the anode current pulse changing its shape and lengthening its time period with increase of frequency due to transit time effects.*

This increase in time over which anode current flows will increase the

* *See* footnote on page 347.

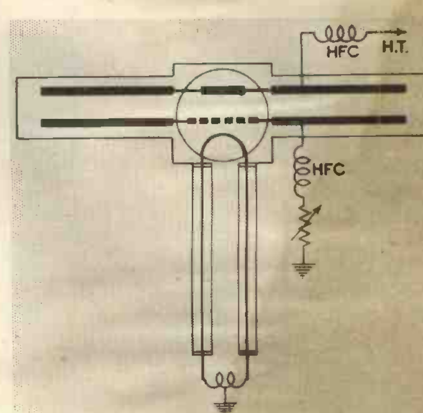


Fig. 4. Circuit recommended for use with valves of the 3B250 type. (See Fig. 6).

power lost by dissipation at the anode, and so reduce the anode efficiency (and also the power output) as the fundamental frequency component of the anode current is reduced.

In addition, it will be necessary to drop the anode volts in order to keep within the dissipation ratings of the valve.

Fig. / shows a typical curve of the change of the relative efficiency of a negative grid amplifier valve with frequency. This curve, which was obtained experimentally up to 240 Mc by the

(*Continued on page* 347.)

The "Ultra" Incendiary Bomb Detector

THE news that Messrs. Ultra Electric, Ltd., have developed an incendiary bomb and fire detector is particularly welcome at the present time when attention is being directed on the more efficient protection of houses and business premises.

One of the problems of fire-watching in the danger areas is the risk run by the watchers in exposed positions on the roof, particularly as their site must be sufficiently open to cover a wide area. If, however, part of the premises under their supervision is protected by an automatic fire indicator the necessity for open positions is not so great and they can be given a correspondingly increased amount of protection.

The Ultra bomb detector is mounted in a circular die-cast case intended to hang on the wall in a convenient position in the room or warehouse to be "covered." In the front of the case is a stout glass dome covering a photo-cell, on the action of which the alarm depends. The appearance of the unit is seen from the photograph at the head of the page.

It is intended for operation from A.C. mains of 200-250 volts 40-100 c.p.s. and the only additional equipment required is a dry battery or accumulator and an alarm bell. The consumption is 15 watts—less than that of an average lamp. In addition to ringing an alarm as soon as light falls on the photo-cell the circuit includes a safety alarm designed to operate when the mains are accidentally cut-off. There is thus no fear that the detector will be rendered inoperative due to local mains failure while the watchers are unaware of it.

Installation

The unit may be installed either as a bulkhead fitting, *i.e.*, so that the cell looks down on the floor, or as a hanging case with the leads at the bottom. The relay in the interior of the case is gravity operated and wrong mounting will affect the performance.

When choosing a site for the unit, care must be taken that there are no local obstructions which would prevent the light falling on the photo-cell. In offices a position near the ceiling is suggested and in stores, overlooking piles of goods. In factory buildings the usual site is near the roof level in one of the valleys. A fair estimate of the distance covered in an unobstructed view of the cell is 200 feet, but in congested areas of floor the detector should not be expected to cover more than 100 feet.

When connecting to the mains the polarity of the leads should be such that the red lead is connected to the "live" side of the mains. The case of the unit can then be properly earthed—an essential point.

After the unit has been wired up and switched on, the control lamp will glow, indicating that it is in order and ready for use. This lamp is connected to a winding on the main transformer through the two left-hand contacts of the relay (*see* circuit diagram). When warmed up, the anode current of the valve is just sufficient to close these contacts and light the lamp.

Valve or mains failure is indicated by the fact that the lamp is out, the relay not having closed.

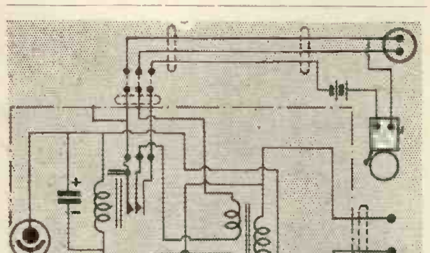
When the unit is ready for use, any extraneous light falling on the photo-cell will cause an increase in the anode current through the valve and close the right-hand contact of the relay, ringing the bell through the local battery. The bell will continue to ring until the relay has been re-set by switching off the unit.

Photograph of the Ultra Incendiary Bomb Detector.

Instead of a local bell and battery device it should be possible to utilise the existing alarm circuit of a factory if this is available, the relay contacts being tapped in at a convenient point on the system. Messrs. Gent, of Leicester, have already devised ways of utilising the detector in conjunction with their alarm systems.

The detector is supplied ready for connexion to the mains together with the necessary instructions. An additional brochure is available for dealers and engineers who wish to demonstrate the unit to interested parties, giving suggestions for correct installation and demonstration conditions.

An important query which is covered in the booklet is the probable effect of moonlight, gunflashes, or flares on the alarm device, and it is pointed out that light falling on the cell from directly overhead may be shielded by a board 2 ft. square fixed over the unit. The possibility of the alarm being operated by flares is of advantage as they are capable of as much damage as an incendiary bomb under certain conditions.



Circuit diagram of detector.

It is also recommended that the alarm be tested periodically in the same way that routine tests are carried out on fire alarm installations. A practical test is to flash a torch across the photo-cell and check that the alarm is given at the control room or wherever the bell is installed.

The maintenance costs are negligible, the only item which may require replacement being the valve. The estimated life of this is six months under normal conditions of use of the alarm from dusk to dawn. The price of the standard unit is £8 15s. net, and it is subject to a guarantee for twelve months, valve excepted.

The unit is not subject to purchase tax.

A question that is often raised with regard to incendiary bomb detectors of this type is whether there is any Government approval.

The I.E.E. Advisory Committee have already made a report to the Ministry of Home Security* and a specification covering the requirements of a satisfactory detector is being prepared by the British Standards Institution. The manufacturers of this device inform us that they are submitting production samples of the detector to the Fire Insurance Offices for approval, and that copies of this approval will be supplied when available.

A sample detector is at present being tested at the offices of this journal and a test report will be published next month.

* *See Electronics and Television*, May, 1941, p. 198.

The "Wobbulator"

Frequency Modulation Applied to Circuit Alignment

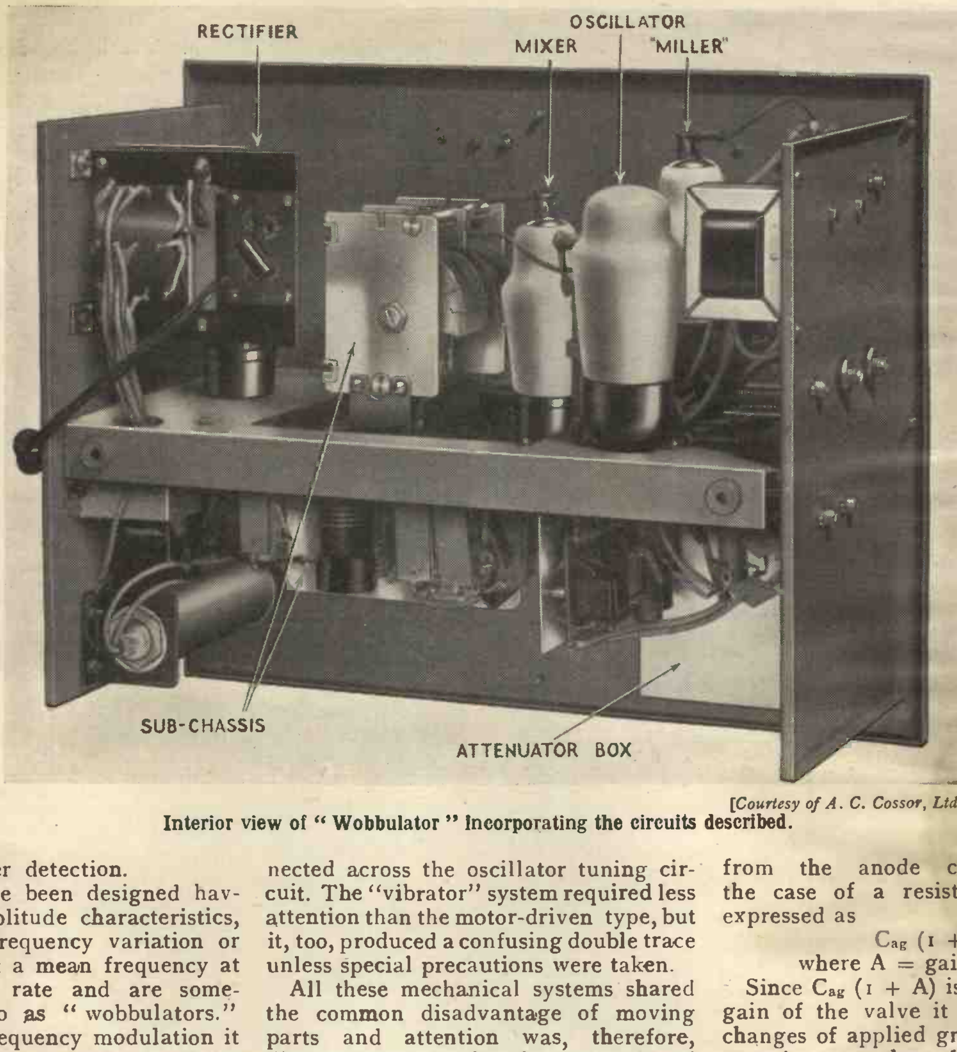
By O. H. DAVIE, Grad. I.E.E.

It has long been realised that the application of oscillograph technique is the quickest and probably the most effective method of recording the response of an electrical network in terms of frequency.

This visual method has come into general use among set manufacturers for production circuit alignment, and is preferred by engineers to the somewhat laborious method of plotting the sensitivity of a receiver either side of the resonant frequency with a signal generator and output meter.

The principle of operation is to apply a constant amplitude, but varying frequency to the circuit under test and let the output voltages so developed produce a Y deflection on a cathode-ray oscillograph.

If the oscillograph tube is scanned horizontally at a rate proportional to the change in frequency the response curve of the circuit will be traced (Fig. 1a). This may be repeated a number of times a second to give a continuous picture. As will be seen in Figs. 1a and 1b the curve may take the form either of a radio-frequency envelope or may appear as a single trace after detection.



[Courtesy of A. C. Cossor, Ltd.

Interior view of "Wobbulator" incorporating the circuits described.

Oscillators have been designed having constant amplitude characteristics, but capable of frequency variation or "wobble" about a mean frequency at a predetermined rate and are sometimes referred to as "wobbulators." To obtain this frequency modulation it is necessary to vary at least one of the oscillator tuning elements either mechanically or electrically.

Mechanical Frequency Modulation.—An early method of frequency modulation employed a motor-driven condenser connected across the oscillator tuning circuit. The vanes were specially shaped to obtain a frequency sweep linear with respect to the angle of rotation of the motor shaft. This permitted the use of a linear time base for X deflection. Unfortunately, the fly-back speed of the frequency sweep could not always be made to coincide with that of the time base and a confusing double trace resulted.

In the place of the motor, some early commercial instruments used a vibrating reed operated at mains frequency. The reed was at earth potential and represented one plate of a condenser connected across the oscillator tuning circuit. The "vibrator" system required less attention than the motor-driven type, but it, too, produced a confusing double trace unless special precautions were taken.

All these mechanical systems shared the common disadvantage of moving parts and attention was, therefore, directed towards electrical methods of modulation.

Electrical Frequency Modulation.—A simple method of varying the frequency of an oscillator is to damp its tuned circuit with a parallel resistance. This resistance can conveniently take the form of a thermionic valve connected as shown in Fig. 2.

The damping effect of this valve is easily controlled by variation of the potential applied to its grid. This arrangement may be modified to give slightly greater variations in frequency by making the capacity of C_2 comparable with C_1, and, therefore, part of the oscillator tuning circuit. It becomes apparent that as the effective resistance to earth presented by the control valve varies, the effective capacity of C_2 thrown across the tuned circuit also varies and a frequency change results.

The foregoing methods are not entirely satisfactory since a certain amount of amplitude modulation is also present and the relation between control voltage and frequency deviation may not be strictly linear.

Miller Valve—By utilising the property of a valve known as the "Miller Effect" another method of frequency modulation is made possible.

The input capacity of a valve can be represented by its standing inter-electrode capacities plus a capacity transferred from the anode circuit which in the case of a resistive load can be expressed as

$$C_{ag}(1 + A)$$

where A = gain of valve.

Since $C_{ag}(1 + A)$ is a function of the gain of the valve it can be varied by changes of applied grid potential. This capacity can then form part of the oscillator tuning circuit.

An oscillator and modulator using this principle of operation is shown in Fig. 3. The Miller valve is a variable-mu pentode connected as a triode and operating on the curved part of its characteristic, so that the change in frequency of the oscillator is linear with respect to the control voltage. This control voltage is applied to the grid of the Miller valve, but is prevented from grid-modulating the oscillator by the low capacity of C_2. C_1 has an optimum value which determines to some extent both the linearity and the amount of frequency sweep for a given control voltage.

It must not be overlooked, however, that the Miller valve has the full oscillator voltage applied to its grid and, therefore, its effective capacity is not the value which may be expected from its static characteristics. It should also be noted that the anode-cathode capacity of the valve is in parallel with its anode load so that as the operating frequency increases the gain of the stage decreases and the effective change of capacity will be proportionately less.

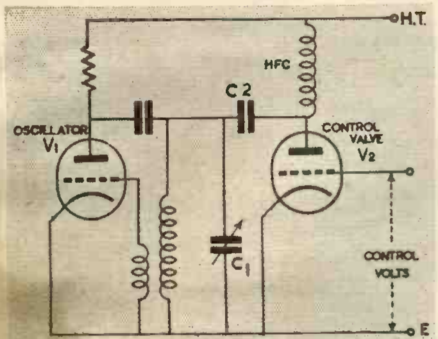


Fig. 2. Valve used as damping resistance.

Reactance Valve.—This system is often referred to as "The Inverted Miller" circuit, a misleading term perhaps, since it has little to do with the Miller Effect just described.

Consider the circuit shown in Fig. 4a. If a potential e_1 is applied between terminal A and earth, a current i will flow through the phase shifting network RL and if the reactance ωL is small compared with R, i will be nearly in phase with e_1.

A voltage e_2 will appear across L and will lead the current i by 90°. In the anode circuit a current will flow which is in phase with e_2 and leading e_1 by nearly 90°. With the current

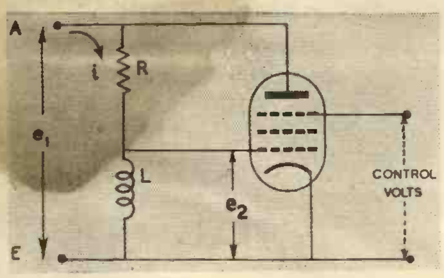


Fig. 4a. So-called "Inverted Miller" circuit.

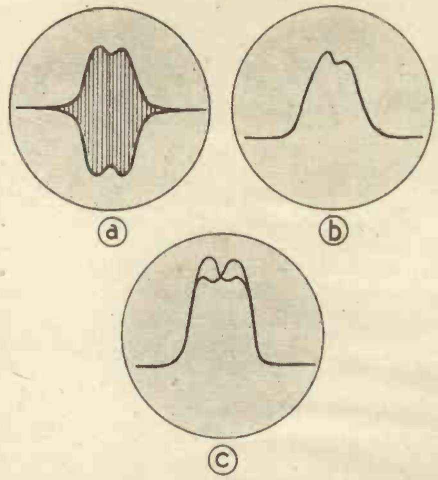


Fig. 1. Appearance of typical response curves.

leading the applied voltage by nearly 90° the network between the terminals AE is almost a pure capacity, its value being controllable by the gain of the valve.

It may be noted that if the inductance L is replaced by a capacity, or the positions of R and L interchanged, the network appears as a variable inductance. This is often useful since then the relation df/f is a constant irrespective of the setting of the tuning condenser.

The circuit diagram of an oscillator operating at 20 Mc/s. is shown in Fig. 4b. A small inductance L_1 consisting of two or three turns of wire on a ½ in. diameter former is included in the phase-shifting network. This produces a true 90° shift, thereby avoiding amplitude variations over the swept frequency band.

Heterodyne Oscillators.—Frequency modulated oscillators used for circuit alignment must have a set frequency sweep irrespective of the mean operating frequency of the oscillator.

As has been explained, a single oscillator can be made to produce an output such that df/f is a constant, but is unable to give an output where df is *independent* of the mean operating frequency.

Heterodyne oscillators can do this, however, by utilising the beat frequency produced by two separate oscillators in much the same way as the intermediate frequency is obtained in a standard super-heterodyne receiver. If one of these separate oscillators is frequency modulated, the beat frequency will also be frequency modulated over an equal band. If, in addition to this, the frequency of the second oscillator is varied, the mean frequency of the beat will vary, but the modulation due to the first oscillator will remain unaltered.

An oscillator of this type is shown in Fig. 5. The circuit in Fig. 3 is used to supply a frequency-modulated input to a triode-hexode valve through a tuned filter. This filter suppresses harmonics, but is damped so as not to introduce amplitude variations over the swept frequency band.

The triode section of the valve is employed as a variable oscillator which is made to beat with the modulated fixed oscillator to produce the desired frequency in the anode circuit. This desired frequency is separated from the other signals in the anode circuit by means of a flatly tuned transformer. A low impedance secondary winding on this transformer then supplies the signal to a standard output attenuator.

"X" Deflection of C.R.O.—It has already been stated that the horizontal scan of the oscillograph tube must be

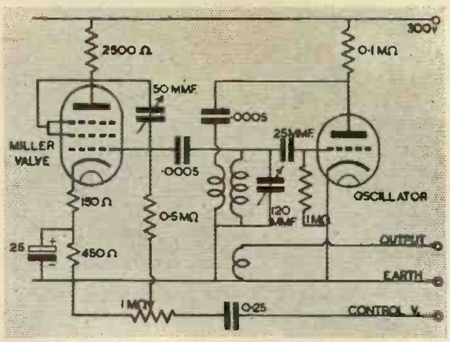


Fig. 3. Input capacity of valve used for tuning.

directly proportional to the frequency sweep of the alignment oscillator.

This synchronising is easily obtained in electronic F.M. oscillators by applying a fraction of the horizontal scanning voltage to the grid of the control valve.

This scanning, or "X" Deflection Voltage, can have any desired waveform but, generally, a saw-tooth wave from a standard time base is applied because it produces a picture of uniform brilliancy.

Double Trace Method of Alignment.—In some networks it is necessary that the response curve should be adjusted until it is either symmetrical or asymmetrical by a known amount about the resonant or the mean operating frequency. By adjustment of control volt-

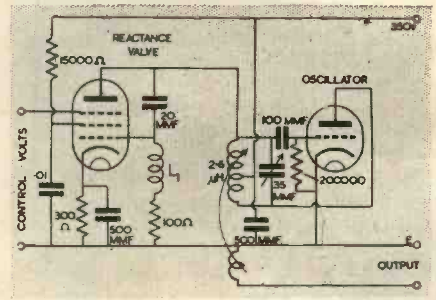


Fig. 4b. Circuit of 20-Mc/s. oscillator.

ages it is possible to trace two curves simultaneously one being the reverse of the other. This is particularly useful since they can be superimposed for direct comparison.

One method of doing this is to scan the tube with a saw-tooth waveform as in Fig. 5a at the same time applying a triangular or pyramidal waveform (Fig. 5b) to the F.M. oscillator. During the first stroke of the time base a response curve from negative to positive in frequency is traced (at a a_1 5a and 5b). Similarly during the second stroke a reversed curve is traced from positive to negative in frequency at b b_1. Since the points a and b are in the centre of the C.R. screen, the two pictures are superimposed, but can be separated by setting the mean oscillator frequency slightly off the resonance point of the network.

