RADIO
Handbook
TWELFTH EDITION

THE RADIO HANDBOOK

Twelfth Edition

by

Editors and Engineers
LIMITED

R. L. DAWLEY
Editor

Associates:
W. W. SMITH
GORDON M. KINGMAN
GEORGE H. CATLIN
B. A. ONTIVEROS (Drafting)

This book is revised and brought up to date by new editions issued at frequent intervals.

PUBLISHED AND DISTRIBUTED BY

EDITORS AND ENGINEERS, LTD.

1300 KENWOOD ROAD, SANTA BARBARA, CALIFORNIA, U.S.A.

THE RADIO HANDBOOK

TWELFTH EDITION

Editors and Engineers, Ltd.
1300 Kenwood Road, Santa Barbara, California, U.S.A.

Printed in U.S.A.

Other Outstanding Books by the Same Publisher

(See Announcements on Pages 311 *to* 315*)*

THE ANTENNA MANUAL

THE RADIO AMATEUR NEWCOMER

THE SURPLUS RADIO CONVERSION MANUALS

RADIO-TELEVISION QUESTIONS AND ANSWERS

RADIO TUBE VADE MECUM (THE WORLD'S RADIO TUBES)

NOTICE

This all-constructional 12th edition does NOT supersede the 11th edition, which contains entirely different material and remains current.

STUDENTS and others requiring extensive simplified theoretical material and reference data, as well as all-different how-to-build-it data, are advised also to order the even-larger 11th edition (by mail, $3.25, postpaid; foreign, $3.50).

THE RADIO HANDBOOK

TWELFTH EDITION

Contents

Chapter One.	Operating Conveniences	7
Chapter Two.	Receiving Equipment	25
Chapter Three.	Exciters and Low Power Transmitters	46
Chapter Four.	Single-Sideband and FM Equipment	82
Chapter Five.	High-Frequency Power Amplifiers	102
Chapter Six.	Mobile Equipment and Installation	134
Chapter Seven.	Speech and AM Equipment	166
Chapter Eight.	Power Supply Construction	198
Chapter Nine.	Transmitter Construction	219
Chapter Ten.	Test and Measurement Equipment	236
Chapter Eleven.	Antennas and Feed Lines	248
Chapter Twelve.	Television and Broadcast Interference	286

EQUIPMENT TABULATION

Shown below are the major items of equipment for which constructional information is given either in the current Twelfth Edition or the previous Eleventh Edition (1947) of the RADIO HANDBOOK.

RECEIVERS AND CONVERTERS

	Eleventh Edition	Twelfth Edition
Two-Tube Regenerative Receiver		25
Four-Tube Superheterodyne for 3.5 and 7 Mc	269	
Double-Conversion Superheterodyne	270	

(Continued on following page)

	Eleventh Edition	Twelfth Edition
One-Tube Superheterodyne Converter, All Bands		28
Tuned Converter for 28 and 50 Mc. Bands	279	
Simple 28 and 50 Mc. Broad-Band Converters	280	
De-Luxe Crystal-Controlled Broad-Band Converter for 28 Mc.		33
6AK5-6J6 Tuned Converter for the 28-Mc. Band	278	
All-Triode Converter for the 144-Mc. Band		38
Inductively Tuned ("Inductuner") Converter		41
Simple 144-Mc. Superregenerative Receiver	284	
Superregenerative Receiver for 2, 1¼, ¾	283	
175-Kc. I-F Channel for the BC-348 Receiver		30
465-Kc. Adapter for Narrow-Band FM Reception	274	
Signal Booster for 28 and 50 Mc.	272	
One-Tube Mobile Converter for the 3.9 and 28-Mc. Bands		147

EXCITERS AND LOW TO MEDIUM POWER TRANSMITTERS

	Eleventh Edition	Twelfth Edition
Simple Breadboard Transmitter for 3.5 and 7 Mc.	287	
Simple 20-Watt Two-Tube Transmitter		46
Simple Two-Tube All-Band Transmitter		49
7C5-807 All-Band Transmitter	288	
6L6-809 All-Band Transmitter	290	
One-Tube Clapp Oscillator V-F-O Unit		51
Simple Two-Tube Operating-Table V-F-O Unit	293	
40-Watt C-W Transmitter with Clapp Oscillator		55
Six-Band Exciter Unit with Collins V.F.O.	297	
3.5-Mc. Two-Tube Exciter with Collins V.F.O.	299	
15-Watt All-Band Exciter with Collins V.F.O.		58
15-Watt All-Band FM or C.W. Exciter Unit with Collins V.F.O.		63
Using the Collins 8Q2 Crystal Calibrator Unit		67
807/HY-69 All-Band Bandswitching Exciter	292	
829B Transmitter R-F Unit for the 28-Mc. and 50-Mc. Bands		71
Narrow-Band FM Exciter Unit	300	
150-Watt All-Band Exciter/Xmtr. with HK-57	302	
257B/4E27 All-Band Transmitter Unit		73
4-65A Exciter/Transmitter for All Bands		76

HIGH-FREQUENCY POWER AMPLIFIERS

	Eleventh Edition	Twelfth Edition
Shielded 807 Amplifier		103
Standard Push-Pull Triode Amplifier	308	111
One-Kilowatt Push-Pull 250TH Amplifier	313	120
4-65A Single-Ended All-Band Amplifier		107
4-125A Single-Ended All-Band Amplifier		108
Push-Pull HK-54 Amplifier, 8¾" Panel	310	
General-Purpose Single-Ended 35TG Amplifier		114
Kilowatt Amplifier for T-125's or 810's	311	
Push-Pull HK-254 Amplifier	312	
Push-Pull 4-250A Kilowatt Amplifier	318	123
150-Watt Push-Pull 807 Amplifier	314	
Bandswitching Single-Ended 813 Amplifier	316	
304TL Grounded-Grid Amplifier		116
Shielded 4-400A Kilowatt Amplifier with Built-In Antenna Coupler		127
829B Amplifier-Tripler Unit	322	
Push-Pull 24G Amplifier for 50 and 144 Mc.	323	
Push-Pull 257B/4E27/8001 Amplifier Unit	325	

EQUIPMENT FOR MOBILE OPERATION

	Eleventh Edition	Twelfth Edition
10-Meter Antennas for Mobile Operation		143
75-Meter Antennas for Mobile Operation		144
One-Tube Mobile Converter for the 3.9-Mc. and 28-Mc. Bands		147
20-Watt Mobile Transmitter for 28 and 50 Mc.	329	
50-Watt Mobile Transmitter; Filament Tubes	330	
12-Watt Mobile Transmitter for 3.9-Mc. and 28-Mc.		152
807 Mobile Transmitter for the 3.9 and 28-Mc. Bands		157
832A Mobile or Fixed Station Transmitter for the 144-Mc. Band		162

EQUIPMENT FOR SINGLE-SIDEBAND AND FM OPERATION

	Eleventh Edition	Twelfth Edition
Narrow-Band FM Exciter Unit	300	
FM Exciter Unit for the 3.9-Mc. Band		97
60-Watt FM Transmitter for 28-Mc. and 50-Mc.	319	
150-Watt SSB Transmitter Unit for the 3.9-Mc. Band		85
Multi-Band SSB Transmitter with Four 807's in the Output		91

SPEECH AND AMPLITUDE MODULATION EQUIPMENT

	Eleventh Edition	Twelfth Edition
Clipper-Filter Speech Amplifier Unit	340	
8-Watt 6L6 Speech Amplifier/Driver Unit	333	
12-Watt Modulator with Push-Pull 6V6-GT Tubes		169
20-Watt High-Fidelity Amplifier	335	
6AS7-G Speech Amplifier or Driver or High-Fidelity Amplifier		177
50-Watt Modulator with Push-Pull 6L6 Output Stage		171
50-Watt Modulator with 815 Output Stage		174
85-Watt Class B 809 Modulator		180
100-Watt Modulator with Type 811 Tubes		182
200-Watt Modulator with Type 813 Tubes and Inverse Feedback		188
250-Watt Modulator with 811's or 5514's	336	
300-Watt Modulator with 8005's or 5514's		185
500-Watt Modulator with Class AB_2 813's		191
500-Watt Modulator with Type 304TL Tubes		194

POWER SUPPLIES

	Eleventh Edition	Twelfth Edition
Receiver Power Supply Unit	357	206
Miniature Test Equipment Power Supply		237
250-Volt Regulated Power Supply	349	
350-Volt 110-Ma. Power Supply		207
Thyratron-Controlled Variable-Voltage Power Supply		209
400-Volt Regulated Power Supply		214
400-Volt 250-Ma. Standard Power Supply		213
600/750-Volt 200-Ma. Power Supply		214
625/1250-Volt Bridge Power Supply	358	
1250-Volt 250-Ma. Power Supply		218
1000/2000-Volt Bridge Power Supply	359	
1750/2000-Volt 300-Ma. Power Supply		235
Regulated Bias Pack and Grid Modulator	337	212

CONSTRUCTION OF COMPLETE TRANSMITTERS

	Eleventh Edition	Twelfth Edition
De-Luxe 4-250A Kilowatt Transmitter	361	
Self-Contained 150-Watt C.W. Transmitter	364	
200-Watt All-Band V.F.O. Transmitter for AM and C.W. Operation		219
40-Watt Phone-C.W. Transmitter	370	
Compact Kilowatt C.W. Transmitter with Push-Pull HK-254 Final		227
400-Watt AM-FM-C.W. Transmitter with 4-125A Final Stage		234
450-Watt AM-C.W. Transmitter with 813 Output	368	

TEST AND MEASUREMENT EQUIPMENT

	Eleventh Edition	Twelfth Edition
Miniature Test Equipment Power Supply		237
100-Kc. Frequency Spotter	422	
One-Tube Sine-Wave Audio Oscillator		238
All-Band Grid-Dip Meter		239
Wavemeter/Harmonic Chaser	423	
Remote-Indicating Field-Strength Meter	424	
"Twin Lamp" with D-C Meter for S-W-R Measurements		245
3-Inch Monitoring Oscilloscope	426	
Audio Oscillator and Test Amplifier	429	

MISCELLANEOUS AND SURPLUS EQUIPMENT

	Eleventh Edition	Twelfth Edition
Screen-Voltage Keyer Unit, with Provision for Break-In Operation		13
BC-312 and BC-342 Series Receivers	431	
BC-348 Series Receivers	435	30
AN/ART-13 Autotune Tranmsitter	437	
PE-110A and PE-110B Power Supplies	441	
BC-1068A Conversion for 144-Mc. Operation	442	
26S-1 Speech Amplifier for Crystal Mike	444	
A-c Power Supply for Model LM Freq. Meter	444	
V.F.O. Unit Using BC-221 Frequency Meter	445	
Antenna Selector Unit With Relay from BC-375 Transmitter		22
8025/8025A Transmitter for 425 Mc	327	

NOTICE

This all-constructional 12th edition does NOT supersede the 11th edition, which contains entirely different material and remains current.

STUDENTS and others requiring extensive simplified theoretical material and reference data, as well as all-different how-to-build-it data, are advised also to order the even-larger 11th edition (by mail, $3.25, postpaid; foreign, $3.50).

CHAPTER ONE

Operating Conveniences

When the average amateur constructs or purchases the items of equipment which will go to make up his station he is most likely to consider at the outset only the more obvious attributes and performance charactertistics of the equipment. Transmitter power output, method of modulation or keying, and frequency coverage are more likely to concern him than are methods of control and built-in operating conveniences. Only such similar primary characteristics are likely to concern him also when he considers receivers, antennas, and other basic items which go to make up the station.

The logical result of this type of thinking and superficial planning is that the initial operating convenience of such a station will in most cases be very poor. It is likely that there will be a confusion of power cords of random length, three-way plugs, control cables, and poorly placed switches on, behind, and below the operating desk. The desirable features of break-in operation for c.w. almost certainly will not be available and it probably will be necessary to operate several switches in changing from transmit to receive.

After the station has been operated in this manner for a period of time, the duration depending more or less upon the operating habits of the station owner, it is likely that the operator will sit back after a particularly hectic period of activity with a thought such as, "This installation is a mess. How can I clean up the haywire and improve the convenience of operation?" Then will follow a period of planning followed by an off-the-air period of rebuilding and re-installation.

It is the purpose of this chapter to enumerate some of the conveniences to station operation that the average amateur would like to have, and which he probably will feel that he needs after a period of operation. Nearly all amateurs have passed through the initial stage of rushing to get the equipment onto the air and then through a subsequent period of rebuilding to improve operating convenience. It is the hope that this chapter will assist those experienced amateurs in planning the rebuilt station for this greater convenience. It is a further hope that the enumerations and suggestions included will enable amateurs who are planning a new station to include in the original station installation some of the operating conveniences which would be desired at a later time.

The most important conveniences to the operation of the amateur station can be broken down into three groups: (1) Power Systems and Controls, (2) Break-In, Keying, and Transmitter-Receiver Control, and (3) Antenna Selection and Control. The first and second topics will be discussed in this chapter while the matter of antenna selection and control will be described in chapters *Eleven* and *Twelve*. It is hoped that a few new ideas for operating conveniences will be gleaned from the suggestions to follow.

Power Systems and Controls

It is certainly true that the average amateur does not give adequate consideration to the a-c line power systems and to the methods for controlling the line power in making his transmitter and receiver installation. He undoubtedly dismisses power systems with a thought such as, "Well, you just plug it into the outlet." Basically, this is a statement of fact—insofar as any single item of equipment in the amateur station is concerned. But the amateur soon discovers, much to his dismay, that all available outlets, three-way plugs, and even a few extension cords are filled before all the units in the station can be operated.

It is probable that the average amateur station that has been in operation for a number of years will have at least two transmitters available for operation on different frequency bands, at least two receivers or one receiver and a converter, at least one item of monitoring or frequency measuring equipment and probably two, a v.f.o., a speech amplifier, a desk light, and a clock. In addition to the above 8 or 10 items, there must be an outlet available for a soldering iron and there should be one or two additional outlets available for plugging in one or two pieces of equipment which are being worked upon.

It thus becomes obvious that 10 or 12 outlets connected to the 115-volt a-c line should be available at the operating desk. It may be practicable to have this number of outlets installed as an outlet strip along the baseboard at the time that a new home is being planned and constructed. Or you might wish to install the outlet strip on the operating desk so as to have the flexibility of moving the operating desk from one position to another. Alternatively, the outlet strip might be wall mounted just below the desk top.

Power Drain Per Outlet When the power drain of all the items of equipment, other than transmitters, used at the operating position is totalled, you probably will find that 350 to 600 watts will be required. Since the usual home outlet is designed to handle only about 600 watts maximum, the transmitter, unless it is of relatively low power, should be powered from another source. This procedure is desirable in any event so that the voltage supplied to the receiver, frequency control, and frequency monitor will be substantially constant with the transmitter on or off the air.

So we come to two general alternative plans with their variations. Plan (A) is the most desirable and also the most expensive since it involves the installation of two separate lines from the meter box to the operating position either when the house is constructed or as an alteration. One line, with its switch, is for the transmitters and the other line and switch is for receivers and auxiliary equipment. Plan (B) is the more practicable for the average amateur, but its use requires that all cords be removed from the outlets whenever the station is not in use in order to comply with the electrical codes.

Figure 1 shows a suggested arrangement for carrying out Plan (A). In most cases an installation such as this will require approval of the plans by the city or county electrical inspector. Then the installation itself will also require inspection after it has been completed. It will be necessary to use approved outlet boxes at the rear of the transmitter where the cable is connected, and also at the operating bench where the other BX cable connects to the outlet strip. Also, the connectors at the rear of the transmitter will have to be of an approved type. It is possible also that the BX cable will have to be permanently affixed to the transmitter with the connector at the fuse-box end. These details may be worked out in advance with the electrical inspector for your area.

The general aspects of Plan (B) are shown in figure 2. The basic difference between the two plans is that (A) represents a "permanent" installation even though a degree of mobility is allowed through the use of BX for power leads, while plan (B) is definitely a "temporary" type of installation as far as the electrical inspector is concerned. While it will be permissible in most areas to leave the transmitter cord plugged into the outlet even

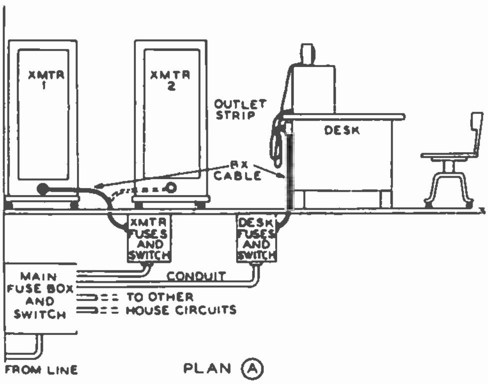


Figure 1.
THE PLAN (A) POWER SYSTEM.

A-c line power from the main fuse box in the house is run separately to the receiving equipment and to the transmitting equipment. Separate switches and fuse blocks then are available for the transmitters and for the auxiliary equipment. Since the fuses in the boxes at the operating room will be in series with those at the main fuse box, those in the operating room should have a lower rating than those at the main fuse box. Then it will always be possible to replace blown fuses without leaving the operating room. The fuse boxes can conveniently be located alongside one another on the wall of the operating room.

though it is turned off, the Fire Insurance Underwriters codes will make it necessary that the cord which runs to the group of outlets at the back of the operating desk be removed whenever the equipment is not actually in use.

Whether the general aspects of plans (A) or (B) are used it will be necessary to run a number of control wires, keying and audio leads, and an excitation cable from the operating desk to the transmitter. Control and keying wires can best be grouped into a multiple-wire rubber-covered cable between the desk and the transmitter. Such an arrangement gives a good appearance, and is particularly practical if cable connectors are used at each end. High-level audio at a moderate impedance level (600 ohms or below) may be run in the same control cable as the other leads. However, low-level audio can best be run in a small coaxial cable. Small coaxial cable such as RG-58/U or RG-59/U also is quite satisfactory and quite convenient for the signal from the v.f.o. to the r-f stages in the transmitter. Coaxial-cable connectors of the UG series are quite satisfactory for the terminations both for the v-f-o lead and for any low-level audio cables.

Outlet Strips The "outlet strips" which have been suggested for installation in the base board or for use on the rear of the desk are obtainable from the large electrical supply houses. If such a house is not in the vicinity it is probable that a local electrical contractor can order a suitable type of strip from one of the supply house catalogs. These strips are quite convenient in that they are available in varying lengths with provision for inserting a-c line plugs throughout their length. The a-c plugs from the various items of equipment on the operating desk then may be inserted in the outlet strip throughout its length. In many cases it will be desirable to reduce the equipment cord lengths so that they will plug neatly into the outlet strip without an excess to dangle behind the desk.

Contactors and Relays The use of power-control contactors and relays often will add considerably to the operating convenience of the station installation. The most practicable arrangement usually is to have a main a-c line switch on the front of the transmitter to apply power to the filament transformers and to the power control circuits. It also will be found quite convenient to have a single a-c line switch on the operating desk to energize or cut the power from the outlet strip on the rear of the

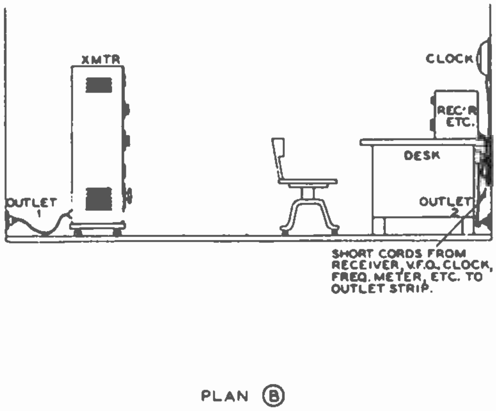


Figure 2.

THE PLAN (B) POWER SYSTEM.

This system is less convenient than the (A) system, but does not require extensive re-wiring of the electrical system within the house to accommodate the arrangement. Thus it is better for a temporary or semi-permanent installation. In most cases it will be necessary to run an extra conduit from the main fuse box to the outlet from which the transmitter is powered, since the standard arrangement in most houses is to run all the outlets in one room (and sometimes all in the house) from a single pair of fuses and leads.

operating desk. Through the use of such a switch it is not necessary to remember to switch off a large number of separate switches on each of the items of equipment on the operating desk. The alternative arrangement, and that which is approved by the Underwriters, is to remove the plugs from the wall both for the transmitter and for the operating-desk outlet strip when a period of operation has been completed.

While the insertion of plugs or operation of switches usually will be found best for applying the a-c line power to the equipment, the changing over between transmit and receive can best be accomplished through the use of relays. Such a system usually involves three relays, or three groups of relays. The relays and their functions are: (1) power control relay for the transmitter—applies 115-volt line to the primary of the high-voltage transformer and turns on the exciter; (2) control relay for the receiver—makes the receiver inoperative by any one of a number of methods when closed, also may apply power to the v.f.o. and to a keying or a phone monitor; and (3) the antenna changeover relay—connects the antenna to the transmitter when the transmitter is energized and to the receiver when the

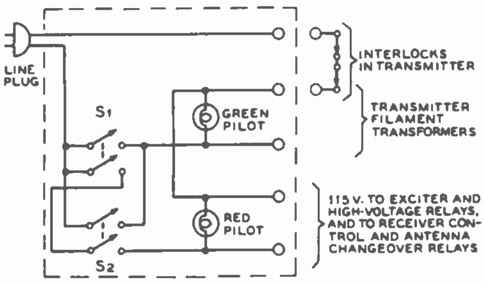


Figure 3.
PROTECTIVE CONTROL CIRCUIT.
With this circuit arrangement either switch may be closed first to light the heaters of all tubes and the filament pilot light. Then when the second switch is closed the high voltage will be applied to the transmitter and the red pilot will light. With a 30-second delay between the closing of the first switch and the closing of the second, the rectifier tubes will be adequately protected. Similarly, the opening of either switch will remove plate voltage from the rectifiers while the heaters remain lighted.

transmitter is not operating. Several circuits illustrating the application of relays to such control arrangements are discussed in the paragraphs to follow in this chapter.

Controlling Transmitter Power Output It is necessary, in order to comply with FCC regulations, that transmitter power output be limited to the minimum amount necessary to sustain communication. This requirement may be met in several ways. Many amateurs have two transmitters; one is capable of relatively high power output for use when calling, or when interference is severe, and the other is capable of considerably less power output. In many cases the lower powered transmitter acts as the exciter for the higher powered stage when full power output is required. But the majority of the amateurs using a high powered equipment have some provision for reducing the plate voltage on the high-level stages when reduced power output is desired.

One of the most common arrangements for obtaining two levels of power output involves the use of a plate transformer having a double primary for the high-voltage power supply. The majority of the high-power plate transformers of standard manufacture have just such a dual-primary arrangement. The two primaries are designed for use with either a 115-volt or 230-volt line. When such a transformer is to be operated from a 115-volt line, operation of both primaries in parallel will deliver full output from the plate supply. Then when the two primaries are connected in series and still operated from the 115-volt line the output voltage from the supply will be reduced approximately to one half. In the case of the normal class C amplifier, a reduction in plate voltage to one half will reduce the power input to the stage to one quarter.

If the transmitter is to be operated from a 230-volt line, the usual procedure is to operate the filaments from one side of the line, the low-voltage power supplies from the other side, and the primaries of the high-voltage transformer across the whole line for full power output. Then when reduced power output is required, the primary of the high-voltage plate transformer is operated from one side to center tap rather than across the whole line. This procedure places 115 volts across the 230-volt winding the same as in the case discussed in the previous paragraph. Figure 4 illustrates the two standard methods of power reduction with a plate transformer having a double primary; (A) shows the connections for use with a 115-volt line and (B) shows the arrangement for a 230-volt a-c power line to the transmitter.

The full-voltage/half-voltage methods for controlling the power input to the transmitter, as just discussed, are subject to the limitation that only two levels of power input (full power and quarter power) are obtainable. In many cases this will be found to be a limitation to flexibility. When tuning the transmitter, the antenna coupling network, or the antenna system itself it is desirable to be able to reduce the power input to the final stage to a relatively low value. And it is further convenient to be able to vary the power input continuously from this relatively low input up to the full power capabilities of the transmitter. The use of a variable-ratio auto-transformer in the circuit from the line to the primary of the plate transformer will allow a continuous variation in power input from zero to the full capability of the transmitter.

Variable-Ratio Auto-Transformers There are several types of variable-ratio auto-transformers available on the market. Of these, the most common are the "Variac" manufactured by the General Radio Company, and the "Powerstat" manufactured by the Superior Electric Company. Both these types of variable-ratio transformers are excellently constructed and are available in a wide range of power capabilities. Each is capable of controlling the line voltage from zero to about 15 per cent above the nominal

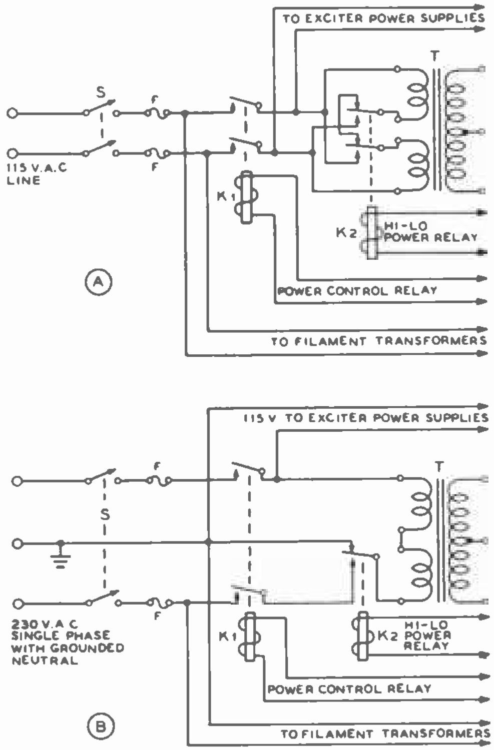


Figure 4.
FULL-VOLTAGE/HALF-VOLTAGE POWER CONTROL SYSTEMS.

The circuit at (A) is for use with a 115-volt a-c line. Transformer T is of the standard type having two 115-volt primaries; these primaries are connected in series for half-voltage output when the power control relay K_1 is energized but the hi-lo relay K_2 is not operated. When both relays are energized the full output voltage is obtained. At (B) is a circuit for use with a standard 230-volt residence line with grounded neutral. The two relays control the output of the power supplies the same as at (A).

line voltage. Each manufacturer makes a single-phase unit capable of handling an output power of about 175 watts, one capable of about 750 to 800 watts, and a unit capable of about 1500 to 1800 watts. The maximum power-output capability of these units is available only at approximately the nominal line voltage, and must be reduced to a maximum current limitation when the output voltage is somewhat above or below the input line voltage. This, however, is not an important limitation for this type of application since the output voltage seldom will be raised above the line voltage, and when the output voltage is reduced below the line voltage the input to the transmitter is reduced accordingly.

One convenient arrangement for using a Variac or Powerstat in conjunction with the high-voltage transformer of a transmitter is illustrated in figure 5. In this circuit a heavy three-wire cable is run from a plug on the transmitter to the Variac or Powerstat. The Variac or Powerstat then is installed so that it is accessible from the operating desk so that the input power to the transmitter may be controlled during operation. If desired, the cable to the Variac or Powerstat may be unplugged from the transmitter and a dummy plug inserted in its place. With the dummy plug in place the transmitter will operate at normal plate voltage. This arrangement allows the transmitter to be wired in such a manner that an external Variac or Powerstat may be used if desired, even though the unit is not available at the time that the transmitter is constructed.

Notes on the Use of the Variac or Powerstat Plate voltage to the modulators may be controlled at the same time as the plate voltage to the final amplifier is varied if the modulator stage uses beam tetrode tubes; variation in the plate voltage on such tubes used as modulators causes only a moderate change in the standing plate current. Since the final amplifier plate voltage is being controlled simultaneously with

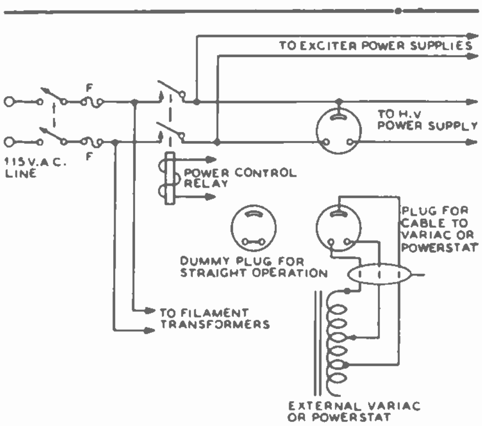


Figure 5.
CIRCUIT WITH VARIABLE-RATIO AUTO TRANSFORMER.

When the dummy plug is inserted into the receptacle on the equipment, closing of the power control relay will apply full voltage to the primaries. With the cable from the Variac or Powerstat plugged into the socket the voltage output of the high-voltage power supply may be varied from zero to about 15 per cent above normal.

the modulator plate voltage, the conditions of impedance match will not be seriously upset. In several high power transmitters using this system, and using beam-tetrode modulator tubes, it is possible to vary the plate input from about 50 watts to one kilowatt without a change other than a slight increase in audio distortion at the adjustment which gives the lowest power output from the transmitter.

With triode tubes as modulators it usually will be found necessary to vary the grid bias at the same time that the plate voltage is changed. This will allow the tubes to be operated at approximately the same relative point on their operating characteristic when the plate voltage is varied. When the modulator tubes are operated with zero bias at full plate voltage, it will usually be possible to reduce the modulator voltage along with the voltage on the modulated stage, with no apparent change in the voice quality. However, it will be necessary to reduce the audio gain at the same time that the plate voltage is reduced.

The manufacturers of the Variac and the Powerstat recommend that changes in the setting of the auto-transformers be made with the power *off*, when the load is inductive. The primary of the plate transformer in an amateur transmitter usually will present an inductive load to the line. Hence it is best that the transmitter be shut down for a moment before the setting of the auto-transformer is changed. If the setting is varied at a time when the transmitter is operating, it is possible that pitting of the surface of the winding and burning of the end of the brush will occur. If this should take place the unit must be disassembled and the contacting surfaces carefully cleaned.

Keying, Break-In, and Transmitter/Receiver Control

To the experienced c-w operator the most satisfactory method of communication between amateur stations is obtained through the use of automatic break-in operation. This type of operation is not obtained easily, nor can it be purchased ready-made at the nearest distributor of amateur components. The components for accomplishing automatic break-in operation are not necessarily expensive, nor are the electrical circuits unduly complex. But this type of operation is a challenge to the operator, since careful planning and skillful tailoring of components and circuits to the equipment of the station will be required before smooth break-in operation with a medium power transmitter can be obtained.

Keying Circuits There is a misconception among many amateurs, particularly those who have done little consistent c-w operating, that the keying of a c-w transmitter is a simple problem which is capable of easy solution. This is far from the truth; it is just about as difficult to obtain smooth and clickless keying of a c-w transmitter, without keying chirps, as it is to obtain full modulation of an AM transmitter without excessive bandwidth. The amateurs who have spent many hours with all sizes of chokes, capacitors, and damping resistors in an attempt to obtain clickless cathode keying of a medium power transmitter are well aware of this fact.

A large variety of keying arrangements for all types of amplifier arrangements have been described in the literature. Many of these circuits are satisfactory with the particular arrangement for which they were developed, but when an attempt is made to apply the circuit to a different amplifier arrangement, difficulty is immediately encountered. So it was decided to set forth the optimum requirements for a keying arrangement which would meet the largest variety of requirements, and then to design a keyer circuit which would meet these requirements. The unit to be described in the following paragraphs is the result of this investigation and development.

Keyer Circuit Requirements In the first place it may be established that the majority of new design transmitters, and many of those of older design as well, use a medium power beam tetrode tube either as the output stage or as the exciter for the output stage of a high power transmitter. Thus the transmitter usually will end up with a tube such as a 2E26, 807, 814, 813, 4-65A, 4E27/257B, 4-125A or similar type, or one of these tubes will be used as the stage just ahead of the output stage.

Second, it may be established that it is undesirable to key further down in the transmitter chain than the output stage or the stage just ahead of the final amplifier. If a low-level stage, which is followed by a series of class C amplifiers, is keyed, serious transients will be generated in the output of the transmitter even though the keyed stage is being turned on and off very smoothly. This condition arises as a result of "pulse sharpening." Even though the keying wave of the keyed stage is very smooth, each successive class C stage will sharpen the keying waveform until the output stage is emitting a very sharply keyed signal—with resulting clicks. This phenomenon is the natural result of the clipping and limiting which takes place in a class C amplifier. In fact, just such a chain of class C amplifiers is used in many radar equipments for the generation of a sharp pulse from a relatively smooth wave—even from a sine wave. So, the output stage or the exciter stage for it should be keyed.

Third, the output from the stage should be completely cut off when the key is up, and the time constant of the rise and decay of the keying wave should be easily controllable.