When only the symmetry of the curve is to be checked, a similar method may be employed. The pyramidal waveform may be replaced by a sine wave (*see* Fig. 5c). The picture is then traced linearly, but the alignment oscillator frequency varies sinusoidally. The non-linearity introduced by this sinusoidally-modulated oscillator is, however, duplicated on either side of the mid point of the response curve, and therefore, the trace will still appear symmetrical.

Repetition Speed.—Repetition speed in F.M. alignment oscillators is an important factor since high repetitive rates are liable to produce damped oscillations (ringing) in high-Q circuits resulting in a distorted trace.

Most commercial instruments operate at about 25 traces per second, although it is sometimes argued that 12½ traces per second should not be exceeded. This low repetitive frequency will cause the trace to flicker, although long-afterglow C.R. tube screens will minimise this unpleasant effect.

Receiver Alignment.—The application of F.M. oscillators to receiver alignment is quite straightforward.

The C.R. oscillograph is a high-impedance voltage-operated device and may be connected to the R.F. circuits without materially effecting their operation, provided certain precautions are taken.

A standard time base is made to provide the " X " sweep at 25 traces per second and the circuit under test provides the " Y " deflection. Before these voltages are applied to the " Y " plates, it is preferable to demodulate in order to convert the modulated carrier (Fig. 1a) into a single trace on the screen (Fig. 1b). The receiver conveniently supplies a circuit for this purpose in the form of the detector which, in the case of a super-het., is generally a diode. The oscillograph may, therefore, be connected directly across the diode load. It is necessary to avoid the use of coupling condensers since the repetition speed or modulation frequency is necessarily low and the time constants of the receiver circuits are too short to faithfully reproduce the curve.

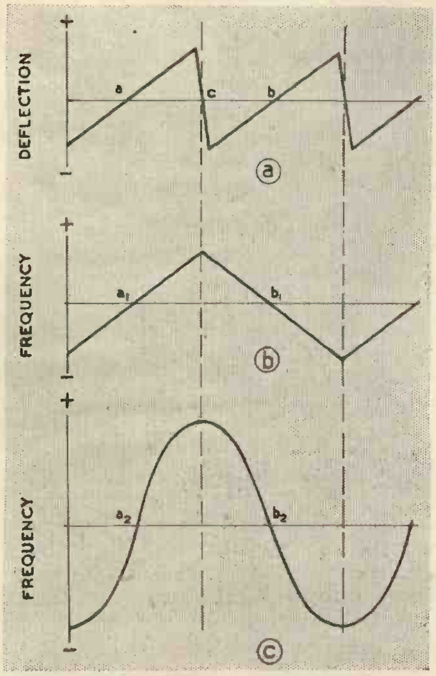


Fig. 5. Method of obtaining double trace.

Before accurate alignment of a receiver is attempted, any special circuits such as those used for the automatic control of volume or tuning, must be made ineffective.

The alignment of the I.F. stages of a super-het. is representative of the method employed for the whole receiver. The local oscillator in the receiver is made inoperative and the alignment oscillator is applied to the control grid of the *last* I.F. amplifier. The oscillator is then adjusted to supply an input signal at the intermediate frequency of the receiver, having a frequency sweep equal to or greater than the bandwidth the stage is required to pass.

By adjustments to the last I.F. transformer its response curve will appear on the screen. It may sometimes be necessary to use an amplifier if the " Y " deflection is too small for qualitative analysis. Most commercial oscillographs incorporate an amplifier having a frequency response flat to less than 25 c.p.s. and capable of amplifying the " Y " voltages without distortion.

When the response of this stage is satisfactory, the oscillator output is applied to the grid of the previous stage and the procedure repeated until all the transformers are in alignment.

Since the final I.F. response curve should be symmetrical it may therefore be checked by one of the " double trace " methods described earlier.

Commercial Instruments.—A number of commercial instruments are manufactured for receiver alignment.* They consist of an oscillator and an oscillograph. Alignment or ganging oscillators generally cover most frequencies between 100 k/cs. and 20 M/cs. and allow for adjustable frequency modulation of the order of ± 15-20 k/c. Four-hundred-cycle amplitude modulation is generally provided for normal circuit testing together with a 400-cycle supply for the low-frequency portion of the receiver. An attenuator is included, but is not necessarily calibrated since the only requirement is that the output voltage should remain constant over the swept frequency band.

The oscillograph incorporates a cathode-ray tube, a linear time base for " X " deflection and " Y " amplifiers capable of handling the low frequencies encountered.

The oscillator and oscillograph are generally manufactured as separate instruments since the oscillograph has wide applications elsewhere.

The author wishes to express his thanks to Mr. A. N. Melchior for his helpful suggestions, and to Messrs. A. C. Cossor, Ltd., for permission to reproduce the circuit details.

**Electronics and Television and Short-wave World.* Jan., 1940, pp. 28, 33. Sept., 1940, p. 413.

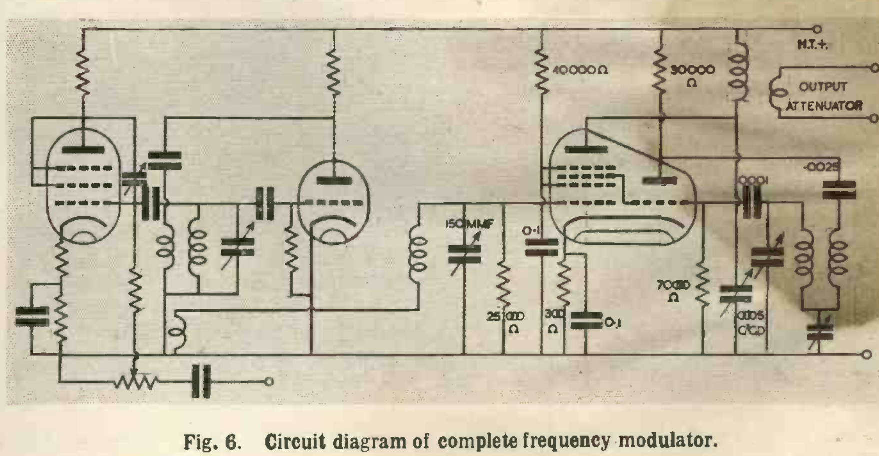
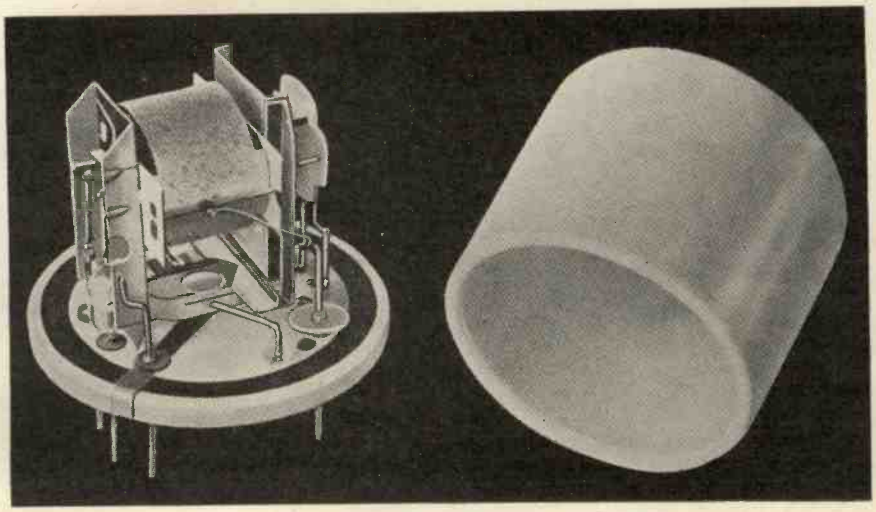


Fig. 6. Circuit diagram of complete frequency modulator.

Ceramics in Valve Construction

By R. HOWARD



A ceramic envelope valve of German construction

DURING the development of a U.H.F. generator it was found at frequencies approaching 3,000 Mc/sec. that the losses in the glass of the valve were considerable. The following notes are the result of an investigation into the use of low-loss ceramic material for the seals, with particular reference to the work which has already been done in Germany.

In that country developments have taken place in the manufacture of direct metal-ceramic seals and seals using glass as an intermediate material (Fig. 1). It would seem that the metal-ceramic seal is the better method, since the glass seal tends to reintroduce the losses, the reduction of which is the main object of the use of ceramic material.

A further disadvantage is that metal-glass seals, such as are used for the sealing of leads into ceramic valves, are very prone to cracking. Attempts have been made to overcome this particular difficulty by covering the whole of the base of the tube with a glass melt. It seems, however, that this is impracticable, and again defeats the original object by reintroducing the glass losses.

Nevertheless, the Steatit-Magnesia A.G. of Berlin have specially designed ceramic materials for the purpose of sealing to glass.

On similar lines the Glasswerk Gust. Fischer, a German glass-manufacturing company, have developed glasses for sealing to ceramics, notably "357," for sealing to "Calit" and "Calan," ceramics made by the Hescho Company and "Frequenta," and "Kerafar," made by Steatit-Magnesia A.G., and also "M Glass," for sealing to "Steatite," made also by Steatit-Magnesia A.G.

These glasses are somewhat harder than lead glasses, and have a coefficient of expansion of about 70×10^{7}* for "M Glass" and 66×10^{7} for "357." The coefficient of thermal expansion for natural steatite is $60-65 \times 10^{7}$.

These glasses are of some importance, for, while it is possible to do away with glass for sealing the leads into the envelope, the problem of sealing the valves on to a vacuum pump (to be referred to later) is still a large one.

To return to the problem of sealing leads to a ceramic envelope. Consider first the problem of a small tube, when glass is used as a sealing means. In most cases the lead is first wetted, and then jigged into position and sealed to the ceramic (see Fig. 1), in some cases in an atmosphere of hydrogen or other neutral pressure.

Hard glasses are mainly used for these small seals, as the soft glasses of similar coefficients of expansion to the ceramic prevent the effectual heating of all the materials to be interconnected, and create difficulties in the choice of materials to be used for the leads.

* See table on page 376

Where larger metal-ceramic seals have to be made, a more favoured method is that of shrinking the metal part on to the ceramic material and using glass as a means of making the joint vacuum-tight, rather than using it to make the joint itself (see Fig. 2).

Another type of seal, which again does not use glass as an actual sealing means, but more as a method for rendering the seal vacuum tight, can be seen in Fig. 3, in which the metal and the ceramic, or the two ceramics, form a butt joint around which a glass melt is formed, thus making the seal vacuum-tight.

A joint in which the glass actually does form the seal is shown in Fig. 4. The glass is used to join the ring of ceramic, which forms a ring seal, to the ceramic tube comprising the envelope.

While there are numerous disadvantages to the metal-glass-ceramic construction, such as fabricating problems, annealing difficulties, unreliability of seals, and, above all, greater losses at ultra-high frequencies, there is very little to be gained, except possibly in reduction of cost.

Now consider the other aspect of the problem, that of direct metal-ceramic seals. Metal-ceramic seals are in the main more expensive to manufacture, but they are not open to criticism on the same grounds as the glass seals. There is no increase in dielectric loss at ultra-high frequencies, they are not sensitive to critical temperature changes, and are therefore easier to de-gas, and are not prone to cracking or seepage and subsequent loss of vacuum.

There are two main types of metal-ceramic seals, the first being a coaxial type of seal very similar to the lead-in seals using glass, previously described, except that the actual sealing metal (in most cases silver) does not extend the whole length of the lead in the ceramic but is melted into a conical depression on the outside of the seal (see Fig. 5).

This method would seem to be rather a crude adaptation of prior metal-glass-ceramic seals.

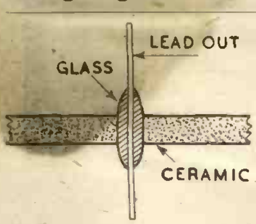


Fig. 1.

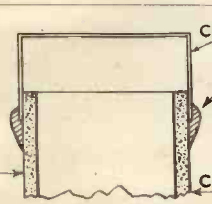


Fig. 2.

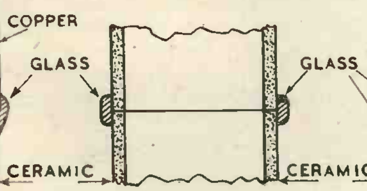


Fig. 3.

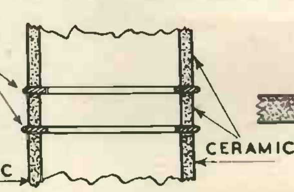


Fig. 4.

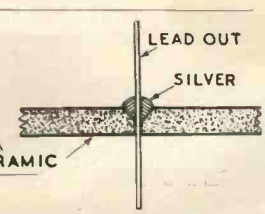


Fig. 5.

The other type of seal is more highly developed, and it is best to describe it in greater detail.

Dealing first with the problem of joining two surfaces of ceramic, a major consideration is that the two surfaces should fit as precisely as possible at the point of contact. A considerable improvement can be made in this respect by grinding the parts in.

An adherent layer of metal is then applied to the two faces, either by sputtering on in vacuum, by electroylisis, or by sintering powdered tungsten or molybdenum on to the surface of the ceramic.

Carbonyl iron has been suggested as an alternative to tungsten or molybdenum.

In the cases where the metal has been sputtered on in vacuum or applied by electrolysis, the mechanical stress of the joint between the metal and the ceramic may be too great if the thickness of the metal exceeds 0.1 mm. The layer must not, however, be so thin as not to fill the spaces which may be left, even after grinding.

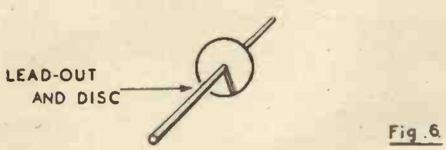


Fig. 6

The ground and metallized faces are now pressed together and raised to the melting-point of the metal used, thus forming a vacuum-tight joint. Alternatively, if it is not desired to heat the joint to a high temperature, a metal or solder with a much lower melting-point can be used to join the metallized faces. It is obvious that in the case of the tungsten or molybdenum surfaces it would be extremely difficult to use the first method.

It has been suggested that the actual metallic layer be used as the lead out, but this presents a number of difficulties.

A logical development of this method of sealing flat surfaces together is the following method of sealing a metal lead through the wall of a ceramic envelope, utilizing an annular disc attached to the conductor as the actual sealing means (see Fig. 6). A bush is formed at the place where it is desired to seal the lead through, with a hole through the centre of the bush of somewhat larger diameter than that of the lead-in.

The flat surface of the bush is metallized by any of the methods described.

The disc on the lead-in fits flush with the flat metallized face of the bush and is soldered to it, thus forming a vacuum-tight joint (see Fig. 7).

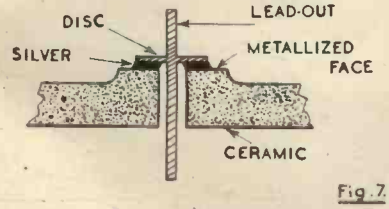


Fig. 7

The disc need not be an integral part of the lead, but may be soldered to it at the same time as the soldered joint to the ceramic is made.

In most cases this type of seal has been made, using a metal of similar coefficient of expansion as the ceramic itself, such as nickel-iron, using silver as the soldering means.

Usually, the soldering operation takes place in a non-oxidizing atmosphere.

There is no apparent reason why, for U.H.F. work, the annular disc should not be made of copper, provided that it is kept thin in cross-section. The whole lead, including the integral disc, could then be machined from a copper rod.

As a matter of interest it is worth while mentioning a method, primarily intended for use in large mercury-arc rectifiers, for sealing a metal lead insulated by a ceramic inset to a metal envelope. In this case the metal is soldered direct to the ceramic, without any prior metallizing whatsoever.

A metal tube is fixed projecting from the envelope (see Fig. 8), and a ceramic tube with an annular groove is fitted to the inside of the projecting metal tube. In a similar manner, a cap carrying the lead-in is fitted to the other end of the ceramic tube. The annular rings are filled with a solder such as silver, in a powder or wire form. The whole is then heated in a reducing atmosphere or vacuum, the solder taking to the metal and the ceramic, thus forming a vacuum-tight joint.

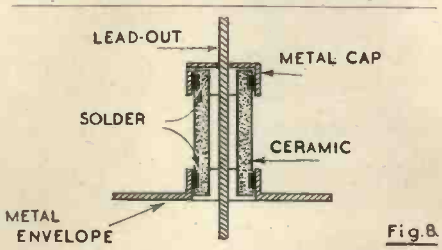


Fig. 8

At this point a more detailed description of the process is interesting. In the first place, the solder is melted in a vacuum (thus the ceramic part is degassed considerably). Bubbles of gas try to rise through the solder, but as soon as it is fully melted a neutral gas, such as hydrogen, is let into the furnace at a pressure of several atmospheres, thus increasing the surface pressure on the solder, which is immediately cooled. As soon as the solder is set the furnace is again evacuated, air only being admitted after the seal is quite cool.

In this way a seal is formed in which the gas bubbles in the solder itself are compressed to a very small volume at the point of contact between the solder and the ceramic, and the seal itself is thoroughly degassed.

Although the technique of sealing leads through the ceramic envelope has progressed considerably, there is still room for a great deal more development.

A further problem which has to be tackled is that of the exhaust tube. This problem can be approached in several ways. The most simple is to seal a tube of one of the specially designed glasses, to a bush on the envelope of the valve (see Fig. 9). This again, however, reintroduces certain undesirable factors into the manufacture of the valve.

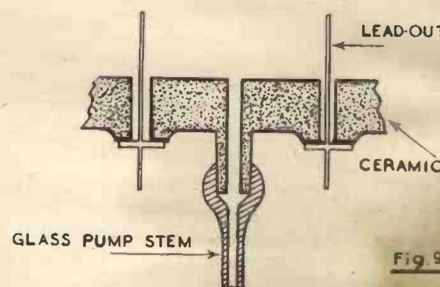
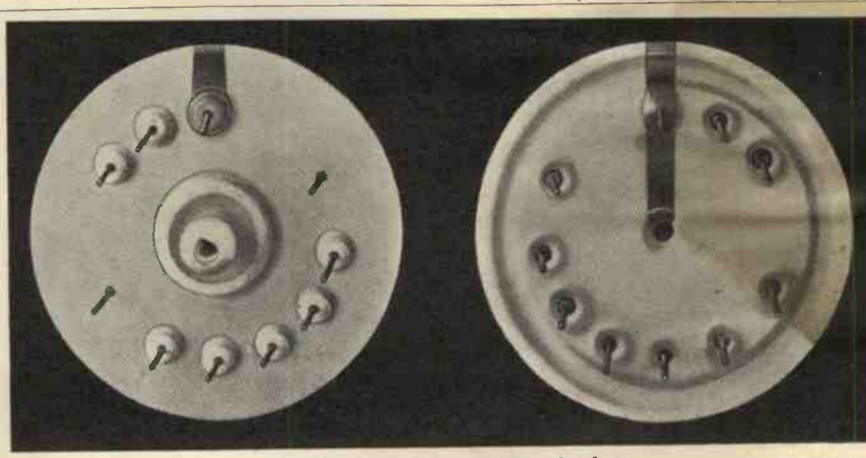


Fig. 9

Another method is that of placing the valve bodily in a container which is attached to the vacuum pump. The valve itself is then evacuated, either through an aperture which is covered by a mesh, or through the actual place where the seal will eventually be made.

When the tube has been exhausted, in the case of the tube with the meshed

(*Concluded on page* 376)



Examples of seals in ceramic valve base

Review of Progress in Electronics

V. — Photo-Electricity

By G. WINDRED, A.M.I.E.E.

" For many years it has been known that the incidence of high-frequency light on to the surface of a negatively charged conductor tended to precipitate a discharge, while Hertz showed that the incidence of the light on an uncharged conductor resulted in its acquiring a positive charge. These phenomena have been shown quite conclusively to depend on the emission of electrons from the surface of the metal, the electrons being set free in some way by the incidence of the light." —Sir J. H. Jeans, " Report on Radiation and the Quantum Theory " (Physical Soc.), 1924.

It was found by Heinrich Hertz[1] in 1887 that a negatively charged body lost its charge very rapidly when illuminated by certain kinds of light, whereas a similar positively charged body gave no such effect. Experiment showed that it was ultra-violet light which was particularly active in this way, and that light of longer wavelength had little or no effect upon ordinary metals.

These conclusions resulted from the work of numerous physicists, among whom may be mentioned Hallwachs,[2] who can be regarded as the pioneer in this field. It was natural that this discovery should stimulate further research with a view to determining the causes of the phenomenon, and a vast amount of work was accomplished in this connexion by the famous experimenters Elster and Geitel, who were the first to establish the definite principles of photo-electricity in an important series of researches[3] commenced shortly after the discoveries of Hertz and Hallwachs.

Since a negative charge of electricity can be regarded as an assemblage of electrons, it follows that loss of negative charge under the action of light, as in the photo-electric effect, must be due to removal of electrons from the material in some way. It is also evident that since light is the only active medium in this case it must be responsible for the ejection of electrons. Owing to the fact that the effect was noticed some time before the advent of the electron theory, there was considerable delay in the development of a definite theory. It was not until 1905, some eighteen years after its experimental observation, that a successful theory was developed.

General Theory

Experiment revealed the fact that certain metals showed the photo-electric effect with visible light, and after this discovery it became evident that the effect was likely to prove of considerable practical importance. These metals are the alkali metals, particulars of some of which are given in the accompanying table:

Metal	Symbol	Atomic Number	Melting Point °C.	Density g/cm³
Lithium	Li	3	186	0.534
Sodium	Na	11	97.5	0.970
Potassium	K	19	62.3	0.870
Rubidium	Rb	37	38.5	1.53
Strontium	Sr	38	800	2.60
Caesium	Cs	55	26	1.87
Barium	Ba	56	850	3.78

Owing to the great chemical activity of these metals, special processes are necessary in using them. The technique of photo-electric cell manufacture is consequently highly specialized.

Theoretical examination of photo-electric phenomena presents numerous problems for which it is difficult to provide consistent or satisfactory solutions without adopting the methods of modern theoretical physics. The photo-electric effect has consequently provided the physicist with an important subject, of which the major details have already been firmly established by his efforts.

For each particular substance there is a definite frequency of the incident light below which there is no observable photo-electric effect. This is called the threshold frequency of the substance, and is usually denoted by ν . On the basis of modern physical theory, it can be supposed that light-energy takes the form of a shower of light-quanta or photons, each having a definite amount of energy, which the quantum theory of Planck estimates as $h\nu$, where ν is the frequency of the light and h is Planck's constant, having the approximate value 6.55×10^{-27} erg. sec. The quantum theory therefore states that the energy of radiation of any kind is dependent only upon its frequency. It follows that light of short wavelength is the most effective from the energy viewpoint, and we should consequently expect this kind of light to give a stronger photo-electric effect for a given substance than would be produced by light of longer wavelength. This is actually borne out by experiment, and we have already noted that for a given substance it is necessary to employ light of more than a certain critical frequency in order to obtain the emission of photo-electrons.

If we suppose that it requires a certain definite amount of energy, say, E, to dislodge an electron from its normal location in a material, this dislodgment will occur only when the incident photon has energy of this amount, that is when the condition $h\nu = E$ is satisfied. Owing to interatomic and other restrictive forces, a certain additional amount of energy is necessary actually to expel the liberated electron from the boundaries of the substance so that for this condition we must have $h\nu > E$. Since modern physical theory shows that it is permissible to apply ordinary dynamical theory to a moving electron, we may equate the dynamical energy of the emitted photo-electron to the surplus of energy resulting from the incidence of a photon for which $h\nu > E$ in the following manner:—

$$\tfrac{1}{2}mv^2 = h\nu - h\nu_0$$

This equation assumes that the whole of the surplus energy is used up in endowing the electron with velocity. It accords very well with experiment, and has been used as a means of determining h for different substances. Experiments by Millikan in this connexion have yielded values of $h = 6.561 \times {}^{-27}$ for sodium and 6.585×10^{-27} for lithium. There seems little doubt that the effects are accurately represented by the foregoing theory, but their actual mechanism remains rather obscure, although several theories have been developed to explain photo-electric action. One of these is based on the radiation theory of Bohr,[4] which supposes that in the process of emitting radiation an atom shrinks to a different state. If we assume that the process is reversible, the incidence of a quantum of energy $h\nu$ on the atom will result in its expansion owing to the absorption of this energy.

Experimental Results

It is interesting to consider the relation between the total light-energy incident upon a photo-electric substance and the total energy represented by the emitted photo-electrons. This question has received the attention of Pohl and Pringsheim, who showed that the incident energy was always many times the energy of emission. In one case it was found that the total energy of the electrons emitted from a potassium surface was only some 2 per cent. or 3 per cent. of the light-energy absorbed. It seems reasonable to suppose that the remaining energy is expended on electrons which do not escape from the photo-electric substance, but actually there is no evidence to show that the whole of the absorbed energy is utilized in disturbing electrons.

Theoretical considerations of photo-electric emission have had important effects upon the theory of light. While it is possible to explain the phenomena of diffraction and interference only by means of the wave theory of light, this theory is incapable of explaining the phenomenon of photo-electric emission, which indicates that light is composed of discrete particles, each of which is possessed of a certain definite amount of energy depending upon the wave-length of the light. These particles, which we have called photons, appear to have a definite existence and are evidently indivisible, since a fraction of a photon is never revealed by experiment. It can be shown experimentally that the direction of the photo-electric emission under the action of plane-polarized light is affected by the polarization, so that the properties of light, in so far as polarization is concerned, depend upon the properties of the ultimate particles. These conditions can be explained only on the assumption of polarization of the photon, and lead to important considerations in the domain of quantum mechanics.[5]

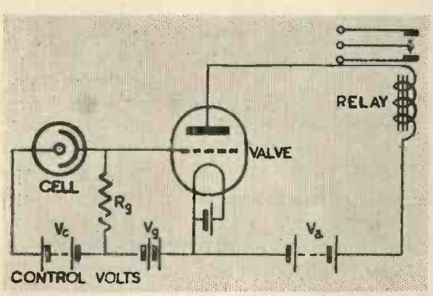


Fig. 2. Photo-cell circuit which operates relay when cell is illuminated.

It appears from experiment that the liberation of photo-electrons is practically simultaneous with the incidence of light. Experiments in this connexion give no evidence for the existence of any definite time-lag, and show that in the event of its existence it must be less than 10^{-3} seconds. Lawrence and Beam[6] have shown that any time-lag which may exist must be less than 3×10^{-9} seconds, both when the light is started and stopped. In this respect, the photo-electric effect is preferable to the photo-conductive effect for many practical purposes.

By enclosing the light-sensitive substance in an evacuated container, into which a gas is introduced at a suitable pressure, it is possible considerably to increase the sensitivity and other characteristics of the emission. The series of experiments in this connexion, which was initiated by the early work of Elster and Geitel,[7] has resulted in a detailed knowledge of such effects, especially with the alkali metals, and has given rise to the gas-filled photo-electric cell, which has played such an important part in recent development. The sensitivity of such cells can be greatly increased by subjecting their light-sensitive element to a discharge in hydrogen. This also has the effect of increasing the sensitivity to red light; the increase in some cases being such that the same emission as an ordinary cell can be obtained from the specially prepared cell with light of nearly double the wavelength. A valuable account of the photo-electric properties of thin films of the alkali metals when subjected to these sensitizing processes has been given by Campbell.[8]

(Courtsey of General Electric Company)

Fig. 1. Typical photo-cell.

Type of Cell

The construction of photo-electric cells follows one general principle, although numerous designs have been produced during its period of development. Two electrodes, one a photo-electric element with a coating of one of the photo-sensitive alkali metals producing electrons when illuminated, and the other a plain electrode for receiving these electrons, are contained in a glass envelope similar to that of an ordinary radio valve.

The envelope may be either evacuated or have a gas filling, according to the characteristics required. The presence of a gas filling increases emission, owing to the increased electron flow due to ionization of the gas. Owing to the marked chemical activity of the alkali metals, an inert gas such as argon, helium or neon must be employed in gas-filled cells.

Applications

The typical photo-electric cell differs from the selenium bridge not only in its principle of operation but also because whereas the selenium bridge will handle a current of several milliamperes the output of a photo-electric cell is expressed in microamperes. For the majority of practical purposes it is therefore necessary to amplify the output.

It is in this connexion that the thermionic amplifier, so well known to the radio engineer, has proved an invaluable auxiliary to the photo-electric cell. Owing to the sensitiveness of the thermionic valve to small changes or grid potential, it is possible to control the output of the valve by means of the minute current changes resulting from the action of a photo-electric cell.

Typical amplifying circuits for D.C. operation are shown in Figs. 2 and 3. In the first case, the connexions are arranged so that when there is no emission in the photo-cell, i.e., when the cell is kept dark, the full negative potential of the grid battery is applied to the grid of the valve. The circuit is arranged so that under these conditions the anode current of the valve is zero, or of too small a value to operate the relay. When the photo-cell is illuminated, electrons travel from the sensitive surface to the collector electrode. This migration of electrons has the effect of reducing the negative potential at the grid of the valve, and causes more anode current to flow. This increase of current energizes the relay winding, or whatever other kind of device is included in the anode circuit.

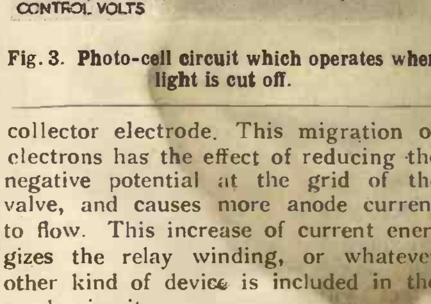


Fig. 3. Photo-cell circuit which operates when light is cut off.

In the case of Fig. 3 the conditions when the cell is dark are precisely the same as before; the full negative potential of the grid battery being applied to the valve grid. When the cell is illuminated, the electrons which travel from its sensitive surface increase the negative potential at the grid of the valve, and thus reduce the anode current. It follows that with this circuit it is possible to arrange that when the cell is dark sufficient anode current flows to operate the relay. The reduction of valve anode current upon illumination of the cell can then be made to release the relay. It will be evident that for mains operation, resistors may be used instead of batteries for obtaining the desired potentials.

When an A.C. supply is used, a circuit of the kind shown in Fig. 4 may

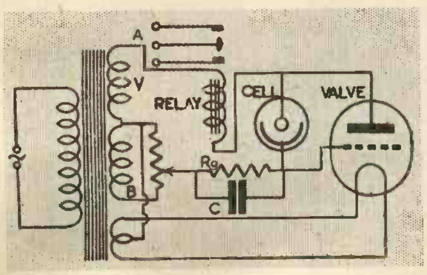


Fig. 4. Circuit for operation of cell from A.C. mains.

be employed. It will be noted that when the anode of the valve is positive, the grid is negative, owing to the fact that it is connected to the opposite end of the transformer winding. It is only when end A of this winding is positive that current can flow through the valve, so that rectified A.C. passes through the relay winding. When A is positive, the collecting electrode of the photo-cell is also positive, and consequently attracts the electrons which are ejected from the sensitive surface of the cell when the cell is illuminated. This migration of electrons causes the grid of the valve to become less negative, so that the anode current increases, and operates the relay. The object of the condenser across the grid resistance is to bring the phase of the grid voltage nearer to that of the anode voltage, so as to make the grid control more effective.

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5 P. A. M. Dirac, "The Principles of Quantum Mechanics," Oxford, 1930.
6 Phys. Rev., 29, 1927, p. 904.
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The Generation of Micro-Waves

(Continued from page 338)

RCA Company on developmental valves similar to the RCA 834[11], is plotted (in an attempt to make it more general) against an "index transit angle" θ i, where θ i is defined as the product of the operating angular frequency and the transit time at a low frequency between cathode and grid for the peak grid voltage. This transit time may be calculated from equation (6) or others in reference (6). By this method the transit time to the grid is represented by the angle θ i where the full period of the applied frequency is 360°. From the previous discussion it will, however, be realized that the generality of these curves is limited to valves having the same ratio for the transit times τ_1 and τ_2 as the ones used for this curve.

In the case of the oscillator, in addition to the loss of efficiency described above we have the effect mentioned in (e). With a typical U.S.W. oscillator circuit shown in Fig. 2a, where the anode and grid are connected across the end of a transmission line, there will exist a fixed phase difference of 180° between the grid-cathode and anode-cathode volts.

As the frequency is increased, the anode current will tend to lag behind the grid volts owing to transit time and, therefore, the required phase relationship for maximum efficiency is departed from to a greater and greater degree as the transit time is increased.

The result is that, quite apart from the extra power required to drive the grid circuit, a valve used as an oscillator will always have a lower efficiency than the same valve used as an amplifier, the actual extent of the drop in efficiency depending on the design and the values of the transit times. This is well illustrated by the second curve in Fig. 5, from which it will be seen that at 30 Mc when the valve as an oscillator stops oscillating, as an amplifier it will deliver nearly half of the low-frequency output.

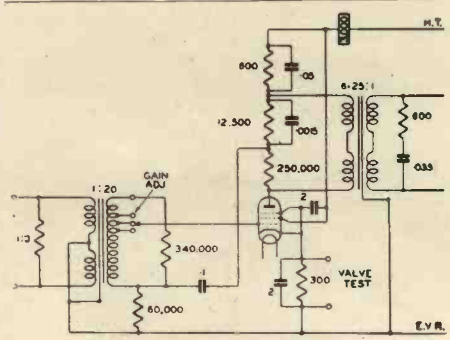
* The input signals present in oscillators and power amplifiers are, of course, much larger than assumed in the normal transit time loss theory, where they are assumed small compared with the applied D.C. voltages. Unfortunately, until recently the transit-time effects with large signals had only been treated in foreign periodicals; there has, however, now appeared an article in the English language on this subject.[18]

Notes: Figures refer to Bibliography to be given in concluding article.

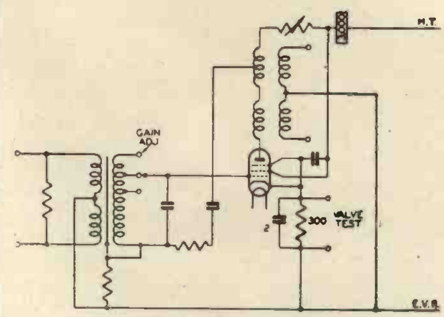
The New Post Office Repeater Amplifier

H. WILLIAMS, writing in the July issue of the *Post Office Electrical Engineers Journal* describes the design of a new repeater and amplifier intended to replace existing types for new work.

Most of the present repeaters incorporate attenuation-frequency equalisers, and both repeaters and amplifiers have a range of gain adjustment. In the new amplifier the correct output level is obtained by an attenuating pad and, where necessary, an equaliser is inserted so that the attenuation of each pair between repeaters is built out to 27 db.



(a) S.T.C. Circuit



(b) G.E.Co. Circuit.

Amplifier.—The amplifier, which has 30 db. maximum gain, was developed in its basic form by the Post Office Research Branch. Owing to differences in manufacturing technique, the two firms manufacturing the amplifier have produced differing circuit diagrams. (*See* Fig.)

The salient points of the S.T.C. amplifier are:

(1) The input impedance is obtained partly by the 1,800 ohm resistance on the primary and partly by the resistance across the secondary of the input transformer.

(2) The feedback is obtained by both series and parallel arrangements, the series portion being from the 600 ohms resistance in parallel with the 0.5 μF condenser and the parallel portion across the 12,500 ohm resistor.

In the G. E. Co., amplifier it will be noted that the details differ from those of the S.T.C. and that, in particular, the "voltage" feedback is obtained by a tapping on the output transformer.

The Technique of Receiver Measurements – Part I.

By G. T. CLACK

NOW that the design and construction of amateur transmitters has ceased for the present, more time can be spent on developing the receiving side of a station.

Many amateurs have probably wondered how their finished receivers compare with commercial products and whether they have obtained the maximum efficiency. Unless absolute figures are obtained an aural valuation of how it sounds does not carry much weight when it comes to making definite comparisons.

The intention of this article is to introduce to those who are not familiar with the subject of receiver measurements a few of the most used methods of recording receiver performance.

Some standards have been fixed upon which these tests are based and for those who are interested, two pamphlets have been published by the R.M.A.,* which deal in full with both electrical and acoustic measurements.

General

The standard frequency for test is 400 c.p.s. and the standard output is taken as 50 milliwatts in a resistive load connected across the speech winding of the output transformer. This resistance should be non-inductive and equal in value to the voice coil impedance at 400 cycles.

Sensitivity is expressed as the least number of microvolts or millivolts input at R.F. or L.F. to produce 50 mW in the output load. For R.F. sensitivity, the carrier input is modulated with 400 c.p.s. at 30 per cent.

There is a tendency to use an output reference level higher than 50 mW, for example, 250 or 500 mW. The reason for this is that it presents a better figure for signal-to-noise ratio in some locations where electrical interference is particularly bad and overrides the required 50 mW. level. When it becomes necessary to use a higher output, then the sensitivity E (in μV) for 50 mW output is obtained by:

$$E = \frac{E_2}{\sqrt{\frac{P_2}{50}}}$$

Where E_2 is the input in μV to produce P_2 mW output.

The input for P_2 must not be so high as to cause A.V.C. operation otherwise the relationship between input and output is not constant and an inaccurate figure for sensitivity will be obtained.

The apparatus required to carry out the described measurements is indicated below:

R.F. Signal Generator,
Output Meter,
L.F. Generator,
Harmonic Analyser
Attenuator box.

The R.F. Generator should cover the long, medium and short wave frequencies; the depth of the modulation must be 30 per cent. at 400 c.p.s. at all test frequencies. If the modulation depth is adjustable up to 100 per cent. it is an advantage as then, among other tests, signal diode (modulation amplitude) distortion can be measured.

The R.F. Attenuator must be calibrated to give a continuously adjustable output from 1 microvolt (or less) to 0.1 volt (or more). It must be correct to ± 10 per cent. up to 10 Mc/s., and ± 25 per cent. beyond 10 Mc/s.

The generator must also possess means whereby the R.F. output can be modulated at a known depth by externally applied frequencies for measuring overall response characteristics. This flexibility of operation is necessary to obtain absolute figures to conform with the R.M.A. specification.

Where the output attenuator is calibrated in arbitrary ratios, it can only be used to obtain comparative data. Despite this, most of the tests mentioned in this article can be carried out with the less expensive type of generator and definite information concerning selectivity, aerial and interstage gain, etc., can be obtained.

The L.F. Generator (invariably a beat oscillator) should have a range of about 50 to 10,000 c.p.s. and together with this there should be available some means of obtaining accurate measurement of voltage between 1 volt and 1 millivolt. This is usually accomplished with the aid of an attenuator resistance box which reduces the output voltage of the generator down to 1/1,000th or 1/10,000th of its original value. The attenuation is carried out in steps of ten, i.e., from 1 to 1/10th, 1/10th to 1/100th and so on, including intermediate points. When the attenuator is connected between generator and amplifier it becomes a simple matter to calculate the voltage input to the amplifier by multiplying the generator output volts by the attenuation figure.