Fourth, it should be possible to make the rise period and the decay period of the keying wave equal to each other. This type of keying envelope is the only one tolerable for commercial work, and is equally desirable for obtaining clean cut and easily readable signals in amateur work.

Fifth, it is desirable that the keying circuit be usable without a keying relay, even when a high-power stage is being keyed.

Sixth, for the sake of simplicity and safety, it should be possible to ground the frame of the key, and yet the circuit should be such that placing the fingers across the key will not result in electrical shock. In other words, the keying circuit should be inherently safe.

Last, it should be possible to use the circuit in conjunction with a break-in system, so that no signal from the exciter stages of the transmitter will be audible in the receiver with the key up.

All these requirements have been met in the keying circuit to be described. The circuit itself has been installed in two of the exciters described in *Chapter Three,* and several keyer units such as illustrated in figures 6, 7, and 8 have been constructed and installed as an added portion of existing transmitters.

Screen-Voltage Keyer Unit The unit to be described may be used as a screen-voltage keyer for any of the tubes previously mentioned. In addition, the circuit principles may be used in designing a keyer unit with larger current capability for screen-grid keying of higher powered beam-tetrode tubes.

Screen-voltage keying was chosen as the most logical keying method for the following reasons: (1) by keying the screen-grid voltage of an amplifier tube it is possible to control a relatively large power input to the plate circuit with a much smaller amount of voltage and current capability in the keyer. (2) As mentioned before, either the output stage or the exciter for the final almost invariably uses a medium power beam-tetrode tube. Grid-block keying could have been used except that: the keyed transmitter-output waveform obtainable with grid-block keying is a function of the excitation conditions of the stage and may vary widely on different bands in a particular transmitter or on different transmitters; the grid-block keying voltage required would vary widely with the manner in which screen voltage is fed to the stage; and the screen voltage could soar to high values with key up and series screen feed. Hence (3), screen-voltage keying offers the advantage of uniformity of keying characteristics in transmitters with widely differing designs since the screen voltage for the tube not only is con-

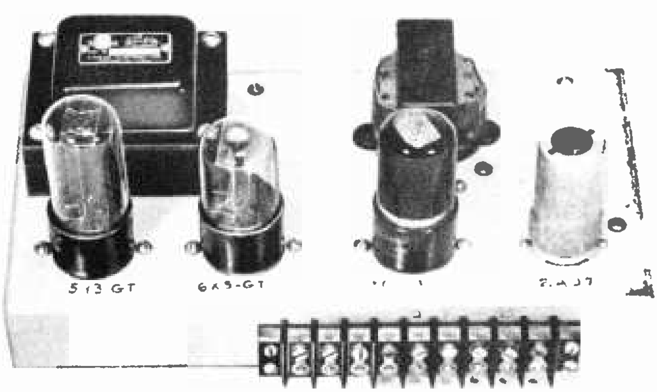


Figure 6.
TOP VIEW OF THE KEYER UNIT.

trolled by the keyer unit but actually *is supplied to the keyed tube by the keyer unit.*

Circuit of the Keyer The keyer itself requires only two tubes: a dual triode (of which one half is used in the break-in circuit and may be eliminated if desired) d-c voltage amplifier, and a cathode-follower output stage. The keyer requires a positive supply of 375 to 400 volts and a negative supply of 275 to 300 volts. The current drain from the positive supply is only slightly greater than the screen current to the keyed stage, and the drain from the negative supply is less than 5 ma. The unit illustrated includes a simple dual-voltage power supply for the positive and negative voltage; the exciters described in *Chapter Three* which use the keyer circuit do not have additional power supplies for the keyer alone but use the normal bias and plate voltage supplies included within the equipment.

The first condition established in the circuit design of the keyer was the fact that the output stage should be a cathode follower. The cathode follower has excellent operating characteristics as a series screen-voltage control tube since it acts effectively as a series resistor, from the plate-voltage supply, whose resistance may be varied over a very wide range. With key down the drop across the tube is less than 100 volts, but with the key up the tube drop is over 400 volts. Note that the drop across the tube with the key up is greater than the plate supply voltage. This condition exists since the cathode of the tube is connected through a relatively large resistor to the negative 275-volt line.

In order for the cathode follower to operate in the desired manner, the grid potential on the cathode-follower tube should vary from a value of about −100 volts with the key up all the way to a value only slightly less than the plate supply voltage with the key down. It would be possible to obtain this voltage variation with a keying relay and two RC circuits. But it is much more convenient if the keying relay may be eliminated and replaced by a vacuum tube operating as a d-c voltage amplifier. The first half of the 12AU7 tube operates in such a manner in the circuit of figure 8. Also, through the use of the d-c amplifier stage, one side of the key may be grounded, and the voltage appearing across the key with key up is fed through such a high value of resistance that no shock is felt when the fingers are placed across the key.

The operation of the half-12AU7 d-c amplifier is as follows: With the key up the voltage appearing at the ungrounded key contact is about −110 volts. But the 1-megohm and 470,000-ohm resistors which control the grid bias on the 12AU7 would tend to set the grid potential at about −85 volts. However, this would place the grid at a positive potential with respect to the cathode; this condition cannot take place due to the high values of feed resistance in the grid lead. Hence the grid voltage is pulled up to the cathode voltage by grid current in the half-12AU7. Since grid current is flowing, the grid is actually slightly positive with respect to the cathode potential.

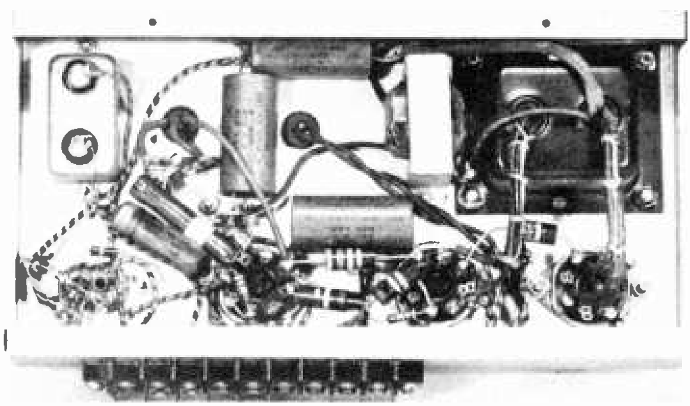


Figure 7. UNDERCHASSIS PHOTO OF THE KEYER UNIT.

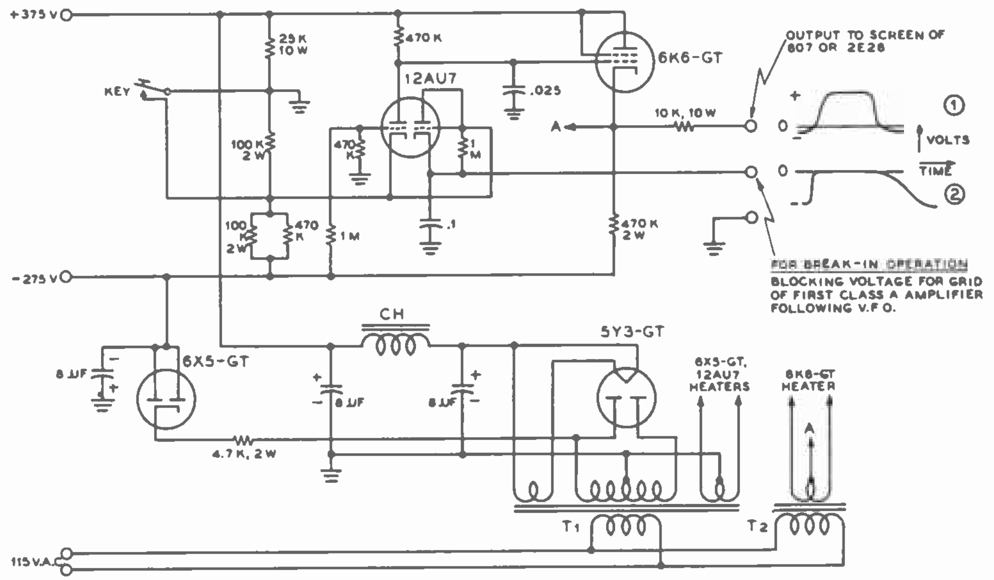


Figure 8.

SCHEMATIC DIAGRAM OF THE KEYER.

CH—Small 40 or 50 ma. filter choke (Stancor C-1706)
T_1—650 c.t. 40 ma., 5 v. 3 a., 6.3 v. 2 a. (Stancor P-6010)
T_2—Small 6.3-volt filament transformer (Stancor P-6134)

With the grid of the d-c amplifier drawing a slight amount of grid current, the tube is in a highly conductive condition as far as cathode-to-plate current is concerned. Since plate current is being fed through a relatively high resistor (470,000 ohms) and since the tube internal resistance is relatively low, the plate of the half-12AU7 is positive only about 20 volts with respect to cathode. Hence the plate of the half-12AU7 operates at a plate potential with respect to ground of about −90 volts.

The plate of the d-c amplifier is directly connected to the grid of the cathode-follower stage. Since the control grid of the 6K6-GT thus is at a potential of about −90 volts and since the cathode current is very low, the tube is essentially cut off. Thus the key-up cathode voltage drops to about −35 volts. This is the voltage which is fed to the screen grid of the tube in the r-f stage being keyed.

When the key is closed the following sequence of events takes place: The cathode of the half-12AU7 is grounded. Since the grid of this tube now is at a potential of about −85 volts, the current flow through the tube is completely cut off. Hence the 0.025-µfd. capacitor from plate to ground is charged exponentially by the 470,000-ohm series resistor from the plate-supply voltage. The grid voltage of the 6K6-GT thus rises smoothly, followed in turn by the cathode voltage. The actual cathode voltage rises from the key-up potential of about −35 volts to a potential of 275 to 350 volts, depending upon the screen current of the r-f tube being keyed. The 10,000-ohm resistor shown in series with the output lead is there simply to limit the maximum screen voltage and screen current to the r-f tube. This resistor may be eliminated for the larger tube types, or it may be increased in value for keying smaller screen-grid tubes.

When the key is lifted again, the 0.025-µfd. capacitor is discharged by the current through the half-12AU7 and the resistor from its cathode to the −275-volt line. Thus the cathode voltage of the 6K6-GT cathode follower falls smoothly to the key-up potential of about −35 volts.

Time Constant Changes The time constant of the keying wave is determined by the resistors in the plate and cathode circuits of the half-12AU7 and by the value of the capacitor from the plate of the 12AU7 to ground. Sharper keying may be obtained by decreasing the value of this capacitor, and softer keying may be had by increasing the value above 0.025 µfd. The value given has proven quite satisfactory for normal service with a straight key or a "bug."

Plate-Current Cut-Off on the Keyed Stage Experience with screen-grid keying circuits has shown that merely dropping the screen potential to zero will not completely cut off plate current in the keyed stage with most beam-tetrode tubes. However, when the screen potential is dropped to about −35 volts with the key up it was found that plate current is completely cut off in the case of all the tube types tested. It is for that reason that provision was included in the circuit illustrated for dropping the screen voltage to a negative value with the key up.

The Exciter Blocking Circuit Also included within the keyer unit is a circuit for supplying a blocking voltage to the low-level stages of the exciter unit. The normal procedure is to feed the exciter-blocking voltage, when break-in operation is desired, to the grid return of the class A amplifier stage which follows the variable-frequency oscillator. This exciter-blocking circuit is included as a portion of both the 70E-8/2E26 exciters described in *Chapter Three.*

The blocking circuit requires only a diode, one resistor and one capacitor. In the unit illustrated the diode consists of the second half of the 12AU7 tube with the grid and plate strapped together. The waveform of the exciter-blocking voltage is illustrated at (2) in figure 8. With key up both cathode and plate of the diode are at the potential of the ungrounded contact of the key—approximately −110 volts.

When the key is closed, the plate of the diode is grounded. A heavy current flows through the diode in discharging the 0.1-μfd. capacitor rapidly. This rapid discharge to zero voltage produces a sharp front on the exciter-blocking wave. Hence the exciter stages come into operation quickly, but the transient generated by this sharp waveform dies out before energy begins to be delivered by the keyed stage. In other words the keying waveform lags behind the exciter *un*-blocking waveform on the "make" of each character.

When the key is lifted the plate of the diode immediately drops to the key potential of −110 volts, and the keying wave (waveform (1) of figure 8) cuts off the output from the transmitter. But the blocking-voltage waveform falls more slowly since the 0.1-μfd. capacitor must be charged through the 1-megohm resistor. Hence, on the "break" of each character the keying waveform is *ahead* of the blocking waveform. Thus, as far as the output stage of the transmitter is concerned the exciter is operating by the time it is turned on and is still operating when it goes off. But listening in the receiver one can hear the exciter stop operating a fraction of a second after the last character has been sent. Thus for continuous rapid keying the exciter is heard steadily in the receiver. But with slow sending, or with a slight break in the regularity of rapid sending, signals may be heard in the receiver on the operating frequency of the transmitter.

Using the Keyer in a Full Break-In System Through the use of the keyer unit just described it is possible to key the transmitter without clicks or chirps, and still be able to receive signals when the key is up. But there are three other functions which may or may not be included within the overall keying system in the complete break-in hookup. These are: (1) shorting of the receiver input whenever the key is closed; (2) automatically blocking the output of the receiver when the key is closed; and (3) automatic control of the transmitter high-voltage supplies.

These three additional possible features of a complete keying system for break-in will be discussed in turn. First, it is usually necessary to short the antenna input of the receiver when a high-power transmitter is in use and when a *separate* antenna is employed for receiving. If the receiver input is not shorted when the key is closed there is a possibility of damage to the receiver as a result of the amount of r-f being picked up by the receiving antenna. Also likely to occur is blocking of the receiver for an interval of several seconds after the transmission of the last character.

Receiver blocking with transmitter keying is desirable to eliminate the strong keying thump in the phones or loudspeaker. The blocking action may be accomplished by means of an external unit, or it may be accomplished by biasing off the receiver at an appropriate point in the circuit. The Collins 75A receiver has included within the detector circuit an arrangement for accomplishing the biasing-off action.

Automatic control of the high-voltage supplies of the transmitter is a desirable feature of a break-in system, especially in the case of a high-power transmitter. Through the use of such a system it is necessary only to touch the key for turning on all the power supplies in the transmitter. The supplies then stay

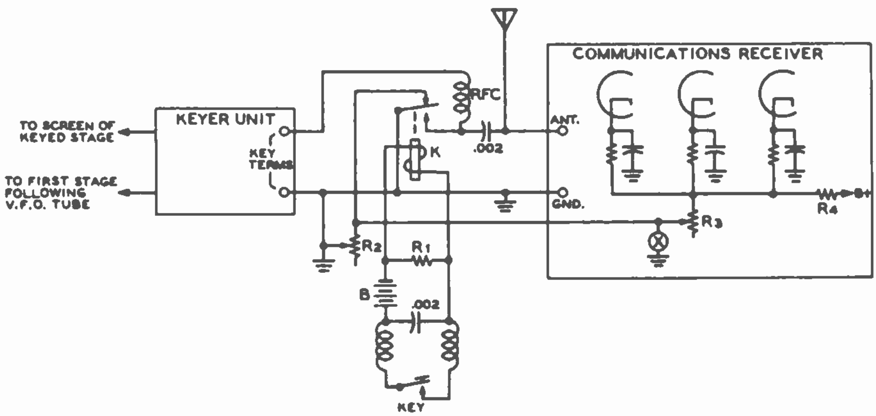


Figure 9.
SCHEMATIC OF BREAK-IN SYSTEM.

R_1—330-ohm ½-watt resistor
R_2—100,000-ohm potentiometer
R_3—Manual gain control inside receiver
R_4—Resistor to positive voltage inside receiver
K—6-volt type 172 "Millisec" relay
B—6-volt dry-cell battery
RFC—R-f choke suitable for band in use—Note that r-f chokes also are connected in series with the key terminals
(X)—Point where ground return of manual gain control inside receiver is broken for connection of lead to external circuit

turned on as long as the operator is sending steadily. But when he pauses for a short period (the period usually is adjustable from a fraction of a second to 10 or 15 seconds) the power supplies automatically shut down.

Shorting the Receiver Antenna Terminals The BC-312 and BC-342 receivers already have built into them a relay for shorting the antenna input of the receiver as the transmitter is keyed. This relay, which is designed to operate on 12 volts d.c., may be wired into the keying circuit so that it closes whenever the key is closed. The coil of this relay may be picked up at terminal J of the large plug on the front of the receiver, and on one side of the SEND-RECEIVE toggle switch at the bottom of the front panel.

Complete Break-In Systems Shown in figures 9, 10, and 11 are three alternative circuit arrangements for accomplishing break-in operation. The three circuits are basically similar, but offer different features and are for use with different types of v-f-o arrangements. The circuit at figure 9 is best suited for use with a home-constructed v.f.o. where it is convenient to get to the grid return of the first stage following the oscillator tube. In this case the exciter blocking voltage is fed to this first r-f stage, while one of the higher level stages in the transmitter is screen keyed by the keyer unit diagrammed in figure 8.

The significant addition included in this circuit is he use of a "Millisec" relay (manufactured by Stevens-Arnold, Inc., 22 Elkins Street, South Boston, Mass.) to accomplish a number of functions in addition to keying the transmitter. The relay itself is operated directly from the key with the aid of a small "A" battery which furnishes 6 volts. The relay drain is about 40 ma. so the life of the battery should be very long. With the key open, the relay is open, and the receiver operates normally. When the key is closed a number of events occur in sequence: First, the moving contact of the relay opens the "muting" circuit of the receiver. This circuit is connected into the communications receiver merely by lifting the ground return of the r-f/i-f gain control of the set, and then bringing out the lead which originally went to ground from this point on the potentiometer. The resistor R_2, which can be mounted externally to the receiver, is then adjusted to a point which will allow the receiver gain to drop to a very low value when the "muting" circuit is in operation.

Then when the moving contact of the "Millisec" relay closes to the bottom contact (at a time about one-thousandth second after the key is closed) the receiving antenna is effectively shorted to ground. At the same time the key terminals of the keyer unit are

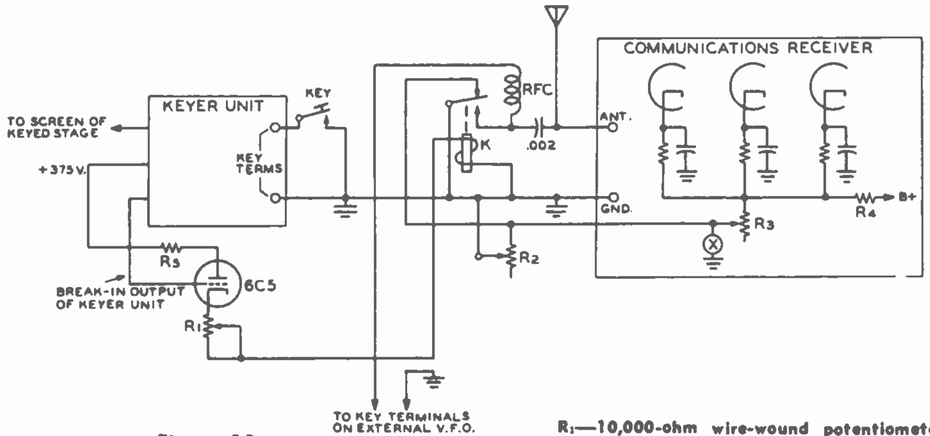


Figure 10.

ALTERNATIVE BREAK-IN SYSTEM.

R_1—10,000-ohm wire-wound potentiometer
R_2, R_3, R_4—Same as in figure 9.
R_5—3300-ohm 2-watt resistor
RFC—R-f choke suitable for band in use
K—18-volt type 172 "Millisec" relay

closed. Thus it can be seen that the receiver already has been muted and its antenna shorted to ground before the emission of a signal from the transmitter. But when the key is lifted the receiver is placed into operation at about the same time that the signal from the transmitter is dying out. Hence, the use of this circuit may result in the presence of fairly strong thumps in the phones each time that the key is raised. However, by proper adjustment of the value of R_2, and sometimes by the addition of a relatively large capacitor from ground to the junction of R_3 and R_4, it usually will be possible to delay the action of the muting circuit to a point where serious keying thumps will not be heard.

The circuit of figure 10 is best suited to use with a v-f-o unit of the manufactured type where it is not practicable or desirable to cut into the v-f-o circuit. In this arrangement the key is connected to the key terminals of the keyer unit and the antenna shorting relay is operated by a vacuum tube connected to the "BREAK-IN" output signal from the keyer unit. One additional triode tube of the 6C5 or 6J5 type is required for the operation of this circuit as compared to those of figure 9 and figure 10.

The action of the circuit of figure 10 is as follows: When the key is closed the potential fed to the grid of the added 6C5 is immediately brought up to ground potential. The tube conducts quickly and closes the "Millisec" relay K. When this relay closes the receiver is muted and the antenna shorted as before. But the added circuit on the shorting relay in this case serves to close the normal keying circuit of the external v.f.o. All this action takes place very quickly, and before the screen voltage output of the keyer unit is sufficiently high so that the keyed tube is ready to conduct. But the screen voltage output of the keyer unit does rise smoothly to the normal value so that full output from the transmitter is delivered.

When the key is lifted, the keying voltage to the keyed stage drops off normally. But due to the delay in the drop off of the voltage fed to the external 6C5, the "Millisec" relay remains closed for a moment. With rapid keying this relay will remain closed, but it will open between words if so adjusted.

The circuit of figure 10 is somewhat more smooth in operation than that of figure 9, but is more complex and hence more difficult to get into operation. The components associated with the relay K must be varied until the timing between the operation of this relay and the operation of the screen-voltage keying circuit is proper for smooth and clickless keying without objectionable thumps in the receiver.

Control of the Transmitter Plate Supplies The operation of the circuits of figures 8, 9, and 10 is based on the assumption that the transmitter plate supplies will be turned on and off manually. A key switch on the operating desk may be closed to turn on the supplies whenever transmission is started, and the plate supplies then may be turned off when a transmission is completed. But for rapid back-and-forth break-in, using the systems mentioned,

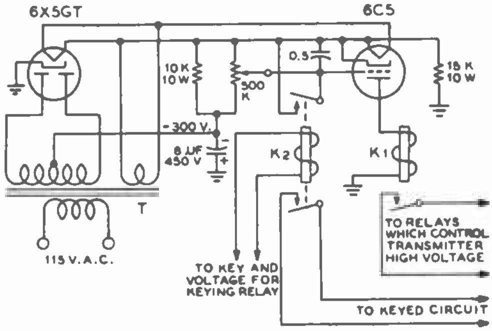


Figure 11.
AUTOMATIC-POWER-CONTROL CIRCUIT.
This circuit automatically turns on the high voltage power supplies when the key is first closed, then keeps the power supplies operating until a few seconds after the transmission of the last character.
K_1—2500-ohm s.p.s.t. relay
K_2—Double-circuit keying relay
T—Small power transformer such as Stancor P-6010 furnishing 650 v. c.t. at 40 ma., 6.3 v. at 2 a., and a 5-volt winding which is not used.

it will be necessary to leave the transmitter plate supplies on substantially all the time. This is a reasonable method of operation in certain cases, especially with a transmitter of moderate power. But in the case of a high-power transmitter the bleeder power alone on the high-voltage supplies becomes an appreciable power drain. Hence it becomes desirable that the plate supplies be turned on as soon as transmission is begun, but that these supplies turn themselves off automatically as soon as a certain time interval has elapsed after the transmission of the last character.

One circuit for accomplishing the controlling of the transmitter plate supplies with the keying circuit was described in the RADIO HANDBOOK, Eleventh Edition, on page 439. This description concerned the conversion and the power supply circuits for an ART-13 transmitter. The essentials of this power-supply control arrangement are given in figure 11.

The circuit of figure 11 operates in the following manner: When the key is closed, the keying relay K_2 closes. One set of contacts on this relay acts to key the circuit in the transmitter which is doing the actual job of keying the output. Alternatively, this set of contacts may be connected to the keyer unit previously described for accomplishing screen-voltage keying of the keyed stage. The other set of contacts shorts the grid of the 6C5 tube to the cathode as it closes. This action causes the 6C5 to draw full plate current which immediately closes relay K_1. As K_1 closes it causes the relay or relays to close which turn on the high-voltage plate supplies to the transmitter. Then, with normal keying, relay K_1 will remain closed thus keeping the plate-voltage supplies operative. Relay K_1 still acts, of course, to key the output of the transmitter.

When the transmission is completed, the 0.5-µfd. capacitor from grid to cathode on the 6C5 finally gets a chance to become charged from the tap on the 500,000-ohm potentiometer between negative high voltage and the cathode of the 6C5, thus cutting off the plate current to the 6C5. The time delay between the transmission of the last character and the opening of K_1 is controlled between a very short period and an interval of about ten seconds by the adjustment of the potentiometer. The 0.5-µfd. capacitor does not have time to build up sufficient charge during normal keying to cut off the tube since it is shorted out each time the key is closed.

An alternative circuit for accomplishing automatic control of the transmitter plate supplies is given in figure 12. This circuit is identically the same as that of figure 10 except that an additional 12AU7 tube and a sensitive relay have been added. The operation of the 12AU7, which is connected as a diode feeding a triode, is the same as the operation of the circuit which operates the "Millisec" relay in figure 10. However, the

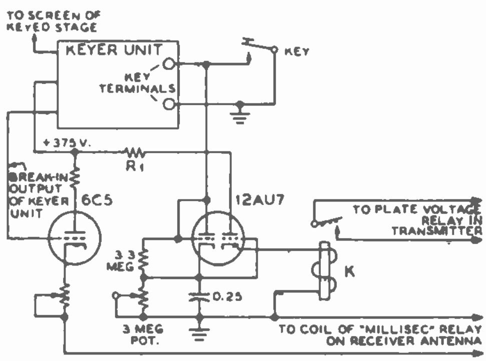


Figure 12.
ALTERNATIVE AUTOMATIC-POWER-CONTROL CIRCUIT.
This circuit is a modification of the circuit of figure 10, with the automatic-power-control circuit added. All circuit details not given are the same as in figure 10.
R_1—4700-ohm 2-watt resistor. Some variation in the value of this resistor will be required to obtain proper timing of the action of the power-control relay, K. Action of this relay may be speeded up somewhat, if required, by placing a 20-µfd. 250-volt electrolytic capacitor across Resistor R_1.
K—2500-ohm s.p.s.t. relay

time constant has been increased considerably so that the transmitter plate supplies may remain turned on during a normal pause in break-in operation of 5 to 10 seconds.

In the case of any of these circuits for automatically controlling the transmitter plate supplies, there is a certain amount of delay from the first closing of the key until the voltages being delivered by the supplies are high enough for normal operation of the transmitter. This means that if one merely starts keying without waiting for the plate supplies to become fully operative, the first dot or a portion of the first dash will not be transmitted. A very simple method for overcoming this condition is available. Simply tap the key for a very short dot an instant before you begin keying. This short dot due to the quick tap on the key will not be transmitted; but an instant later you may begin keying normally since all the control relays will have been operated by the first dot. This quick tap before you begin keying soon will become automatic in your operating. The timing is not at all difficult, since the control relays will be heard to close following the short tap, giving the signal that the transmitter is ready.

Figure 13.
AN INSTALLATION OF THE BREAK-IN RELAY.
The "Millisec" relay, installed on the antenna posts of a BC-348, is operating as a portion of the break-in circuit of figure 10.

Similarly, the transmitter control relays will be heard to drop out after a period of transmission. It is then obvious and more or less automatic to give the key a tap for closing the relays before actual keying of the transmitter is begun.

Receiving Antennas for Break-In One of the problems associated with break-in operation is the matter of the receiving antenna. For break-in operation on the lower frequency bands, where directive antenna arrays are not normally used, the normal procedure is to use a separate antenna for receiving. The receiving antenna usually is somewhat smaller than the transmitting antenna and may consist of a straight piece of wire located as far as possible from the transmitting antenna. Signal strengths on the lower frequencies usually are great enough so that a smaller and less efficient antenna than that used for transmitting may be used for receiving.

But for operation on the 14-Mc. band and above, it usually becomes desirable to use the transmitting antenna also for receiving, even for break-in operation. This becomes almost a necessity when a directive antenna array is used for transmitting. One satisfactory system for accomplishing the changeover is to tie the operation of the antenna changeover relay to the operation of the "Millisec" relay at the antenna posts of the receiver. A procedure such as this will involve a lot of clatter at the antenna changeover relay unless the time constants of the circuits accomplishing operation of the changeover relay are carefully controlled. But in any event it is necessary that the antenna changeover relay close quickly when the key is closed so that no sparking will take place at the changeover relay as a result of the power emitted by the transmitter. The opening of the changeover relay should be timed so that it will remain closed for a word, but will open between words and between sentences. Solenoid-type changeover relays are not rapid enough in their action, and are too noisy, for use with break-in; however, the simpler clapper-type of relay has proven to be rapid enough.

An alternative type of control for the changeover relay, which has proven satisfactory for the dx type of break-in operation or for traffic break-in where a delay in breaking of a few seconds may be tolerated on occasion, is to tie the changeover relay into the operation of the high-voltage plate supplies. This would require a control circuit such as figure 11 or figure 12, with the changeover relay

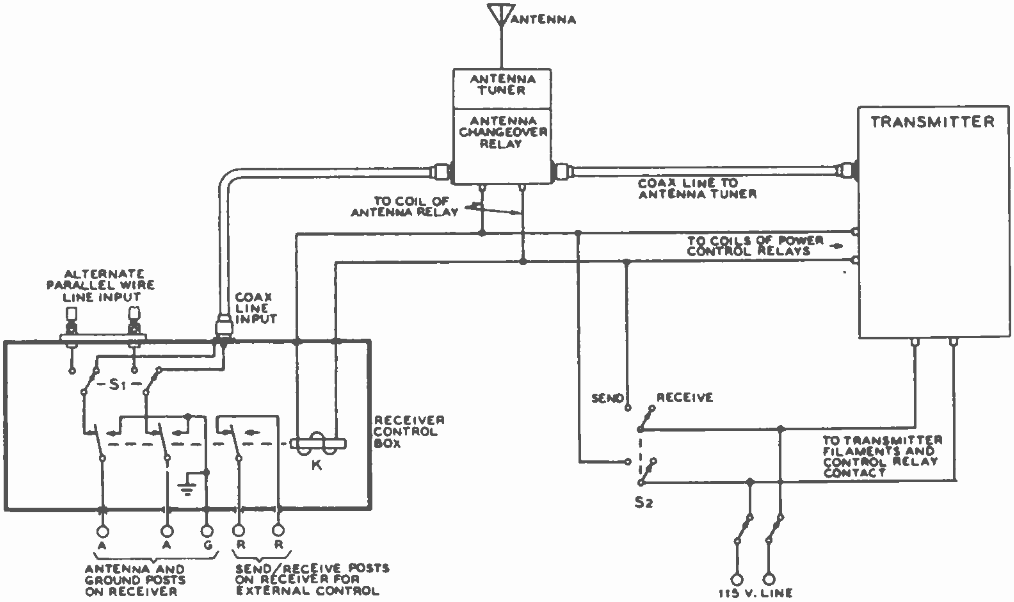


Figure 14.
SEND-RECEIVE CIRCUIT FOR PHONE OPERATION.
Switch S_1 changes the receiver from two-wire line to coaxial input. The relay K is a standard ceramic insulated antenna-changeover relay with a third set of contacts on the center of the relay structure for receiver control.

coil connected across the primary of one of the high-voltage transformers.

When using the above system of break-in with a strong received signal, a breaking signal usually can be heard on the leads from the receiver to the changeover relay, even though the antenna is connected to the transmitter. When operating with a relatively weak received signal, it will be necessary to pause periodically to listen for a breaking signal, thus allowing the plate supplies to shut down and the change-over relay to connect the antenna to the receiver. It has been found desirable in certain cases to connect a switch in series with a power supply control circuit such as figure 11 or figure 12, with the changeover relay may be shut down briefly and the antenna changed over for a short listening period.

In any event a complete, automatic, and smoothly operating break-in system is a relatively complex problem which will require a solution differing in details for each station installation. The control systems and procedures described in the previous paragraphs will prove helpful, with careful study, in setting up a complete control circuit for automatic break-in operation. Careful planning, followed by cut-and-try testing, will allow satisfactory break-in operation to be attained.

Antenna and Transmitter Control for Phone Operation

Control systems for the antenna, for the transmitter, and for the receiver at the station using mostly phone operation or using c.w. without break-in, are considerably simpler than those for break-in c-w operation. In the main, the conditions of "transmit" and "receive" are established in nearly all cases by the operation of a single switch which may have either two or three positions. When a third position is used it usually is for the position where both the transmitter and the receiver are inoperative.

A more or less standard control circuit for transmitter, receiver, and antenna changeover relay is diagrammed in figure 14. A minimum of three relays are required for this system. These relays are: the antenna changeover relay, the main power control relay in the transmitter, and the receiver control relay. When the control switch S_2 is placed in the transmit position, all three relays close more or less simultaneously. The antenna changeover relay disconnects the antenna from the receiver and connects it to the transmitter; the receiver control relay disables the receiver and shorts the antenna input posts; and the transmitter power control relay or relays turn on the ex-

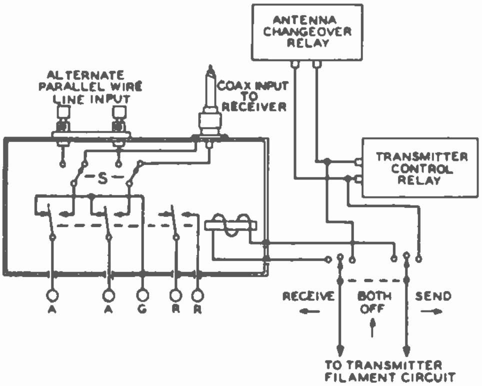


Figure 15.
SEND-RECEIVE CIRCUIT WITH CENTER OFF POSITION.
This circuit provides an off position on the transmit-receive switch for disabling both the transmitter and the receiver. The balance of the circuit is the same as that of figure 14.

citer and apply plate voltage to the transmitter.

The Receiver Control Box may best be placed at the rear of the receiver, and may conveniently be grounded to the receiver chassis. An alternate switch has been shown as a portion of the receiver control box for changing the connections inside the box for operation of the receiver from a two-wire line instead of operation from coaxial-cable input.

In many installations it may be found that when the SEND-RECEIVE switch is changed to the RECEIVE position, the receiver will be blocked for an instant by the signal emitted from the transmitter. This condition is the result of the energy stored in the filter capacitors of the transmitter. These capacitors frequently will hold enough charge so that the transmitter will continue to emit a signal for a moment after the switch is placed in the receive position. Since the receiver input is opened and the receiver turned on at the same time that the transmitter is turned off, this last bit of signal from the transmitter may block the receiver.

If the blocking condition is serious enough to cause trouble, the transmitter-receiver-antenna control circuit may be changed over to that illustrated in figure 15. In this arrangement a three-position switch is used for the SEND-RECEIVE control. In one position the transmitter is turned on and the antenna changeover relay is in the transmit position. In the center position both the transmitter and the receiver are inoperative. And in the third position the receiver is turned on. If the control switch is consciously stopped in the center position when going from TRANSMIT

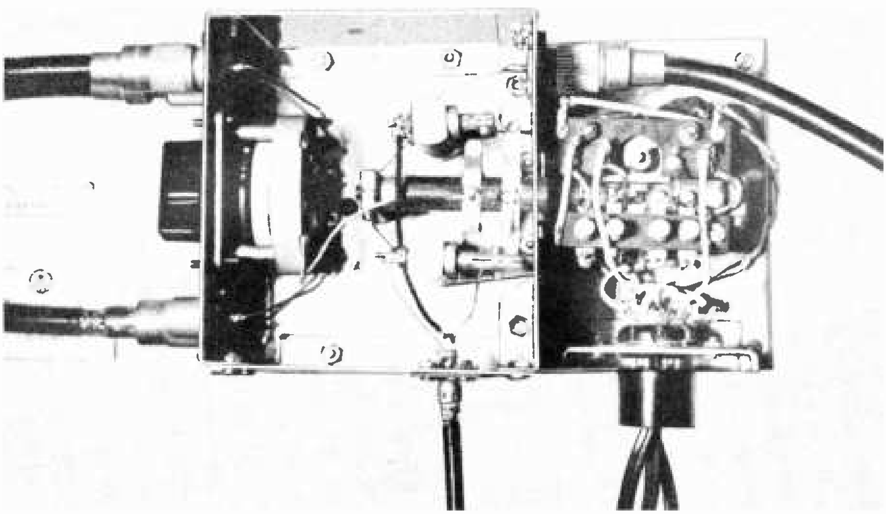


Figure 16.
SHOWING THE BC-375 CONTROL RELAY AND ANTENNA SELECTOR.

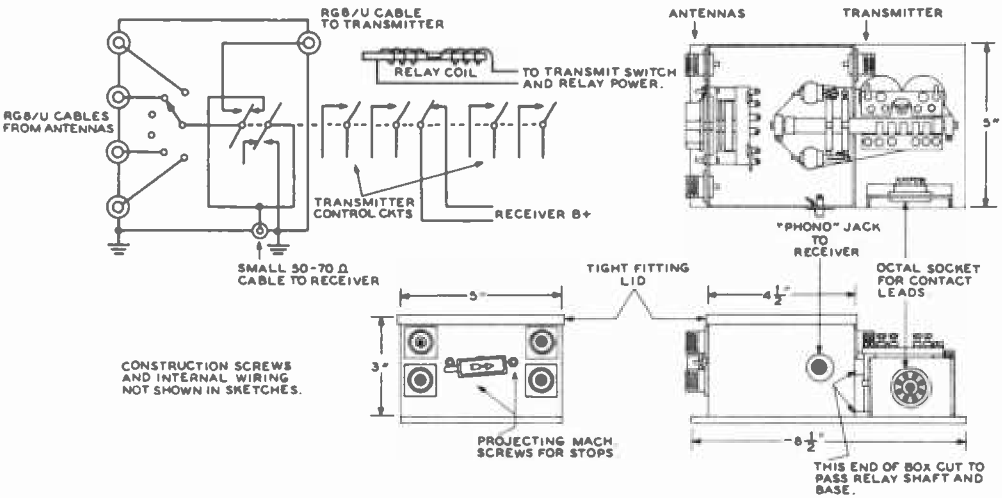


Figure 17.
SCHEMATIC AND SKETCH OF THE CONTROL RELAY AND ANTENNA SELECTOR.

to RECEIVE, the blocking condition in the receiver can be eliminated. The receiver input remains shorted, and the receiver is in the inoperative condition until the control switch is placed in the RECEIVE position. In fact, there are switches available on the market which have a stop in the center position of such a nature that it is necessary to press the switch lever twice to go from one extreme position to the other extreme. The switch is pressed once to go from the SEND to the neutral position, then the force is released, then the switch is pressed once more to go from the neutral to the RECEIVE position. The use of a switch of this type will insure that an instant's time delay is allowed, even by a guest operator, in going from SEND to RECEIVE.

Using the Multiple-Control Relay from the BC-375E Shown in figures 16 and 17 is a method for using the multiple-circuit relay from a BC-375E, along with one of the ceramic deck switches from the same transmitter, as a complete transmitter-receiver-antenna control unit. The relay is from the main transmitter section of the equipment, while the switch and the knob for it are from one of the "TU series" tuning units.

The control-circuit portion of the relay is left unchanged since a large number of circuit possibilities already are provided by the original contact arrangement. However, the antenna-changeover portion of the relay is modified by moving two of the contact posts. In the original unit there are a long and a short contact post on each of the ceramic support pillars. Two of these contact posts are changed in position so that both long posts are on one support pillar while both short contact posts are on the other support pillar. Then the contact to the two "flipper" arms is made by soldering a flexible wire to the screw which holds the arm to the micalex support rod. In this way, after proper adjustment of the contact spacing, the antenna changeover portion of the relay becomes a conventional double-pole double-throw arrangement.

The unit illustrated in figure 16 was constructed for use with a group of antenna systems having coaxial feed lines. The transmission lines to the transmitter and to the receiver from the control box also are of the coaxial type. Hence, the changeover portion of the relay and the antenna selector switch are enclosed in an aluminum shield box—which in this case was fabricated from aluminum-base broadcast transcription discs. The base of the complete assembly is of ¼-inch plywood which has been covered with sheet aluminum from the same source.

The r-f portion of the relay switches the antenna from the receiver to the transmitter, and at the same time grounds the end of the coaxial cable which runs to the receiver input. The power-control end of the relay removes plate voltage from the receiver, and at the same time will control up to four separate power circuits within the transmitter. An octal socket on the chassis of the unit serves as termination for the power-conrol circuits, from which cables run to the transmitter and the receiver.

The relay requires approximately 25 volts at ½ ampere for positive operation. This power may conveniently be obtained through the use of a full-wave bridge rectifier and a filament transformer of the type designed for use with 24-volt surplus receivers. In the case of the unit illustrated, the power supply for the control relay was made up from an ancient battery-charging-type of bridge copper-oxide rectifier of unknown characteristics, and a multiple-voltage transformer salvaged from a defunct tube tester. No filter was required for hum-free and chatter-free operation of the multi-circuit relay.

The changeover-relay assembly illustrated has been in use for an extended period of time with several hundred watts of power on the 50-Mc. and 28-Mc. bands. No tendency toward break-down of the dielectric material of the switch has been noticed.

CHAPTER TWO

Receiving Equipment

It is generally conceded by the amateur fraternity that the most economical method of obtaining the basic station receiver is to purchase a standard factory model. Excellent commercial receivers are available on the market in all price range groups. Many of these receivers have been expressly designed for amateur communication. To equal the performance of these equipments would require the expenditure of about the same amount of cash plus a large amount of time and energy which might more effectively be spent on the transmitter and its control systems, or on antennas. Further, the cash outlay in a good communications receiver is a sound investment. True, there will be depreciation. But the depreciation is gradual and may be written off to operating satisfaction over a period of many years.

Satisfactory surplus receivers such as the BC-348, BC-312, and BC-342 also are available at a cost much less than the market price of components equivalent to those used in the equipments. True, these receivers do not offer in themselves coverage of the amateur bands above 14.4 Mc., but convenient and satisfactory multiband converters are available from several manufacturers for adding coverage of the higher frequency bands. Alternatively, many amateurs prefer to construct the higher frequency converters so that they will be able to obtain peak performance on a particular band.

As a result of this trend, this chapter is devoted to the construction of converters and adapters for operation with the regular station communication receiver. An exception is the simple regenerative receiver which has been described to enable the beginner in amateur radio to obtain a familiarity with the operation of simple radio circuits. Even then, a modification procedure has been described whereby the simple regenerative receiver may be changed over to result in a simple, though excellent, one-tube converter for the bands below 30 Mc.

Two-Tube Regenerative Receiver

A simple two-tube regenerative receiver is illustrated by figures 1 through 4. The receiver is designed primarily for operation from a simple a-c power supply, though it may also be operated from a 6-volt "A" battery and either a vibrator power pack or 180 volts of "B" battery.

The receiver employs a 6J7 tube as a regenerative detector with a 6J5 tube as an audio amplifier. Loud signals are delivered to high-impedance headphones (2000 ohms or over). All the amateur bands from 1.8 through 30 Mc. are covered, and a simple

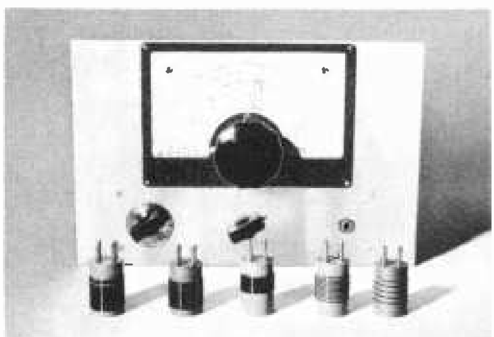


Figure 1.
FRONT OF THE REGENERATIVE SET, SHOWING COILS.

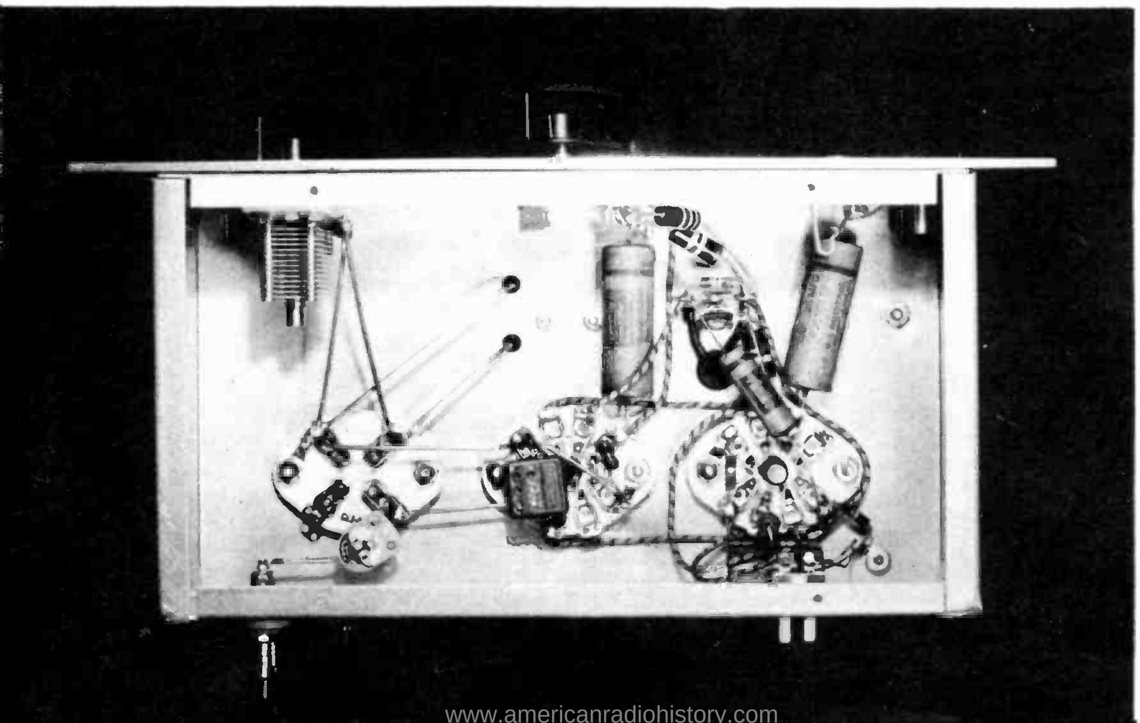
Figure 2.
TOP PHOTO OF THE
REGENERATIVE RECEIVER.

single-wire antenna may be used for receiving on all the bands.

Chassis and panel construction is used with an aluminum panel (8 by 12 inches by 0.125 inches thick) and an aluminum chassis 5½ by 10 by 3 inches (ICA no. 29004). The layout of the components on the chassis and the panel is not especially critical and may be made from inspection of the photographs. The large dial drives the main tuning capacitor and the small knob to the left of the lower panel drives the band-set capacitor. The knob below the tuning dial is the regeneration control and the phone jack is on the right end of the front panel. All power connections to the receiver are made to a 4-prong Jones plug which may be seen on the rear of the chassis. The antenna terminal post also is mounted on the rear of the chassis.

Receiver Adjustment The following steps should be taken in adjusting the regenera-

Figure 3.
UNDERCHASSIS OF THE REGENERATIVE RECEIVER.



COIL TABLE FOR REGENERATIVE RECEIVER

1.8 Mc.	68 turns no. 28 enam. closewound, cathode tap at 9 turns. Bandset dial set at approximately 4.
3.5 Mc.	30 turns no. 22 enam. closewound, cathode tap at 3½ turns. Bandset dial set at approximately 3.
7.0 Mc.	19¼ turns no. 22 enam. closewound, cathode tap at 2¾ turns. Bandset dial set at approximately 7.
14 Mc.	9¾ turns no. 22 enam. spaced to ⅞ inches, cathode tap at 2½ turns. Bandset dial set at approximately 7.
21 Mc.	Use 28-Mc. coil. Bandset dial set at approximately 4.
28 Mc.	4¾ turns no. 22 enam. spaced to ⅞ inches, cathode tap at 1½ turns. Bandset dial set at approximately 8.

All Coils wound on 1-inch diameter National XR-1 coil forms.

tive receiver for operation: (1) Connect 4-wire power cable between power unit and receiver. (2) Plug 3.5-Mc. coil into coil socket of receiver. (3) Insert power-supply line plug into 115-volt a-c outlet and throw switch in power supply to ON position. (4) Insert headphone plug into jack on receiver panel and allow about one minute for all tubes to heat fully. (5) Set bandset capacitor on lower left of receiver panel to about dial division 3. (6) If a test oscillator is available, feed a signal of 4000 kc. into receiver, and adjust regeneration control until a beat note is heard. Calibrate receiver main dial for this frequency and proceed down through the band to obtain additional calibration points.

If a test oscillator is not available and cannot be borrowed from a friend or radio serviceman, connect antenna and ground to the receiver and listen to signals on the 3.5-Mc. band in the evening. The two ends of the band may be determined with fair accuracy by noting the points beyond which no more amateur signals appear.

The calibration operation described above must be repeated for the coils which give operation on the other amateur bands. The approximate settings for the bandset capacitor for each of the amateur bands are given in the coil table. The antenna coupling capacitor should be adjusted to the minimum amount which will give satisfactory reception

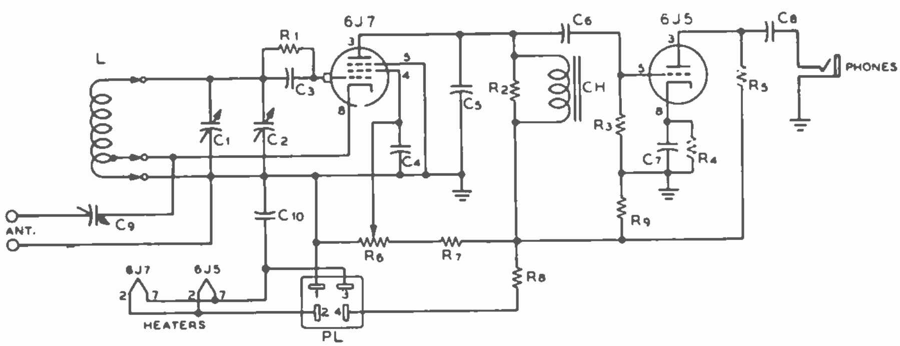


Figure 4.

SCHEMATIC OF THE REGENERATIVE RECEIVER.

C_1—100-μμfd. midget variable (National UM-100)
C_2—15-μμfd. midget variable (National UM-15)
C_3—0.0001-μfd. midget mica
C_4—0.05-μfd. 400-volt tubular
C_5—0.00025-μfd. mica
C_6—0.01-μfd. 400-volt tubular
C_7—25-μfd. 25-volt electrolytic
C_8—0.05-μfd. 400-volt tubular
C_9—7-35-μμfd. ceramic trimmer (Centralab 820C)
C_{10}—0.003-μfd. midget mica
CH—Secondary winding of Stancor A-4742 audio transformer
L—See "Coil Table for Regenerative Receiver"
R_1—2.2 megohms ½ watt
R_2—100,000 ohms ½ watt
R_3—470,000 ohms ½ watt
R_4—1000 ohms ½ watt
R_5—100,000 ohms 2 watts
R_6—50,000-ohm potentiometer (IRC D11-123 linear taper)
R_7—100,000 ohms 2 watts
R_8—22,000 ohms 2 watts
R_9—47,000 ohms 2 watts
PL—Jones P-304AB
Connections to PL are:
1—Ground, negative side of plate voltage
2—6.3 volts to heaters
3—6.3 volts to heaters
4—Plus 250 volts d.c.

Note: If batteries are to be used, or if the receiver plate supply delivers less than 200 volts, resistor R_8 should be omitted from the circuit, resistor R_9 should be omitted and the lead from terminal 4 on PL should go to the junction of R_7, CH, and R_9.

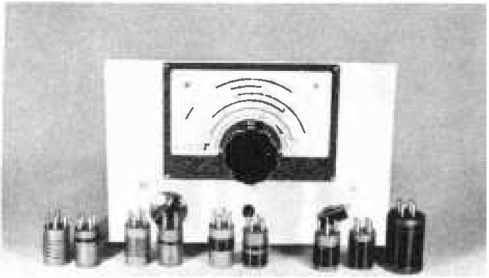


Figure 5.
FRONT OF THE SUPERHET CONVERTER, SHOWING ALL COILS.

of signals on all bands. The regeneration control should be set for the minimum amount of regeneration which will give good reception. This control should be set at the point where the detector tube is barely oscillating for c-w reception, and should be set at the point just below oscillation for the reception of radiophone signals.

One-Tube Superheterodyne Converter

The regenerative receiver just described will pull in an amazing number of signals on all the amateur bands, when consideration is given to the fact that only two tubes are used. But the regenerative receiver leaves much to be desired in the way of selectivity, and is somewhat critical in tuning.

Superheterodyne reception may be had on all amateur bands through the use of a superheterodyne converter and a broadcast receiver or a short-wave receiver with limited coverage. One of the least expensive arrangements which will still be found quite adequate is the use of a surplus BC-454A receiver to cover the 3 to 6 Mc. range directly, and then the use of this receiver in conjunction with a simple superheterodyne converter to cover all the other amateur bands.

The converter unit to be described may be used in conjunction with any receiver capable of tuning either to 1.5 Mc. (such as a broadcast receiver) or to 3 Mc. (such as a BC-454A, a BC-312, or a BC-348). When the converter is to be used with a broadcast receiver it will of course be used to cover all the amateur bands. When used with a BC-454A it will be used to cover all bands except 3.5 Mc., and when used with a BC-348 or BC-312 it will probably be used only to cover the 21-Mc. and 28-Mc. bands.

The converter illustrated in Figures 5 through 8 is designed to be constructed as a modification of the regenerative receiver just described. The modification is accomplished as follows: Remove all components from the receiver except the two tuning capacitors and the coil socket. Then reverse the octal socket in the center of the chassis so that the slot for the locating pin is away from the coil socket. Then install another four-prong ceramic tube socket in the position formerly occupied by the socket for the 6J5 tube. Install a switch of the toggle type in the position formerly occupied by the regeneration control, and place a 100-$\mu\mu$fd. variable tuning capacitor in the place formerly occupied by the phone jack. The adjustable capacitor across the output coil in the plate of the 6SA7 is mounted on the chassis in such a position that the adjusting nut projects through the hole in the chassis which formerly passed the wires for the choke in the plate of the 6J7.

With these changes made, which involve very little additional metal work, the converter may be wired as shown in figure 8. The coil socket which originally was in the regenerative receiver is used as the oscillator coil socket—and all of the coils made for the regenerative receiver can be used intact as the oscillator coils for the converter. The added coil socket is for the tuned circuit which couples the signal from the antenna into the signal grid of the 6SA7.

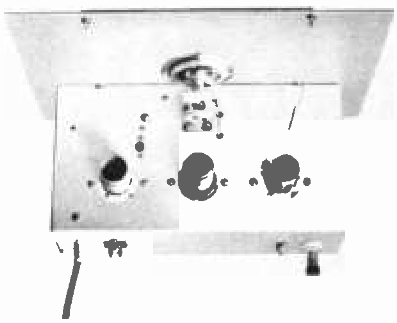


Figure 6.
TOP VIEW OF THE SUPERHET CONVERTER.
The oscillator coil is on the right and the mixer grid (antenna) coil plugs into the coil socket on the left.

COIL TABLE FOR SUPERHETERODYNE CONVERTER

BAND	OSCILLATOR COIL	ANTENNA COIL
1.8 Mc.	Use 3.5-Mc. coil from the regenerative receiver.	54 turns no. 22 enam. closewound on 1½" dia. form (National XR-4). Ant. coil 8 turns no. 22 enam.
3.5 Mc.	Use 3.5-Mc. coil from the regenerative receiver.	35 turns no. 22 enam. closewound on 1" dia. form. Ant., 7 turns.
7.0 Mc.	Use 7-Mc. coil from the regenerative receiver.	18 turns no. 22 enam. closewound on 1" dia. form. Ant., 6¾ turns.
14 Mc.	Use 14-Mc. coil from the regenerative receiver.	7¼ turns no. 18 enam. spaced to ⅝". Ant. coil 4 turns no. 22 enam.
21 Mc. and 28 Mc.	Use 28-Mc. coil from the regenerative receiver.	5¾ turns no. 18 bare spaced to ⅝". Ant. coil 5 turns no. 22.

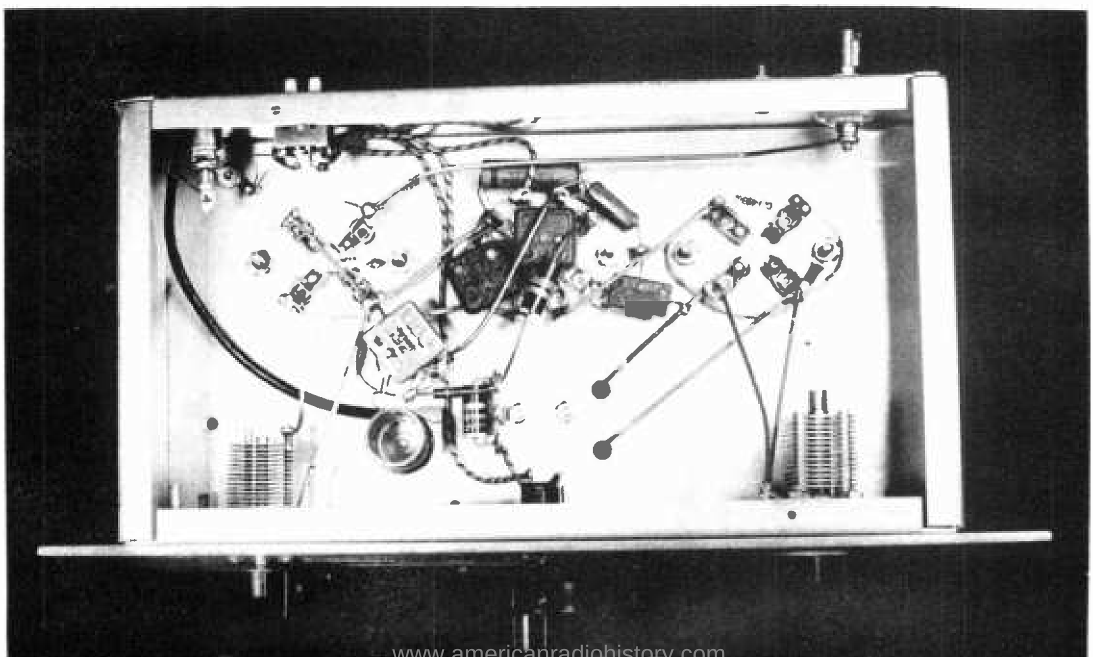
Antenna coils for the converter all are wound on National XR-1 coil forms with the exception of the coil for 1.8 Mc. which is wound on a 1½-inch diameter, National XR-4 coil form.

Tuning Procedure The tuning procedure for the converter is relatively simple. Plug in coils for one of the amateur bands and couple the output of the converter to the input of the receiver with which it is to be operated. The tuned circuit in the plate of the 6SA7 must of course tune to the same frequency as the input circuit of the receiver with which the converter will operate. Apply plate and heater voltage to the converter and turn on the receiver which is fed by the converter. Turn up the gain on the receiver, and tune it to 3000 kc. (assuming that a receiver which will tune to this frequency is being used). A fair amount of noise output should be heard. Then tune the capacitor across the coil in the plate of the 6SA7 for maximum noise output from the receiver. A fairly sharp increase in noise level output should be heard when the plate circuit of this tube is tuned to the same frequency as the input circuits of the receiver which it is feeding.

Then attach an antenna to the converter and set the bandset knob to approximately the same position as was used when the unit was used as a regenerative receiver. Then peak up the grid circuit of the 6SA7 for maximum noise level and tune for signals.

It will be found, if the unit has been wired

Figure 7.
UNDERCHASSIS OF THE SUPERHET CONVERTER.



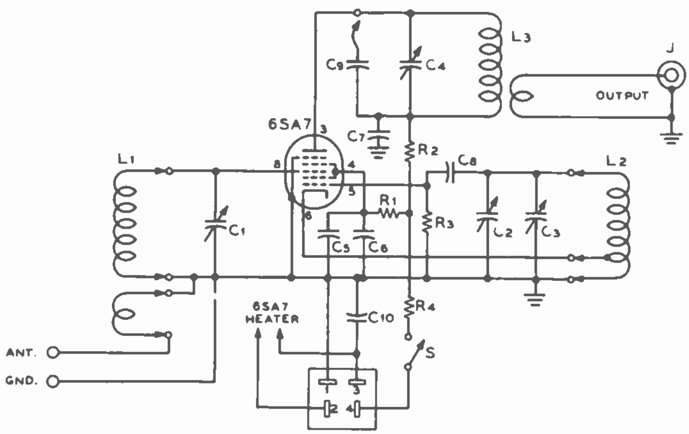


Figure 8.
SCHEMATIC OF THE SUPERHETERODYNE CONVERTER.

C_1, C_2—100-μμfd. midget variable (National UM-100)
C_3—15-μμfd. midget variable (National UM-15)
C_4—20-125 μμfd. ceramic variable (Centralab 823-BN)
C_5—0.003-μfd. midget mica
C_6—0.01-μfd. 400-volt tubular
C_7—0.0068-μfd. midget mica
C_8—75-μμfd. midget mica
C_9—75-μμfd. midget mica (Note: C_9 is included in the circuit only for operation with 1.5-Mc. i.f. For 3-Mc. i.f. it is omitted.)
C_{10}—0.003-μfd. midget mica
L_1, L_2—See "Coil Table for Superheterodyne Converter"
L_3—1 3/16 inch no. 28 enam. on ¾-inch dia. Amphenol no. 24. Link, 8 t. no. 22 enam.
R_1—22,000 ohms, 2 watts
R_2—100 ohms, ½ watt
R_3—22,000 ohms, ½ watt
R_4—47,000 ohms, 2 watts
S—S.p.s.t. toggle switch
J—Auto-antenna-type connector

correctly, that the converter is quite a "hot" unit. Excellent results should be obtained on all bands through 30 Mc. It will be found that the peaking of the 6SA7 signal grid circuit (the knob on the right of the front panel) tunes fairly sharply for maximum signal, but a fair portion of each of the amateur bands may be covered by tuning the main tuning dial only, without re-peaking of the mixer (6SA7) grid circuit. Pulling in frequency between the mixer grid circuit and the oscillator tuned circuit is negligible as long as the mixer circuit is tuned to peak up the signal strength. The oscillator portion of the converter may be operated either higher or lower than the signal frequency by the output frequency of the converter. Thus if 3 Mc. is to be the output frequency of the converter (and hence the input frequency of the receiver being fed by the converter) the oscillator may be operated either 3 Mc. above the signal frequency or 3 Mc. below, whichever is most convenient with the coils being used.

For c-w reception with the unit, the best oscillator in the associated receiver should be turned on. If the receiver does not have a beat oscillator, one may be added.

Adding 175-Kc. I.F. to the BC-348Q Series

Many users of the BC-348 series receivers have found that the i-f channel of the receiver is much too broad for satisfactory c-w operation on the dx bands, or for completely satisfactory phone operation on any of the bands. It is possible, of course, to add an external adapter unit with a lower frequency i-f channel to accomplish the sharpening. In fact, some operators have changed the local-oscillator frequency and the r-f alignment of the BC-453A receiver so that its 85-kc. i-f channel could be fed from the 915-kc. i-f output of the BC-348.

However, the vacant space left by the removal of the dynamotor from the BC-348 leaves a convenient space for the inclusion of the "sharp i-f channel." Many operators originally installed the power supply for the BC-348 in the space formerly occupied by the dynamotor. However, the relatively large amount of heat given off by an a-c power supply sufficiently large to operate the BC-348 has in most cases resulted in an excessive amount of drift in the receiver, at least as far as c-w operation is concerned. So, since

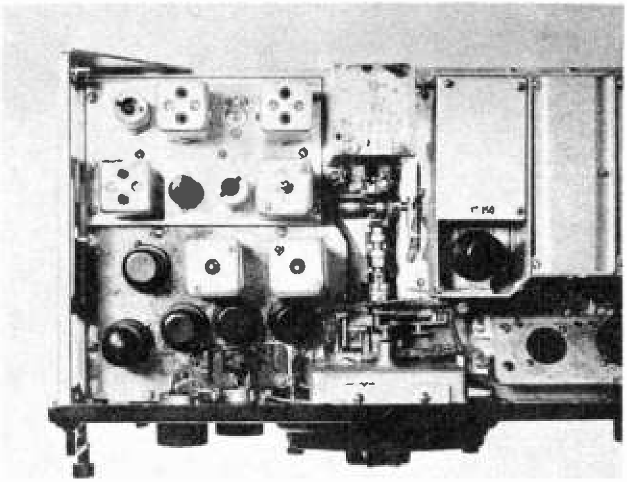


Figure 9.
TOP VIEW OF THE BC-348 WITH THE 175-KC. I-F CHANNEL INSTALLED.
The ceramic coupling capacitor between T_2 and T_3 may be seen mounted physically between them in this photograph. The added socket with the 6V6 tube may be seen occupying the position formerly occupied by the third 915-kc. i-f transformer.

the power supply is best mounted externally anyway, the neat dynamotor space is ideal for the installation of the 175-kc. i-f channel.