To assist in visualising the sequence of testing, the circuit diagram of Fig. 1 shows a typical receiver. The figures given in the test are actually taken from such a set and can be used to provide comparative figures.

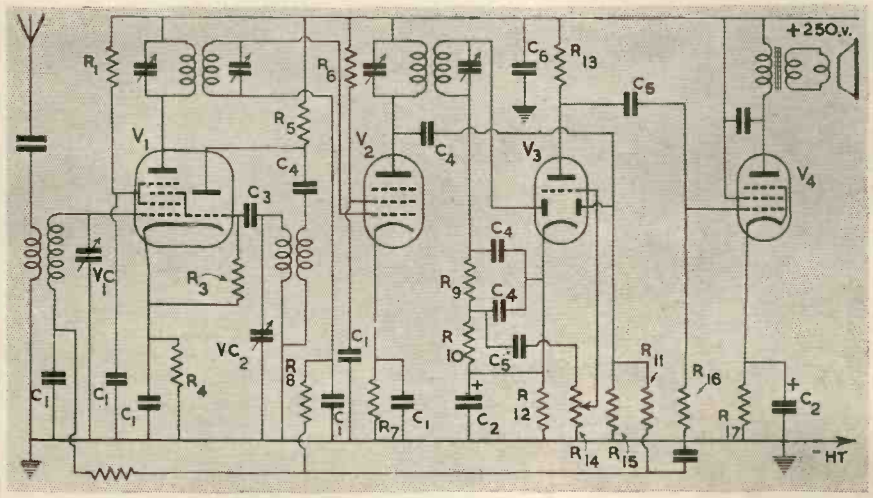


Fig. 1. Typical circuit diagram of a standard radio receiver.

Values of Components

C_1	0.1 mfd.	R_1	70,000 Ω	R_7	500 Ω	R_{13}	5,000 Ω
C_2	50 mfd.	R_2	1.0 meg Ω	R_8	1.0 meg Ω	R_{14}	0.5 meg Ω
C_3	500 pf	R_3	40,000 Ω	R_9	0.25 meg Ω	R_{15}	2.0 meg Ω
C_4	100 pf	R_4	100 Ω	R_{10}	0.5 meg Ω	R_{16}	0.5 meg Ω
C_5	.01 mfd.	R_5	30,000 Ω	R_{11}	1.0 meg Ω	R_{17}	200 Ω
C_6	8 mfd.	R_6	100,000 Ω	R_{12}	1,000 Ω		

V_1 = TH4B, V_2 = VP43, V_3 = TDD4, V_4 = PENA4

L.F. Output

The first test to carry out is one of L.F. sensitivity at the grid of the output valve (V4 in Fig. 2) and reference to the valve makers figures will provide a lead. For example, with the average

* Obtainable from the R.M.A., 52 Russell Square, W.1, price 2s.

2- to 4-watt output pentode, the figure given may be approximately 0.3 volt for 50 mW.; this value of voltage at 400 c.p.s. applied between grid and chassis should produce 50 mW. of audio output across the load.

This can be measured with the aid of an output meter connected across the speech winding, with the voice coil disconnected, and a reading taken direct in watts or milliwatts. Most meters can be adjusted to match any load from 2.0 to 20,000 ohms, and it is necessary to adjust the input impedance of the meter to replace that of the voice coil in use.

If a high resistance A.C. voltmeter is employed instead of the wattmeter, it can be connected across the primary winding of the output transformer in series with a condenser of about 2 mfd. (Fig. 3) or alternatively, directly across the load resistance connected to the speech winding.

It must be remembered that where all " electrical " tests are concerned, the speaker voice coil is disconnected and replaced with a resistance. This is done to prevent cone resonances modifying the results.

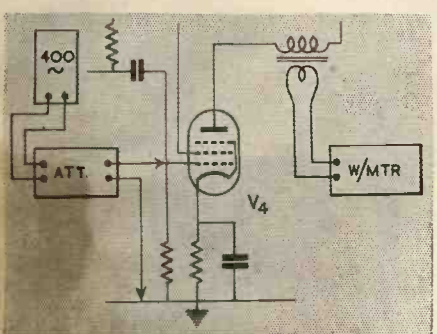


Fig. 2.

For a valve of the PENA4 class, about 0.3 volt input should produce 50 mW output, but in practice the sensitivity may be of the order of .4 or .5 of a volt. This can be due to variations in valves and/or in some cases transformer efficiency, which can vary so much in practice with different makes that it is difficult to give a definite figure.

The 400 c.p.s. signal from the L.F. Generator should be adjusted until the output reaches 50 mW. With an output wattmeter this is read directly, and with an A.C. voltmeter the power is calculated by $W = E^2/R$, where E is the measured audio volts across the transformer primary and R is the load presented by the transformer.

The transformer load should agree very closely with the optimum load figure of the valve if the maximum power output is required. For a PENA4 it is of the order of 8,000Ω so the voltage developed across the primary for the standard output is :—

$$E = \sqrt{8{,}000 \times .05} = 20 \text{ volts.}$$

Should the sensitivity be very much

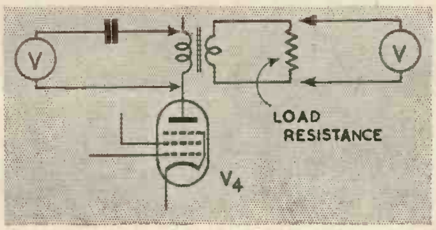


Fig. 3.

lower it will be necessary to check anode and bias potentials and if these are in order the output transformer may be suspected for either serious mismatching or shorted turns.

The simplest procedure for ascertaining the impedance offered by the transformer is to first measure the primary to secondary ratio by applying a known A.C. voltage to one of the windings and then measuring the induced voltage in the other. With the average output transformer it is quite in order to apply the full mains voltage (50 c.p.s.) to the primary winding and measure the volts across the secondary which are of a fairly low order, usually between 2 to 10 volts. The mains voltage divided by the secondary volts will give the turns ratio (N) of the transformer. Then knowing the voice coil impedance (Z_s) the primary impedance (Z_p) presented to the plate of the output valve is obtained by

$$Z_p = Z_s N^2$$

Power Output

For output power measurements the equipment normally employs a harmonic analyser and an output wattmeter connected as shown in Fig. 4.

The analyser is connected either to the primary or secondary winding and

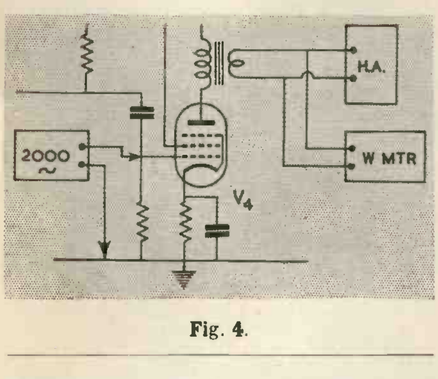


Fig. 4.

indicates directly the percentage of 2nd and 3rd harmonics contained in the output. The distortion does not vary very much with frequency, but if this test is carried out at about 1,000 to 2,000 cycles, a good idea of the average distortion will be obtained.

Few amateurs are in a position to obtain the use of such an analyser, but nevertheless power output measurements can be carried out almost as well with a high resistance A.C. meter and a cathode-ray oscilloscope. (*See* Fig. 5).

The input is adjusted until the peaks of the wave form seem on the C.R.O. just begin to flatten out a little (B). If the top and bottom peaks begin to flatten at the same time it indicates the transformer is fairly closely matched to the valve. The ideal wave form is that illustrated in A, but as output figures are based upon a tolerance of 5 per cent. (total 2nd and 3rd harmonic) distortion, it is permissible to adjust the input until there is just sufficient evidence (and no more) of departure from the ideal waveform, then

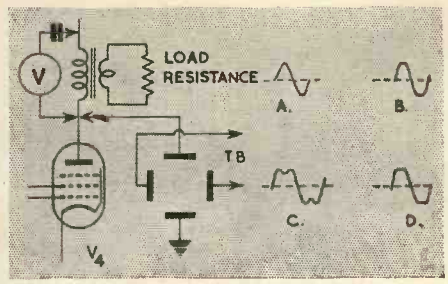


Fig. 5.

under these conditions the square of the voltage measured by the A.C. voltmeter, divided by the anode load of the valve will indicate the watts output. If the power is calculated for a condition as shown in C, it will contain a very high percentage of 3rd harmonic which is most undesirable. The other condition as illustrated in D is due to grid current as a result of excessive input.

If the valve will not deliver the full rated output, assuming H.T. and other potentials in order, then it is worth while arranging for the secondary winding to be tapped so that ratios above and below the calculated figure are available.

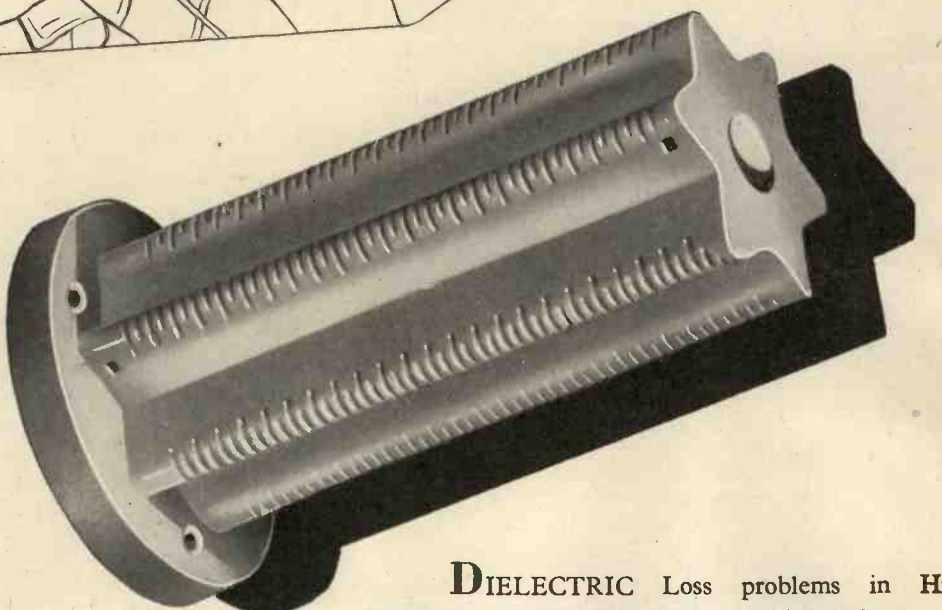
It then becomes a simple matter to select without question the ratio which gives the maximum output with the least distortion.

In the circuit diagram it will be seen that the 1st L.F. Amplifier is the triode portion of V_3, which also includes signal and A.V.C. diodes. The major portion of the L.F. gain takes place in the pentode stage (V4) which is approximately 40 times. With the values given for the coupling components in the anode of the T.D.D.4 (V_3) the gain for that stage is 20 times. It must be borne in mind that the slope of the triode is much less than that of the pentode which is $8^{ma}/v$ as opposed to $3^{ma}/v$ of the triode.

It is necessary to arrange the L.F. section so that the output valve overloads before the 1st L.F. stage, as this makes sure that at all times the maximum output can be realised with the minimum distortion from the previous stage.

(*Continued on page* 360)

"Everything O.K. Sir!"



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Electronic Engineering

DATA SHEETS VI, VII & VIII

On the Resonant Length of Capacity Loaded $\frac{1}{4}$-Wave Transmission Line

WITH the more extensive practical application of wavelengths below 3 metres the use of transmission lines as circuit elements has become much more important. The reason for the superiority of transmission line elements is two-fold: (a) with the normal type of inductance the radiation loss, which increases rapidly with frequency, soon becomes excessive and the dissipative loss also becomes high. Both these losses may be greatly reduced with a properly designed transmission line; (b) at very short wavelengths the inductance required is so small that it becomes difficult to provide sufficient coupling to it. A suitable transmission line enables increased coupling to be obtained.

One of the most common applications is that where the line forms with its termination an anti-resonant circuit, as for example when a line is used as the tuned circuit of an oscillator, or when a line acts as the tuned circuit between the aerial and an amplifying valve or diode. In both the above examples a line is terminated at one of its extremities by a reactance in parallel with a resistance, and in most cases the reactive loading is capacitative.

It is the object of this month's and next month's Data Sheets to provide charts by means of which the length of line required to resonate with a given capacity may be easily calculated.

The sending end impedance Z_s of a transmission line (Fig. 1a) with uniformly distributed constants is given by

$$Z_s = \frac{E_s}{I_s} = \frac{Er + Ir\ Z_0 .\ \tanh pl}{Ir + (E_r/Z_0)\tanh pl} \quad \ldots \quad (1)$$

where l is the line length and p is the Propagation Constant and

$$p = \sqrt{(R_0 + j\omega L_0)\ (G_0 + j\omega C_0)} \ldots \quad (2)$$

As at high frequencies with low-loss air dielectric lines $\omega L_0 \gg R_0$ and $G_0 \ll j\omega C_0$ we can write

$$p = \alpha + j\beta \quad \ldots \quad (3)$$

where $\alpha = R_0/2Z_0$ = the attenuation constant per unit length of line ... (4)

$\beta = 2\pi/\lambda$ = the wavelength constant (5)

and βl = electrical length of line in terms of the wavelength λ.

If we now consider the case of a line shorted at the receiving end (Fig. 1b) we have $Er = 0$ and $Z_s = Z_2 \tanh pl$ (6)

r when α is very small

$$X_s \approx j\ Z_0 \tan\beta l \quad \ldots \quad \ldots \quad (7)$$

From equation (7) it will be seen that a shorted line provides an inductive reactance for line lengths between

$$\beta l = \pi(n) \text{ to } \tfrac{1}{2}\pi(1 + 2n) \quad \ldots \quad (8)$$

and a capacitative reactance for line

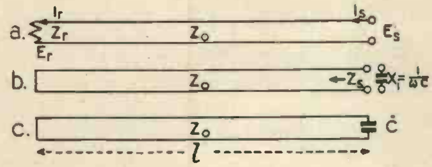


Fig. 1.

LIST OF SYMBOLS

R_0	Resistance in ohms per unit length of line.
G_0	Leakage conductance in mhos per unit length of line.
L_0	Inductance in henries per unit length of line.
C_0	Capacity in farads per unit length of line.
Z_0	Characteristic Impedance of line in ohms.
Z_s	Sending end impedance of line in ohms.
Z_r	Load Impedance at receiving end of line in ohms.
E_s, I_s	Voltage and current at sending end of line.
E_r, I_r	Voltage and current in load Zr.
p	Propagation Constant $(=\alpha + j\beta)$
α	Attenuation Constant $(=R_0/2Z_0)$.
β	Wavelength Constant $(=2\pi/\lambda)$.
λ	Wavelength.
l	Line length.
C	Terminating capacity of line in farads.
ω	$= 2\pi f$.

λ, l and the line constants must be expressed in the same units throughout.

lengths between

$$\beta l = \tfrac{1}{2}\pi(1 + 2n) \text{ to } \pi(1 + n) \quad (9)$$

Also the reactance is infinite for

$$\beta l = \tfrac{1}{2}\pi(1 + 2n) \quad \ldots \quad (10)$$

and the reactance is zero for

$$\beta l = \pi(1 + n) \quad \ldots \quad (11)$$

where n is any integer (n = 0, 1, 2, 3, etc).

This is illustrated by the full line curves on Fig. 2 which is a plot of equation (7). Expressing βl in terms of λ we have a line acting as an inductance for line lengths between 0 and $\lambda/4$, and also between $\lambda/2$ and $\frac{3}{4}\lambda$, etc.

Now in order to produce an anti-

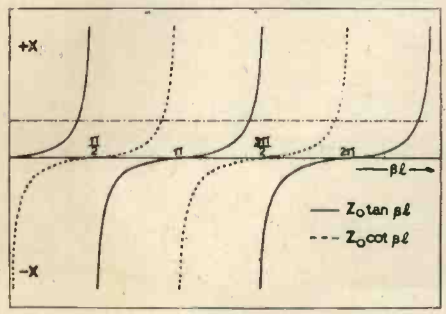


Fig. 2.

resonant circuit from a line terminated at its sending end by a condenser of capacity C, we have to adjust the length of line so that the resulting sending-end reactance is infinite.

If the reactive component of Z_s is written as $(\pm\ jX_s)$ and the reactance of $C = -j/\omega C = -jX_s$ then it is required that

$$\frac{-jX_1\ (\pm jX_s)}{-jX_1 + (\pm jX_s)} = \text{infinity} \quad (12)$$

This relation can only be satisfied if

$$jZ_0 \tan \beta l = jX_s = jX_1 \ldots \quad (13)$$

i.e., the line acts as an inductance.

$$1/\omega C = Z_0 \tan \beta l = Z_0 \tan (2\pi l/\lambda) \quad (14)$$

As we are interested in the line length "l" required to satisfy (14) we write

$$l = \lambda/2\pi\ (\tan^{-1}(1/\omega CZ_0)) \ldots \quad (15)$$

In line work one generally visualises line dimensions in terms of fractions of a wavelength; it is, therefore, more convenient to express equation (15) entirely in terms of the wavelength λ of the applied signal rather than its frequency, and also for short wavelengths to express both λ and l in centimetres. Equation (15) then becomes

$$l = \lambda/2\pi .\ \tan^{-1}(\lambda/(5{\cdot}3\ C\ Z_0))\ \text{cms.} \quad (16)$$

where l and λ are in cms., C in $\mu\mu$F and Z_0 in ohms.

In Data Sheet 6 Equation (15) has been plotted over a wavelength range of $7\frac{1}{2}$ cms. to $52\frac{1}{2}$ cms. in the form of a series of curves for values of the product C Z_0 between 0 and 800 ohms x $\mu\mu$F, while on Data Sheet 7 a wavelength range of 40 to 260 cms. is covered for C Z_0 values between 0 and 4,000 ohms x $\mu\mu$F. In both Data Sheets the length given is that required to produce an anti-resonant quarter-wave line. If it is desired to employ a $\frac{3}{4}\lambda$ line or a $5\lambda/4$ line it is only necessary to add to the line length given by the curves a length equivalent to $\frac{1}{2}\lambda$ cms. or λ cm. respectively.

Equation (16) may be converted into a more general form by expressing the line length as a fraction of a quarter wavelength: $l/\frac{1}{4}\lambda$ =

$$2/\pi .\tan^{-1}((\lambda/C) \div 5{\cdot}3Z_0)\ \text{cms.} \quad \ldots \quad (17)$$

by plotting $l/\frac{1}{4}\lambda$ in terms of the factor λ/C for different values of Z, it is possible to produce a universal set of curves applicable to any wavelength. Such a set of curves is given on Data Sheet 8, from which curves such as shown on Data Sheets 6 and 7 may be computed for any other wavelengths with the minimum of labour.

In next month's issue examples of the use of Data Sheets 6, 7 and 8 will be discussed, together with the question of the effective length of the shorting link. The case of the open-ended line will also be treated.