Since we are operating on the receiver anyway, an additional audio stage and the noise limiter may conveniently be installed at the same time that the 175-kc. "sharp channel" is added. A considerable degree of variation in the conversions and additions is permissible, but the data given herein has resulted in a very satisfactory receiver. The selectivity is excellent, permitting the copying of either sideband of a conventional AM phone signal, and allowing "single-signal" c-w reception either with or without the receiver crystal in the circuit.

The Modified Circuit The wiring of the receiver is left unmodified up to and including the second i-f stage. The secondary of the second i-f transformer then is coupled into a 6BE6 mixer, which converts the 915-kc. i.f. to 175 kc. The output of the 6BE6 then passes through two loosely coupled 175-kc. i-f transformers into a 6BA6 175-kc. i-f stage and then into a 6AL5 combined diode detector and noise limiter. The 6BE6, 6BA6, and 6AL5 with their associated components are on a small chassis which is mounted in the place formerly occupied by the dynamotor. The output of the 6AL5 then feeds back through the gain control on the front panel into a 6SJ7-6V6 audio channel which has been installed on the original "plate chassis" which still mounts the two 915-kc. i-f stages. The 6C5 beat oscillator tube, which operates on 915 kc. simply because the 915-kc. beat oscillator transformer already is installed, is installed on the original chassis behind the 6V6 and 6SJ7 tubes.

Modification Procedure Figure 11 shows the modified circuit of the output end of the receiver. Before making any modification in the set it is advisable to make sure that the front end up to and including the second i-f stage is operating properly. If the unmodified receiver already is in operation, no problem will be introduced. But if the receiver is in its original condition and has not been tested, it will be well to re-wire the heater circuits for 6.3-volt operation and check out the set. Note that, with the receiver in the unmodified state it will be necessary to short pin 2 to pin 6 on the connection plug on the rear of the receiver before operation can be obtained.

After the set has been checked out in its original state, the changeover can be started with the assurance that the unmodified portion is capable of operating properly, so that only the added portions need be gotten into operation. The first step in the changeover is to remove all components associated with the 3rd i-f stage, the 2nd det.-a.v.c.-c.w. osc. stage, and the output audio stage. The wires to the beat-oscillator transformer, the audio output transformer, and the AVC-OFF-MCW switch should be removed, but the components should be re-installed. The 3rd i-f transformer is removed and an octal socket installed in its place.

The 175-kc. i-f channel and noise limiter are constructed on a chassis-plate with fin-

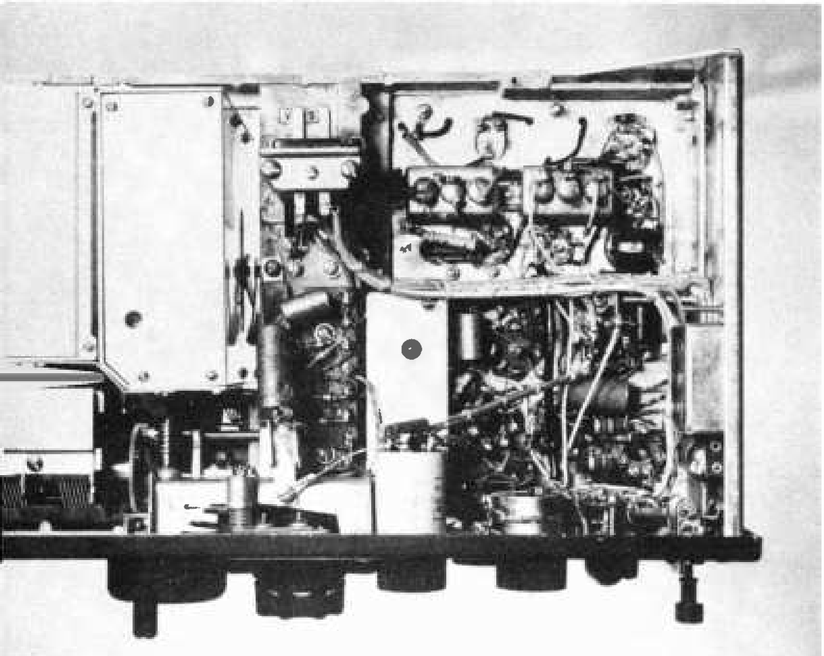


Figure 10. UNDERCHASSIS VIEW OF THE MODIFIED BC-348.

ished dimensions of 3-⅞ by 6 inches. A ⅜-inch lip is bent *upward* along each of the 6-inch sides of the chassis-plate. This means that the original dimensions of the aluminum plate before bending are approximately 4-⅝ by 6 inches. After the chassis has been bent to shape a clearance hole for the locating pin on the main chassis may be made in the aluminum plate and the holes for the four mounting screws drilled. The 175-kc. i-f channel may be built, wired, and tested externally to the main receiver. The installation of the chassis in the main receiver is then a simple problem.

The two audio stages and the beat oscillator are then wired to the three socket holes in the main chassis of the receiver alongside the two 915-kc. i-f stages which were left unmodified. Shielded leads are used to the output transformer from the 6V6 and from the output transformer to the two phone jacks on the panel. The low-impedance winding on the output transformer is run to one phone jack and the higher impedance winding to the other phone jack. The low-impedance winding is best for headphone reception and the higher-impedance winding will feed a PM dynamic speaker with a 2000-ohm to voice coil transformer included with the speaker. The leads from the noise limiter to the volume control and from the volume control to the grid of the 6SJ7 also are run in shielded wire throughout their length.

The action of the AVC-OFF-MVC switch is changed somewhat as a result of the use of an external a-c operated power supply. The new wiring arrangement of the switch is shown in figure 11. Resistor 101-2 (5000 ohms) and capacitor 64 (0.05μfd.) in the time-constant changing circuit associated with the beat-oscillator switch are removed.

Alignment Procedure It is best to have a signal generator available for the alignment of the 175-kc. channel. If one is available, the 175-kc. stages should be aligned first, with the output of the 6AL5 being fed through an audio amplifier to an output meter or loudspeaker. Then, with the aid of a broadcast receiver coupled to the output of the 6BE6 mixer, the tuning capacitor across T_1 is tuned until a signal is heard in the broadcast receiver on 1090 kc. The signal generator is then tuned to 915 kc. and the trimmer on T_1 varied slightly until the 915-kc. signal from the signal generator comes through in the center of the 175-kc. pass band. Some variation in the sharpness of the 175-kc. channel may be obtained by varying the setting on the 5-20 $\mu\mu$fd. trimmer which couples T_2 and T_3.

If a signal generator is not available, the

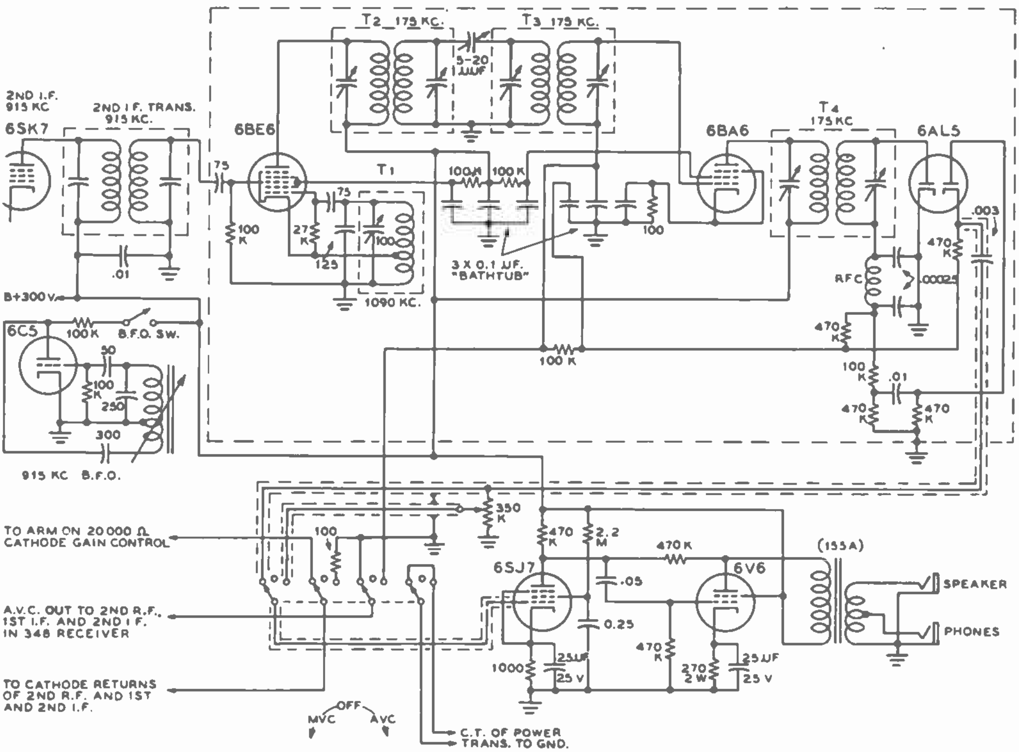


Figure 11.
SCHEMATIC OF THE CIRCUITS ADDED TO THE BC-348.

RFC—8 mh. r-f choke (Meissner 19-2078)
T_1—Broadcast-band "6SA7 type" oscillator coil (Meissner 14-1033) mounted in shield can with 100-µµfd. APC trimmer.
T_2, T_3—175-kc. "interstage" i-f transformers (Meissner 16-6650)
T_4—175-kc. "output" i-f transformer (Meissner 16-6651)

i-f channel may be tuned by using it as a broadcast receiver, with an antenna coupled through a tuned circuit to the grid of the 6BE6 mixer. Tuning of a portion of the broadcast band in the vicinity of 900 kc. may be obtained by varying the tuning of the circuit in the grid of the 6BE6 while the oscillator frequency is varied by tuning the 100-µµfd. trimmer across T_1.

The 6SJ7-6V6 audio channel installed in the BC-348 chassis may be checked separately if desired, but little difficulty should be encountered with its operation. After the 175-kc. i-f channel is installed, it may be desirable to retrim the capacitor across T_1 slightly to insure that signals in the center of the 915-kc. channel of the BC-348 will be converted to such a frequency that they will fall in the center of the 175-kc. channel. Only a very slight trimming of the capacitor across T_1 should be required. It may be desirable, for c-w operation, to displace the frequency of T_1 a few kc. to one side or the other from 1090 kc. so that single-signal selectivity may be obtained with a c-w signal in the center of the response curve of the 175-kc. channel. The crystal filter of the BC-348 should be in operation when this alignment is being made.

28-Mc. Broad-Band Crystal Converter

The unit shown in figures 12 and 13 and diagramed in figure 14 was designed to fill two general needs: 1. To give complete coverage of the 27 and 28 Mc. bands for those receivers which do not cover this frequency range. Many surplus receivers such as the BC-348, BC-312 and BC-779 give excellent operation on the lower frequency bands but are limited to an upper frequency range of 18 to 20 Mc. In conjunction with this con-

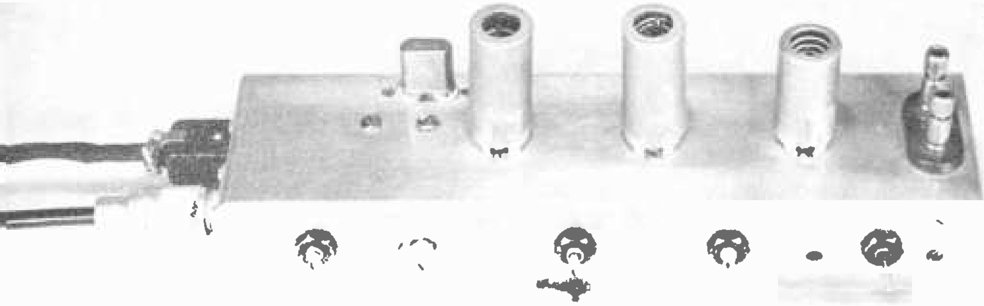


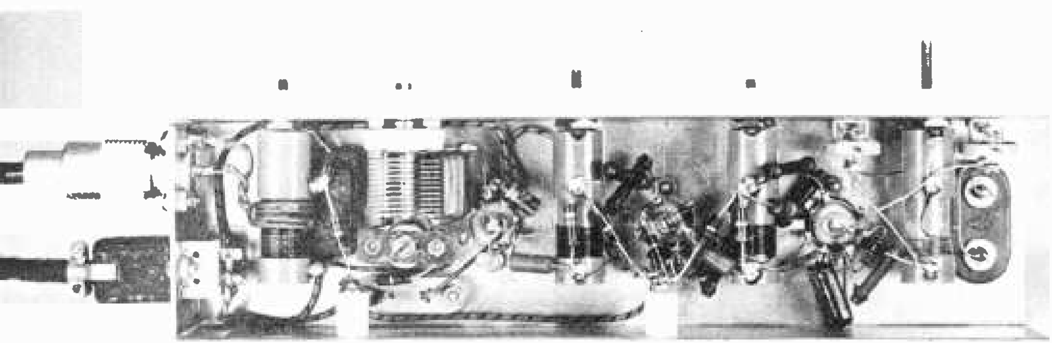
Figure 12.
TOP VIEW OF THE CRYSTAL-CONTROLLED CONVERTER.

verter these receivers will give excellent coverage of the 10 and 11 meter range. And 2, to provide improved stability of operation for 28 Mc. c-w reception. Many of the less expensive communications receivers which do cover the 28 Mc. band do not have sufficient local oscillator stability to give completely satisfactory crystal filter operation in this frequency range. Through the use of this converter the 27 to 29.7 range is transferred to the range from 7 to 9.7 Mc. where local oscillator stability in the receiver is usually greatly improved. Since the 20-Mc. high frequency beating oscillator in the converter is crystal controlled, oscillator stability within the converter itself is a negligible factor in overall stability.

The converter is substantially flat in response over the 3 Mc. range from 26.8 to 29.8 Mc. Coverage of this wide a frequency range requires the use of broadband amplifiers with their relatively large power drain. The actual power requirements of the unit are 0.925 ampere at 6.3 volts and about 25 ma. at 120 to 150 volts. In many cases it will be found that this power drain is in excess of that which the power pack in the associated receiver can deliver. Hence it will be necessary to construct a small external unit for operation of the converter. In some cases this external power supply may consist merely of a filament transformer and a selenium-rectifier filter system operating directly from the 110-volt line. However, in cases where it is not acceptable to ground one side of the receiving equipment to the grounded side of the 110-volt a-c line, a small power supply with a 40-ma. power transformer, a 6X4 or a 6X5-GT rectifier and an R-C filter can be used to deliver the 150 volts to the converter.

Circuit Description Experience with many types of broadband converters has lead to the conclusion that at least two r-f stages within the converter are required for completely satisfactory operation. In the first place the converter must have sufficient signal output to override the mixer and front-end noise which exists in any communications receiver. If the output level of the converter is not sufficiently high, the effective signal to noise ratio of the receiver-plus-con-

Figure 13.
UNDERCHASSIS OF THE 28-MC. CONVERTER.



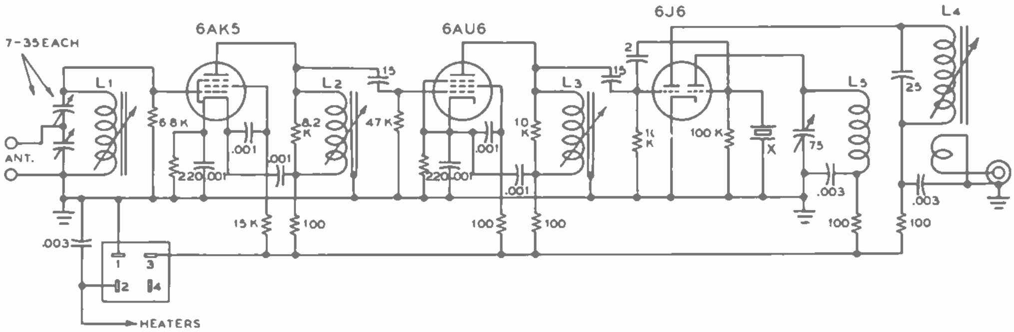


Figure 14.
SCHEMATIC OF THE BROAD-BAND 28-MC. CONVERTER.

L_1—10 turns no. 24 enam. closewound on National XR-50 form
L_2, L_3—13 turns no. 20 enam. closewound on National XR-50 form
L_4—28 turns no. 24 enam. closewound on National XR-50 form with 4-turn link of hookup wire at cold end
L_5—12 turns no. 24 enam. closewound on ½" dia. ceramic pillar insulator
All resistors are one-half watt

verter combination will be poorer than that of the receiver alone. Another reason for having a high signal-voltage output level from the converter is that the high signal voltage will assist in overriding the few signals in the 7 to 9.7 Mc. range which inevitably get through. If the converter and the coaxial cable between it and the receiver along with all connectors were completely shielded, no low frequency signals would be passed through the converter. However, no receiver is completely shielded and in most cases it will be found that one or two powerful commercials and perhaps any neighboring amateurs on the 7 Mc. band will deliver signals of sufficient intensity to be heard. With a moderate degree of experimenting with grounding and shielding it will be possible, however, to reduce these interfering signals to a sufficient degree that they will cause little trouble to reception on the 28-Mc. band.

R-F Stages In the unit shown two pentode r-f stages have been cascaded to provide a high signal level at the grid of the 6J6 mixer. The first stage is a 6AK5 with the popular "R9'er" input coupling circuit. The plate circuit of the 6AK5 is coupled by means of a broadband circuit to the grid of the succeeding stage. Next stage is a 6AU6 with another broadband coupler between its plate circuit and the grid of the 6J6 mixer. A considerable degree of flexibility is permissible in the selection of these two r-f amplifier stages. In fact as long as grounded grid stages are not used in either circuit position it is probable that no change will be required in the coils which have been shown. One combination which would be satisfactory but which gave less gain when tried would be to use two stages of cathode-coupled 6J6. Coupling from the antenna to the grid of the first tube can best be accomplished with the same input circuit which has been shown for the 6AK5. Alternatively, a pair of 6AK5's could be used for both stages. Changing the second stage to a 6AK5 gave an almost negligible gain increase.

A very slight improvement in noise factor for the complete system can be obtained by using a 6J4 in the first stage of the amplifier feeding a 6AK5 second stage. However, the use of a 6J4 as a grounded-grid amplifier brings with it a requirement for a different type of input circuit. The cathode impedance of the 6J4 is approximately 50 ohms so that excellent results with this tube may be obtained by feeding its cathode directly from the center conductor of a 50-ohm coaxial line. An alternative input circuit of this type is shown in figure 15. Due to the difficulty in tuning for maximum response when using a 6J4 or other grounded-grid input stage, it is recommended that the input circuit shown in figure 14 be used in all cases except when the amplifier is to be fed from a coaxial transmission line.

The 6J6 Oscillator-Mixer A type 6J6 tube is used in this converter unit as an oscillator-mixer. The oscillator circuit is the conventional tuned-

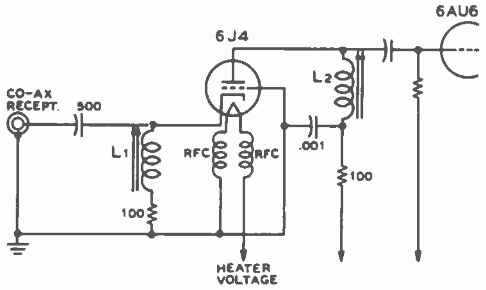


Figure 15.
ALTERNATIVE INPUT CIRCUIT FOR USE WITH COAXIAL LINE.
L_1 and L_2 are the same as described in figure 14. The r-f chokes in the heater leads of the 6J4 may be Ohmite type Z-28 chokes. One-half of a type 6J6 tube may be used in place of the 6J4 with slightly reduced performance.

plate crystal-grid arrangement with a 20-Mc. crystal from grid to ground. The particular unit shown in the photographs uses a crystal manufactured by Standard Piezo, their type HF-20. The plate circuit of the 6J6 is tuned approximately to 8350 kc. If the receiver used with the converter has an "antenna trimmer" control on the panel this control may be peaked to give maximum response in the particular portion of the band being used at the moment. As in the case of all converters of this general type, it is necessary merely to put the numeral 2 mentally in front of the dial reading on the communications receiver to obtain the frequency of the signal being received. This a signal of 28,680 kc. would be received on the communications receiver at 8,680 kc.

In the event that the high degree of stability of the 20 Mc. crystal oscillator is not required, the crystal may be replaced by a tuned circuit. The use of a self-controlled oscillator in the converter portion of the unit will give exactly the same result at the output when operating in conjunction with the conventional communications receiver except that the stability of incoming signals will be a function both of the self-excited oscillator in the converter and the self-excited oscillator in the receiver. A suitable oscillator circuit for use in a converter of this type was shown in the 11th edition of the RADIO HANDBOOK on page 281.

Operation at 120 volts on the plates of the tubes in the converter unit will give completely satisfactory operation. No improvement will be obtained at higher voltages and the tubes may be damaged if the voltage should be allowed to run much higher than 150. The power supply should be checked with the unit operating from it to insure that the plate voltage is not in excess of about 165 volts.

Alignment The first step in getting the converter into operation is to tune an additional receiver in the station to 20 Mc. and then to tune the plate circuit of the oscillator in the converter until oscillation is heard on 20 Mc. If a crystal is being used as the controlling element in the oscillator, it is merely a question of whether the circuit is oscillating or not. However, if a self-excited oscillator is being used in place of the crystal its frequency should be set quite accurately to 20 Mc.

The next step will be to couple the output of the converter to the input of the communications receiver and then to tune the communications receiver to 8350 kc. The variable slug in coil L_4 then is adjusted for maximum noise level output at the 8350 kc. point. A signal generator on 28,350 kc. should then be coupled to the input of the converter and the signal thus received should be tuned in by the communications receiver. Coils L_3 and L_4 should then be peaked for maximum output. This procedure will insure that these coils have been wound properly and that they are capable of hitting the center of the frequency range to be covered. An antenna then should be connected to the antenna terminals of the converter, the slug of L_1 should be set at about the middle of its range and the two trimmer capacitors in the input coupling network should be adjusted for maximum response to noise as received on 28,350 kc.

After the converter has been roughly aligned in this manner on a single frequency, the communications receiver should be tuned across the band completely from 26.9 Mc. to 29.7 Mc. It will be found that there is a considerable drop-off in sensitivity at both ends of the frequency range. Since single-tuned circuits are used as interstage coupling impedances, it is necessary to stagger tune these circuits in the manner used for TV broad-band i-f amplifiers.

The converter unit has a quite high signal gain coupled with a satisfactory noise factor. Hence it is possible to use the noise generated across a resistor at the input of the unit as a signal in the alignment procedure. The first step is to place a resistor, of the same value as the impedance of the transmission line which will be used to feed the converter, across the input terminals of the unit. Since 300-ohm Twin-Lead probably will be used as feed-

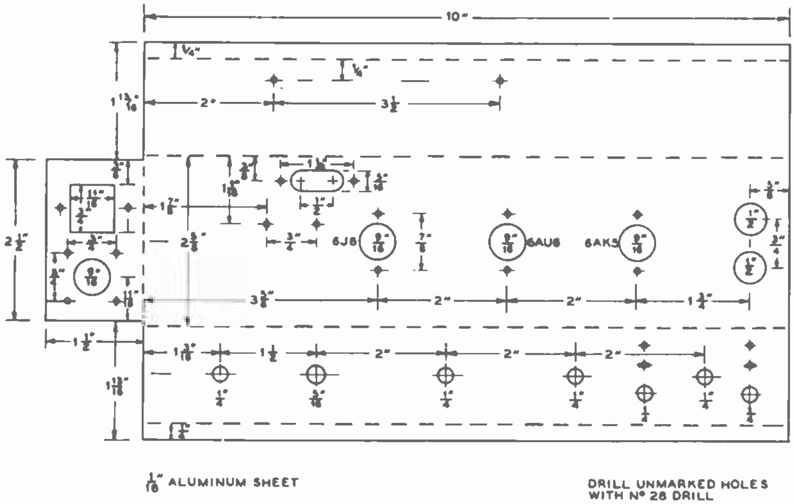


Figure 16.
CHASSIS LAYOUT DRAWING FOR THE BROAD-BAND CONVERTER.

er to the set, connect a 270-ohm ½-watt resistor across the input terminals of the converter.

Tune the communications receiver to 9.3 Mc., peak up the antenna trimmer control on the front of the communications set for maximum noise output. Then peak up both capacitors in the "R9'er" input circuit of the 6AK5 for maximum noise. It probably will be found that greatest noise output will be obtained with the trimmer having one side grounded set to maximum capacitance, and the other trimmer at slightly greater than minimum capacitance. Coil L_3 in the plate circuit of the 6AU6 should then be peaked for maximum noise by moving the tuning slug with a screwdriver. All the above adjustments are made with the communications receiver set at 9.3 Mc., corresponding to a signal frequency of 29.3 Mc.

The communications receiver is now set to 7.4 Mc. and the trimmer knob on the communications set again peaked for maximum noise. It is probable that no change in the setting of the trimmer will be necessary. Now coil L_2 in the plate circuit of the 6AK5 is peaked for maximum noise output. The communications receiver is then tuned to 8.3 Mc. and the "R9'er" circuit peaked for maximum noise output at this frequency. If the procedure has been done correctly the input circuit of the converter should be peaked in the center of the range, at 28.3 Mc., the tuned circuit in the plate of the 6AK5 will be peaked at 27.4 Mc., the plate circuit of the 6AU6 will be peaked at 29.3 Mc., and the plate circuit of the 6J6 mixer will be tuned approximately to 8.3 Mc. but will be capable of being tuned more or less over the 6.9 to 9.7 Mc. frequency range by the antenna trimmer knob on the communications receiver.

Checking Noise Factor As we tune the communications receiver over the 6.9 to 9.7 Mc. frequency range we should hear a relatively constant and quite high noise level, with the noise somewhat greater between 8 and 8.5 Mc. and falling off somewhat at the ends of the range. The crucial test is then to short the grid of the 6AK5 to ground (to the shield in the center of the miniature socket) by means of a very short piece of wire. The wire should be soldered to ground at the end and then should be bent so that it may be made to touch the grid terminal of the tube when it is pushed with a pencil or plastic neutralizing wrench. Whenever the grid of the 6AK5 is grounded in this manner there should be a sharp decrease in the noise-level output as heard in the communications receiver. This sharp decrease in noise level when the grid is shorted should take place all the way from 6.9 to 9.7 Mc. as heard on the communications receiver. As we tune beyond these two frequency extremes the decrease in noise as the grid is shorted will become so small as to be negligible.

The noise-decrease test discussed in the previous paragraph is a way of checking, with no additional test equipment, in a qualitative manner the equivalent noise factor of any receiver or converter. The test simply shows the approximate percentage of the total noise output of a receiver which is coming from thermal agitation in the resistances associated with the first tuned circuit of the receiver. Note that the input circuit must be matched to its normal antenna load for the test to have any value. In the converter being described, the 270-ohm resistor across the input simulates the characteristic impedance of the antenna transmission line which will be used with the unit.

In the case of a perfect receiver, all noise output would cease when the grid of the first tube was shorted to ground. In the case of a very good receiver or converter, and the unit being described is an example, the noise output will drop about one-half when the grid of the first tube is shorted to ground. A poor or mediocre receiver or converter will show only a very slight decrease in noise level when this test is made with a resistor of the rated value matched to the input circuit.

When this test is made on the converter it may be found that the performance is better at one end of the band than at the other. Or it may be desired to peak up the performance in a particular portion of the band with a sacrifice at the two ends of the range. In any event, a much more accurate check on the performance of the converter may be obtained in this manner than by attempting to tune up the unit with a signal generator of the conventional type or with the aid of amateur signals received.

After the adjustment procedures have been completed the 270-ohm resistor should be removed from the input and the antenna transmission line connected. If the band is open, a profusion of signals should be received in the 26.9 to 29.7 Mc. range, but these signals will be received with the receiver stability characteristic of the 6.9 to 9.7 Mc. coverage.

Construction The converter is constructed on a U-shaped chassis bent up from soft sheet dural in a tinshop. The overall dimensions of the chassis along with the positions and sizes of the major holes are given in figure 16. The power socket and the coaxial connector for the output cable are mounted on a lip bent down on one end of the chassis. The two-terminal strip for the antenna leads is mounted on the top of the chassis at the opposite end, but of course this connector may be mounted on a lip bent down at the other end if that should be desirable from a mechanical standpoint.

Construction of the unit after the chassis has been bent and drilled is a relatively simple process. Experience in building these units has shown that it is necessary to use low-inductance ceramic by-pass capacitors in all the high-frequency circuits (Centralab D6-102) rather than the more conventional mica units. Complete stability in the converter could not be attained until the mica capacitors originally employed were replaced with the low-inductance ceramic units. Also, use the very shortest leads possible in attaching the ceramic by-pass capacitors. Note in addition that the plate and screen by-pass capacitors for the two r-f amplifier stages are returned to one cathode terminal of the tubes (pin 7), while the other cathode terminal (pin 2) receives the cathode resistor and by-pass capacitor. Since pin 2 is the suppressor terminal only on the 6AU6 a lead is run directly from pin 7 to pin 2 across the bottom of the socket. A mica capacitor is used for filament by-pass, and it is placed directly across pins 3 and 4 on the 6AK5 socket.

All-Triode Converter For 144 Mc.

The converter illustrated in figures 17, 18, and 19 will give a good account of itself when operating into the regular station communications receiver for the reception of stabilized AM signals on the 144-Mc. band. It uses two dual triodes, may be operated into an intermediate frequency from 11 to 16 Mc., and requires 150 volts of plate potential at about 30 ma.

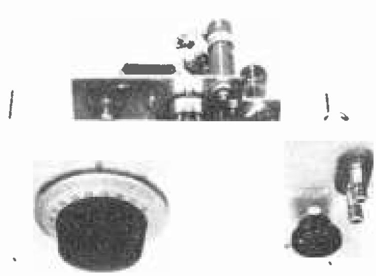


Figure 17.
LOOKING DOWN ON THE 144-MC. CONVERTER.

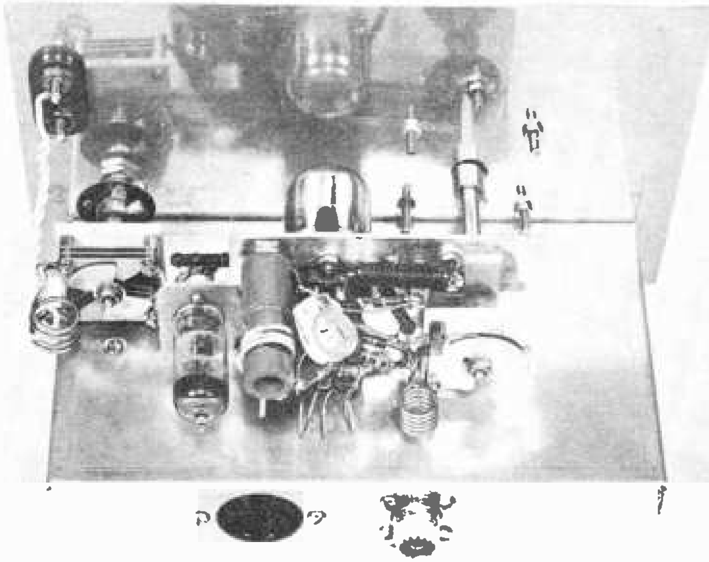


Figure 18.
REAR PHOTO OF THE 144-MC. CONVERTER.
Showing placement of components and the method of mounting the 6J6 and 7F7 tubes both through the same plate but projecting in opposite directions.

Circuit Description The all-triode converter uses a 6J6 as a cathode-coupled r-f amplifier operating into a 7F7 oscillator-mixer. It was desired as a feature of the unit to use a separate tuning control for the first tuned circuit in the grid of the 6J6 r-f amplifier. The use of a separate control for the first tuned circuit allows the antenna coupling and circuit tuning to be varied until optimum signal-to-noise ratio is obtained with any antenna system.

Since separate tuning of the antenna circuit is used, it is necessary that frequency pulling between the antenna control and the local oscillator frequency be minimized. This requirement for minimum pulling between the two circuits ruled out an earlier version of the converter which used a 6J6 as a push-pull neutralized r-f amplifier with ganged tuning of the grid and plate circuits. It was determined, as a result of experiments with this earlier model, that a broadly resonant circuit would be required in the output of the r-f stage if pulling were to be eliminated. The simplest way of accomplishing this requirement proved to be through the use of a 6J6 tube as a cathode-coupled r-f amplifier.

The tuned circuit in the grid of the 6J6 uses a miniature butterfly capacitor with the rotor grounded and the grid of the 6J6 connected to one side of the tuned circuit. The other side of the tuned circuit is left floating. Capacitive balance beween the two sides of the first tuned circuit is obtained by mounting the butterfly capacitor in the manner illustrated in figure 18 so that the capacitance of the bottom stator to ground is somewhat greater than that of the upper stator. Then the grid of the 6J6 tube is connected to the upper of the two stators. This procedure gives good circuit balance since the input capacitance of the 6J6 is about equal to the extra capacitance to ground of the lower stator. A one-turn link from the antenna posts is coupled to the center of the four-turn coil in the first tuned circuit.

The self-resonant 3-turn coil in the plate of the 6J6 and grid of the 7F7 mixer is mounted on one of the small 3-lug tie-point strips. The turns of this coil are squeezed or spread until the circuit peaks in the center of the 144-Mc. band. Capacitive coupling to the grid of the mixer portion of the 7F7 is used both from the plate of the 6J6 r-f amplifier and from the grid of the oscillator portion of the 7F7. The capacitance coupling to the grid of the 7F7 from the oscillator is much smaller than that from the 6J6 so that loading of the oscillator by the mixer will be at a minimum.

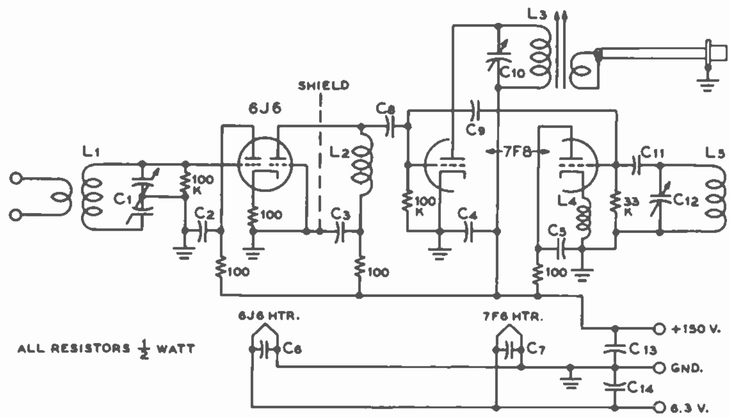


Figure 19.
SCHEMATIC OF THE 144-MC. CONVERTER.

C_1—2 to 7 μμfd. midget butterfly variable (Cardwell ER-8-BF/5)
C_2, C_3, C_4, C_5, C_6, C_7—500-μμfd. midget ceramic by-pass (Centralab)
C_8—10-μμfd. midget ceramic (Centralab)
C_9—1.0-μμfd. midget ceramic (Centralab)
C_{10}—4.5 to 25 μμfd. ceramic trimmer (Centralab 822AZ)
C_{11}—10-μμfd. midget ceramic (Centralab)
C_{12}—10-μμfd. midget variable (Cardwell ZR-10-AS)
C_{13}, C_{14}—0.0068-μfd. mica
L_1—4 turns no. 14 tinned ½" dia. by ½" long, one-turn link
L_2—3 turns no. 18 tinned ½" dia. by ½" long
L_3—18 turns no. 24 enam. closewound on National XR-50 form, 3-turn link
L_4—4-μhy. r-f choke (National R-60)
L_5—5 turns no. 14 tinned ⅜" dia. by ½" long

The circuit of the oscillator portion of the 7F7 is somewhat unconventional, but is quite adequate for use in the v.h.f. range. The plate of the oscillator tube is by-passed to ground, the tuned circuit is connected between grid and ground, and the cathode of the tube is fed by means of an r-f choke suitable for the desired frequency of oscillation. The circuit is quite stable and gives excellent results near the upper frequency limit of a triode oscillator tube.

The combination of a permeability-tuned coil and a variable capacitor is used in the plate circuit of the mixer portion of the 7F7. Thus the plate circuit of the mixer may easily be tuned to a frequency in the range from 11 to 16 Mc. In fact, if it is desired for some reason, the i.f. output of the converter may be raised to a considerably higher frequency. The oscillator control is not ganged to the r-f tuning control so that there is no tracking problem introduced by selection of a different intermediate frequency. The oscillator is operated on the low side of the incoming frequency and covers a frequency range somewhat greater than the 4 Mc. of the 144-Mc. band. Hence the oscillator range may be moved about to accommodate a change in the output intermediate frequency.

In the unit illustrated the oscillator covers the range from about 98 Mc. to 135 Mc. With this coverage the oscillator may be operated on the low side with an i.f. down to 13 Mc. to give coverage of the 144-Mc. band. Of course the oscillator range may be shifted merely by squeezing or spreading the turns of the oscillator coil. The oscillator coverage given will also give full coverage of the FM broadcast band by using a standard 10.7-Mc. i.f. and operating the oscillator on the high side of the signal frequency. It will be necessary to place a padder capacitor across the tuned circuit in the grid of the 6J6 to lower the frequency from the 144-Mc. amateur band to the FM broadcast band. The coupling coil between the plate of the r-f stage and the grid of the mixer should be increased to 5 turns with the same spacing and diameter.

It may be desired to limit the frequency range of the local oscillator so that the 144-Mc. amateur band may be spread across the full dial. This may be accomplished by placing an APC-25 trimmer across the entire oscillator coil, and then tapping the oscillator tuning capacitor across a sufficient portion of the oscillator coil that the 144-Mc. band is spread across as much of the oscillator dial as is desired. Tuning of the r-f stage tuned circuit is quite sharp; resonating the circuit even with the antenna disconnected will give a sharp increase in the noise output of the equipment. However, the r-f tuning control need not be touched for normal tuning of the band. But if a weak signal is encountered, the r-f tuning control may be peaked for greatest volume and signal-to-noise ratio.

Construction The converter is built on a 4½ by 8 by 1½ inch aluminum chassis. The panel is cut from 0.051" dural and is 5-¾ inches in height by 9 inches in length. All components for the unit with the exception of the r-f tuned circuit and the connectors are mounted on an aluminum plate supported 2½ inches behind the main panel. Although a separate small plate is used in the unit illustrated to support the 6J6 tube, a single plate with dimensions of 5 by 2-¾ inches may be used to support all components. The plate illustrated uses a ½-inch flange turned out at 90° from the bottom of the plate for mounting the plate to the chassis. The 6J6 tube should be shielded from the 7F7 portion of the converter. The shielding may be accomplished by a metal plate with dimensions of about 1 by 1½ inches as in the unit illustrated, or a standard shielded socket may be used for the 6J6 tube.

Inductively Tuned Converter

For uses where bandspread is not of prime importance, and where continuous coverage of a very wide frequency range is desired, the converter illustrated in figures 20 through 25 will fill a worthwhile need. The converter uses one of the Mallory "Inductuner" assemblies as the tuning elements. It is possible to use the Inductuner in a wide variety of applications for covering different frequency ranges. In the unit illustrated it is possible to cover the range from 26 to 135 Mc. in one continuous spread, or by using a slightly different hookup of the components it is possible to tune continuously the range from 50 Mc. to about 230 Mc. Or, if desired, the assembly may be modified, in accordance with instructions available from the P. R. Mallory Co., to make an excellent TV tuner for channels 2 through 13. No modification in the chassis or dial arrangement is necessitated to operate the assembly for any of the three types of operation described above.

Circuit Description The Mallory Inductuner consists of three ganged 10-turn coils in a shielded cast housing. The coils are rotated by means of a shaft and dial to cause a slider mechanism to short out unused turns. Ten turns of the shaft are required to change the inductance of the three ganged coils from a maximum of 1 microhenry down to a minimum of about 0.02 microhenry. Hence a dial capable of recording ten rotations as well as the divisions within each rotation must be used. A Crowe dial, their number PT-100, and a dial made by the Helipot Corporation, type W-10, are available for this application. The Helipot dial has been used on the unit illustrated, but the Crowe dial could have been used—and the Croname Model PT-100 offers the additional advantage that a blank space is included for notations as to band coverage.

The electrical circuit of the unit uses a 6AK5 as r-f amplifier, a 6AK5 mixer, and one-half of a 6J6 as oscillator. Tuning capacitors all are of the ceramic trimmer type since tuning is accomplished by variation in the inductance of the three coils. Figures 20, 21, 22, and 23 illustrate the unit as connected for coverage from 50 to 230 Mc. The under-chassis view of figure 24 and the modified schematic of figure 25 illustrate the changes required for coverage from 26 to 135 Mc.

The output circuit of the 6AK5 mixer is slug tuned to permit changing the i-f output

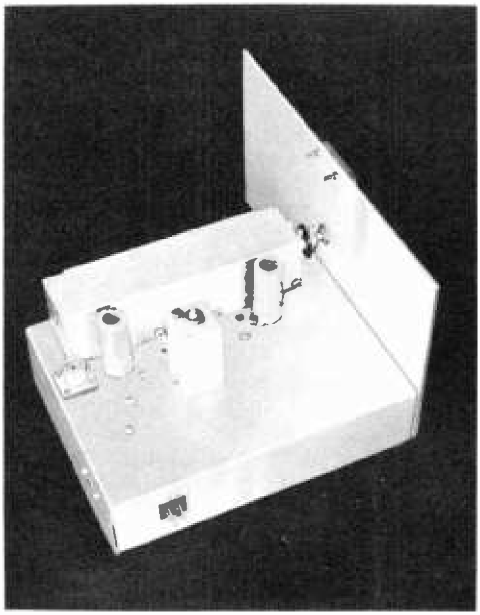


Figure 20.
SIDE VIEW, SHOWING PLACEMENT OF THE INDUCTUNER.

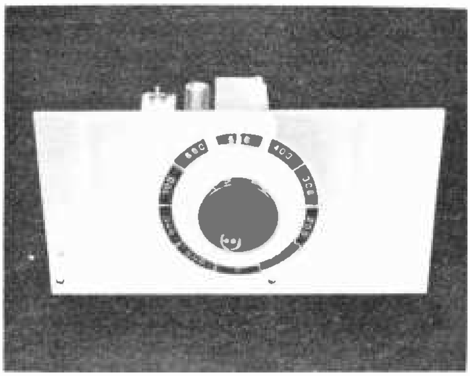


Figure 21.
FRONT VIEW, SHOWING TEN-TURN DIAL.

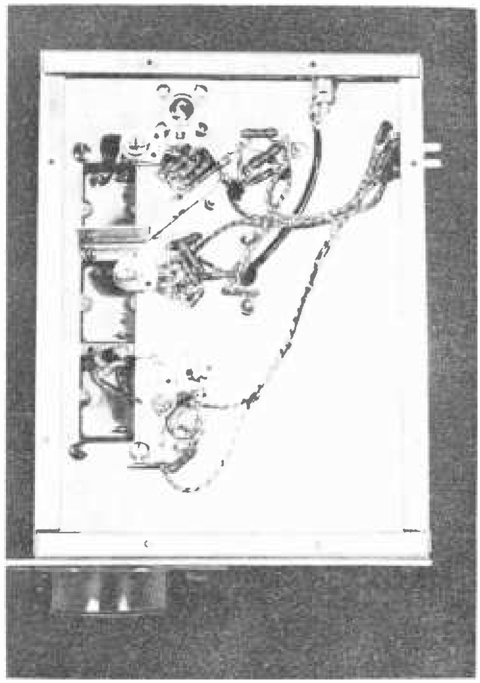


Figure 22.
UNDERCHASSIS OF THE CONVERTER.
The unit is connected for the 50 to 230 Mc. range in this photo.

frequency of the converter. Best operation for coverage of the range from 50 to 230 Mc. is obtained with the output of the mixer on 11 Mc. For coverage of the 26 to 135 Mc. range the output circuit of the mixer should be tuned to 18 Mc. In either case a conventional communications receiver may be used as the i.f. and audio channel to follow the converter. However, if it is desired to receive unstabilized signals on the 144 and 220 Mc. bands, it will be best to operate the converter into a broad-band 10.7-Mc. or 11-Mc. i-f channel. The i-f channel may well include an FM detector as well as a conventional diode detector so that the FM broadcast band and amateur FM signals may be received. Slight deviations from perfect tracking over the wide frequency range of the converter will be of less significance with a wide i-f channel.

Tuning and Aligning The first step in tuning the converter for operation over the 50 to 230 Mc. range is to adjust the components associated with the oscillator until the oscillator covers the range from 61 through 241 Mc. The oscillator of course must operate 11 Mc. away from the tuned frequency of the unit, and in this case the oscillator is placed on the high side. Either an accurately calibrated wavemeter or a receiver capable of covering this frequency range will be required for the adjustment of oscillator coverage.

The steps in the adjustment are as follows: Turn the dial fully counter-clockwise so that the maximum amount of inductance is in the circuit. Then adjust C_{11}, the oscillator padder, until the frequency of oscillation is 61 Mc. Now rotate the dial fully clockwise so that the inductance in the circuit is at a minimum, and check the frequency of oscillation. If it is higher than 241 Mc., the half-turn end inductor L_4 should be spread slightly to increase its inductance and thus lower the frequency of operation. If the frequency is too low, the end inductor should be pinched together somewhat to lower its inductance and raise the frequency of oscillation. It will be found that variation in the adjustment of L_4 will have little effect on the frequency of oscillation at the low-frequency end of the dial, but will have a considerable effect at the high-frequency end. The setting of C_{11}, however, will cause a great variation in the frequency of oscillation throughout the range of the dial. Hence C_{11} must be set for the low-frequency end and then not touched while adjustment is made in L_4 for the high-frequency end.

After the frequency coverage of the oscillator has been adjusted, the output of the mixer should be coupled to the input of a communications receiver. Then the slug in

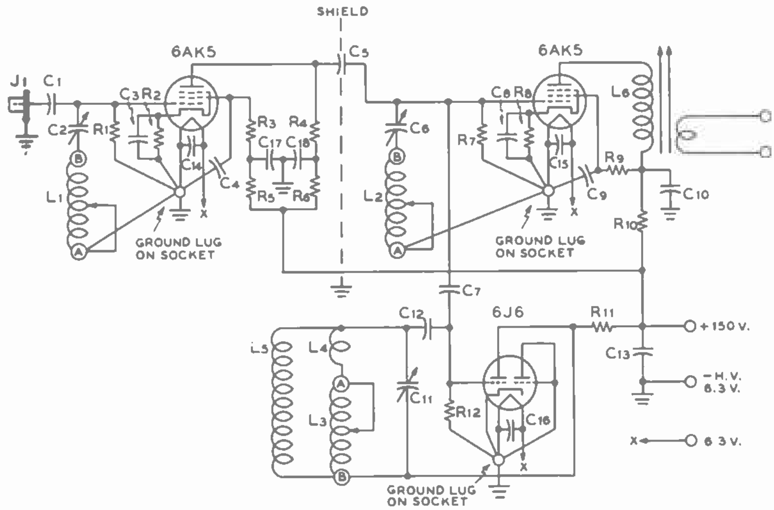


Figure 23.
SCHEMATIC OF THE CONVERTER.

C_1—10-μμfd. fixed ceramic
C_2—4-20-μμfd. ceramic trimmer
C_3, C_4—500-μμfd. ceramic by-pass
C_5—10-μμfd. fixed ceramic
C_6—4-20-μμfd. ceramic trimmer
C_7—3-μμfd. fixed ceramic
C_8, C_9—500-μμfd. ceramic by-pass
C_{10}—0.001-μfd. ceramic by-pass
C_{11}—2.6-6 μμfd. ceramic trimmer
C_{12}—5-μμfd. fixed ceramic
C_{13}, C_{14}, C_{15}, C_{16}, C_{17}, C_{18}—500-μμfd. ceramic by-pass
R_1—47,000 ohms ½ watt
R_2—220 ohms ½ watt
R_3, R_4, R_5—47,000 ohms ½ watt
R_6—22,000 ohms ½ watt
R_7—47,000 ohms ½ watt
R_8—220 ohms ½ watt
R_9—47,000 ohms ½ watt
R_{10}—22,000 ohms ½ watt
R_{11}—10,000 ohms ½ watt
R_{12}—47,000 ohms ½ watt
L_1—Rear section of Mallory Inductuner
L_2—Center section of Mallory Inductuner
L_3—Front section of Mallory Inductuner
L_4—One-half turn no. 18 wire with ¾" radius
L_5—28 turns no. 30 enam. closewound on ¼" polystyrene rod
L_6—49 turns no. 28 enam. closewound on National XR-50 coil form
J_1—Receptacle for coaxial plug

coil L_6 is adjusted for maximum noise output in the communications receiver at 11 Mc.

R-F Tracking The r-f stage is designed for operation from a coaxial line with characteristic impedance between 50 and 90 ohms. So the antenna should be connected for alignment, or a 50 to 90 ohm resistor should be connected across J_1. It is best if a signal generator covering the range from 50 to 230 Mc., is available for the alignment process, although harmonics of a 7-Mc. or 14-Mc. crystal oscillator may be used. First alignment is best accomplished at a frequency between 60 and 70 Mc. This point will fall about three full turns in from the low-frequency end of the dial. Capacitors C_2 and C_6 are peaked for maximum response to the signal generator or to the crystal-oscillator harmonic. Then the dial should be turned until only about one-third turn is left and a signal on about 210 Mc. picked up. Once the signal has been tuned in, capacitors C_2 and C_6 should be re-peaked for maximum response. If more capacitance is required to resonate the r-f stages, a small amount of end inductance should be connected between point (B) and capacitors C_2 and C_6. This end inductance may consist of additional lead length or a very small half loop of wire. If less capacitance is required to tune to resonance at 210 Mc. it will be necessary to reduce the inductance of the circuit by shortening leads or by using copper strap for the connections.

After these adjustments have been completed the tracking of the converter should be quite adequate for operation into a broadband i-f system. When used with a narrow i-f system such as a communications receiver the tracking will be fairly good but optimum operation in any particular band will best be obtained by peaking C_2 and C_6 for that band. Bandspread is very small on the 220-Mc. band, hence tuning is quite sharp. Tuning

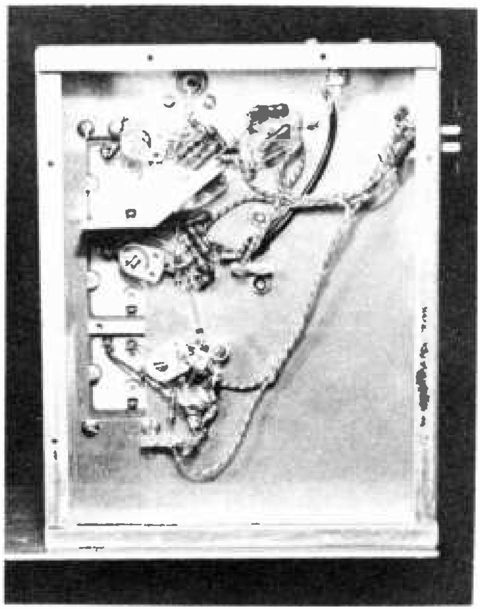


Figure 24.
UNDERCHASSIS OF THE CONVERTER FOR 26 TO 135 MC. COVERAGE.

of the other frequency ranges is quite satisfactory.

It will be found, by inspection of the circuit of the equipment, that it is possible for strong signals in the vicinity of 11 Mc. to pass directly through the converter from J_1 to the output of the mixer. Hence, the antenna system used with the converter should be fed with coaxial cable or be of another type which is characterized by negligible response to signals in the vicinity of 11 Mc.

Operation on the 26 to 135 Mc. Range For coverage of the range down to 26 Mc. the converter is wired in accordance with figures 24 and 25. Essentially the changes are: The coils in the r.f. and mixer grid circuits are parallel tuned to reduce the resonant frequency to the desired range and to eliminate the possibility of response through the converter to signals on the new intermediate frequency of 18 Mc. C_{11}, L_4, and L_5 are eliminated from the oscillator circuit and replaced by a larger capacitor as C_{19} and a smaller inductance as L_7. The coil in the plate of the mixer is tuned to 18 Mc. and this is used as the new intermediate frequency.

Tuning and Alignment Alignment procedure is essentially the same as for the higher frequency range. The oscillator is adjusted so that it covers the range from 44 to 153 Mc., by setting C_{19} for the low-frequency end of the range and by changing the value of the lead inductance to the (A) terminal of L_3 for the high-frequency end. In the unit illustrated it was not necessary to use an appreciable end inductance with the circuit for obtaining this coverage. Then the r-f and mixer stages are aligned at about 35 Mc. and the alignment checked at the upper end of the range. A small amount of inductance may be required between the (B) end of the inductors and the tuning capacitors for accurate tracking over the band.

With the circuit as illustrated in figure 25A a relatively high impedance antenna circuit will give maximum response. Also, as in the previous alignment, the trimming of the tuned circuits should be accomplished with the antenna connected. An alternative antenna in-

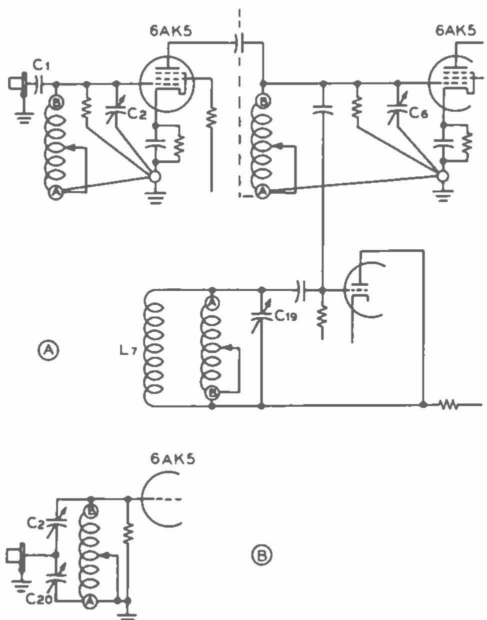


Figure 25.
CIRCUIT MODIFICATIONS FOR 26 TO 135 MC. COVERAGE.

All components have the same values except those listed below.

C_{19}—Oscillator trimmer; change to 4.5 to 25 μμfd. zero-coefficient ceramic
C_{20}—12 to 60 μμfd. zero-coefficient ceramic trimmer
L_7—24 turns no. 30 enam. closewound on ¼" dia. polystyrene rod

put circuit of the pi-network ("R9'er") type is shown in figure 25B. By variation in the capacitance of C_2 and C_{20} a satisfactory impedance match between the input of the converter and a wide range of antenna impedances may be obtained. As in any circuit of this general type, capacitor C_{20} determines the coupling between the tuned circuit and the antenna system while C_2 serves the usual function of tuning the circuit to resonance. The capacitance used at C_{20} should be as large as will give satisfactory coupling between the antenna system and the input circuit of the converter. Hence the tune-up procedure should be started with the maximum available capacitance at C_{20} as C_2 is used to tune the circuit to resonance. Then the capacitance of C_{20} should be decreased to give greater antenna coupling and C_2 used to re-resonate the circuit. Only a very small change in C_2 should be required to restore resonance. As soon as a capacitance setting at C_{20} requires a large change in C_2, or only a very broad resonant peak is obtained, the antenna coupling is too great.

Construction The converter is constructed on a 7 by 9 by 2 inch aluminum chassis. The Inductuner can, of course, be centered on the chassis if desired. In the unit illustrated the chassis was mounted off center to clear other components when the complete converter was mounted on top of the separate power supply and i-f amplifier chassis. Note that a small aluminum shield is mounted between the r-f stage and the mixer stage beneath the chassis. The installation of this small shield eliminated any tendency toward instability in the 6AK5 r-f stage over the complete frequency range.

Convenient terminals for the no. 30 wire used for coils L_5 or L_6 may be made by heating a short length of no. 18 tinned wire with a soldering iron while forcing it through the polystyrene rod. As soon as the soldering iron is removed, the no. 18 wire will be gripped firmly by the cooled polystyrene. The ends of the no. 30 wire, after the enamel is removed, may then be soldered to the no. 18 leads which then are used for connecting the inductor into the circuit.

Exciters and Low Power Transmitters

Several different types of equipment, designed to meet the needs of amateurs with different tastes and needs, have been described in this chapter. The first two units are quite simple two-tube transmitters especially constructed to meet the needs of the newcomer to the field of amateur radio. Then there is described a relatively simple but still quite stable v.f.o. suitable for operation with any transmitter. The next unit is a 30 to 40 watt v.f.o. transmitter with an 807 in the output; this item would serve well as a standby c-w transmitter or as a station transmitter with good capabilities in the medium-power medium-price classification. Then there are described two de-luxe v-f-o units, both using a Collins 70E-8 oscillator unit and both ending with a 2E26 as the output stage but having quite different circuit arrangements in between. Finally, three complete transmitter r-f units, which alternatively could be used as exciters for a higher powered stage, are described and illustrated.

Simple 20-Watt C.W. Transmitter

The unit illustrated in figures 1, 2, and 3 is especially suitable for construction and use by the beginner in amateur radio since its circuit is relatively simple and straightforward. No complicated adjustments are required to tune the transmitter or to operate it on the 1.8, 3.5, or 7 Mc. amateur bands. A power supply especially constructed for use with the transmitter is illustrated in figures 12, 13 and 14 of Chapter 8.

It is possible to use a keyed crystal oscillator working directly into the antenna as a transmitter. But the crystal oscillator, power amplifier transmitter illustrated offers additional stability, greater power output, and freedom from the keying chirps usually encountered when keying a crystal oscillator which is heavily loaded by an antenna.

Circuit Description The crystal oscillator tube is a 6AG7. It operates as an untuned Colpitts oscillator with the crystal between grid and ground. The output energy from the untuned plate circuit of the tube is capacitively coupled into the grid of the 6L6 amplifier. The output circuit of the 6L6 is the only tuned circuit in the transmitter. Variations in the tuning and loading of the output circuit have no effect on the frequency of oscillation or activity of the crystal circuit.

Bias for the 6AG7 is obtained from the drop caused by grid current through the 100,000-ohm grid leak, plus a small amount of bias developed across the 100-ohm cathode resistor and the d-c resistance of the r-f choke. Grid bias for the 6L6 is obtained exclusively as a result of grid current flowing through the 47,000-ohm grid leak for the tube. Hence, plate voltage must not be applied to the 6L6 unless it is receiving excitation from the crystal stage. This matter is discussed in more detail in the section devoted to *Adjustment and Operation.* Screen voltage for both the

Figure 1.
FRONT OF THE SIMPLE TWO-TUBE TRANSMITTER.
The associated power supply unit from Chapter Eight is shown alongside the transmitter r-f unit.

tubes in the transmitter is obtained from the plate-voltage supply through series screen resistors. Shunt feed of the plate voltage to the 6L6 through RFC_3 is employed so that plate voltage will not be present at any point on the top of the transmitter. The plate coil, L_1, of the 6L6 is at ground potential as far as d.c. is concerned. However, this coil does have the full r-f voltage output of the stage across it; hence it is possible to obtain a painful r-f burn from the coil even though no electrocution danger is present.

The Power Supply The power supply for the transmitter (described in Chapter Eight) is mounted on a separate chassis so that it may be used conveniently at a later date in conjunction with other items of equipment. The power unit is capable of delivering from 350 to 375 volts at a load current of 75 to 110 ma. In addition the unit supplies 6.3 volts a.c. at any current up to 4.5 amperes for lighting the heaters of the tubes in items of equipment connected to it. For the sake of convenience, the keying jack and the key-click filter for the associated transmitter are included in the power supply chassis.

Construction Both the r-f unit and the power supply are mounted on 5½ by 10 by 3-inch dural chassis (ICA No. 29004). Other types of chassis with similar dimensions may of course be used in place of those specified. This same consideration in regard to substitution applies to all the other components which go to make up the transmitter and its power supply. Other makes may be substituted for the components which have been specified, so long as the electrical characteristics are the same as those used in the equipment.

All wiring must be done neatly, with the shortest possible leads used for r-f circuits, and with neatly placed leads for the power supply circuits. Use a good grade of insulated hookup wire and mechanically affix each lead to the point where it is to be connected before applying solder. Solder should be used as a means of insuring a good electrical connection;

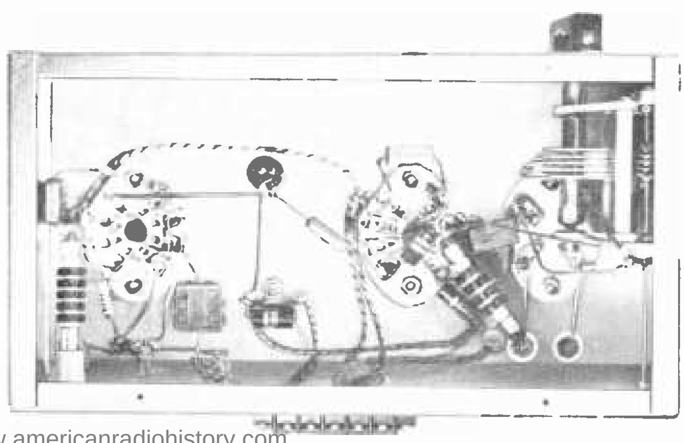


Figure 2.
UNDERCHASSIS OF THE TWO-TUBE R-F UNIT.
Illustrated is the simple version of the transmitter, without the plate milliammeter and the added tuned circuit for the 6AG7.

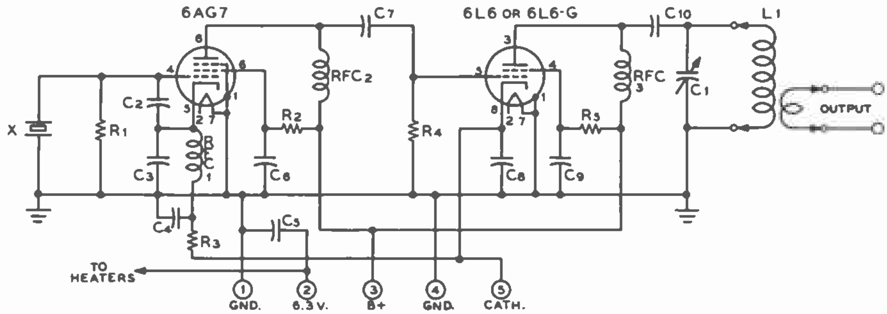


Figure 3.

SCHEMATIC OF THE SIMPLE TRANSMITTER R-F UNIT.

The terminal designations match with those of the associated power supply unit described in Chapter Eight.

C_1—100-μμfd. variable (National TMS-100)
C_2—20-μμfd. midget ceramic (Centralab)
C_3—100-μμfd. midget ceramic (Centralab)
C_4, C_5, C_6—0.0068-μfd. midget mica
C_7—50-μμfd. midget mica
C_8, C_9—0.0068-μfd. midget mica
C_{10}—100-μμfd. midget mica
R_1—100,000 ohms ½ watt
R_2—39,000 ohms 2 watts
R_3—100 ohms ½ watt
R_4—47,000 ohms 2 watts
R_5—22,000 ohms 2 watts
$RFC_{1,2,3}$—2½-mh. 125-ma. chokes (National R-100U)
X—Crystal for desired band, see Table (James Knights H-73)
L_1—See Coil and Crystal Table

it should not be relied upon for mechanical support. No difficulty whatsoever will be encountered with the actual procedure of soldering if all components and wires are clean before soldering is attempted, if a good grade of rosin-core solder is used, and if a good quality electric soldering iron is used to make the joint. Do not solder one end of a component to a fixed part and then leave the opposite end dangling from a wire going to the next fixed part. Use the simple paper-bakelite "tie points" such as have been used in the units shown. Tie points are quite inexpensive and are readily available from retailers of electronic components.

Adjustment and Operation The adjustment procedure for the transmitter is quite simple, but a moderate degree of care is required in the antenna coupling operation to insure that the maximum amount of the available power is actually being fed into the antenna system. The tuning procedure is as follows:

First, turn on the station receiver, without its antenna connected, and tune the receiver approximately to the frequency of the crystal to be used in the transmitter. A 1.8-Mc. band, a 3.5-Mc. band, or 7-Mc. band crystal may be used. Then apply filament voltage to the tubes in the transmitter by turning on the a-c line switch in the center of the power-supply chassis. The key plug should be inserted into the key jack on the front of the power supply chassis. After a period of about 30 seconds, apply plate voltage to the transmitter by turning on the switch on the right end of the power supply chassis. If a d-c voltmeter is available, measure the voltage at the output of the power supply unit—it should be about 425 volts when the power supply is unloaded as it now is. If a voltmeter is not available, and if there is no sparking or overheating inside the 5Y3-GT rectifier it may be assumed that the power supply is delivering voltage to the transmitter. Now make a series of dots or short dashes with the key, while tuning the receiver back and forth across the crystal frequency. The crystal oscillator should be heard in the receiver each time the key is pressed. If the crystal is not heard, there is some trouble either in the power supply, crystal oscillator, or key leads, or else the crystal is defective. But defective crystals are rare these days so it will be best to check the circuits carefully if oscillation is not obtained.