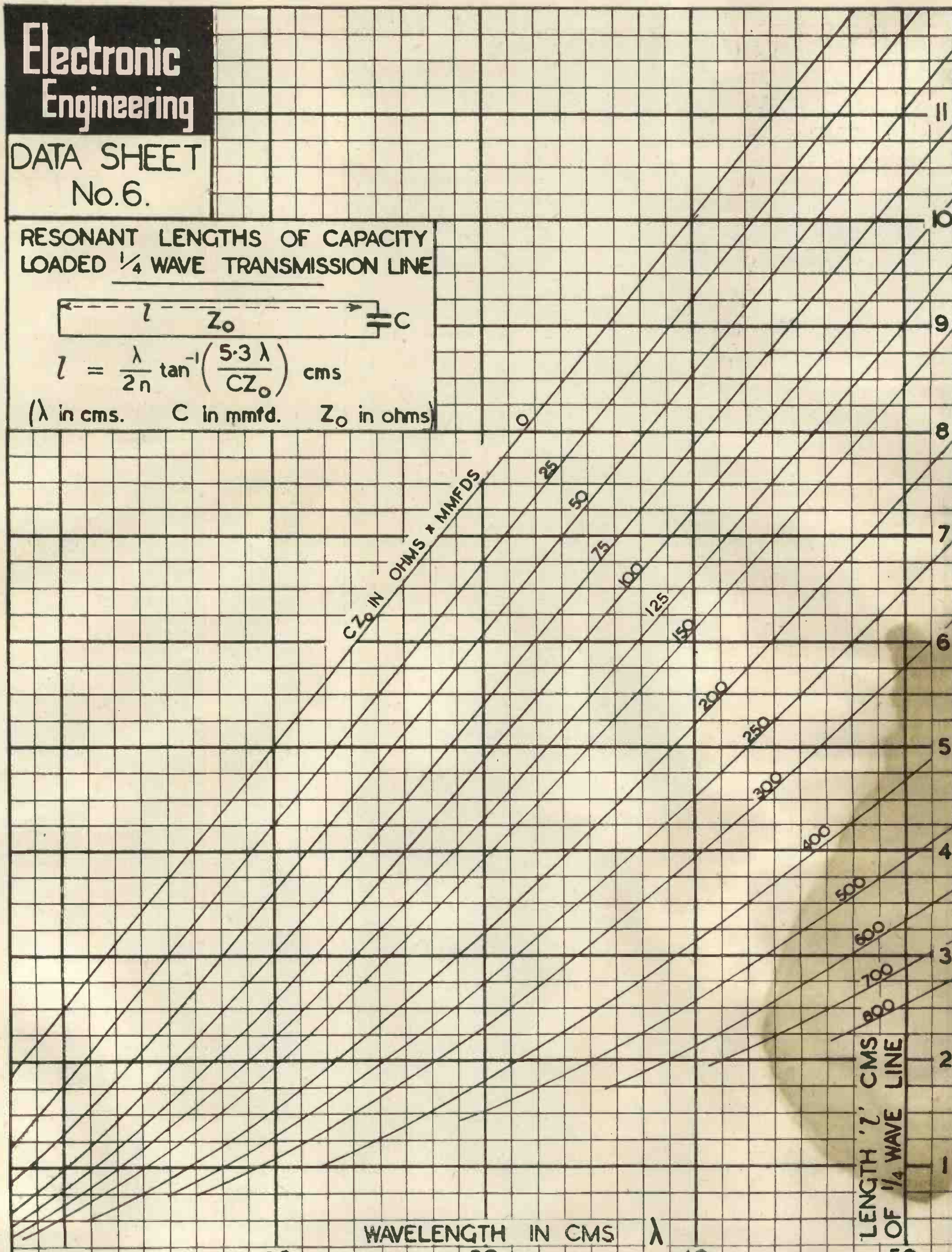
Electronic Engineering

DATA SHEET No.6.

RESONANT LENGTHS OF CAPACITY LOADED 1/4 WAVE TRANSMISSION LINE

$$l = \frac{\lambda}{2\pi} \tan^{-1}\left(\frac{5 \cdot 3\,\lambda}{CZ_0}\right) \text{ cms}$$

(λ in cms. C in mmfd. Z_0 in ohms)



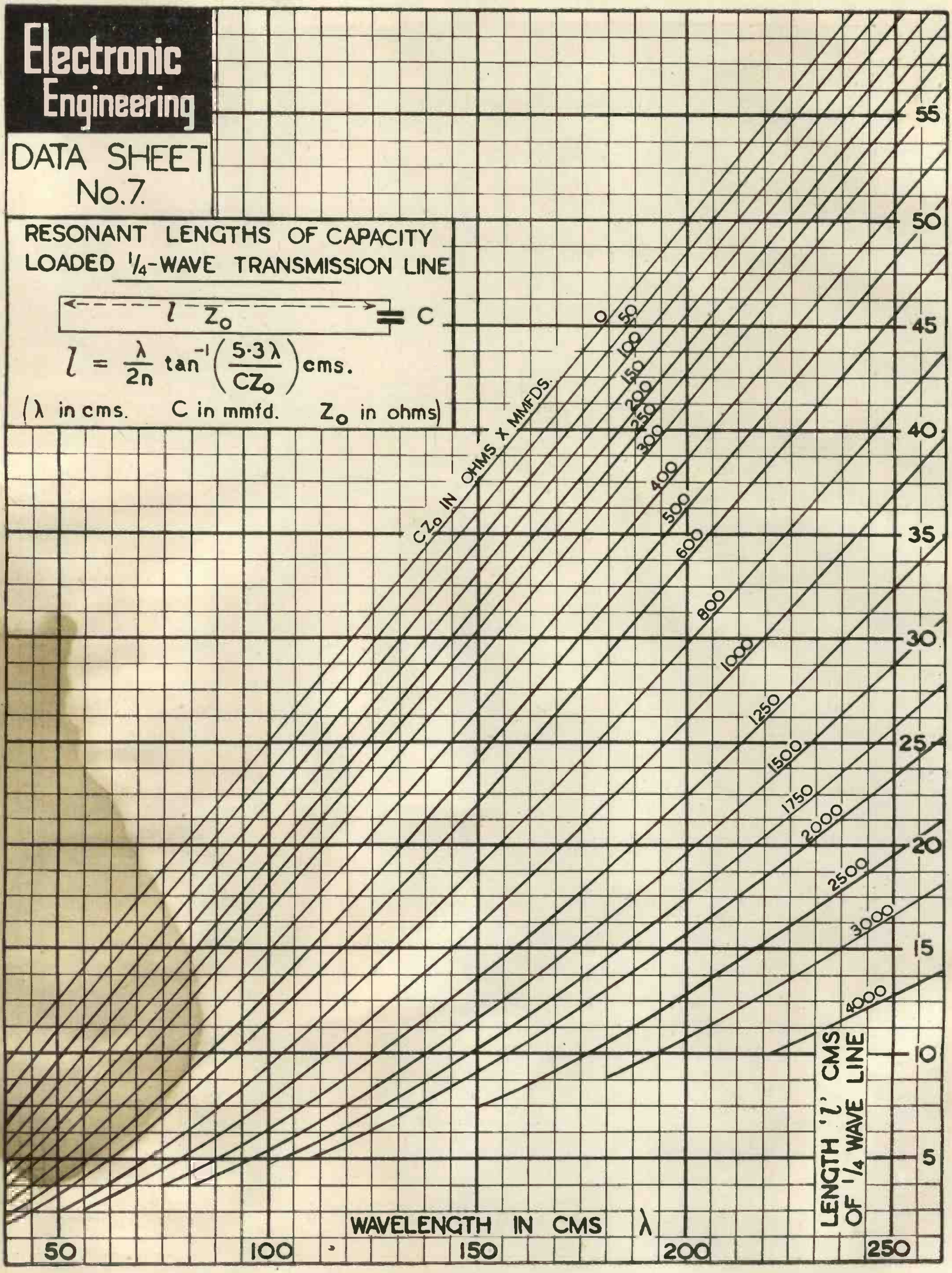
Electronic Engineering

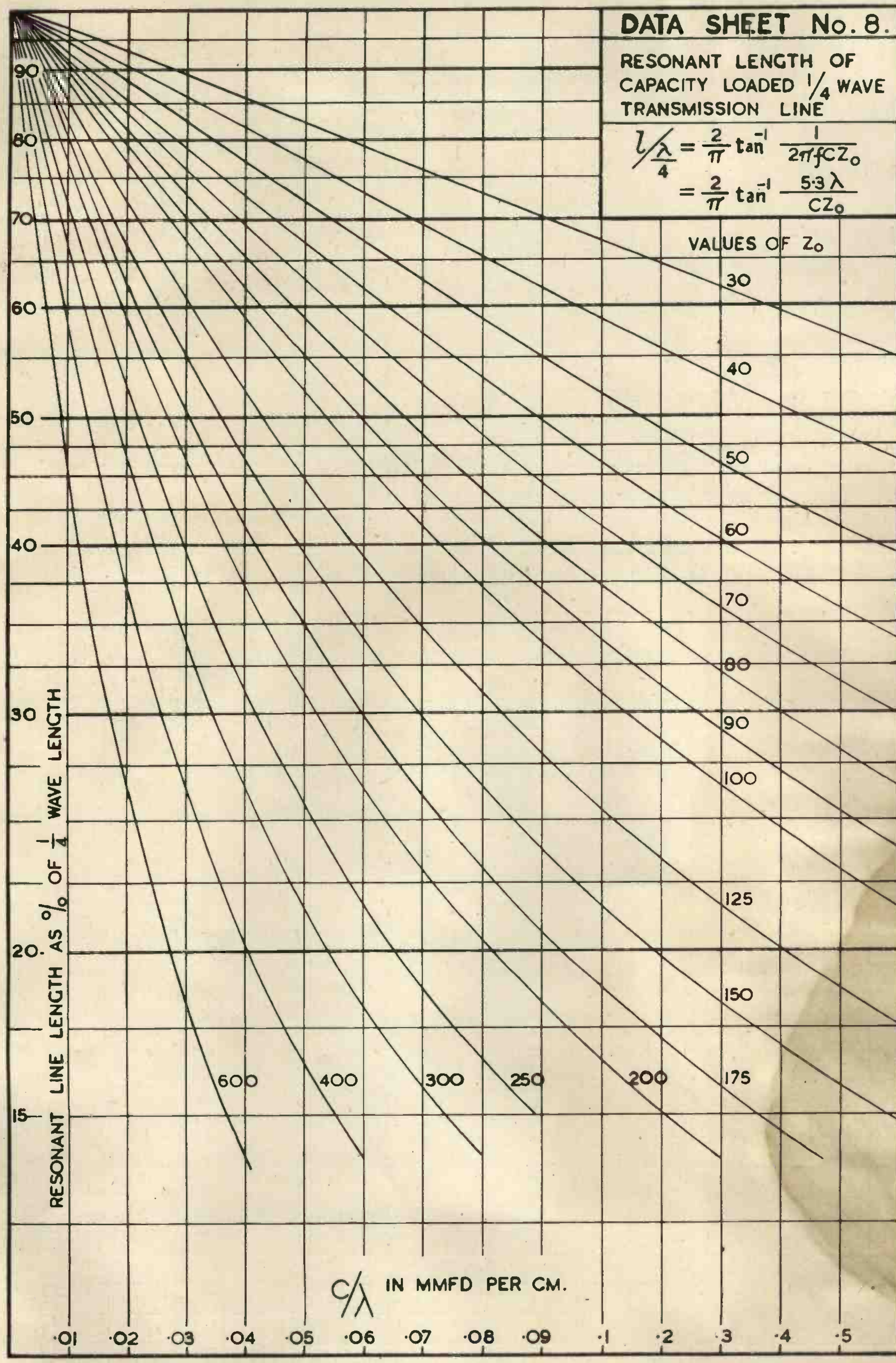
DATA SHEET No.7.

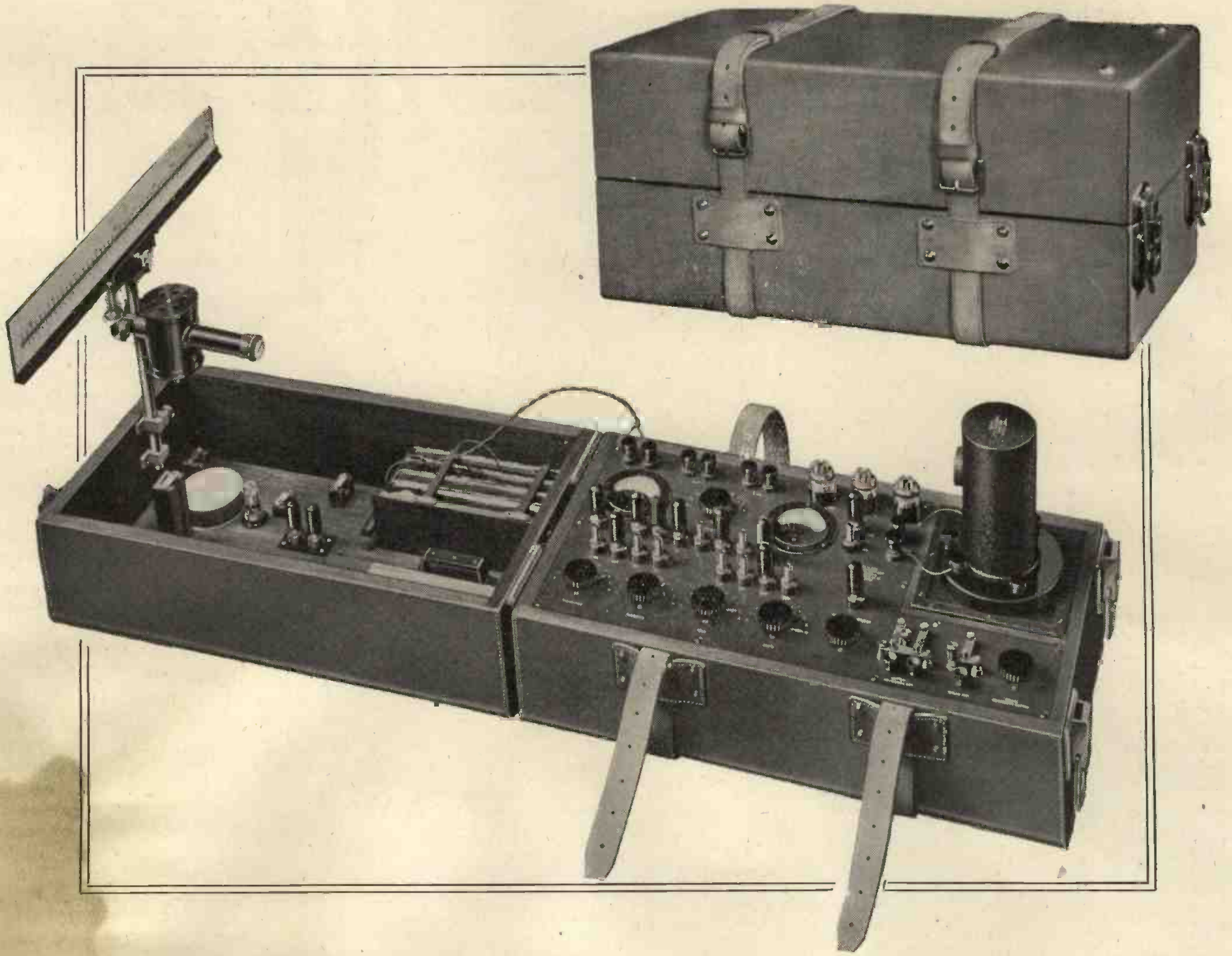
RESONANT LENGTHS OF CAPACITY LOADED ¼-WAVE TRANSMISSION LINE

$$l = \frac{\lambda}{2\pi} \tan^{-1}\left(\frac{5\cdot 3\lambda}{CZ_0}\right) \text{cms.}$$

(λ in cms. C in mmfd. Z_0 in ohms)




DATA SHEET No. 8.
RESONANT LENGTH OF CAPACITY LOADED 1/4 WAVE TRANSMISSION LINE
$\frac{l}{\lambda/4} = \frac{2}{\pi}\tan^{-1}\frac{1}{2\pi f C Z_0} = \frac{2}{\pi}\tan^{-1}\frac{5 \cdot 3\lambda}{C Z_0}$
VALUES OF Z_0
30
40
50
60
70
80
90
100
125
150
175
200
250
300
400
600
RESONANT LINE LENGTH AS % OF 1/4 WAVE LENGTH
90
80
70
60
50
40
30
20
15
C/λ IN MMFD PER CM.
·01 ·02 ·03 ·04 ·05 ·06 ·07 ·08 ·09 ·1 ·2 ·3 ·4 ·5



The Decibel : Does It Need Clarification ?

By W. BACON, B.Sc.

THE decibel is a very convenient and much used unit. Unfortunately, like many other much used things, a certain amount of confusion has arisen over its meaning and application. It is the purpose of this article to re-state as clearly as possible the nature of the decibel and to offer some suggestions for the clearing up of the confusion.

The bel is a measure of power ratio. If we have two powers W_1 and W_2 watts (or for that matter any other unit, provided it is the same in both cases) the first power is said to be $\log_{10} (W_1/W_2)$ bels "up" on the second power The bel is too large a unit for practical purposes; a unit one-tenth the size of the bel is hence used and is called the decibel.

Thus decibels (or db) $= 10 \log_{10} (W_1/W_2)$

The three fundamental points to be noted in the nature of the decibel are :

1. It is a measure of ratio. It does not express absolute values, though we may choose some datum value and express absolute values as db " up " or " down " on this.

2. It is logarithmic. Hence db are added where the quantities they represent are multiplied.

If we have powers W_1 and W_2, the second is $10 \log_{10} (W_2/W_1)$ db $= \alpha_1$ up on the first.

If we have powers W_2 and W_3, the second is $10 \log_{10} (W_3/W_2)$ db $= \alpha_2$ up on the first.

Hence W_3 is up on W_1 by $= 10 \log_{10} (W_3/W_1)$ db.

$$= 10 \log_{10} \left(\frac{W_3}{W_2} . \frac{W_2}{W_1}\right)$$

$$= 10 \log_{10} \left(\frac{W_3}{W_2}\right) + 10 \log_{10} \left(\frac{W_2}{W_1}\right)$$

$$= \alpha_1 + \alpha_2$$

i.e., the db are simply added.

3. It expresses the relationship between two powers.

In spite of the fact that the db is a power relationship it may be used to express voltage ratios in the following manner :

If we have a voltage V_1 and another V_2 both applied across R ohms then the respective powers are given by

$$W_1 = V_1^2/R \qquad W_2 = V_2^2/R.$$

Hence db up of W_1 on W_2 =

$$10 \log \left(\frac{W_1}{W_2}\right) = 10 \log \left(\frac{V_1^2}{R} . \frac{R}{V_2^2}\right)$$

$$= 10 \log \left(\frac{V_1}{V_2}\right)^2 = 20 \log \left(\frac{V_1}{V_2}\right)$$

This simple formula holds so long as the voltages are applied across resistances of equal value; if, however, they are applied across resistance R_1 and R_2 the expressions become more complicated.

$$W_1 = V_1^2/R \qquad W_2 = V_2^2/R$$

Hence db up of

$$W_1 \text{ on } W_2 = 10 \log (W_1/W_2)$$

$$= 10 \log \left(\frac{V_1^2}{R_1} . \frac{R_2}{V_2^2}\right)$$

$$= 10 \log (V_1/V_2)^2 + 10 \log (R_2/R_1)$$

$$= 20 \log (V_1/V_2) + 10 \log (R_2/R_1)$$

$$(\text{or alternatively} = 20 \log (V_1/V_2) - 10 \log (R_1/R_2))$$

These two cases are comparatively well known. A problem that is less often considered is that of two voltages acting across two impedances which are only partly resistive. The following relationship is then obtained :

$$I_1 = V_1/Z_1 \qquad I_2 = V_2/Z_2$$

$$\therefore W_1 = I_1^2 R_1 = \frac{V_1^2 R_1}{Z_1^2} \text{ and } W_2 = \frac{V_2^2 R_2}{Z_2^2}$$

$\therefore$ db up of W_1 on W_2

$$= 10 \log_{10} \left(\frac{V_1^2 R_1}{Z_1^2} . \frac{Z_2^2}{V_2^2 R_2}\right)$$

$$= 10 \log_{10} (V_1/V_2)^2 + 10 \log_{10} (R_1/R_2) + 10 \log_{10} (Z_2/Z_1)^2$$

$$= 20 \log_{10} (V_1/V_2) + 20 \log_{10} (Z_2/Z_1) + 10 \log_{10} (R_1/R_2)$$

It will be observed that putting $Z_1 = R_1$, $Z_2 = R_2$ reduces the formula to the previous one, and putting $Z_1 = Z_2 = R_1 = R_2$ reduces it to the original.