After the crystal oscillator has been heard in the receiver, couple a dial lamp and a loop of wire *loosely* to the coil in the plate circuit of the 6L6 (See Coil and Crystal Chart) and tune the tank to resonance by tuning for maximum brilliancy. More power output will be obtained with a crystal for the same frequency as the plate tank coil, but good output on 3.5 Mc. with a 1.8-Mc. crystal can be had, and a moderate amount of output on the

COIL AND CRYSTAL CHART

BAND OF OPERATION	CRYSTAL FREQUENCY RANGE, Mc.	COIL IN PLATE OF 6AG7	COIL IN PLATE OF 6L6
1.8 Mc.	1.8 - 2.0	None	1.8 Mc.
3.6 Mc.	1.75 - 2.0	None	3.6 Mc.
3.6 Mc.	3.5 - 4.0	None	3.6 Mc.
7.0 Mc.	1.75 - 1.825	3.6 Mc.	7.0 Mc.
7.0 Mc.	3.5 - 3.65	3.6 Mc.	7.0 Mc.
7.0 Mc.	7.0 - 7.3	None	7.0 Mc.
14 Mc.	3.5 - 3.6	7 Mc.	14 Mc.
14 Mc.	7.0 - 7.2	7 Mc.	14 Mc.
21 Mc.	7.0 - 7.15	7 Mc.	21 Mc.
21 Mc.	10 -10.225	7 Mc. (Tune to 10 Mc.)	21 Mc.
27 Mc.			
(27.16-27.43)	6.79 - 6.8575	14 Mc.	28 Mc.
(26.96-27.23)	6.74 - 6.8075		
28 Mc.	7.0 - 7.425	14 Mc.	28 Mc.
50 Mc.	8.334- 9.0	21 Mc. (Tune to 25 Mc.)	50 Mc.

COIL WINDING DATA

Frequency Band	6AG7 Plate Coils	6L6 Plate Coils
1.8 Mc.	None Required.	54 turns no. 22 enam. on 1½-inch dia. form (National XR-4). Link, 8 turns no. 22 enam.
3.5 Mc.	35 turns no. 22 enam. closewound on 1-inch dia. form (Nat. XR-1).	35 turns no. 22 enam. closewound 1-inch dia. form. Link, 7 turns no. 22 enam.
7.0 Mc.	23 turns no. 22 enam. closewound on 1-inch dia.	18 turns no. 22 enam. closewound 1-inch dia. form. Link, 6¾ turns no. 22.
14 Mc.	10 turns no 22 enam. spaced to 1-inch on 1-inch diameter form.	7¼ turns no. 18 enam. spaced to ⅝ inch, 1-inch dia. Link, 4 turns no. 22.
21 Mc.	None required.	Use 28-Mc. coil.
28 Mc.	None required.	4¼ turns no. 14 enam. spaced to ⅞-inch, 1-inch dia. Link, 4 turns no. 22.
50 Mc.	(Coil tunes to 25 Mc.) 5¾ turns no. 18 enam. spaced to ⅝-inch on one-inch diameter form.	4 turns no. 8 bare wire unsupported. ⅞-inch inside diameter by 1¼ inches long.

7-Mc. band may be obtained with a crystal between 3.5 and 3.65 Mc. in the grid of the 6AG7.

The transmitter may now be checked for power output by coupling a 25-watt 115-volt lamp to its output circuit. The best procedure for accomplishing this is to wind temporarily 10 turns of hookup wire around the 6L6 tank coil and then solder the ends of this temporary external coil to the side and center contacts of the 25-watt lamp. The lamp should light nearly to normal brilliancy as the plate tank circuit is tuned to resonance, either with a 7-Mc. crystal and 7-Mc. output or with a 3.5-Mc. crystal and 3.5-Mc. output. For checking on the 1.8-Mc. band about 20 turns of hookup wire around the coil will be needed. The transmitter should now be keyed, and the keying characteristics checked with the 25-watt lamp serving as a dummy load. The keying should be clean, without noticeable clicks or chirps, but some thump will be noticed in the receiver due to its operation in the immediate vicinity of the transmitter. The transmitter may now be coupled to the antenna system. If a doublet or folded dipole is to be used, the output terminals of the transmitter may be connected to the feed line. With other types of antenna systems it will be found better to link couple the output of the transmitter to an external tank circuit similar to that used in the plate of the 6L6. The antenna is then fed and matched by the external antenna-coupling circuit.

Two-Tube All-Band Transmitter

Illustrated in figures 4, 5, and 6, is a simple two-tube transmitter r-f unit which may be used, with appropriate crystals, on all the

Figure 4.
FRONT OF THE ALL-BAND TRANSMITTER UNIT.
Coils for operation of the unit on all the amateur bands through 54 Mc. are illustrated along with the r-f unit.

amateur bands from 1.8 through 54 Mc. It may be used either for c-w operation or the 6L6 tube in the final stage may be plate modulated. The transmitter unit may be constructed by modifying the simple beginners transmitter just described, or of course it may be built at the outset. If constructed as a modification, the changes are quite simple and involve essentially only the addition of a tuned circuit in the plate of the 6AG7, the installation of a 0-100 d-c milliammeter, and the winding of coils for the higher frequency amateur bands.

With the r-f unit modified in accordance with figures 4, 5, and 6 it is possible still to operate the unit in the original manner on the 160- 80- and 40-meter bands—that is, without the plate coil for the 6AG7 in the coil socket. For this type of operation the plate tuning capacitor for the 6AG7 is turned to "100" on its control knob so that it is at minimum capacitance. If this tuning capacitance is increased from minimum capacitance, its shunting effect will reduce the amount of excitation voltage available at the grid of the 6L6, and the power output from the 6L6 will be reduced.

However, the modified transmitter is capable of operating on all the higher frequency bands. But it is important to remember that, when the transmitter is to be operated with a coil plugged into the plate circuit of the 6AG7, the 6L6 stage always must operate as a frequency multiplier. In other words, the coil in the plate circuit of the 6AG7 (which coil, of course, is also the grid circuit of the 6L6)

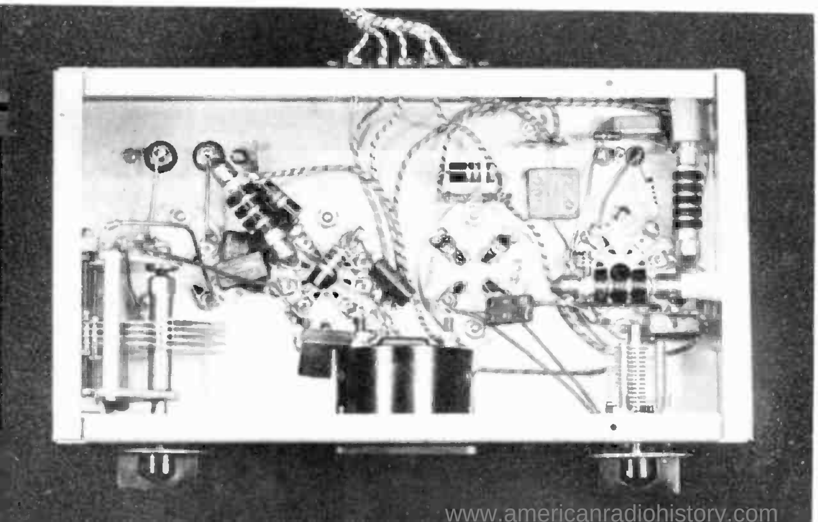


Figure 5.
UNDERCHASSIS OF THE ALL-BAND R-F UNIT.

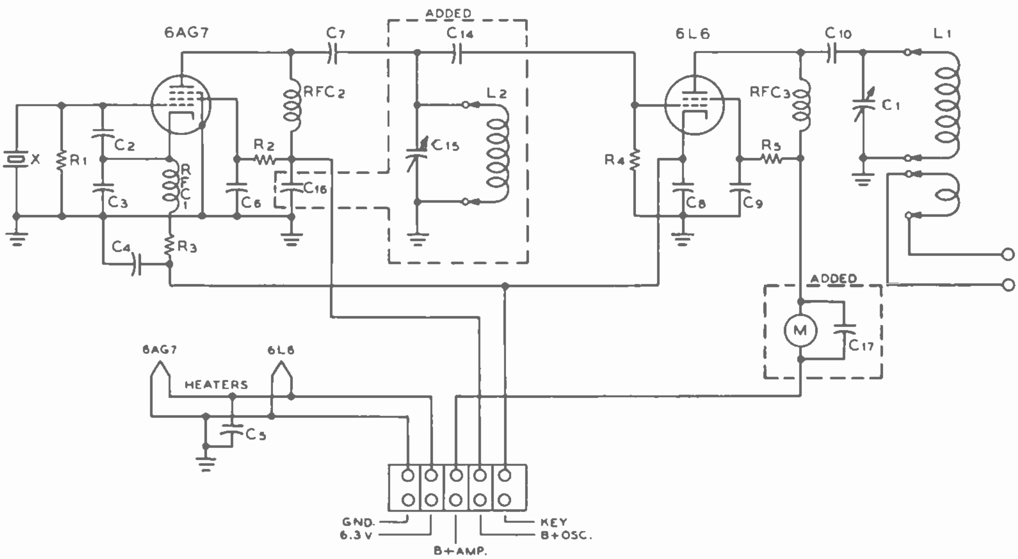


Figure 6.
SCHEMATIC OF THE ALL-BAND R-F UNIT, SHOWING MODIFICATIONS.
The components to be added to the transmitter of figures 1, 2, and 3 are enclosed by dashed lines. New components only are listed below.

C_{14}—75-μμfd. midget mica
C_{15}—100-μμfd. midget variable (National UM-100)
C_{16}, C_{17}—0.0068-μfd. midget mica
M—0-100 d-c milliammeter (Simpson no. 127)
L_2—See coil table

must be tuned to one-half or one-third the frequency to which the coil in the plate circuit of the 6L6 is tuned. If this is not done, and if the grid circuit of the 6L6 is tuned to the same frequency as the plate circuit, the 6L6 stage will oscillate. Self-oscillation in the 6L6 is very likely to result in out-of-band operation and poor frequency stability since the crystal no longer will be controlling the frequency of transmission. Therefore, always make sure with a simple wavemeter that the grid circuit of the 6L6 (plate of the 6AG7) is tuned to a fraction (either one-half or one-third) of the output frequency of the transmitter.

Operation of the output stage of the transmitter as a frequency multiplier results in a slight reduction in the power output capabilities of the transmitter. But the reduction in power output is so small as to be negligible. Extensive tests of the transmitter, operating in conjunction with the modulator shown in figures 2, 3, and 4 of Chapter 7 have shown that plate modulation of the 6L6 as a frequency doubler gives quite satisfactory results with a good modulation percentage and excellent voice quality on all amateur phone bands through 54 Mc. The effective modulation percentage on the 6-meter band (50 to 54 Mc.) is down somewhat from that obtained on all the other bands, as it is viewed on the cathode-ray oscilloscope in the laboratory. But checks of the transmitted signal over the air have shown that the effective modulation percentage and audio quality of the signal as heard are excellent.

The Coil and Crystal Chart indicates the proper combination of coils and crystal frequencies to be used on each of the amateur bands. It will be noted that there are several possible ways of obtaining output on several of the lower frequency amateur bands. Any of these combinations may be used, depending upon the particular crystal frequencies available to the operator of the transmitter. If crystal frequencies are selected carefully, it will be seen from the chart that many crystals may be used on three harmonically related bands. Thus a crystal between 3.5 and 3.6 Mc. may be used on the 3.5-Mc., 7.0-Mc., and 14-Mc. bands. The same consideration applies to 1.8-Mc. and 7-Mc. crystals.

One-Tube V.F.O. Unit

The simple v-f-o unit shown in figures 7 through 10 was designed for use primarily on the lower frequency amateur bands. Its stability is quite adequate for phone operation on all the bands with the 6AG7 oscillator tube operating directly into a frequency multiplier, even directly into the final amplifier for operation on the 160-meter band. The oscillator itself tunes the frequency range from 1700 to 2000 kc., with a small amount of coverage extra at each end of the frequency range. Since the v.f.o. is designed for use on the 160-meter band as well as on the higher frequency amateur bands, the plate circuit of the 6AG7 tube is broadly tuned to about 1850 kc. About one-quarter watt of output power is available over the entire frequency range from 1.7 to 2.0 Mc. If it is desired to use the v.f.o. only for operation on the amateur bands higher than 3.5 Mc., the plate circuit of the 6AG7 may be tuned to about 3700 kc., thus sacrificing operation on the 160-meter band, but eliminating the requirement for a doubler stage in the transmitter from the 160-meter to the 80-meter band. If this is to be done the plate coil for the 6AG7 should be the same in construction as the grid coil for the 6AG7, except that the output link is wound around it.

Circuit Description The 6AG7 tube is operated in a standard Clapp oscillator circuit with output power being taken from the plate circuit of the tube by electron coupling. Due to the excellent stability of the Clapp oscillator circuit, plus the fact that output from the tube is taken by electron coupling, it is possible to operate the oscillator portion of the circuit on the same frequency as that to which the output is tuned. Thus the exciter unit may be used on the 160-meter band to feed a transmitter, even though the oscillator itself is operating on the same frequency as the output of the transmitter. This sysem of operation has proven quite satisfactory, and through this procedure it is not necessary to have the oscillator portion of the v.f.o. in the broadcast band, as would be the case if it were a requirement to have the oscillator of the v.f.o. on one-half the output frequency of the transmitter.

The oscillating circuit of the v.f.o. is series resonant and consists of coil L_1 which is tuned to resonance by capacitors C_1, C_2, and C_3 in parallel. The high current which passes

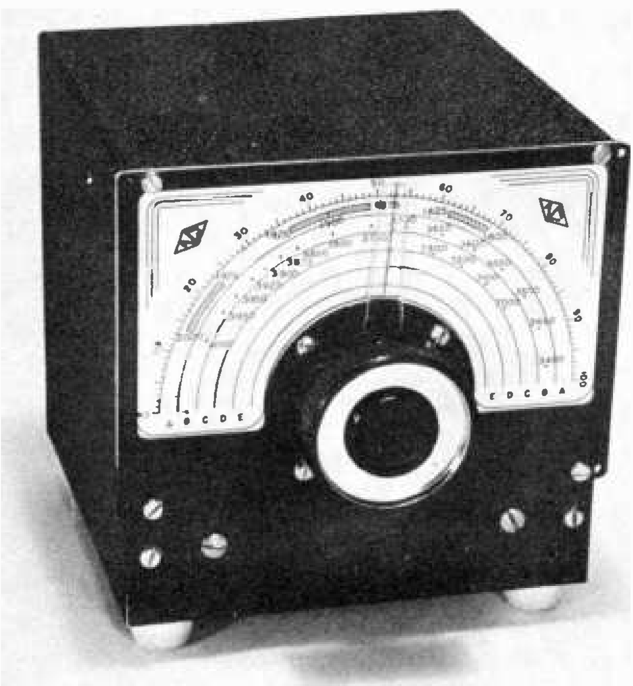


Figure 7.
FRONT VIEW OF THE ONE-TUBE V.F.O. UNIT.

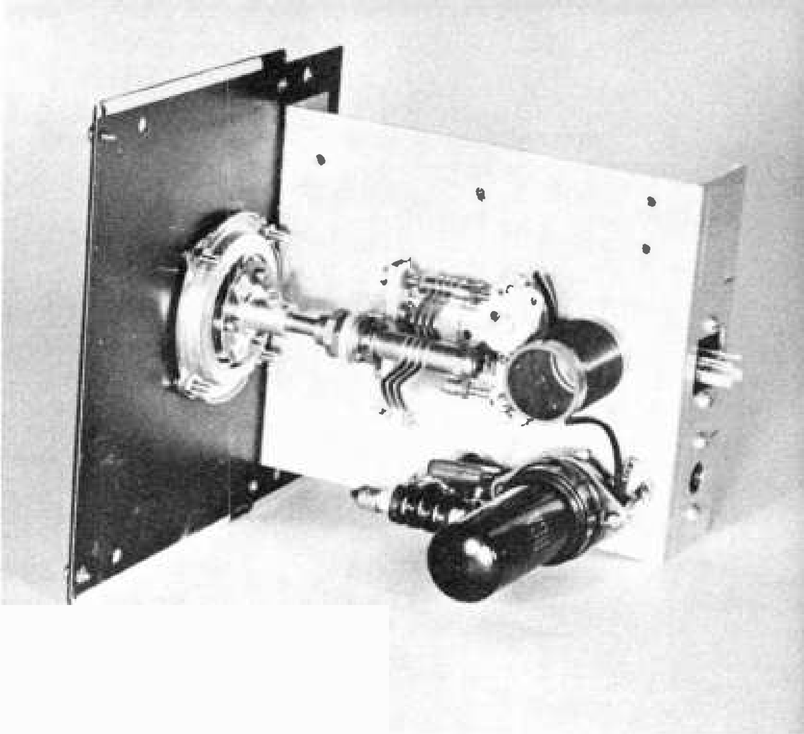


Figure 8.
TOP CHASSIS OF THE ONE-TUBE V.F.O.

through the series-resonant circuit at resonance also passes through the two silver-mica capacitors C_4 and C_5. This resonant current causes a small voltage drop across the capacitive reactances of C_4 and C_5. This relatively small voltage is impressed on the grid of the 6AG7 as excitation, while the cathode of the tube feeds current to the tuned circuit to keep it in a state of oscillation.

It is important that the mode of oscillation of the Clapp circuit be kept in mind, as described briefly in the paragraph above. The mode of operation is quite different from that of the more conventional type of oscillator; in the conventional oscillator circuits the tube is connected to a high impedance point on the oscillating circuit, but in the Clapp oscillator the tube is connected to a low impedance point which has a relatively small amount of coupling to the resonant circuit. It is these two facts (tube across a low-impedance point in the circuit and tube loosely coupled to the circuit) which permit the greater frequency stability of the Clapp oscillator with respect to variations in tube parameters. But it must not be overlooked that variations in the components which go to make up the *resonant circuit* of the oscillator will have just as much effect on the frequency of oscillation as they will have in any other oscillator circuit.

The tuned circuit of the Clapp oscillator should have relatively low C for best operation, but most important of all, the capacitors C_4 and C_5 should be as large a value as will sustain oscillation over the desired frequency range. If these two capacitors are too large, the circuit will not oscillate at all, or will operate only over a portion of the frequency range. But if the two capacitors are made too small in capacitance, the coupling between the tube and the resonant circuit will be too great resulting in increased effect of tube variations on the frequency of oscillation. The values shown have been found to be optimum for the circuit illustrated. The output of the oscillator just begins to fall off as the frequency of oscillation reaches 2000 kc.

Oscillator Stability As in the case of all variable frequency oscillators, some provision must be made for temperature compensation of the frequency of oscillation. If no temperature compensation is used, the frequency of oscillation of the unit will drift to a lower frequency as the components in the frequency determining circuit become heated. This is to say that the normal coils and capacitors used in an oscillating circuit have a positive temperature coefficient. In order to afford temperature compensation it is then necessary to include some component in the circuit which has a negative temperature coefficient. The negative coefficient component must give the correct amount of compensation and it must be placed such that its temperature will rise and fall at

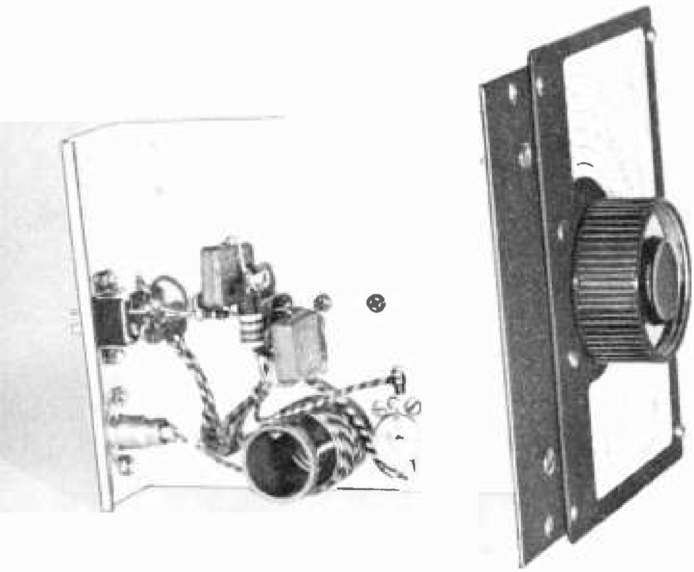


Figure 9.
UNDERCHASSIS OF THE ONE-TUBE V.F.O.

the same time and at the same rate as the other components in the frequency determining circuit.

Temperature compensation in the unit illustrated is attained through the use of the 10-μμfd. negative-coefficient capacitor used as C_3. The value for this capacitor was determined as a result of a number of drift tests on the unit with various values of compensating capacitor. With the value shown, the unit drifts about 150 cycles at 1800 kc. in the first 25 minutes of operation and then settles down to a constant value of operating frequency.

Several notes are in order at this time in regard to the temperature stability of other components in the unit. First, it is important that silver-mica capacitors be used for C_4 and C_5 in the unit. Ordinary mica capacitors are likely to be somewhat unstable with a moderate amount of drift, and the "hi-capacitance" type of ceramic by-pass capacitor (such as used for C_6) is characterized by a relatively large amount of drift with changing temperature. A zero-coefficient ceramic trimmer capacitor is recommended for C_2, but if one is not available a good quality brass-plate APC capacitor may be used. Do not attempt to use one of the "war surplus" aluminum-

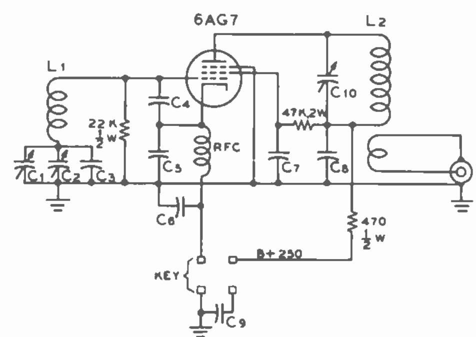


Figure 10.
SCHEMATIC OF THE 6AG7 V.F.O. UNIT.

C_1—35-μμfd. small variable (National ST-35)
C_2—4.5 to 25 μμfd. zero-coeff. ceramic trimmer (Centralab 822AZ)
C_3—10-μμfd. negative-coefficient ceramic (Centralab CC20Z)
C_4—0.002-μfd. silver mica
C_5—0.0025-μfd. silver mica
C_6—0.001-μfd. ceramic by-pass or mica
C_7, C_8—0.0068-μfd. mica
C_9—0.001-μfd. ceramic by-pass or mica
C_{10}—Same as C_2.
L_1—1" no. 28 enam. closewound on 1" dia. form (National XR-2)
L_2—1" no. 32 enam. closewound on 1" dia. form (National XR-2), with 8 turns no. 20 hookup wire as link
RFC—2½-mh. 125-ma. r-f choke (National R-100)

plate APC-type capacitors; they are characterized by a strong positive drift in frequency with increasing temperature.

Construction The unit is housed in a 6 by 6 by 6 inch steel cabinet (Bud CU-1098). The components for the unit are assembled on a miniature aluminum chassis which just fits into the cabinet (Bud CB-1629). A National type SCN dial is used to tune capacitor C_1. This dial is slightly greater in width than the cabinet, but the overhang is less than ⅛ inch on each side so that appearance is not materially impaired. All grid-circuit components of the oscillator are on the top side of the chassis while plate-circuit components are on the bottom side. The socket for the 6AG7 tube is supported above the chassis on ½-inch spacers, while all leads which feed below the chassis are brought through a rubber grommet directly below the tube socket.

It was felt at the outset that it would be necessary to include provision for ventilation of the components inside the cabinet. However, tests of the unit have shown that the radiation of heat from the black crackle finish of the box is very good, so that the components inside the housing stabilize in temperature within a period of time less than one-half hour. The cabinet runs at a temperature just perceptibly warm to the touch after the temperature has stabilized. In addition to the shielding action, the complete enclosure of the oscillator unit insures that the frequency of operation of the oscillator will not be subject to rapid frequency change as a result of drafts hitting the unit.

Operation The oscillator operates from 6.3 volts at 0.65 ampere for the heater of the 6AG7 and 200 to 275 volts at 15 to 20 ma. for plate supply to the oscillator tube. The frequency stability of the oscillator is excellent with regard to plate-voltage variations, so that careful stabilization of the plate supply is not necessary for operation on the 80-meter and 160-meter bands. For c-w operation on the higher frequencies where the line voltage varies with keying, it is desirable that the plate-voltage supply to the oscillator tube be stabilized by a pair of VR tubes.

A 4-prong small-size Jones plug feeds power to the oscillator unit, while the r-f output is taken from the unit by means of an auto-antenna type of coaxial connector. Small-diameter coaxial cable such as RG-58/U should be run from the v-f-o unit to the stage in the transmitter which it feeds. Link coupling to the tuned circuit in the grid of the tube being fed will produce the greatest voltage output from the signal delivered by the v.f.o.

40-Watt C-W Transmitter

It is often convenient to have a 30 to 40 watt c-w transmitter available in the amateur station as a unit of standby equipment. Then the standby transmitter may be used for net operation or to maintain schedules when the main transmitter is down for repairs or rebuilding, or when the station transmitter is more or less permanently tied down to one of the higher frequency bands. The equipment illustrated in figures 11 through 14 has been constructed to fill that need. In addition, the equipment is well suited to serve as an initial transmitter to the amateur who has been off the air for an extended period; or the equipment would make an excellent next step for the newcomer after he has completed and mastered one of the simpler transmitters described at the beginning of this chapter.

The transmitter unit is completely self-con-

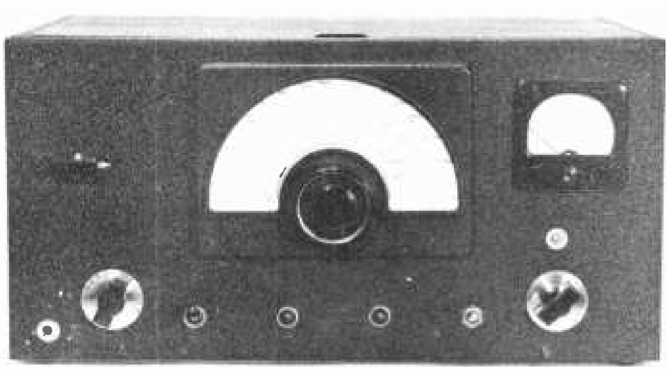


Figure 11.
FRONT VIEW OF THE 40-WATT TRANSMITTER.

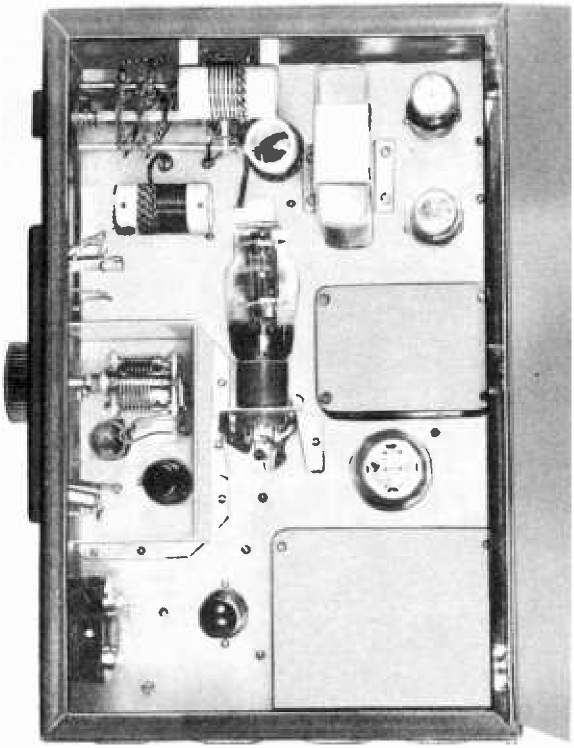


Figure 12.

LOOKING DIRECTLY INTO THE TOP OF THE TRANSMITTER.

The shield compartment for the oscillator portion may be seen between the 807 tube and the front panel of the unit. The bandswitched plate circuit for the 807 is mounted near one end of the chassis near the plate end of the 807.

tained, with built-in v.f.o., power supply, and bandswitching. The 807 in the output stage may be run at 35 to 40 watts input on the 3.5-Mc., 7-Mc., and 14-Mc. c-w bands, although operation on the 14-Mc. band is not specifically recommended due to the relatively low power output of the equipment and to the fact that the 807 operates as a doubler on this band. The 807 runs straight through as an amplifier on the 3.5-Mc. and 7-Mc. bands.

Description of the Circuit The 6SK7 oscillator uses the Clapp series-resonant circuit and tunes from 1750 to 2000 kc. with a moderate leeway at each end of the dial. The output from the plate circuit of the 6SK7 is capacitively coupled to the grid of the 6V6 stage, with a broadly tuned coil in the plate of the 6SK7. Through the use of a 300-$\mu\mu$fd. variable capacitor in the plate circuit of the 6V6 it is possible to deliver excitation to the 807 on both the 3.5-Mc. and 7-Mc. bands without coil switching in the 6V6 plate circuit.

The 6SK7 tube is located in a small shielded compartment, with all the grid-circuit components located inside this shield and above the chassis. A single feed-through bushing passes through the chassis with the lead from the tank circuit to the grid of the 6SK7. Plate-circuit components for the 6SK7 oscillator are located below the chassis between the socket of the 6SK7 and the 6V6 socket.

The 807 tube is mounted above the chassis in a horizontal position by means of a small bracket bent from aluminum sheet. Separate coils are used in the plate circuit of the 807 for each of the three bands. A 3-position deck switch selects the coil for the desired band of operation. The switch used in the model was made up from a Centralab Switchkit and consists of one ceramic section of the 90-degree indexing type, and two wafer sections for

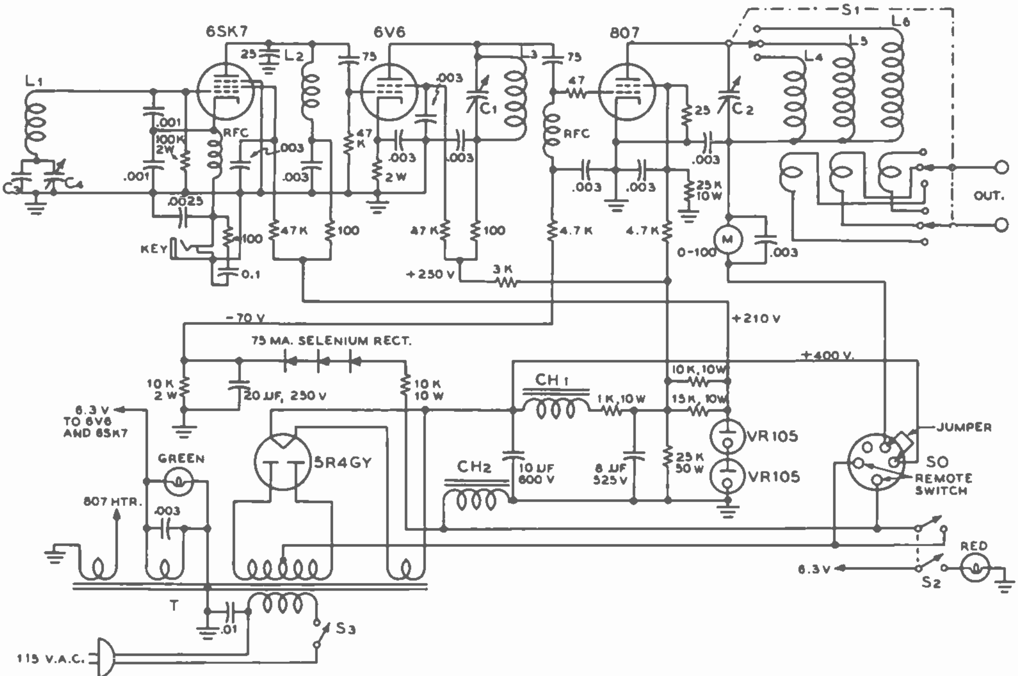


Figure 14.

SCHEMATIC OF THE 40-WATT TRANSMITTER.

C_1—300-μμfd. variable (National TMS-300)
C_2—100-μμfd. variable (National TMS-100)
C_3—115-μμfd. zero-coefficient ceramic (Centralab 75 μμfd. and 40 μμfd. in parallel)
C_4—75-μμfd. two-bearing variable (National ST-75)
L_1—54 turns no. 28 enam. closewound on 1" dia. form (National XR-2)
L_2—1-1/8 inches no. 30 enam. closewound on 1" dia. form (National XR-2)
L_3—18 turns no. 24 enam. closewound on 1" dia. form (National XR-2)
L_4—32 turns no. 22 enam. closewound on 1¼" dia. ceramic form (National XR-16) 8-turn link
L_5—19 turns no. 14 enam. closewound on 1¼" dia. ceramic form (Nat. XR-16) 6-turn link
L_6—8 turns no. 14 enam. closewound on 1¼" dia. ceramic form (Nat. XR-16) 2-turn link
RFC—2½-mh. 125-ma. chokes (National R-100U)
M—0-100 d-c milliammeter (Marion 535N)
CH_1—7-hy. 160-ma. choke (UTC R-20)
CH_2—20-hy. 225-ma. choke (UTC S-31)
T—1050 v. c.t. 250 ma., 5 v. 3 a., 6.3 v. 3 a., 6.3 v. 3 a. (UTC S-40)
S_1—3-pole 3-position switch, one ceramic and two fiber wafers (see text)
S_2—Double-pole single-throw toggle switch
S_3—Single-pole single-throw toggle switch

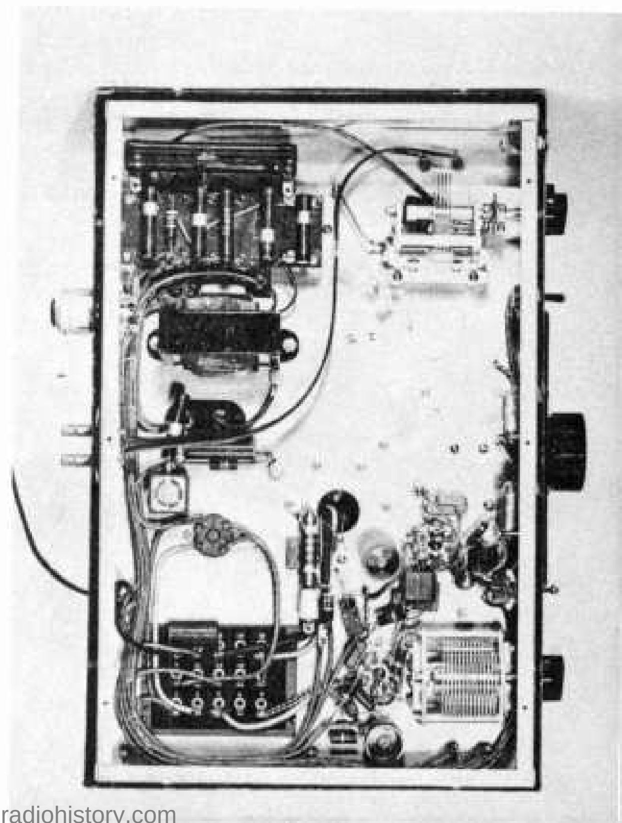


Figure 13.

UNDERCHASSIS OF THE TRANSMITTER.

The plate-circuit capacitor for the 807 is near the top of the panel in this photograph, while the plate-circuit capacitor for the 6V6, which has a much larger number of plates, is at the opposite end of the chassis.

link switching. A 90-degree index is used with the switch sections, and the appropriate sections of the wafer switches are picked up at the 90-degree indexing points.

Keying of the transmitter is accomplished in the cathode of the 6SK7 v-f-o stage. The 6V6 stage following the oscillator operates with cathode bias in addition to that developed across the grid leak, while a fixed minimum bias of −70 volts is used upon the control grid of the 807 output stage.

Power Supply A single power transformer supplies all the needs of the transmitter. A 5R4-GY rectifier, with a choke-input filter having the choke in the negative lead, supplies 400 volts for the plate of the final amplifier, and through dropping resistors feeds the oscillator and multiplier stages plus the screen of the final amplifier. A portion of the ripple voltage across the choke in the negative lead in the filter for the high-voltage supply is rectified by a miniature selenium rectifier to provide bias for the final amplifier. A 10,000-ohm resistor in series with the selenium rectifier serves to limit the peak current through the rectifier. The value of this resistor may be varied over a moderate range to allow variation in the bias voltage furnished to the grid of the 807. Through the use of this type of auxiliary bias supply it is possible to use a switch in series with the center tap of the plate transformer for controlling the application of plate voltage to the equipment. When the plate voltage has been turned off, the grid bias supply also is inoperative.

Mechanical Construction The complete transmitter is constructed in a cabinet of the type used for a National NC-100 receiver. Blank cabinets of this type are available from the National Company. The designation of the cabinet used is C-NC-100. An aluminum chassis with dimensions of 11 by 17 by 3 inches is used inside the cabinet for mounting the components of the transmitter and its power supply. The calibrated dial for the v.f.o. is the illuminated National Type ICN. Two dial lights mounted behind the panel serve to furnish illumination to the scale of the dial.

15-Watt All-Band Exciter Unit

The exciter unit shown in figures 15 through 18 has been designed for those operators who desire a high degree of operating flexibility. The unit may be operated on all bands below 54 Mc. Operating features are so numerous that it is well to list them in tabular form:

1. 15 watts output, 3.5 to 54 Mc.
2. V-f-o operation, 3.5 through 29.7 Mc.
3. Crystal operation all bands including 50 Mc.
4. Bandswitching exciter and final amplifier on v.f.o.
5. Coils for use with any crystal may be inserted.
6. All power supplies self-contained.
7. Built-in 100-kc. crystal calibrator.
8. Built-in break-in keying circuit.

General Circuit Description A Collins 70E8 permeability-tuned variable-frequency oscillator is used in connection with two broadly-tuned multiplier stages and a 2E26 beam tetrode in the output stage. The 2E26 stage operates as an amplifier on the 3.5 Mc. and 14 Mc. bands and acts as a doubler on the 7, 21, 27 and 28 Mc. bands. With crystal excitation to the final it may be operated on any band through 54 Mc. either as a straight amplifier or as a multiplier. Ample power output is available to drive a triode final amplifier to 200 to 400 watts input and more than sufficient power

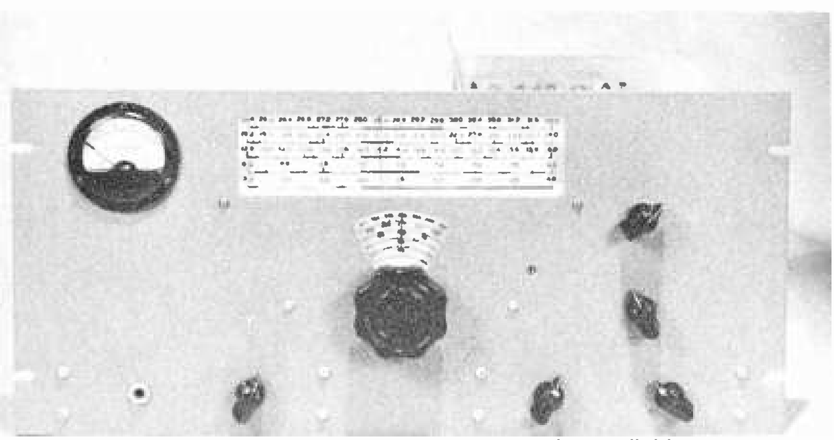


Figure 15.
FRONT-PANEL VIEW OF THE EXCITER UNIT.

is available to drive a pair of beam tetrodes to 1 kw. input.

The V.F.O.-Multiplier Circuit The permeability-tuned oscillator is supplied with 255 volts which has been regulated by a VR-105 and VR-150 connected in series. This v-f-o unit, with fundamental on the 160-meter band, delivers an output signal having excellent stability characteristics and negligible drift on all the v-f-o bands.

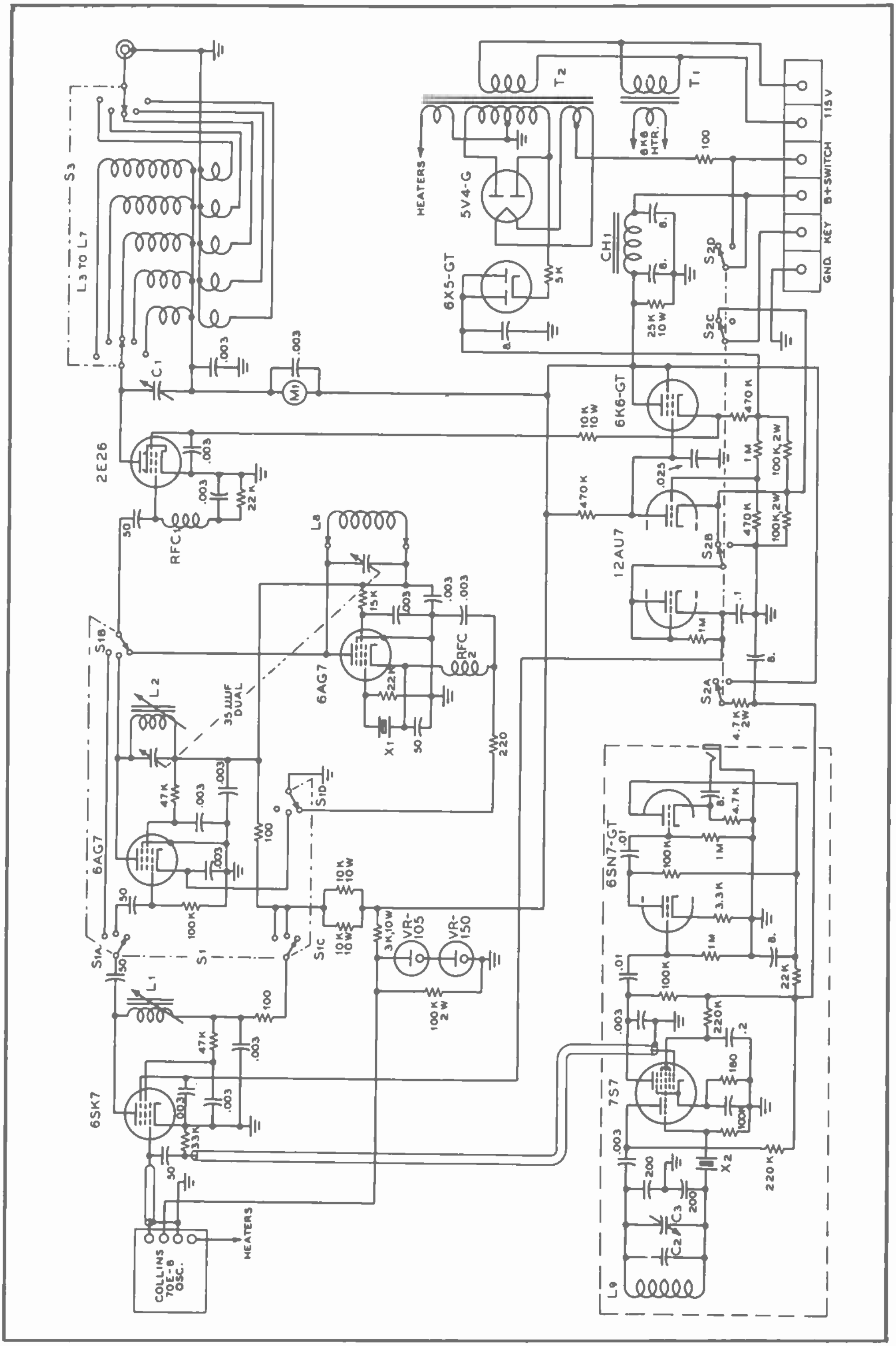
The v-f-o exciter portion of this equipment is essentially the same as that described on page 297 of the RADIO HANDBOOK, 11th Edition. However, the circuit does differ in the following respects: (1) A 6SK7 is used as a first amplifier/multiplier after the v.f.o. with back wave blocking applied to its suppressor grid. (2) An additional position is included on the exciter control switch S_1 to permit driving the 2E26 from a 6AG7 crystal oscillator circuit.

The first 6SK7 amplifying doubler stage operates into a broadly-resonant slug-tuned coil L_1. When tuning up the exciter unit this coil is peaked at 3600 kc. The stage then will deliver substantially constant output over the range from 3200 to 4000 kc. For operation of the 2E26 over this frequency range or as a doubler for operation on the 7-Mc. band, the switch S_1 is placed in the upper position as shown on the schematic.

The 6AG7 multiplier operates either as a tripler or as a quadrupler. Hence its output circuit is tuned approximately to 10.8 Mc. or to 14.2 Mc. One half of a miniature 35 $\mu\mu$fd. variable capacitor is used to tune the plate circuit of this stage. The other half of this capacitor of course tunes the plate circuit of the crystal oscillator as shown in figure 17. The plate circuit of the 6AG7 multiplier tunes rather broadly. However, for maximum output from the 2E26 stage on frequencies above 14 Mc. this tuned circuit should be peaked to resonance.

Output Circuit The plate tank coil of the 2E26 stage consists of a B&W BTEL 5-band turret with modifications. The regular coils of the BTEL for the 80, 40 and 20 meter bands are not modified. The 10-meter coil is completely removed from the turret. Then two turns are removed from the 15-meter coil. This latter coil then is used for output on the 10-meter, 11-meter and 15-meter bands. Then the new 6-meter coil is installed across the contacts on the selector switch of the BTEL which were used for the original 10-meter coil. The added 6-meter coil consists of 4 turns of no. 14 bare wire wound ¾ inch in diameter and spaced to 1 inch in length. A one turn link around the 6-meter coil is connected to the link-selector deck of the BTEL. The 2E26 final stage operates with approximately 375 volts on the plate. Plate current on the tube should be limited to a maximum of 85 ma. as specified by the tube manufacturer. A coaxial cable re-

Figure 16.
REAR VIEW OF THE EXCITER UNIT.
All the r-f portion of the exciter unit is mounted on the left chassis, the v.f.o. is in the front center, the crystal calibrator is on the small chassis in the rear center, and the power supply and keyer portion are on the right side chassis.



S3
L3 TO L7
C1
.003
M1
2E26
RFC1
22 K
50
L8
15 K
RFC2
6AG7
22 K
X1
220
35 µµF DUAL
L2
47 K
6AG7
100 K
S1B
S1A
S1
S1C
S1D
L1
100
6SK7
33 K
COLLINS 70E-8 OSC.
HEATERS
10 K 10 W
3 K, 10 W
VR-105
VR-150
100 K 2 W
T2
T1
HEATERS
5V4-G
6X5-GT
6K6 HTR.
CH1
25 K 10 W
100
115 V
B+SWITCH
KEY
GND.
S2D
S2C
6K6-GT
470 K
1 M
100 K, 2W
12AU7
.025
S2B
S2A
4.7 K 2W
6SN7-GT
3.3 K
7S7
220 K
180
X2
L9
C2
C3
200

Figure 17.
COMPLETE SCHEMATIC OF THE 15-WATT ALL-BAND EXCITER.

CH_1—10.5-hy. 110-ma. choke (Stancor C-1001)
C_1—50-μμfd. midget variable (Hammarlund MC-50-S)
C_2—150-μμfd. ceramic, zero coefficient (Centralab NPO CC35Z)
C_3—10-100-μμfd. ceramic (Centralab 823BN)
S_1—4-pole 3-position ceramic, 2 deck (Centralab 2515)
S_2—4-pole 2-position wafer, 1 deck (Centralab 1409)
T_1—6.3 volts 1.2 amp. fil. trans. (Stancor P-6134)
T_2—700 v. c.t. 120 ma., 5 v. 3 a., 6.3 v. 4.7 a (Stancor P-6013)
RFC_1—150-ma. r-f choke (Johnson 102-750)
RFC_2—7 turns no. 14 bare, ½" dia., space to 1"
M_1—0-100 d.c. milliamperes (Marion HM-2)
L_1—National XR-50 form with one layer closewound and 22 turns on second layer no. 30 enam. Scotch tape between layers.
L_2—National XR-50 form with 19 turns no. 24 enam.
L_3 to L_7 and S_3—B&W BTEL modified as per text
L_8—Coil for crystal to be used. For 50-Mc. band use 3½ turns no. 14 bare, ½" dia. by ¾" long, inserted inside National XR-1 form.
L_9—8-mh. unshielded air-core r-f choke (Meissner 19-2078)
X_1—Crystal for any band. For 50-Mc. band use 25-Mc. crystal (James Knights type H-173)
X_2—100-kc. standard crystal (James Knights type H-16)

ceptacle has been placed on the rear of the chassis. At the transmitter the coaxial cable should be link coupled to the grid circuit of the stage being driven by the exciter.

Crystal Calibrator Circuit A 100-kc. standard crystal has been included within the unit for checking the calibration of the dial on the v.f.o. and to assist in spotting accurately the edges of the amateur bands. Operation of the crystal calibrator unit is selected by placing switch S_2 in the lower of the two positions. The crystal calibrator circuit is unique in that it requires the use of only two double tubes to obtain adequate headphone output of the beat notes between the harmonics of the 100-kc. crystal oscillator and the output of the v-f-o unit. A 7S7 loctal tube has been used for a combined crystal oscillator and detector. This tube is essentially similar to the type 6K8 but was used in preference to the 6K8 because of its single-ended construction.

The triode portion of the 7S7 acts as a Colpitts crystal oscillator whose operating frequency is controlled by the 100-kc. crystal. Sufficient variation in the frequency of operation can be obtained by varying C_3 to enable setting the crystal frequency exactly on 100 kc. This setting can best be accomplished by beating the output of the crystal oscillator in a communications receiver against one of the frequencies transmitted by WWV. The mixer portion of the 7S7 receives signal on its injection grid directly from the crystal oscillator portion by a connection within the tube. A small amount of signal from the v.f.o. is coupled directly into the number one grid of the 7S7 through a short length of coaxial cable. The detected beats between the v.f.o. and the harmonics of the crystal oscillator are amplified in the plate circuit of the 7S7 and coupled to the 6SN7-GT.

The 6SN7-GT tube acts both as an additional audio stage and as a cathode follower to obtain an approximate match into a pair of standard low-impedance headphones. Strong beat notes are obtained in the headphones at all the 100-kc. and 50-kc. points on the 80-meter band. Weaker heterodyne signals can be heard at the 25, 33-1/3 and 66-2/3 kc. points throughout the 80-meter band. Through the use of these beat notes it is possible to set the operating frequency of the transmitter with a high degree of accuracy.

The Crystal Oscillator Circuit On the lower position of switch S_1 the v-f-o multiplier stages are cut off and excitation for the 2E26 is obtained from the 6AG7 harmonic crystal oscillator. This provision was included primarily in order to permit operation on the 50-Mc. band with a 25-Mc. crystal in the grid of the 6AG7. However, the circuit is designed so that a crystal for any band may be plugged into the crystal socket and an appropriate plug-in coil inserted as L_8. Operation on the fundamental frequency of crystals up to the 7-Mc. band may be employed and operation on the second or third harmonic of higher frequency crystals is satisfactory.

Keying Circuit The keying circuit included within this exciter unit has been described in detail in connection with the keyer unit shown in Chapter One. However, the application of the keying circuit in the exciter shown will be described. When the key is up the suppressor grid of the 6SK7 first amplifier tube is at a potential of approximately −100 volts. As a result of this highly negative bias on the suppressor, the exciter portion of the transmitter is completely inoperative. A very weak signal directly from the v.f.o. can be heard on the 3.5 Mc.

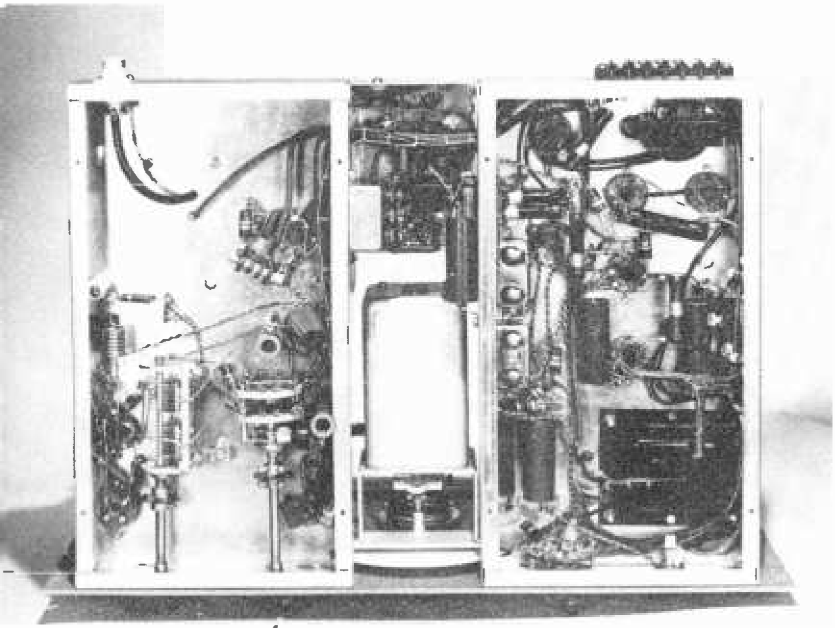


Figure 18.
EXCITER UNDERCHASSIS VIEW.
The small split-stator capacitor in the left chassis is used as two separate capacitors. The forward section tunes the plate coil of the crystal oscillator, which is mounted along the outside edge of the chassis. The rear section tunes the coil L_2 in the plate circuit of the 6AG7 multiplier stage.

band but nothing is audible on 7 Mc. or higher frequencies with key up. Also, while the key is in the up position, the screen potential on the 2E26 is about 35 volts negative with respect to ground. Hence the plate current on this stage is completely cut off.

A notable feature of the circuit is that the frame of the key may be grounded directly. In addition, while the hot circuit contact of the key is at a potential of approximately −100 volts, no shock and only the slightest sensation is felt by putting the fingers across the key. Hence it is not necessary to use a keying relay with the exciter unit as a safety precaution. A keying relay may be desirable, however, because of external circuit considerations.

When the key is depressed the plate and grid of the left half of the 12AU7 are grounded. Hence the cathode potential is rapidly pulled up to ground potential as a result of the conduction through the diode-connected half of the 12AU7. The relatively heavy current passing through this diode connected tube discharges the 0.1-μfd. capacitor from cathode to ground and brings the suppressor grid of the 6SK7 up to ground potential very quickly. This action by itself would produce a strong click except for the fact that the screen voltage on the 2E26 is prevented from rising rapidly by an RC circuit. This time constant circuit is made up of the 0.025-μfd. capacitor from grid to ground on the 6K6-GT and the 470K resistor which feeds this capacitor. After the click at the front end of the exciter has passed, the screen voltage on the 2E26 rises to its normal operating potential of about 200 volts and the 2E26 delivers its full excitation power.

It must be remembered of course that all this action takes place in a very short period of time. The original click is over in a few microseconds and the 2E26 tube is delivering substantially full output in less than one-hundredth of a second.

When the key is lifted a somewhat different sequence of events takes place. First, the amplifier half of the 12AU7 is permitted to draw full plate current. This plate current then tends to discharge the 0.025 capacitor at a moderate rate. As the 0.025 capacitor discharges the cathode voltage of the 6K6-GT cathode follower drops in a smooth manner to a potential of about −35 volts. However, during the period that the screen potential on the 2E26 has been falling, the 6SK7 suppressor grid voltage has been falling much more slowly. After the 2E26 has been cut off for a short period of time, the 6SK7 suppressor voltage reaches a potential sufficiently negative so that the output of the exciter is again cut off.

The net result of this action is that the output signal from the exciter is delivered with a smoothly rising and falling wave which produces no clicks in the output. On the other hand, during the intervals when the key is up, the complete exciter portion of the unit is cut off so that no signal is heard in the receiver. Break-in operation is thus made practicable through the use of this double keying circuit.

Construction As can be seen from the chassis photographs, a rather unconventional method of construction has been used for the exciter unit. This type of construction was necessitated by the fact that it was necessary to mount the exciter on an 8¾ by 19 inch panel. In order that the dial could be lowered sufficiently on the panel it was necessary to use three small chassis rather than one single large chassis. The v-f-o unit then fits into a space between three chassis. All the r-f portion of the exciter is in the left-hand chassis as seen in the back view photograph. The right-hand chassis contains all the power supply components, the voltage regulators and the keying circuit. In addition the terminal strip for external connections to the exciter is mounted on the back of the power supply chassis. The crystal calibrator section of the exciter is mounted on a small additional chassis between the two larger sections. This small chassis was bent to shape from aluminum sheet. The power supply and exciter sections of the assembly each are mounted on 7 by 12 by 2 inch dural chassis.

A De-Luxe All-Purpose Exciter Unit

The exciter unit illustrated in figures 19 through 23 is a rather complex unit of equipment which will probably be duplicated exactly by few persons. Nevertheless, the unit does represent a step in the development of the "ultimate" in exciter units, and its design incorporates a number of ideas and design features which are well worth considering in the design of the next step toward the "ultimate" objective. Further, the features incorporated within the equipment have been proven desirable and useful over an extended period of operation at several amateur stations.

The equipment is the next logical step in the course of development and incorporation of features following the all-band exciter unit just described. The features incorporated into the unit are as follows:

1. High-stability v-f-o unit (Collins 70E-8A)
2. Built-in phase modulator for FM
3. Crystal calibrator for checking dial calibrations
4. Double-tuned broad-band exciter for 2E26 final
5. Built-in clickless "no back wave" keying circuit
6. Communications switch controls transmitter as well as v.f.o.
7. Built-in speech amplifier
8. Plate, filament, and bias supplies included on the chassis
9. Can be used as a complete 15-watt phone or c-w transmitter on all amateur bands from 3.5 through 29.7 Mc.

One of the most convenient features, at least for some operators, is the fact that the unit is a complete and self-contained transmitter. It may be used for c.w. on any amateur band, and with FM radiophone on those bands wherein FM is authorized.

Since the transmitter/exciter contains several circuit groupings, as well as separable components, it is considered best to describe these various portions of the exciter unit individually, even though most of them are mounted on the main chassis.

The Oscillator Unit The v-f-o portion of the exciter is a standard Collins 70E-8A oscillator unit. It is fed from a regulated 258-volt supply with an OA2 (150 volts) connected in series with an OB2 (108 volts) for voltage stabilization. A slight amount of ripple was encountered in the oscillator as a result of the proximity of the oscillator unit to the induction fields of the power transformer and filter choke. This ripple was eliminated by mounting a 1/16-inch soft iron shield around the oscillator can on three sides. The placement of the iron shield is shown in the top-view photograph of the exciter assembly. Type RG-58/U coaxial cable is run from the output of the oscillator unit to the phase modulator and thence to the crystal-calibrator unit. The v.f.o. operates continuously as long as line voltage is being applied to the exciter unit.

The Phase-Modulation System Since built-in FM operation of the exciter was desired, and since the oscillator unit is a completely enclosed entity, it was felt that the best way of obtaining FM would be by phase modulating the output signal from the v.f.o. Through this procedure the stability and calibration of the oscillator unit is unaltered, yet excellent FM operation is obtained. The phase modulation is applied directly to the 160-meter output of the v-f-o unit, so that sufficient deviation is obtained for FM operation on the 75-meter amateur band. The deviation control must be turned down to a much lower point for 14-Mc. and 28-Mc. FM, as compared to the setting for the 3.9-Mc. band. This is a natural result of the fact that the deviation is multiplied by the same amount that the frequency is multiplied when operating on the higher frequency bands.

The phase modulator itself consists of a pair of 6SA7 tubes with their plates in parallel and with out-of-phase r-f voltages applied to their number-one grids. The actual phase angle between the voltages applied to the two grids varies somewhat with the v-f-o frequency, but is in the vicinity of 120 degrees.

The speech amplifier consists of a 6SJ7 voltage amplifier coupled into a 6SN7-GT. The first section of the 6SN7-GT acts as a voltage amplifier, with the deviation (gain) control connected between the output of the 6SJ7 and the grid of this first section. The second section of the 6SN7-GT acts as a "hot-cathode" type of phase inverter with its signal grid connected directly to the plate of the first section of the tube. When the exciter is to be used for FM, the push-pull output of the phase inverter is fed to the two injection grids of the 6SA7's.

When the exciter is not to be used for FM, the injection grids of the 6AS7's are removed from the output of the speech amplifier and are connected to the keyer circuit. Under these conditions the 6SA7's act simply as though they were in parallel as a buffer or isolating amplifier. When the key is up, or when the exciter is in the standby condition, the 6AS7's are biased off automatically so that a back-wave from the oscillator will not be heard in the receiver. As was mentioned before, the v-f-o unit in the exciter operates continuously so that maximum frequency stability will be obtained.

Phase shift to the two grids of the 6SA7's is obtained through the use of resistance-reactance circuits. An RL series circuit feeds the grid of one tube while an RC circuit feeds the grid of the other 6SA7 from the output of the v.f.o. An inductance of approximately 100 microhenrys is required for L_1. This value of inductance was obtained by removing about 2/3 the turns from one coil of an iron-core 455-kc. i-f transformer. The other coil of the i-f transformer is removed completely.

To adjust the phase modulator the 7-45 ceramic capacitor in the grid of the other 6SA7 is set to about one-half capacitance (a Centralab 822BN ceramic trimmer is used), a small audio signal is applied to the speech amplifier, and the output signal from the exciter is monitored (preferably with an FM receiver and an oscilloscope, although slope detection with a conventional receiver will serve). The tuning slug in L_1 is then varied until the greatest deviation is obtained for a given audio signal, with the least amount of harmonic distortion. The adjustment is not critical for satisfactory results. But for greatest deviation with least distortion some variation of the inductance of L_1 and the setting of the 7-45 $\mu\mu$fd. trimmer will be required. Once the adjustment has been made with the v.f.o. set to about 1800 kc., no further adjustment will be required at any time for operation on any band.

Figure 19.
FRONT VIEW OF THE EXCITER UNIT.

From left to right on the front panel are: microphone jack, deviation (gain) control, phone jack for crystal calibrator, communications switch (under v.f.o. dial), and on the same level as the v.f.o. dial to the right are the 2E26 plate turret switch and plate tuning capacitor. The band selector switch for excitation to the 2E26 is on the bottom of the panel below the 2E26 plate tuning capacitor.

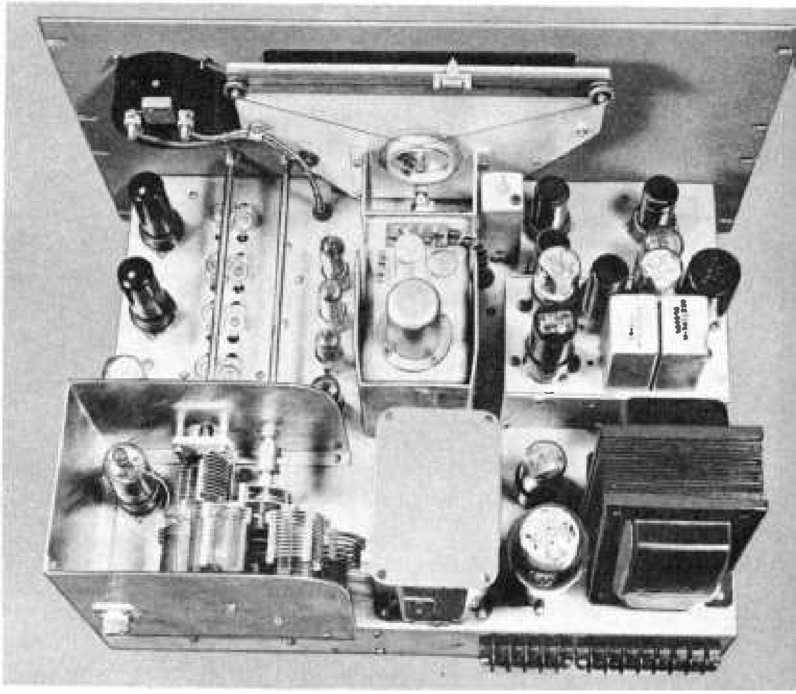


Figure 20.
LOOKING DOWN ON THE EXCITER UNIT.
On the right side of the chassis in front is the speech amplifier and phase modulator, behind these is the chassis of the crystal calibrator, and the power supply is in the rear. Just to the left of the v.f.o. can are the two miniature VR tubes and the two miniature tubes of the vacuum-tube keying circuit. The multiplier tubes, with the trimmers for the interstage coils, are on the extreme left of the chassis.

The Crystal Calibrator Unit The inclusion of a crystal oscillator frequency sub-standard is probably an unnecessary refinement since the calibration of the 70E-8A is reliable to within a few kilocycles on the 28-Mc. band. But when operaion very close to a band edge is desired the crystal calibrator is a worthwhile feature.

The crystal calibrator unit used in the exciter is an 8Q2 CFI unit of the type included within the ART-13 transmitter. These units have been widely available on the surplus market for a very low price. The only difficulty in using these units is that they seldom come complete with the 200-kc. crystal for which they were designed. But if one can be obtained, and a 200-kc. crystal obtained from the same or another source, the assembly is very useful in the amateur station. Two types of crystals are available, one in a round can and one in an FT-243 type of holder. If a surplus crystal cannot be obtained for the 8Q2, one can be ground for it by a crystal manufacturer.

The 8Q2 unit used originally a pair of 12SL7-GT tubes and a single 12SA7. One half of one of the 12SL7-GT tubes acted as a 1000-cycle oscillator in conjunction with a small tapped coil. This coil is removed and an octal socket for the 6SN7-GT tube added. The 8Q2 unit is then rewired as shown in figure 22 and all the heaters are connected in parallel. Then the 12SL7-GT's and the 12SA7 are replaced with their 6-volt counterparts. If no changes are made in the balance of the circuit of the unit, no difficulty should be had in getting the modified unit to operate. As is shown in the modification diagram, the original detector half of the 6SL7-GT feeds through a two-stage audio amplifier consisting of the second half of the detector 6SL7-GT and the first half of the 6SN7-GT. The second half of the 6SN7-GT acts as a cathode follower to feed the beat-note signals to the phone jack on the front panel of the exciter unit.