To illustrate the difficulties which arise in the application of db, consider the case of an amplifier used for P.A. work, and working from a pick-up. This has an input of very little power applied to a high resistance, and an output of considerable power which may be across any resistance, though generally one of a much lower order.

Various systems may be used to describe the amplifying properties of such a unit.

There is the atrocious one of " voltage db " = obtained by using the formula db $= 20 \log (V_1/V_2)$ and entirely neglecting any change of resistance. This has the sole virtue of showing the voltage gain of the amplifier, but is scientifically incorrect and fails to show the properties of the amplifier with regard to power—which is after all what we are trying to obtain. On the other hand, using the academically correct formula db $= 20 \log(V_1/V_2) - 10 \log (R_1/R_2)$ fails to give any idea of the voltage gain of the amplifier, though it does give correct information with respect to the power. The absurdities to which this formula can give rise may be seen by considering an amplifier of 50,000 ohms input impedance, 50 db true power gain. By simply changing the input potentiometer to one of 500,000 ohms the gain of the amplifier becomes 60 db, *i.e.*, it has apparently increased 10 db. Yet there would be no appreciable change in the real properties of the amplifier

One drastic way out of the difficulty is to throw dbs overboard and state the properties of an amplifier as : " a " volts through " b " ohms applied to the input will produce a power of " w " watts across " r " ohms. This is true and comprehensive, but cumbersome and not easy to use for comparison purposes. It also prevents easy calculation of the properties of amplifiers in series.

Author's Suggestion

A scheme which the author suggests as the answer to these difficulties is as follows :—

Decibels are divided into two parts and instead of saying, for example, 6 db, we might say 6 plus 3 db. For a given power the first figure represents the " db " up of the voltage on one volt, the second represents the " db " up of the resistance on one ohm. Thus for a voltage V across a resistance R

$$\text{db} = 20 \log V - 10 \log R,$$

or to take a practical example, 10 volts across 100,000 ohms gives :

db $= 20 \log 10 - 10 \log 100{,}000 = 20 - 50$.

In an amplifier both input and output would be rated in this way, *i.e.*, for input 10 volts across 100,000 ohms; output 100 volts across 100 ohms, the rating would be :

Input = 20 − 50 db.
Output = 40 − 20 db.

Subtracting the figures in the first column gives us the voltage gain of the amplifier, *i.e.*, 40 − 20 = 20 db. Subtracting the figures in the last column gives us the change in resistance, *i.e.*, − 20 plus 50 = 30 db. If we wish to know the true power gain of the amplifier we add these figures together and find it is 20 plus 30 = 50 db.

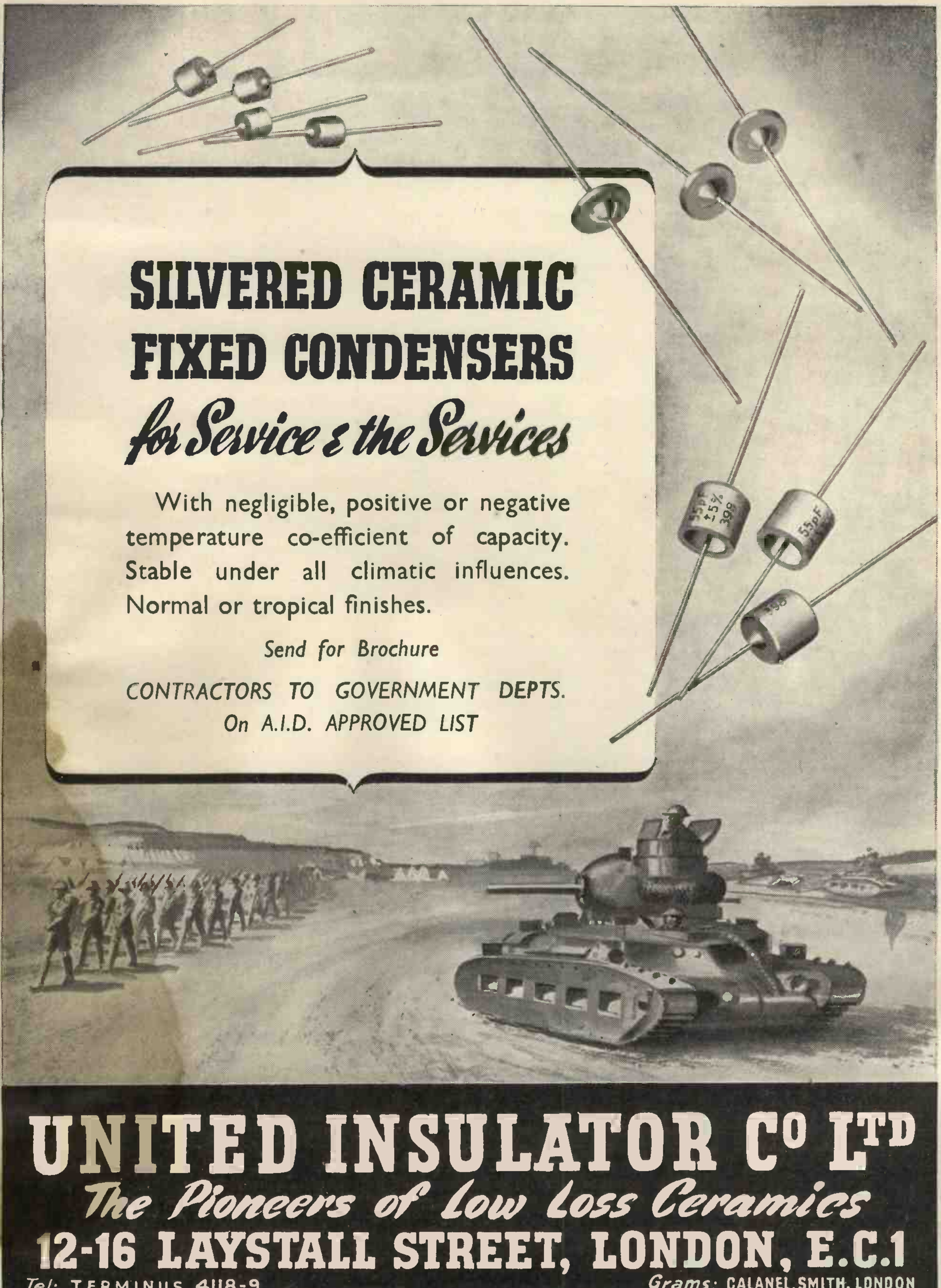
The significance of the sign is brought out in the second example of an amplifier with an input of 1.0 mV. into 100,000 ohms and an output into 0.5 ohms of, say, 10 volts.

The rate is then

Input −60 − 50
Output +20 + 3

and subtracting algebraically as before, the result is expressed as 80 + 53 or 133 for the true power gain.

(*Concluded on page* 358)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Grams: CALANEL, SMITH, LONDON

(*Continued from page* 356)

The system thus has the following advantages :—

1. It shows the absolute value of any power (as db above one watt, obtained by adding the two parts of the expression together), and also what voltage this represents applied across a given resistance. Thus we have an actual measure of the input sensitivity and output power of an amplifier.

2. It automatically analyses the performance of an amplifier, showing voltage gain, power gain, and input and output resistance.

3. It permits of the easy calculation of the properties of amplifying or attenuating units in series.

A further interesting application of this system is to the rating of transformers. A transformer of turns ratio T is rated as 20 log T db. Output voltage and resistance db may then be obtained simply by adding this value numerically to each of the input terms. For example, a transformer rated at 6 db, and having an input of 40 – 20 db would have an output of 46 – 26 db. Expressed conventionally this is equivalent to saying that a transformer with a step-up ratio of 2 has an input voltage of 100 and an output voltage of 200, with an input impedance of 100 and an output impedance of 400.

Editorial Note:—Proofs of Mr. Bacon's article were submitted to several radio engineers for comment. It is regretted that space only permits of two of the replies being printed this month. Further correspondence on this subject is invited and will appear in next issue.

DEAR SIR,—I was interested to read Mr. Bacon's article on the shortcomings of the decibel and of his proposals for reform. I am afraid, however, that these proposals will not receive the approbation of telecommunications engineers, who after all are the persons chiefly concerned with the decibel system.

The Bel (and decibel) were legalised as the international quantities at the Telecommunications Conference of Washington, 1927, although the decibel had been in use for some considerable time prior to that date under the name of Transmission Unit (T.U.) having been first used by the Bell Laboratories, and American Telephone & Telegraph Company. It is, therefore, well established and this is a good reason for leaving it alone if possible.

The prime function of the decibel is to express the attenuation of transmission circuits such as overhead lines and cables and in such use no difficulty regarding impedance arises as the impedance of a line or cable is usually the same measured in each direction. The db. in fact replaced the "Standard Mile of Cable" which was the quantity previously used to express transmission loss or improvement. A natural extension was to use the system to denote improvement due to the use of repeaters *i.e.,* amplifiers inserted in a transmission line to neutralise its attenuation). In these amplifiers the impedances of the inputs and outputs are designed to match the line and are usually identical so that it became convenient to denote the gain of repeaters in decibels. No difficulty need ever arise in the use of decibels if it is always borne in mind that they represent logarithms of power ratios. This is sometimes forgotten and people occasionally try and express in decibels quantities which have no power relationship, such as for example resistances. It is quite justifiable, however, to express voltages in decibels relative to some arbitrary voltage where the same impedance is involved in each case, as for example in denoting field strengths in decibels relative to 1 microvolt per metre. Thus a field of 10 microvolts per metre would be + 20 db.

Mr. Bacon refers to the fact that in public address equipment there is a wide difference between the impedance of the pick-up and the impedance of the loud speaker, which makes it difficult to assess the gain of the amplifier.

In telephone and commercial radio equipment it has become almost general practice to design equipment for an impedance of 600 ohms in the case of balanced circuits as this is a good average value for the impedance of open line circuits and cable circuits. In certain special cases where unbalanced, *i.e.,* coaxial circuits, are used, equipment is designed for an impedance of 75 ohms. Curves II and VI on Data Sheet No. 4 of your July issue illustrate this point. There would seem to be some advantage if manufacturers of public address equipment followed this example. This would mean that the pick-up would be combined with a transformer such that the secondary or output circuit presented an impedance of 600 ohms to line. Similarly the loud speaker would have a transformer integral with it having a primary circuit which presented an impedance of 600 ohms to line. All amplifiers would have input and output impedances of 600 ohms. Thus it would be possible to associate any pick up with any amplifier and any loud speaker.

This system is already largely used on commercial radio telephone receivers and in large transmission laboratories. A commercial traffic receiver is usually built in sections each section of the receiver proper being mounted on separate panels provided with break jacks and are all designed to have input and output impedances of 600 ohms, so that any section can be cut out at will and a substitute inserted by using cords and plugs, generally known as "patch cords," the process being referred to as "patching."

To illustrate the flexibility of the arrangement I may mention that I have seen, for test purposes, a long wave single side band receiver patched out in a few seconds to become a low power single side band transmitter simply by reversing each section in turn. The same arrangement with laboratory equipment confers great potentialities. It enables any two items of equipment to be connected without difficulty about matching their impedances. Thus large assemblies of equipment can be mounted on bays and then inputs and outputs brought to jack fields where easy interconnection is possible.

The adoption as far as possible of similar methods of building all equipment to standard impedances in other branches of light current engineering would, I feel sure, lead to simplification and economy in use which would justify the slight addition of expense involved.

One other point, Mr. Bacon in his letter speaks of so many decibels *up* or *down* on some quantity. I suggest it is better to say "plus x decibels or minus x decibels relative to a particular quantity." The signs indicate gain or loss.

—Yours faithfully,

A. J. GILL.

Engineer-in-Chief's Office,
G.P.O., London.

DEAR SIR,—When I was taught about radio, the all-powerful decibel had not achieved the popularity which it now enjoys. Consequently, it has never had the same effect upon me as upon some of the advertisement writers (particularly in certain types of journal) who bandy decibels about just as though they did know what they really were.

In its proper place, *i.e.,* when calculating land-line losses and the necessary repeater gains, etc., the decibel is a most helpful unit which can save a vast amount of labour. When, however, the gain of an amplifier intended for P.A. work is the only information given about it (except the price) it is high time to call a halt.

I do not know whether the P.A. engineer will take kindly to Mr. Bacon's suggestion whereby a row of figures replaces, say, "12 w. into 30Ω (addl. output @ 15 & 7.5Ω)" or whatever the amplifier output is, but time will tell. I fear that it will be a long time before the box containing an amplifier will represent anything else to me than something capable of so many max. undistorted watts output for which so many millivolts input (direct to grid) are required. The transformers, if any, at either end being replaceable without affecting the amplifier, are a separate subject to my mind, although naturally when they are included permanently information relative to them is of importance.

However, quite apart from my own feelings, Mr. Bacon's ventilation of this important subject, and particularly his effort to reduce confusion by showing the decibel "where it gets off" deserves every encouragement.—Yours faithfully,

P. G. A. H. VOIGT.

London, S.E.19.

Technique of Receiver Measurements (contd.)

This can be checked quite easily with a C.R.O. as follows:—

Inject a frequency, say 1,000 c.p.s., from the L.F. generator to the grid of the first L.F. valve (V3) and with the C.R.O. connected between plate of pentode and ground, or across the primary winding or secondary winding of the output transformer and increase the input until there are definite signs of distortion on the observed waveform. Then, leaving the input fixed, disconnect the C.R.O. from the pentode and connect it between anode and earth of V3. There should be no sign of distortion until the input is increased still further. Should distortion exist then it is possible that the distortion in the output is not due to overloading, but coming chiefly from the 1st L.F. stage. With R13 at 50,000Ω there is very little chance of distortion occurring in this stage until after the pentode V4 is well overloaded. In this instance V3 will handle up to 1.0 volt input without serious distortion and this means that about 20 volts of signal is available at the anode. As V4 requires about 7 volts at the grid for maximum output V3 will always operate with the minimum of distortion. Gain and signal handling capacity of V3 are controlled chiefly by the value of the anode load, so it is best to compromise and employ a value that will handle the highest input expected without distortion.

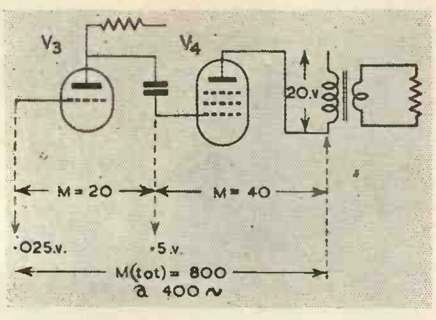

Fig. 6.

Sensitivity of the 1st L.F. stage is now measured by injecting a 400 c.p.s. signal into the grid of V3 and adjusting the input until a level of 50 mW is reached in the output load. For the receiver circuit shown in Fig. 1 this was in the region of .025 volt and this now enables to calculate the overall L.F. voltage gain (Fig. 6) to be calculated.

For an input of 25 millivolts to the grid of V3 an output voltage of 20 is produced, which shows a gain figure of 800 times and represents a fair figure for the valve combination.

It is now necessary to repeat the output power test, but this time with the 400 c.p.s. input applied to the grid of V3. There should be no complications and the earlier figure for output watts should be repeated for the same amount of distortion.

A last L.F. sensitivity test is taken at the signal diode. It will be seen in Fig. 1 that the diode load acts as a potentiometer and delivers only a part of the rectified R.F. voltage to the audio section of the receiver. The L.F. grid is referred (assuming the volume control set to maximum) to the junction of R9 and R10, so the L.F. sensitivity is in effect reduced and dependent upon the ratio of R9 and R10. For the valves shown only one half of the rectified signal is amplified. An L.F. sensitivity measurement taken by injecting 400 c.p.s. between signal diode anode and chassis was found to be about 50 mW, thus confirming the ratio between the filter R9 and the combined effect of R14 in shunt with R10.

Much can be said about the diode load values and its effect on fidelity, but readers are referred to the many publications that deal at length with this subject.

Briefly there are two points to consider, one is the modulation impedance offered by the diode load between anode and cathode and the other is the D.C. resistance to the rectified carrier. The capacitance in the diode circuit controls the modulation impedance and when this impedance falls below a particular value, set by the diode C.R. constants, distortion occurs on a deeply modulated carrier. It is desirable, if possible to keep the ratio between the D.C. and A.C. impedance as low as possible as then no serious distortion will occur.

A test to ascertain the maximum depth of modulation that the diode will handle without distortion is to apply about 1 volt modulated R.F. or I.F. to the receiver and examine the output waveform on a C.R.O. First examine the waveform at a low level of modulation, say 20-30 per cent. then increase it until distortion is just beginning to show. The figure should not be less than about 80 per cent. if good quality reproduction is desired. This test can be carried out at various modulation frequencies, although it is with the higher frequencies that the diode modulation impedance falls.

Lewis's Technical Library

Messrs. H. K. Lewis, of 136 Gower Street, W.C.2, whose library of technical and medical books is well known to readers, regret to announce that owing to increased overhead expenses they have been compelled to increase the subscription rate to the library as from July 1.

Full particulars of their unique technical library service can be obtained from the address above. A free bi-monthly list of new books is sent free to subscribers and customers.

A C.-R. Tube Scanning Coil Assembly

A COMPACT scanning coil arrangement which is readily assembled round the neck of a cathode-ray tube is shown in Fig. 1 It has several advantages when it is desired to accommodate the coil system round a constricted portion of the tube neck as indicated.

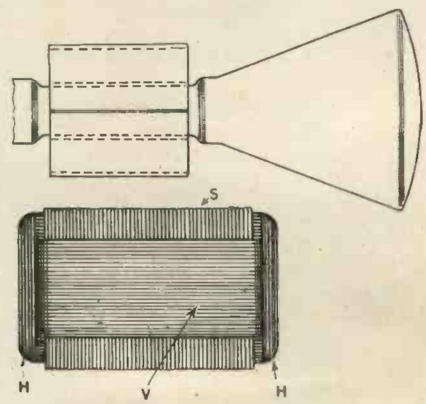

Fig. 1 (top) and 2.

The assembly consists, of a pair of horizontal deflecting coils of the well-known "saddle" variety, provided with a surrounding magnetic sheath on which are wound the vertical deflecting coils. The latter coils are connected so as to set up mutually opposing fluxes in the sheath and are arranged in the spaces between the longitudinal portions of the saddle coils. Ready assembly of the system is achieved by making the sheath in two halves with one vertical scanning coil wound on each half. The saddle coils are thus first placed in position on the neck of the tube and the halves of the sheath carrying the vertical scanning coils can then be fitted compactly over them.

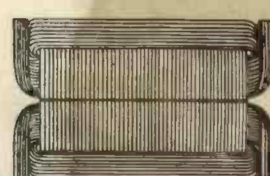

Fig. 3.

Figure 2 shows a plan view of a single saddle coil, H, with one of the halves of the sheath, S, and one vertical scanning coil, V, wound on it placed in position over the saddle coil. Figure 3 shows a side elevation of the whole assembly.

—R.C.A. Laboratories.

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An Improved Interference Suppressor

A RECENT development reported from the R.C.A. Laboratories describes an effective method for eliminating interference in radio or television. An important advantage of this method is that the suppressing action is not affected by variation in the strength of the desired signals.

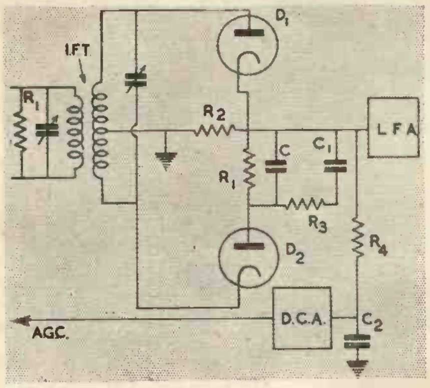


Fig. 1.

Figure 1 shows how the method may be applied in the sound channel of a television receiver. The diode D_1 is the usual signal demodulator, and diode D_2 functions as a peak rectifier in conjunction with the resistance-capacity combination R_1C in its anode circuit so that the potential of its anode just follows the modulation envelope, as indicated by the dotted curve in Figure 2, and never in normal circumstances becomes fully conducting. In the presence of an interference pulse, however, it conducts to an almost identical degree with diode D_1 with the result that practically no interference potential is built up across the load resistance R_2, the two pulse currents flowing in opposition in this resistance. Thus, with this circuit all interference pulses exceeding the amplitude of the carrier envelope are practically entirely balanced out.

It is, of course, necessary to choose the time constant R_1C correctly to obtain this result. It must be long compared with the duration of a pulse, but sufficiently short for the circuit to be able to follow the modulation. In order to avoid lengthening the incoming interference pulses it is necessary to damp the I.F. transformer IFT by the resistance R_1 in order to obtain a pass band considerably wider than the frequency band occupied by the sound channel. In the case of a television receiver having a sound channel frequency band between 60 and 8,000 cycles, the I.F. channel is designed to pass a frequency band 200,000 cycles wide, the resistance R_1 is made equal to 20,000 ohms and the condenser C is made equal to 100 mmfds.

If some attenuation of the higher frequencies can be tolerated, the time constant of the R_1C biasing circuit may be increased so that the bias ceases to follow the modulation envelope at these frequencies. In this case, there will be some loss in the higher frequency components of the sound signal fed to the low-frequency amplifier LFA, but the amount of interference energy fed to that amplifier will be still further reduced. The resistance R_3, which may be of 100,000 ohms, is shown connected is series with the condenser C_1 of 0.025 mmfds. and in shunt with resistance R_1, and condenser C, and may, if desired, be variable so as to provide an adjustable tone control.

Unless a tone control adjustment is desired which will lower the high frequency response, it is preferable that the condenser network should have a sharp cut-off just above the highest modulating frequency. For most purposes a simple R.C. network meets this requirement, but the use of an inductance coil L in the bias network may be desirable to increase its sharpness of cut-off if the network time constant has been made small enough to enable the bias to follow the sound envelope more or less closely. In certain cases a network consisting of inductance coils and a condenser only may be desirable.

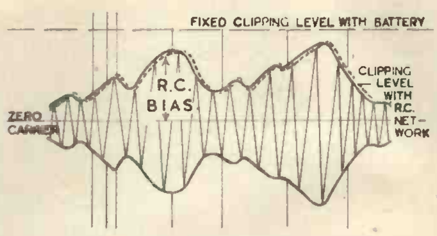


Fig. 2.

The potentials set up across the resistance R_2 may be used to obtain automatic gain control in the usual way, a filter comprising resistance R_4 and condenser C_2 being provided together with a D.C. amplifier which reverses the polarity of the gain control voltage before it is applied to the I.F. stages.

It will be appreciated that even if the bias applied to the diode D_2 only follows the D.C. and low frequency variation in the rectified current of diode D_1, some advantage is obtained, since the level at which limiting takes place will be automatically adjusted as the mean amplitude of the received signal varies due to fading, etc. In the case of television picture signals, the bandwidth is so wide that if the bias were arranged to follow the picture signals, it would also tend to follow the interference pulses and the limitation would not be very effective, and in order to obtain some useful limitation the circuits in which the bias is developed are arranged to respond only to D.C. and very low frequency signals, comparable with the frequencies to which A.V.C. circuits are usually responsive.

Figure 4 shows a circuit suitable for use in a vision channel and with the

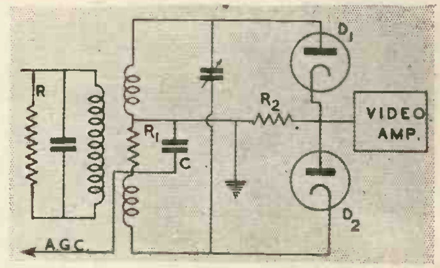


Fig. 3.

American type of waveform in which synchronising pulses correspond to maximum carrier wave amplitude. Instead of choosing the time constant of the R_1C combination as already described, it is given as large a value as that which would be employed in a gain control circuit, so that the bias for opposing the current flow in the diode D_2 does not follow the carrier envelope, but instead varies only in accordance with the strength of the incoming signals. In this case, the tone control circuit may be omitted, and the gain control voltage may be applied directly from the junction point of the resistance R_1 and the cathode of the diode D_1 to the I.F. stages in the usual fashion. The circuit limits all impulses appreciably greater than the synchronising impulses.

As is usual in circuits required to pass peaky transients, the voltage supply filters in the I.F. amplifier, such as the control grid circuit filter, should be designed to have a very short time constant or a very long time constant in order to prevent " overhang " of interference pulses.

Fluorescent Lighting Saves Metal Scrap

Molybdenum, tantalum, stainless steel, and nickel scraps are being identified and separated positively and quickly by characteristic colour tinges appearing on the different metals under daylight fluorescent lighting.

Sheet molybdenum and tantalum, especially, look alike and cannot be separated by inspection. With fluorescent lighting, however, this method is so foolproof that these materials are now sold separately with a purity guarantee, where formerly tantalum pieces were interspersed with the rest of the mass which had to be salvaged and sold as mixed scrap.—*From Westinghouse Overseas Letter*, May, 1941.

Automatic Background Control of Television Pictures

THE July, 1940 number of ELECTRONICS AND TELEVISION AND SHORT WAVE WORLD* contained a brief note describing an automatic method of achieving background control of television pictures, but although the method described has the virtue of simplicity and produces the desired potentials, it cannot provide a wide range of values of background briliancy.

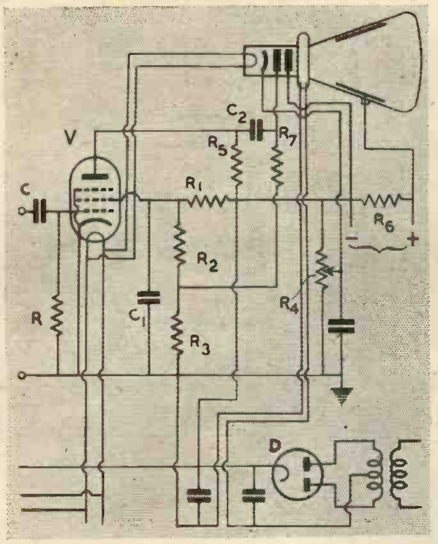


Fig. 1.

An improved method illustrated by the diagrams is now reported from the General Electric Company of America. The vision-signal amplifier V in Figure 1 having in its grid circuit the grid-coupling condenser C and grid leak R re-establishes by grid rectification a signal component at its grid which is dependent upon the background briliancy of the transmitted picture. From the anode of this valve vision signals are fed to the control grid of the cathode-ray tube, but on account of the coupling condenser, C_2, to this grid the background component in the signals is not supplied to the cathode-ray tube over this path. The background signal is, however, established separately in the screen grid circuit of amplifier V by virtue of the load resistance R_1 in the screen lead and the smoothing condenser C_1, and is fed to the control grid of the cathode-ray tube through the network of resistance R_2, R_3 and R_7 by which a steady bias is applied to the tube. Adjustment of this bias is effected by adjustment of the cathode potential of the cathode-ray tube by means of the potentiometer R_4.

Preferably, the resistance R_2 and R_3 are chosen so that the same change of potential drop occurs across resistance R_3 as occurs across the anode load resistance R_5 with change of overall briliance of the picture. In this way, the gain of valve V for the picture component applied to the modulator grid is the same as the gain for the D.C. or background component and these two components are thus maintained in their appropriate relationship.

Selection of the relative values of the resistances R_2 and R_3 to produce an increase or a decrease in the voltage drop across resistance R_3 enable the background changes to be exaggerated or they may be made sub-normal. Compensation may thus be effected for attenuation of the background component in the receiver preceding the valve V.

Suitable values for the components shown are as follows :—

Resistance	R_2	2.2 megohms.
,,	R_3	1 ,,
,,	R_1	56,000 ohms.
,,	R_4	10,000 ,,
,,	R_5	1,800 ,,
,,	R_7	zero
,,	C_1	.25 microfarads.
,,	C_2	.25 ,,

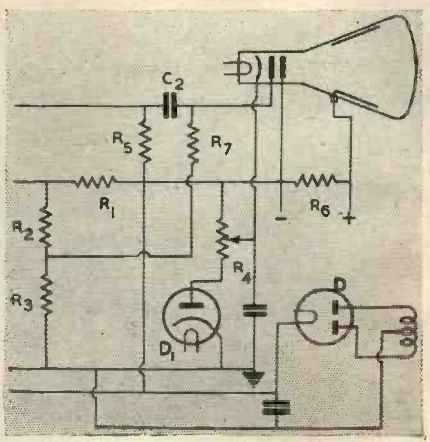


Fig. 2.

In the modified arrangement shown in Figure 2 the lower terminal on resistance R_4 is connected to earth through a diode D_1 so that during the initial heating up period of diode D_1, the resistance R_4 and hence the cathode of the cathode-ray tube is at the full potential of the rectifier D. The grid of the cathode ray tube is maintained near earth potential through resistance R_3 and it is strongly negative relative to its cathode. The beam is thus prevented from impinging upon the screen until the deflection circuits are in operation and the cathode of the diode D_1 is heated.

The arrangement of Figure 3 differs from Figure 1 in that the lower terminals of resistances R_4 and R_3 are connected to a point P which is negative with respect to earth. This arrangement is preferable when it is desired to operate the cathode of the cathode-ray tube at or near the potential of that of the valve V so that both cathodes may conveniently be heated from the same supply source.

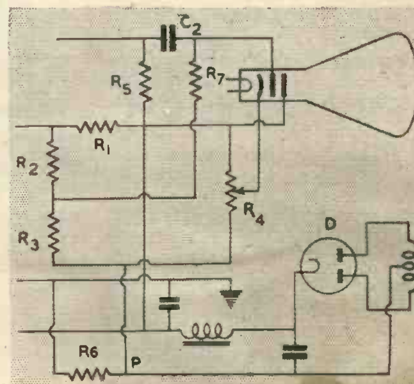


Fig. 3.

* Page 234.

A Standard Frequency Generator

The Hallicrafters Model H.T.7.

THE Hallicrafters H.T.7 Frequency Standard is an accurate instrument for checking frequencies throughout the broadcast range. It consists of a stable crystal oscillator providing either 1,000 kc or 100 kc output, together with a 10 kc multi-vibrator and a harmonic amplifier. By means of a switch on the front panel, harmonics of 1,000 kc, 100 kc or 10 kc can be selected. With the output of the frequency standard fed into the receiver, accurate marker frequencies spaced 10, 100 or 1,000 kc apart will appear across the dial in any frequency range up to 30 Mc.

The frequency of the 100 kc crystal is adjustable over a narrow range, so that it is possible to set its frequency to zero beat with a standard frequency transmission or domestic broadcast stations. A tuned circuit, placed at the output of the harmonic amplifier, increases the level of the higher harmonics.

The 1,000 kc frequency is ground to a tolerance of .05% and has a temperature coefficient of about 23 Mc/sec. per ° C. The 1,000 kc harmonics should be used only as markers to locate the even 100 kc divisions, and for accurate measurements the crystal switch should be placed in the 100 kc position.

In this position the crystal has a temperature drift of about to Mc/sec. per ° C. Temperature variations in normal service over several hours may cause frequency variations of approximately 50 parts per million.

The harmonics of the 100 kc oscillator become noticeably weak above 7 Mc. A harmonic amplifier with a tunable output circuit is therefore provided to raise the output level so that it will be usable through the 30 Mc band, and by setting the "Band Switch" to positions 2, 3, 4 or 5, and adjusting the "Output Tuning" control, a point will be found where sufficient output is provided for all checking purposes.

With the crystal switch set at the 10 kc position, a multivibrator, locked to crystal frequency, is connected into the circuit. This provides output signals which will be heard every 10 kc apart between the 100 kc points.

The presence of the 10 kc harmonics allows the standard to be set to zero beat with any domestic broadcast station if they are spaced 10 kc apart.

For greatest accuracy in measurement it is recommended that the unit be turned on and allowed to warm up for at least thirty minutes before using.

A Bliley resonator crystal in a new low capacity crystal holder with a double balance bridge circuit allows a high degree of rejection of unwanted

signal even when interfering signal is closely adjacent.

Specification

GENERAL COVERAGE

The frequency generator covers 43.5 to 0.54 Mc/sec. in four band positions as follows:

Band 1. 0.54-1.73 Mc/sec.
Band 2. 1.7-5.1 Mc/sec.
Band 3. 5.0-15.7 Mc/sec.
Band 4. 15.2-43.5 Mc/sec.

The band-spread calibration covers the 80, 40, 20 and 10-metre amateur bands.

The main tuning dial is translucent and illuminated when the generator is switched on. It is directly calibrated in frequency.

Cabinet dimensions: 19¼ in. wide, 9½ in. high, 10⅛ in. deep.

List of Components

RESISTORS

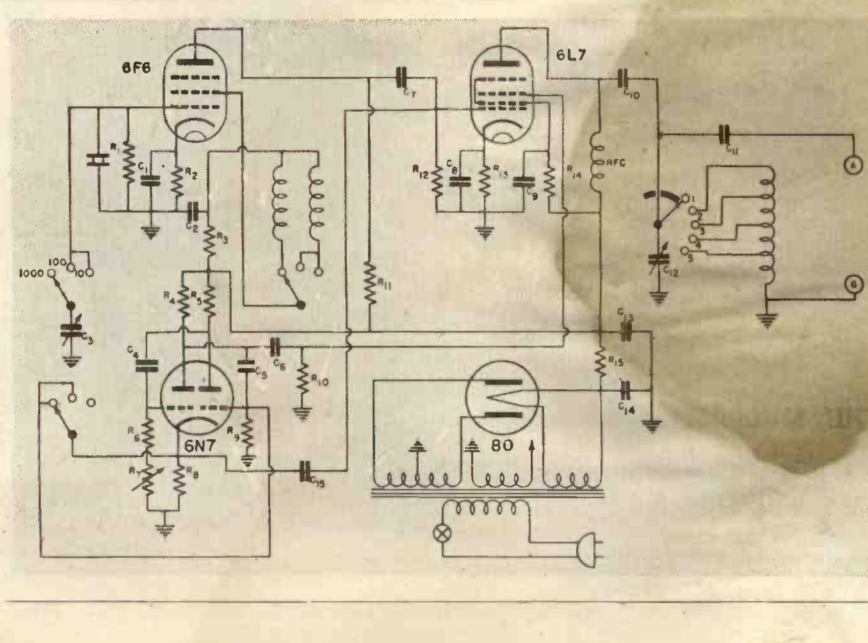
R1	5,000,000	ohms	⅓	watt.
R2	500	,,	⅓	,,
R3	25,000	,,	1	,,
R4	2,500	,,	1	,,
R5	2,500	,,	1	,,
R6	20,000	,,	½	,,
R7	15,000	,,	variable.	
R8	300	,,	⅓	watt.
R9	30,000	,,	½	,,
R10	50,000	,,	⅓	,,
R11	500,000	,,	⅓	,,
R12	100,000	,,	½	,,
R13	500	,,	⅓	,,
R14	15,000	,,	1	,,
R15	10,000	,,	10	watts.

CONDENSERS

C1 .1 mfd. 200 volts.
C2 .1 mfd. 400 volts.
C3 25 mmfd. Air variable.
C4 .002 mfd. Mica.
C5 .002 mfd. Mica.
C6 .002 mfd. Mica.
C7 .001 mfd. Mica.
C8 .01 mfd. 400 volts.
C9 .01 mfd. 400 volts.
C10 .002 mfd. Mica.
C11 10 mmfd. Mica.
C12
C13 8 mfd. 350 volts electrolytic.
C14 8 mfd. 350 volts electrolytic.
C15 10 mmfd. Mica.

VALVES

6SK7 r.f. amplifier
6K8 first detector and oscillator
6SK7 first i.f. amplifier
6SK7 second i.f. amplifier
6SQ7 diode detector, AVC and first a.f. amplifier
6F6G power amplifier
76 beat frequency oscillator
80 rectifier
6H6 noise limiter



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Obtainable for operating from 6 and 12-volt D.C. supplies with outputs of up to 20 watts.

This vital circuit is employed exclusively by Masteradio Ltd. and has been developed for use with highly sensitive Communication type Receivers operating on all frequencies. It has been tested with many well-known makes with complete satisfaction.

The new Vibratorpack is self-contained in a Cadmium Plated Steel Case measuring $8\frac{3}{4}'' \times 4\frac{3}{4}'' \times 5\frac{3}{4}''$ high, weighs approximately $8\frac{1}{2}$ lbs. and is therefore completely portable.

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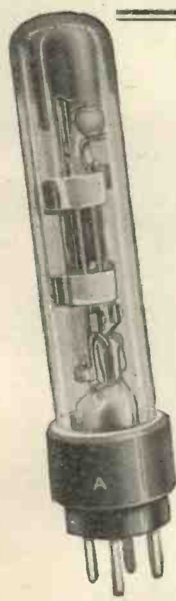

THE vacuum switch shown in the illustration is mounted on a standard 4-pin valve base.

It is a light and convenient relay to handle up to 5 amps A.C. or D.C.

Its principal features are:

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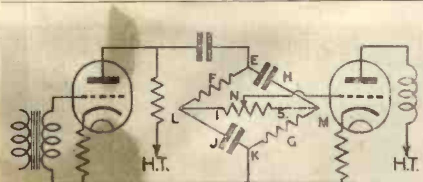
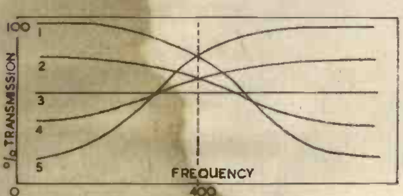
THE **SUNVIC** HOT WIRE
VACUUM SWITCH
SUNVIC CONTROLS LTD., 1, KINGSWAY, W.C.2
Temple Bar 8202

Tone Control Using a Bridge Circuit

A SIMPLE but adaptable tone control operated by a single adjustment has been developed by the General Electric Company of America.

The device employs a bridge circuit, as illustrated in Fig. 1, in which audio frequency currents are fed to an amplifier valve whose anode is coupled by condenser to the input terminal E of a bridge. The bridge consists of approximately equal resistors F and G in one pair of opposite arms, and approximately equal condensers H and J in the other pair of arms; the bridge is earthed at the input terminal K opposite E, and the output terminals L and M are connected through a potentiometer whose resistance is high compared with the resistance arms. The single adjustment is made by the potentiometer slider N, which provides control voltage to the grid of the succeeding output valve. The capacity values of H and J are chosen so that their reactance at a datum mid-point in the desired audio frequency range is equal to the resistances F and G.





When the slider contact is at the position marked 1 the cathode and grid of the output valve are connected simply through condenser J, thus providing a low reactance, and therefore a strong attenuation, at the high frequency end of the range, and a high reactance, corresponding to little attenuation, at the low frequency end of the range. On the other hand, when the slider contact is at position 5 the grid and cathode are connected through resistance G, thus providing, by virtue of the series connection of G with condenser H, weak attenuation at the high frequency end and strong attenuation at the low frequency end of the range. At intermediate positions of the slider intermediate results are, of course, obtained the central position in particular affording constant attenuation throughout the frequency range. Fig. 2 shows the voltage transmission curves for five positions of the slider indicated in Fig. 1, in a case where the datum mid-point of the audio frequency range is taken as 400 c.p.s.

H.F. Tuning Inductance

IT is often advantageous to tune high frequency circuits by varying the inductance instead of the capacity in the circuit, particularly when very high frequencies are involved. Tuning of a high frequency circuit may be accomplished by using an inductance comprising a non-magnetic core movable with respect to a coil. But a disadvantage of such an arrangement, which is particularly noticeable at the higher frequencies, is that movement of the core usually causes an increase in the distributed capacity of the windings so that the net change of frequency is less than it would be if the capacity of the coil could be maintained constant.

These undesirable variations can be almost entirely eliminated by electrostatically shielding the coil from the movable core, and an example of such an arrangement due to the General Electric Co. of America, is shown in the accompanying figures.

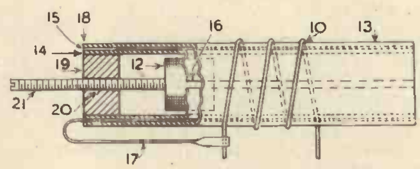


FIG. 1

The conductor 10 is wound on a tubular former 13 which comprises inner and outer cylinders 14 and 18 of insulating material and an intermediate shell 15 of thin metal foil.

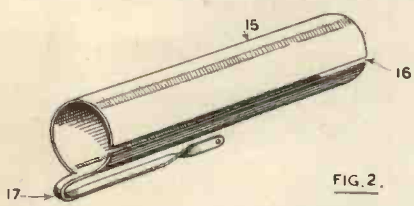


FIG. 2.

The shield 15, shown separately in Fig. 2 has a gap 16 extending along its entire length so that it does not present closed current paths linked with the magnetic flux surrounding coil 10.

The inductance of the coil is varied by means of the non-magnetic core 16 mounted on a threaded shaft 21 arranged in a hole 20 in the end disk 19 of the former 13.

The electrostatic shield 15 provides an equipotential surface of substantially constant capacity with respect to the core 12 irrespective of the position of the core. The inductance of the coil can thus be decreased or increased by adjusting the shaft 21 so that the core is moved towards or away from the coil 10 without affecting the distributed capacity of the winding, and maximum frequency variation is obtained for a given movement of the core.

ABSTRACTS OF ELECTRONIC LITERATURE

Television and C-R. Tubes

Television Film Transmitters Using Apertured Scanning Disks

(D. C. Espley and D. O. Walter)

This paper outlines various methods which can be used for the production of interlaced signals by apertured-disk film scanners. A novel arrangement using an intermittent magnification optical system is described, and details are given of a complete transmitter according to this method. The continuously moving film is illuminated by a split optical system to remove picture flicker, and a device is included for the exact compensation of film shrinkage.

Comprehensive details are given of the construction of high-speed disks and of punches and dies for the production of scanning holes only 30-40 microns in diameter. It is shown that, for a given noise level at the input of the vision channel, the scanning resolution obtainable is proportional to the strength/density ratio of the disk material and the limit is well above present television standards.

Synchronising signals are all derived from the disk, and various mechanical arrangements are shown by which multiple and sub-multiple frequency signals are available for control purposes. —*Journ. I.E.E.*, Vol. 88 (Part 3), No. 2, page 145.

Thermionic Tubes

Initial Velocity Currents in Thermionic Valves

(J. A. Darbyshire)

The electrons emitted from a thermionic cathode possess enough energy to enable them to reach other electrodes in the system providing the opposing potential is not too great.

The current flowing across to any electrode when there is no actual applied potential on the electrode is referred to as the "initial velocity current" from the cathode to that electrode.

The magnitude of this current depends on the temperature of the emitting cathode, the contact potential difference between the cathode and the collecting electrode, and several other features. Experimental results are given which show the relative importance of these effects on the magnitude of the initial velocity current—*Proc. Phys. Soc.*, Vol. 53, Part 3, No. 257, page 219.

Operation of Electrostatic Photo-Multipliers

(R. C. Winans and J. R. Pierce)

This paper discusses the operation and characteristics of electrostatic photo-multipliers, using the Western Electric D 159076 photo-multiplier as an example to illustrate specific points. —*Rev. Sci. Inst.*, Vol. 12, No. 5, page 269.

Development of the Glow-Switch

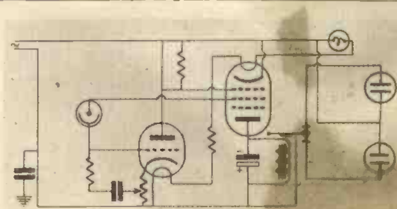
(R. F. Hays)

Successful operation of hot-cathode fluorescent lamps is dependent upon a satisfactory starting device. Details are given of the glow switch which is a small, simple two-wire thermal relay enclosed in a glass envelope and operated by the heat from a glow discharge. It is claimed that the glow-switch performs automatically the necessary functions for lamp starting and is also finding application in relay circuits.—*Electrical Engineering*, May, 1941, page 22.*

Applications of Photo-Electric Apparatus

(Windred)

Characteristic curves for various types of photo-electric cells and typical single and two-stage amplifier circuits are given, one of which is given below.—*Electrical Engineer*, June 21, 1941, page 188.



Circuits

A Review of Broadcast Receivers

(N. M. Rust, O. E. Keall, J. F. Ramsay and K. R. Sturley)

Considerable progress has been made in the development of broadcast receivers since 1929, and this paper is intended to assist the designer in taking stock of the present position. Part 1, compiled from an examination of over 1,000 circuit diagrams is a review of receiver circuits which have stood the test of production.

Part 2 gives details of fundamental problems and the lines of possible development. Selectivity, fidelity, electrical interference and automatic accessory circuits for volume, frequency, selectivity, and remote control are some aspects of receiver design to which attention is devoted.—*Jour. I.E.E.*, Vol. 88 (Part 3), No. 2, June, 1941, page 59.

Voltage Multiplier Circuits

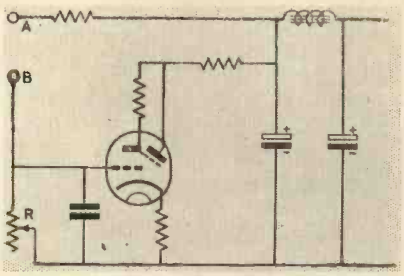
(D. L. Waidelich)

A circuit with a voltage output between that of the voltage doublers and that of the voltage quadrupler is the voltage tripler. Details and circuit diagrams of a half-wave voltage doubler, a full wave voltage doubler, a voltage tripler and voltage quadrupler are given.—*Electronics*, Vol. 14, No. 5, page 28.

ABSTRACTS *(contd.)*

Insulation Test Set

(J. S. Forrest)



The instrument consists of a tuning indicator operated from a conventional mains supply unit. The insulation to be tested is connected to AB in the diagram and the leakage flows through R, altering the grid potential and the shadow angle.

If the insulation resistance is "r" and the test voltage "E," then $r = R(E - E_0)/E_0$ where E_0 is the increase in grid potential due to the leakage current through R. For a given increase in shadow angle, r is thus proportional to R, which can then be calibrated directly in megohms. A 150,000 ohms resistor is connected in series with the test supply in order to avoid overload.—*Wireless World*, July, 1941, page 178.

Industry

New Electrical Devices in the Chemical Industry

(Howat)

Particulars are given of the application of the "electric ear" and the "electric eye" to the manufacture of cement and ceramics. The electric ear is applied to ball mill grinding and operates by controlling the feed according to the noise intensity of the mill. An improvement in output of 11 per cent. over ordinary manual control is claimed. The electric eye or photo-electric cell is applied to the regulation of the feed to rotary kilns where temperatures must be maintained within very narrow limits. Details are given of the control system.—*Chemical Age*, May 31, page 305.*

Theory

Theory of Dielectric Loss

(B. Gross)

When a sinusoidal voltage is applied to a condenser containing an absorptive dielectric the absorption current can be split up into components, one in phase and another in quadrature with the voltage. In this paper, direct relations, suitable for numerical calculation, are established between these components, and a general relationship between the dielectric constant and the dielectric loss is given.—*Phys. Rev.*, Vol. 59, No. 9, page 748.

* Supplied by the courtesy of Metropolitan-Vickers Elec. Co., Ltd., Trafford Park, Manchester.

BOOK REVIEWS

Elementary Mathematics for Wireless Operators

W. E. Crook (Sir Isaac Pitman and Sons, 63 pp. 42 figs. 3/6 net.)

Mr. Crook has already produced a handbook for Wireless Operators, and this is obviously a companion volume to be read in conjunction with it. As he says in the preface, the lack of mathematics in radio operator trainees is a crushing handicap, and the fact that he sets out to lighten this handicap in 63 pages of text speaks well for his powers of condensation and clear writing. Necessarily a great many steps are omitted—the classical definition of a logarithm is not followed by a definition of a base, nor is the word "characteristic" mentioned. This does not prevent the trainee from using the log. tables, but it places him at a disadvantage when talking to others who have had a sounder mathematical grounding. An "outline of algebra" is followed by chapters on geometry, trigonometry, and graphs. The final chapter on Mechanics would, in the reviewer's opinion, have been better omitted in favour of more lengthy explanations of some of the algebraic processes. (Did any beginner *ever* remember the rules for changing sign and apply them correctly from the start?) As an adjunct to the training classes for wireless operators, this is a most useful book, and in spite of its price should have a large sale.

Wireless Servicing Manual

(6th Edition). W. T. Cocking (Iliffe & Sons. 300 pp. and appendix. 100 figs. 6/- net.)

This is the sixth edition of this deservedly popular handbook, and in spite of paper restrictions the quality and style of the book have not suffered. The diagrams are, as usual, the acme of legibility and neatness.

For those who have not yet become acquainted with the contents, the chapters cover: interpretation of meter readings, mains hum, motor-boating, instability, adjustment of ganging, superhet, whistles and A.G.C. systems, to name only the principal features. At the end of the book a chapter on television receivers and the use of cathode-ray test gear is included. The author makes an interesting point which is not always appreciated by users of home-made test apparatus—the resonance curve traced by a C.R. tube is badly distorted by inadequate l.f. response in the associated amplifier.

The appendix forms almost a separate booklet, with information on circuit constants, valve characteristics and formulae. Instructions and working diagrams are also given on making a capacity and resistance bridge and valve testing bridge.

This book could truthfully be called the Service Engineer's *Vade Mecum*. The beginner will find all that he requires, and it will help him in many a problem which would baffle even the old hand.

Radio Laboratory Handbook

(2nd Edition). M. G. Scroggie. (395 pp., including appendix. 212 figs. Iliffe & Sons. 10/6 net.)

Will the amateur radio laboratory of the future be a "Scroggie" laboratory? It seems probable in view of the wide popularity of the first edition of this handbook and the still wider circulation which it will have among war radio men.

The author's revision has obviously been carried out under difficult circumstances and yet is very thorough. He has corrected a formula on p. 330, to quote one detail, and has added an explanation of the double-beam cathode ray tube. Two new sections deal with the use of transmission line circuits and the measurement of characteristic impedance, both of which are of importance at the present time.

One of the outstanding features of this book is that Mr. Scroggie describes apparatus that he has used and that works. There is no omission of vital information which is so common in reputedly "practical" handbooks, and the purchaser of the book will never feel that his money has been wasted, either in buying it or in making the apparatus described in it.

The Radio Amateur's Handbook

American Radio Relay League Publication. $1.00 in U.S.A. and 8/6 in this country.

In spite of the curtailment of transmitting in this country the eighteenth edition of this book will have as strong an appeal to the amateur as ever.

The section on transmitters and receivers for U.H.F. will make many amateur mouths water at the present time, but they can pass the waiting time in studying the frequency modulation circuits in the succeeding chapter. It is only to be expected that the bibliography at the end of each chapter would be confined to references to QST as the editorial staff of that journal were responsible for the production of the book. It is, however, suggested that the amateur does not confine his technical reading to that paper, and that references to the *Jour. I.R.E.* or corresponding publications would increase the value of the handbook. At its price it still represents one of the best value-for-money books in radio literature. Copies can be obtained while they are in stock from Webbs' Radio, Soho Street.

PATENTS RECORD

RADIO AND COMMUNICATIONS

Reception

Frequency Changer

The invention relates to radio receivers employing the beat reception principle and uses, preceding the mixing valve, a high frequency (signal) amplifier which is connected as a dynatron and serves to generate the local oscillation.

The amplifier may be a so-called secondary-emission valve whose control grid circuit is tuned to the aerial oscillations and whose secondary cathode circuit is tuned to the local oscillation. —Philips Lamps, Ltd. Patent No. 536,440.

Transmission

An electric communication system including an unattended repeater situated between two attended stations in which the power supply for the repeater is fed as direct current from the attended stations, low tension being fed from one of the stations and H.T. from the other.—*Siemens Bros. & Co., Ltd., and J. H. Mole. Patent No.* 535,618.

An aerial suitable for use on ultra high frequencies consisting of a number of resonant radiating components connected to adjacent components by phase inverting means, and mounted on a centrally placed conductive mast.—*Marconi's Wireless Telegraph Co. and G. H. Brown. Patent No.* 529,522.

TELEVISION

Reception

Improved Filters

This invention is to provide improved filters which are comparatively flexible in design and will facilitate the production of wide-band amplifiers of great selectivity and with a flat topped response curve such as will give good signal-to-noise ratio. The primary application of the invention is for television amplifiers and intermediate frequency amplifiers for broadcast and similar receivers. Although pure negative resistance produced by a valve arrangement is used to cancel the positive resistance, the cancellation of reactive effects is produced by quarter-line action.—*Marconi's Wireless Telegraph Co., Ltd., N. M. Rust, J. D. Brailsford and E. F. Goodenough. Patent No.* 536,171.

Scanning

The invention relates to improved methods of bias control for thyratron time bases.

In the time base a high resistance is connected in series with a charging impedance for the condenser, which is connected across the whole of the resistance. The anode-to-cathode path of the thyratron is connected across a part of the resistance common to that associated with the condenser, and a grid biasing connexion for the thyratron is made to a point in the resistance chain which is negative with respect to the cathode.

In order to improve the wave-form the resistance chain may include a diode. — *Standard Telephones and Cables, Ltd., and D. S. B. Shannon and P. K. Chatterjea. Patent No.* 536,217.

Electron Multipliers

This invention relates to improvements in electron discharge devices employing electron multiplication in order to obtain increased intensity on the finally produced image. This image may be formed on a fluorescent screen when desired to view it directly or on a a mosaic screen when it is desired to transmit the image for television purposes.

In one feature there is provided a method which causes the stream to be displaced laterally from its initial direction of motion, and then being caused to move parellel to the initial direction of motion to impinge normally upon a solid surface from which secondary electrons are emitted. — *H. G. Lubszynski and H. Miller. Patent No.* 536,417.

Transmission

Gamma Correction

The pictures of subjects transmitted by television, normally require a gamma of between 1.5 and 2.0. In order to produce a pleasing effect, it is usual to transmit television signals at a gamma of approximately unity and to allow the necessary correction to be affected at the receiver.

With a mechanical or cathode-ray scanning tube and photo cell, the output will have the same gamma as that of the film which is scanned. As most commercial films have a gamma of 1.5 to 2.0 some provision must be made for correction unless special films are employed.

The required correction calls for the introduction of a fractional power conversion law between the input and output, and known forms of circuit arrangement do not provide for the easy operation of such a conversion law.

In this patent a circuit arrangement is described for providing an output potential which is related in a non-linear manner with an input potential. This comprises a triode valve in the cathode circuit of which a valve of high impedance is connected arranged to have its anode current controlled by the input potential.

A connexion from the cathode of the triode is provided from which an output potential proportional to the variation in the effective grid-cathode potential may be taken.—*A. D. Blumlein. Patent No.* 536,089.

Ceramics in Valve Construction

(Continued from page 344)

aperture, some form of solder is melted, thus filling the holes in the mesh and forming a vacuum-tight seal. In the other case, the seal is moved into position and soldered in a similar manner.

The latter method of pumping the valve appears to be the most satisfactory, and a similar method of pumping all-metal valves is at present being production-tested in the United States.

In general, while great strides have been made since the original attempts to use glass as sealing means, development has by no means reached an optimum.

It is noticeable that very little work has been published other than in Germany, workers in this country and the United States having left the field almost entirely to the Germans.

Although great strides have been made in the generation of ultra-high frequencies, in most cases a more or less conventional glass construction has so far been used, and it is hoped that this article will stimulate the development of a more specialized method of construction for these frequencies.

TABLE I.

Material.	Coefficient of Thermal Expansion.
Copper	165×10^{-7}
Lava	90×10^{-7}
Platinum	90×10^{-7}
"M-Glass"	79×10^{-7}
"357" Glass	66×10^{-7}
Commercial Steatite	60 to 70 $\times 10^{-7}$
Low Loss Steatite	60 to 65 $\times 10^{-7}$
Molybdenum	48 to 52 $\times 10^{-7}$
Tungsten	40 to 45 $\times 10^{-7}$
Porcelain	30 to 60 $\times 10^{-7}$

All figures for 20°C. to 100°C. approximately.

A Method of Detecting Metallic Foreign Bodies

Recently a speaker on the German Radio described a new device by which, he claimed, bullets, shell splinters, needles and other metal objects can be readily located.

This metal finder developed by Siemens and their medical advisers depends on the use of a high frequency oscillator of small intensity. The tuning coil of a small short-wave transmitter is fitted into a sterilisable porcelain probe, 10 cm. long and 10 mm. in diameter. If this coil approaches a metallic substance, such as a splinter in the operation area, the inductance of the coil will change and hence so will the frequency of the transmitter. The change of frequency which may be very minute, can be made audible by combining these oscillators with those of a second short wave transmitter, oscillating at a slightly different frequency and so obtaining oscillations at the beat frequency, amplifying them and passing them to a loudspeaker.

The apparatus is extremely sensitive and can trace the minutest particles, but all metal instruments within a 10 cm. radius must be removed while the probe is in use.—*Lancet,* May 31, 1941, p. 699.

G.E.C. "Microgram"

A modified and improved version of their "Microgram" amplifying equipment is announced by the General Electric Co., Magnet House, Kingsway.

It embodies a three-stage amplifier with microphone and gramophone input, transverse current microphone, turntable, and 50 ft. of cable, contained in a portable oak cabinet $20\frac{1}{2}$ in. by 17 in. by $13\frac{1}{2}$ in. Both inputs can be independently controlled.

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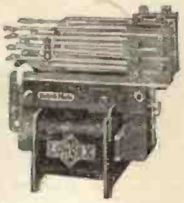

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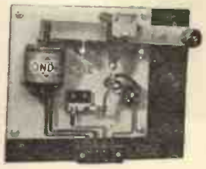

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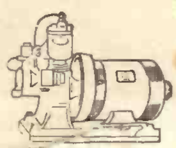

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