The crystal calibrator unit illustrated includes a frequency divider circuit which generates a 50-kc. signal from the 200-kc. output of the crystal oscillator. This 50-kc. signal is fed to the 6SL7-GT beat-note detector. Strong beat notes are obtained every 100 kc. on the 3.5-Mc. band, fairly strong ones are available every 50 kc., while the 25-kc., 33-1/3 kc., and 66-2/3 kc. beat notes are strong enough to be usable.

If one of the 8Q2 calibrator units is not available, a 100-kc. crystal calibrator such as is employed in the "15-Watt All-Band Exciter Unit" described just ahead in this chapter may be used. This simpler type of calibrator unit will give quite satisfactory results, but intermediate crystal check points will be somewhat weaker due to the use of a 100-kc. reference signal instead of one on 50 kc.

The phone plug on the front panel is of the type which closes an external circuit when the phones are inserted. This external circuit is used to apply the plate voltage to the calibrator unit whenever the phone plug is inserted. The crystal calibrator should not be in operation when the exciter is feeding a transmitter and the transmitter is radiating a signal; hence the phone plug should be removed from the calibrate jack except when the exciter is being calibrated. If the calibrator were in operation when the associated transmitter were on the air, the presence of the 50-kc. signal at the front of the r-f channel would result in the radiation of weak beat-note "birdies" between the 50-kc. signal and the v-f-o signal.

The Band-Pass Exciter Unit The multiplier stages are of the double-tuned band-pass variety, with a selector switch S_1, for feeding the desired frequency to the grid of the 2E26. The coil L_2 in the plate circuit of the 6SA7's is broadly tuned to the center of the 1.8-Mc. band. Hence the first 6AG7 operates as a frequency doubler with its output covering the range from 3375 to 4000 kc. The next 6AG7 operates with either of two coils in its plate circuit. With S_1 set

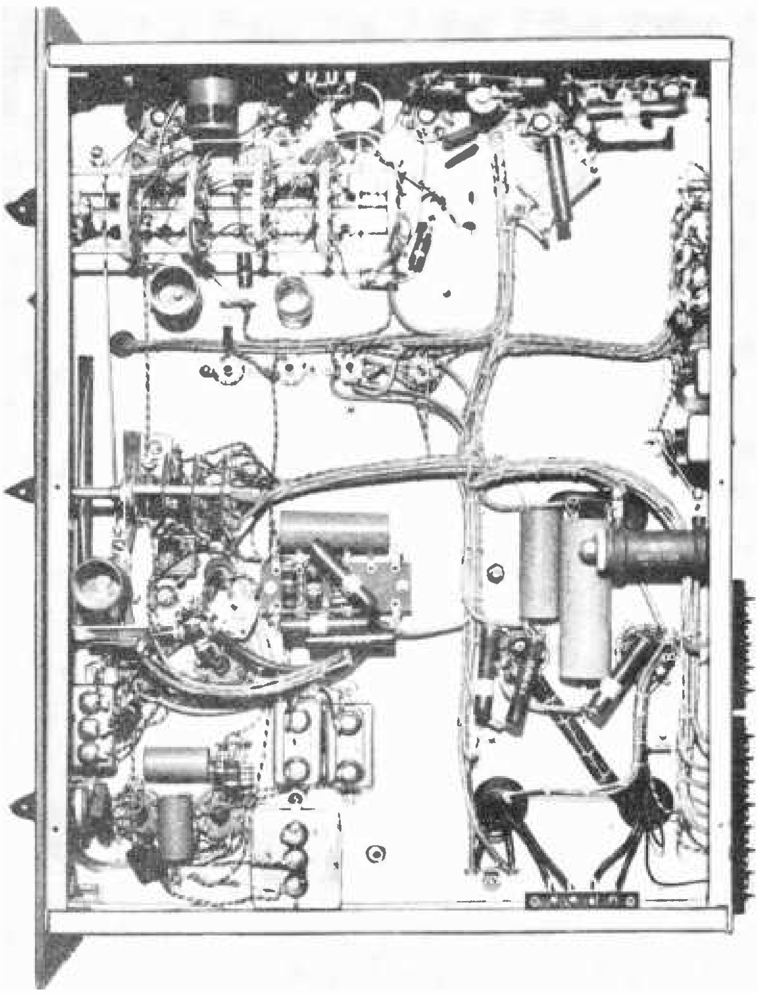


Figure 21.
UNDERCHASSIS OF THE EXCITER UNIT.
The power supply and control leads have been cabled to improve the appearance of the unit, and to keep the wires out of the r-f fields. Only four switch wafers are required for the excitation switch, there being an unused deck in the equipment illustrated.

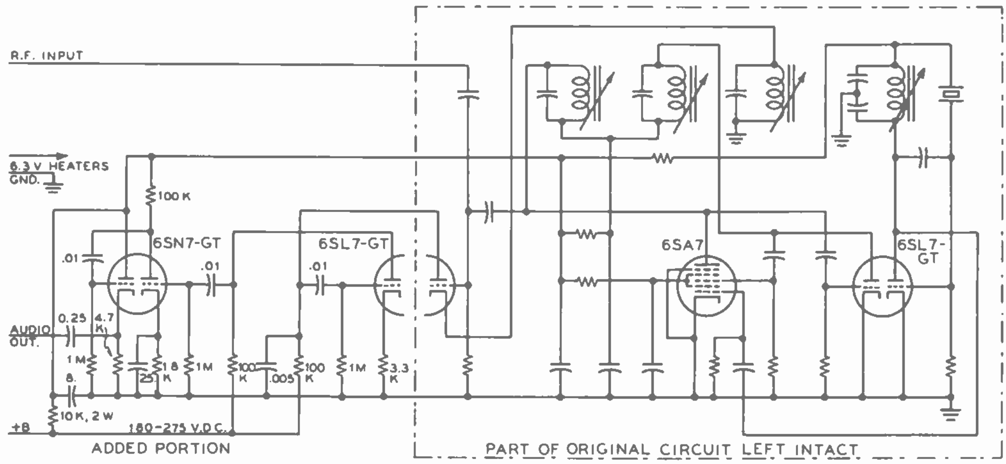


Figure 22.
SCHEMATIC OF THE MODIFIED 8Q2 CRYSTAL CALIBRATOR UNIT.

for either 40-meter or 15-meter output, the tube operates as a doubler to cover the 7.0 to 7.3 Mc. range. With S_1 set for 20-meter or 10-meter output, the tube operates as a quadrupler to cover the 13.5 to 14.85 Mc. range. The 6V6-GT operates only with S_1 set for 15-meter operation, whence this tube operates as a frequency tripler to cover the 21.0 to 21.45 Mc. range. The 2E26 output stage operates as a straight-through amplifier on all bands through 21.45 Mc. When operating with output in the 26.96 to 29.7 Mc. range the 2E26 acts as a frequency doubler.

Coils L_3, L_4, L_5, and L_6 each are double-tuned transformers. Centralab dual ceramic trimmers are used for each of the transformers, although of course a pair of ceramic or APC-type trimmers could be used. The primary and secondary windings of each of the transformers are tuned to different frequencies, the primary being tuned slightly higher in frequency than the lower edge of the band and the secondary being tuned somewhat in from the high edge. Alignment of each of the transformers is obtained with the aid of a 0-250 d-c voltmeter connected from the point (V) to ground, so that the meter reads the total grid bias on the 2E26 tube. The "communication" switch S_2 should be in the second position from the left ("Calibrate") and the key should be up for these adjustments. Note that there is 18 to 20 volts of fixed bias on the 2E26 in the absence of excitation. With full excitation the grid bias on the 2E26 will vary from 70 to 150 volts over the frequency ranges of the different bands.

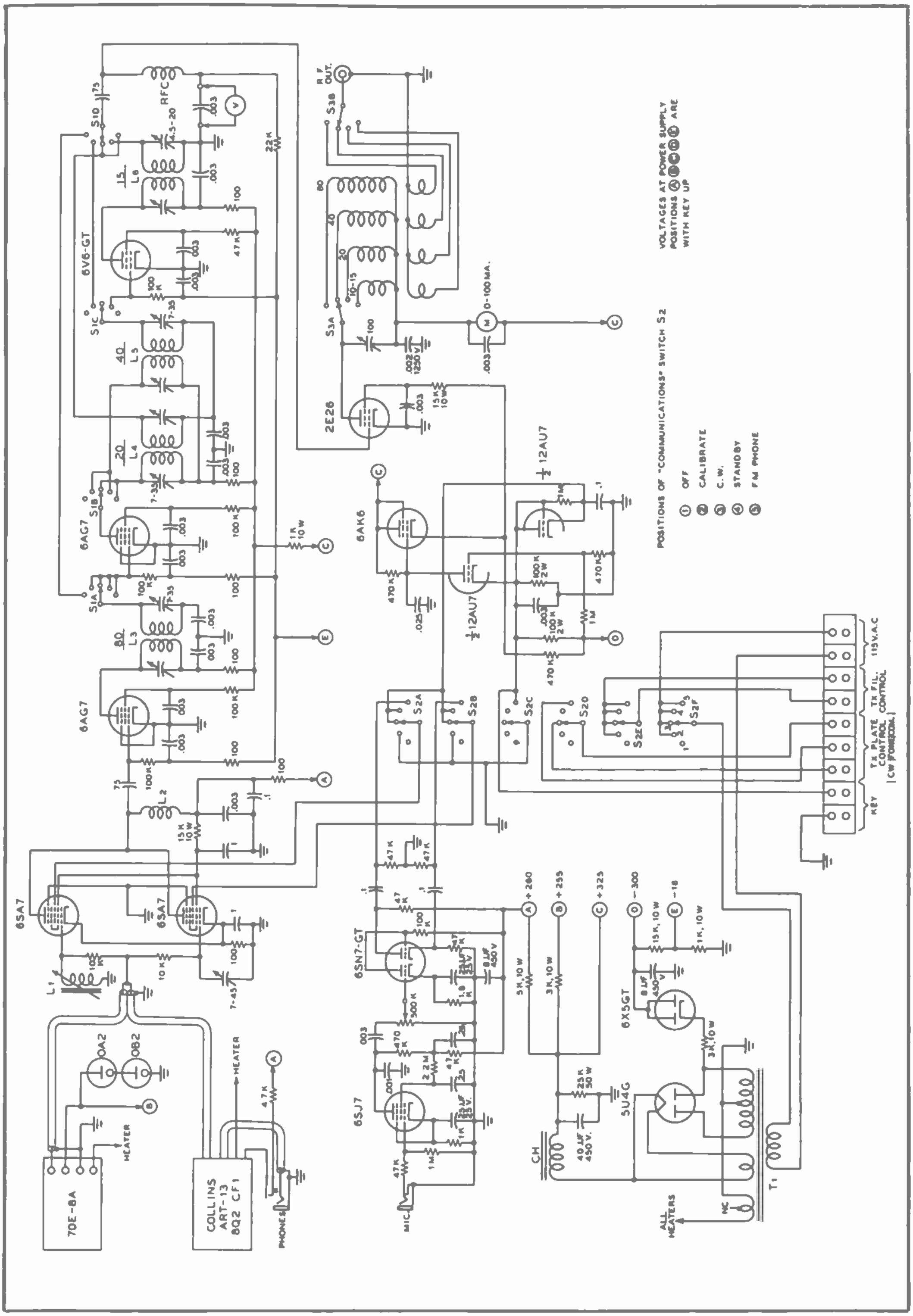
The alignment frequencies are as follows, and the alignment procedure should be followed from the lowest to the highest band.

Bandswitch, S_1 Position	V.f.o. setting (using 3.5-Mc. scale)	Align for max. 2E26 grid-bias
80 meters	3375	pri L_3
80 meters	3850	sec L_3
40 meters	3525	pri L_5
40 meters	3625	sec L_5
20 meters	3375	pri L_4
20 meters	3700	sec L_4
15 meters	3515	pri L_6
15 meters	3560	sec L_6

No additional alignment is required for the 11 and 10 meter bands, since the output stage of the exciter acts as a frequency doubler.

The Break-In Keying Circuit Two additional tubes are required in the exciter unit for the break-in keying circuit. Through the use of these tubes, a 12AU7 dual triode and a 6AK6 miniature power pentode, an unusually satisfactory keying characteristic is built into the exciter. The operation of the keying circuit used in this exciter is described in some detail in Chapter One, but the application of the circuit to this exciter unit will be explained.

The first half of the 12AU7 acts as a d-c voltage amplifier with its plate connected directly to the grid of the 6AK6 pentode. When the key is up, the cathode of this tube is at



POSITIONS OF "COMMUNICATIONS" SWITCH S2
① OFF
② CALIBRATE
③ C.W.
④ STANDBY
⑤ FM PHONE
VOLTAGES AT POWER SUPPLY POSITIONS ⒶⒷⒸⒹⒺ ARE WITH KEY UP
6V6-GT
6AG7
6AG7
6SA7
6SA7
2E26
6AK6
12AU7
12AU7
6SN7-GT
6SJ7
6X5GT
5U4G
OA2
OB2
70E-8A
COLLINS ART-13 8Q2 CF1
RF OUT.
0-100 MA.
KEY
TX PLATE CONTROL (CW POSITION)
TX FIL. CONTROL
115 V.A.C.
ALL HEATERS
MIC.
PHONES
HEATER
+280
+255
+325
-300
-18

Figure 23.

SCHEMATIC OF THE ALL-PURPOSE EXCITER UNIT.

Similarly lettered points (all A's for example) are to be connected together as common power-supply connections.

L_1—One coil of 455-kc. iron-core i-f transformer with about 2/3 of turns removed. Approx. 100 µhy.
L_2—1-1/8" no. 28 enam. closewound on 1" dia. National XR-2 form
L_3—Two coils of 1/2" no. 30 enam. closewound on XR-2, separated 1/4"
L_4—Two coils 25 t. no. 28 enam. closewound on XR-2, separated 1/2"
L_5—Two coils 12 t. no. 24 enam. closewound on Amphenol no. 24 form (3/4-inch dia.), separated 1/2"
L_6—Two coils 8 turns no. 18 enam. closewound on XR-2, separated 1/2"
S_1—Assemble from Centralab Switchkit, with four single-pole 6-position ceramic wafers and appropriate hardware
S_2—6-pole 5-position wafer switch (Centralab 1425)
S_3—Included as a portion of B&W BTEL turret
CH—20-hy. 225-ma. filter choke (UTC S-31)
RFC—2.5-mh. 125-ma. r-f choke (National R-100U)
T_1—850 v. c.t. 200 ma., 5 v. 3 a., 6.3 v. 5 a., 6.3 v. 3 a. (UTC R-13)

a potential of about –65 volts. Since the grid of this tube section is nominally at a potential less negative than the cathode, with key up, this means that the grid is slightly positive with respect to the cathode so that the tube is highly conductive. Since the tube is highly conductive, and since the plate is fed by a rather high value of resistance (470,000 ohms), the plate potential approaches the cathode potential to the extent of going to about –50 volts. The plate of this tube is directly connected to the grid of the 6AK6 cathode follower, so the cathode potential of the 6AK6 falls to about –38 volts with the key up. Since the screen of the 2E26 is fed with its potential from the cathode of the 6AK6, the 2E26 screen is now negative and plate current on the 2E26 is cut off.

When the key is pressed, the cathode of the first half of the 12AU7 is grounded, and the tube is cut off by the grid bias of about –90 volts. Since the tube is cut off, the 0.025-µfd. capacitor from grid to ground on the 6AK6 is charged by the 470,000-ohm resistor running to the plate of the 6AK6. This action gives a smoothly rising voltage on the grid of the 6AK6, which is followed by the cathode of the 6AK6 and thence by the screen of the 2E26. After about 15 milliseconds the cathode of the 6AK6 is at a potential of about plus 250 volts, and the screen of the 2E26 is being fed in the normal manner through the 15,000-ohm dropping resistor. The 2E26 is now delivering full output, and there has been no click due to the shaped voltage wave being applied to the 2E26 screen. When the key is lifted, the reverse effect takes place, and the screen voltage of the 2E26 is smoothly dropped until plate current and output of the 2E26 are cut off.

The above effects all take place when the transmitter is keyed with the "communications" switch S_2 in the second or "calibrate" position. In this position the number three grids of the 6SA7's at the front end of the exciter are grounded, and all the exciter stages up to the grid of the 2E26 are delivering full output. Also, with this type of operation a strong "back-wave" is heard in the station receiver as a result of the small amount of radiation taking place from the exciter stages.

Break-In Operation For break-in operation it is important that no back wave be heard when the key is lifted. Hence, an anti-back-wave circuit has been incorporated into the keyer portion of the exciter. This circuit is operative with S_2 in positions 3 and 4. It will be noted from the main circuit diagram that the injection grids of the two 6SA7's are connected, when S_1 is in position 3 or 4, to the cathode of the second half of the 12AU7. With the key up, the 0.1-µfd. capacitor from cathode to ground is charged to a potential of –65 volts by the 1-megohm resistor. This value of negative potential effectively cuts off the 6SA7 tubes so that no excitation is delivered to the succeeding stages of the exciter. Hence no back wave is audible, since the v-f-o unit itself cannot be heard except on its fundamental, the 160-meter band.

When the key is pressed the plate and grid of the second half of the 12AU7 are immediately pulled to ground potential. The diode-connected section of the 12AU7 conducts heavily, the 0.1-µfd. capacitor is discharged quickly, and the 6SA7's become operative since their injection grids now are at ground potential. Thus the exciter portion of the equipment, up to the grid of the 2E26, becomes operative a very short time after the key is pressed. This sharp wavefront would produce a strong click on the air if it were transmitted. But the screen voltage of the 2E26 still is rising relatively slowly as a result of the time constant in the grid of the 6AK6. Thus the click and slight chirp resulting from the sudden loading of the v.f.o. already have died out by the time that the 2E26 screen voltage has risen to the point where output is being delivered by the exciter unit to the transmitter.

When the key is lifted the output of the 2E26 immediately begins to fall in accordance with the time constant of the screen-voltage circuit. But due to the effectively greater time constant in the circuit which applies bias to the grids of the 6SA7's, the output of the multiplier stages remains substantially constant until after the time when the output from the 2E26 has fallen to zero as a result of the falling screen voltage.

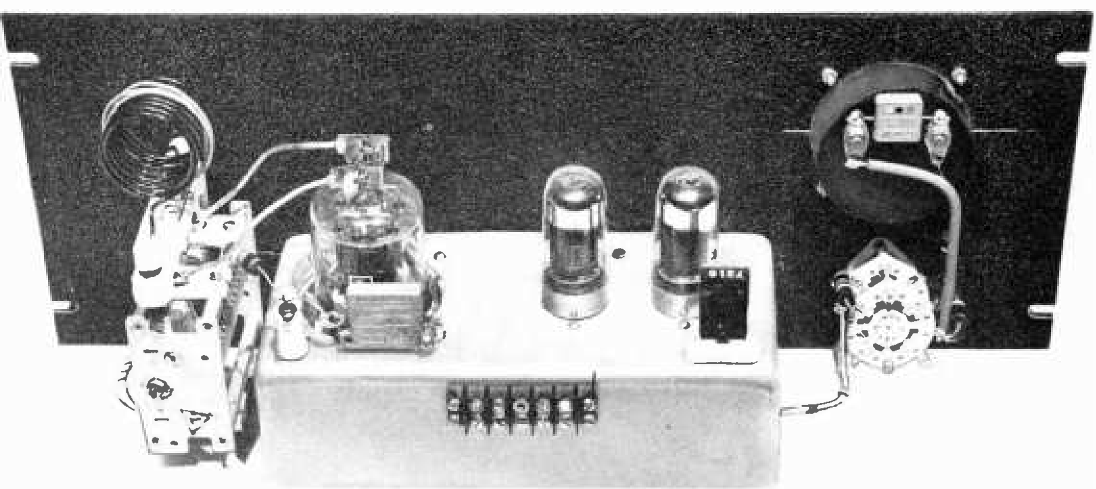
The net result of these rather complex actions is that the excitation to the 2E26 comes on an instant before the tube begins to conduct, and lasts for an instant after the tube ceases to conduct. When one listens in a receiver to the multiplier stages, the click and tail existing in the r-f envelope of these stages may be heard. But listening on the air to the transmitted signal shows only a very smoothly keyed carrier. And, as a result of all this action, no signal is heard on the transmitting frequency with the key up. The system operates so smoothly that many successful break-in contacts were had on 14-Mc. c.w. with European and African stations from California. The exciter unit was used as driver for the push-pull 4-250A amplifier described in Chapter Five, operating with one kilowatt input to the 4-250A's. A small separate antenna was used for receiving.

The 2E26 Output Stage Aside from the screen keying circuit, the 2E26 output stage is quite standard. The tube operates with 2 to 5 ma. of grid current, the screen voltage is dropped to about 160 by the 15,000-ohm 10-watt resistor in the lead from the screen keyer tube, and the plate current runs 65 to 75 ma. with normal loading. The output turret is a B&W assembly with the 10-meter coil removed and the 15-meter coil cut down to 5 turns for covering the 10-meter, 11-meter, and 15-meter bands. The output stage is shielded from the other portions of the unit, and output is taken from the stage by means of a coaxial cable fitting mounted on the rear shield.

Power Supply The complete power supply for the exciter/transmitter is included on the chassis. A 5U4-G supplies about 325 volts at up to 200 ma. for plate current to all stages of the unit. In addition, a 6X5-GT, with its cathode connected to one side of the high-voltage secondary by means of a 3000-ohm 10-watt resistor, supplies about 300 volts as the negative supply for fixed bias and for the operation of the vacuum-tube keying circuit. The power supply operates continuously so long as the 115-volt supply is being fed to the transformer; hence conservatively rated components are used.

Control Circuits The communications switch, S_2, has five posi-

Figure 24.
REAR VIEW OF THE 829B TRANSMITTER.



tions: OFF, CALIBRATE, C.W., STAND-BY, and FM PHONE. Keying of the unit will deliver output on positions 2, 3, and 4. Straight keying (with back wave) is obtained on position 2 and break-in keying on the other two positions. On position 5 (FM PHONE) the carrier is emitted continuously, and can be frequency modulated by plugging a crystal microphone into the jack on the front panel and turning up the gain control. For amplitude modulation of the stage being fed by the exciter, the FM gain control in the exciter unit is turned off. Several additional circuits are wired into S_2 so that the entire transmitter may be controlled, by means of relays, through the switch on the exciter unit.

Mechanical Construction The exciter unit is constructed on a 13 by 17 by 3 inch aluminum chassis (ICA no. 29024). The panel is a standard 10½ by 19 inch dural unit with gray wrinkle finish. The oscillator unit is supported about ⅛ inch above the chassis, with a slot cut in the front of the chassis to clear the bandspread dial of the v-f-o unit. The shield for the 2E26 output stage was cut and bent from 0.040-inch sheet aluminum.

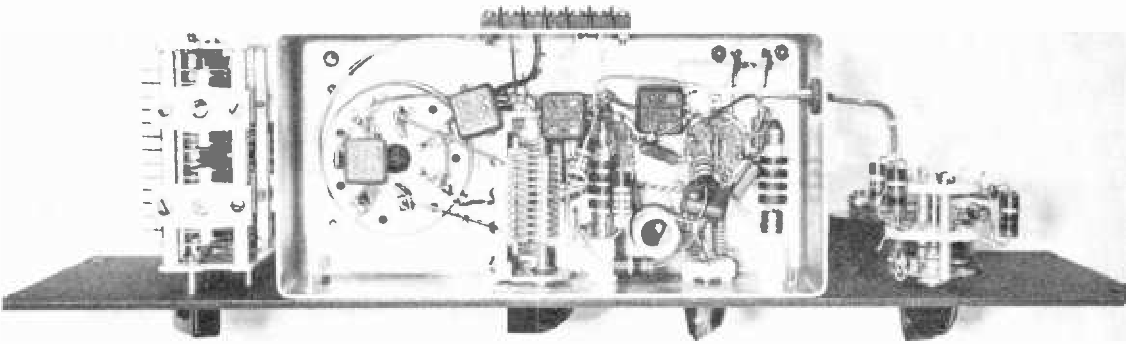
829B Transmitter Exciter For Ten and Six

The 829B tube has proven very popular for use on the 10 and 6 meter bands both as a final amplifier and as a buffer stage. Aside from the relatively low price of the tube on the surplus market, it has the advantages of small size, low interelectrode capacitances, and the capability of running a quite sizable amount of input at a relatively low plate voltage. The unit shown in figures 24 and 25, and diagrammed in figure 26, is designed to take advantage of the capabilities of this tube in the 10 and 6 meter bands. Inputs up to 90 watts may be run on both bands with natural cooling of the 829B tube. In the event that it is desired to run greater input, the 829B may be cooled by directing a stream of air from a small blower or a fan at the envelope. The maximum rated input for the tube with forced-air cooling is 120 watts with 600 volts on the plate.

Circuit Description Two 7C5 tetrode tubes are used in the exciter for the 829B. In turn the 829B may either be operated as a final amplifier or as a buffer amplifier for a high-power triode final. The first 7C5 tube is connected in a Colpitts harmonic oscillator circuit. It is designed for use with crystals in the 7-Mc. range for output on the 10-meter band and in the 8.4-Mc. range for output on the 6-meter band. The plate coil for the first 7C5 stage is fixed. For operation on 10 meters the plate circuit is tuned to 14 Mc. or twice the crystal frequency. For operation with an 8.4-Mc. crystal the plate circuit of the first 7C5 is again tuned to twice frequency or approximately 16.8 Mc.

The second 7C5 tube operates as a multiplier on both bands. The plate coils for this tube are soldered in place across the push-pull tuning capacitor which feeds the grids of the 829B. For operation on 10 meters the second 7C5 acts as a doubler to the 28-Mc.

Figure 25.
UNDERCHASSIS OF THE 829B TRANSMITTER.



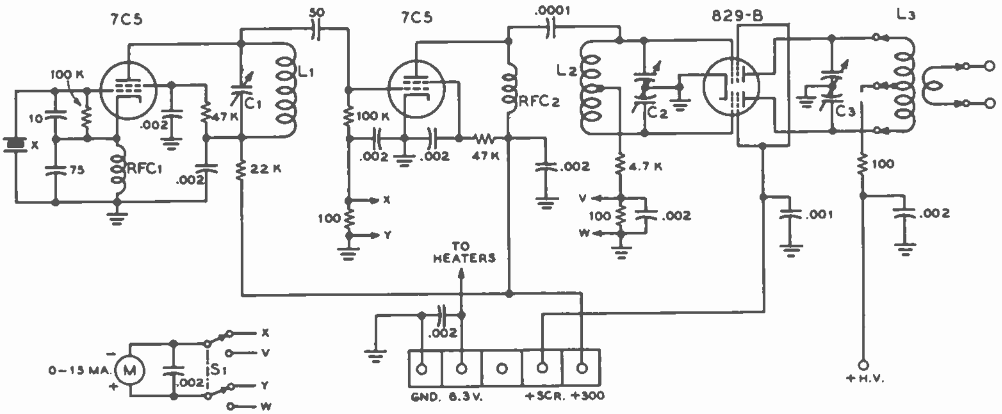


Figure 26.
SCHEMATIC OF THE 829B TRANSMITTER.

C_1—50-μμfd. APC with shaft
C_2—Dual 35-μμfd. per section
C_3—Dual 50-μμfd. per section, or 27-plate unit from 375E tuning unit with stator split.
L_1—9 turns no. 18 enam., ¾" dia.
L_2—28 Mc., 11 turns from B&W 3010
50 Mc., 5 turns from B&W 3010
L_3—28 Mc., 8 turns no. 12, 1½" dia. 1½" long
50 Mc., 6 turns no. 12, 1-⅛" dia., 2" long
RFC_1, RFC_2—2½-mh. 125-ma. r.f.c., National R-100U
S_1—D.p.d.t. wafer deck switch suitable
X—7-Mc. crystal for 28 Mc., 8.4 Mc. for 50 Mc.

band. For operation on 6 meters the second 7C5 triples the 16.8 Mc. output of the first stage into the 50-Mc. band. The coils for the second 7C5 stage are cut from B&W Miniductor type 3010.

In the event that it is desired to operate the transmitter with excitation from a v.f.o. it is necessary to make an alteration in the first 7C5 stage. The most convenient way for accomplishing this change is simply to place a .003 μfd. mica capacitor from cathode to ground and then to feed the excitation from the v.f.o. into the crystal socket.

The 829B Output Amplifier The 829B final amplifier may be operated at Any voltage from approximately 400 to 600 volts on both bands. Plate current of the tube is limited to 210 ma. for natural cooling and to 240 ma. for blower cooling. However, as was stated in a previous paragraph, the input to the stage must be limited to 90 watts with natural cooling and 120 watts with forced air cooling. Screen voltage for the 829B is preferably fed from the secondary of the modulation transformer through a series screen resistor. The value of this resistor will be about 6000 ohms for 400 volts on the plate of the tube and 12,000 to 15,000 ohms for 600 volts on the plate of the 829B.

Plate tank coils for the 829B are self-supporting. They are mounted upon Millen type 40305 plugs. The tank coil assemblies plug into a Millen type 41305 jack base which is mounted by means of angle brackets to the top of the plate tuning capacitor. The plate tank capacitor for the 829B may be any type having approximately 50 μμfd. per section with a split stator. The particular unit used in the equipment shown in the photographs was made by sawing the stator of a capacitor taken from a BC-375 tuning unit.

Metering Provision is made within the unit for measuring the grid current both of the 7C5 second stage and of the 829B final amplifier. The meter switch S_1 selects the appropriate grid current. The plate current milliammeter for the unit shown was mounted on a separate modulator panel. However, if it is desired to have all meters located within the unit, an additional 0-300 d-c milliammeter could be mounted in the center of the panel. The meter may be connected either to read plate current only or to read the sum of plate and screen current.

Construction The complete unit is mounted upon and supported from a 7 by 19 inch dural panel. The chassis used in the unit shown actually was a drawn aluminum box obtained from a surplus metal concern. However, standard chassis with dimen-

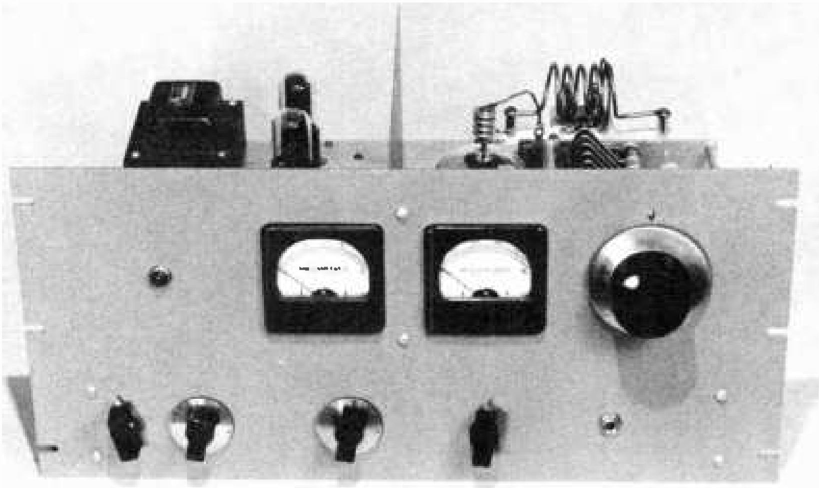


Figure 27.
PANEL VIEW OF THE 4E27/257B TRANSMITTER.
The dial lamp to the left of the two d-c instruments is connected in parallel with the 6.3-volt filaments to serve as a pilot light.

sions of 5 by 9½ by 2½ inches are available from several chassis manufacturers. This size chassis will prove satisfactory for mounting all the components since it is slightly larger than the aluminum can shown in the photographs.

257B/4E27 Transmitter

The HK-57 exciter transmitter shown in the Eleventh Edition RADIO HANDBOOK proved to be unusually popular with equipment constructors. The unit shown in figures 27 through 32 was designed in an effort to answer the requests of many persons for a basically similar unit designed for the widely available 4E27 tube. Another similar unit designed around the 4-65A tube is also shown in this chapter.

The transmitter is best suited for use on c.w., or on FM with an external FM exciter unit, operating with 1250 to 2000 volts on the plate of the final tube. Plate modulation may be used, however, if the d-c plate voltage is limited to 1250 and if a provision is added for modulating the screen potential along with the plate voltage.

Normal plate current to the 4E27 should be limited to 150 ma. for c-w or FM operation and 135 ma. for high-level amplitude modulation. Hence the input power may be run to 175 watts on phone or 300 watts on c.w. or FM.

Circuit Description The exciter consists of a 6AG7 harmonic crystal oscillator and a 6L6 multiplier. The output of either the first stage or the second stage may be used to excite the 4E27/257B. Alternatively, switch S_1 may be moved to its other position so that the output of an external v-f-o or FM exciter may be fed to the grid of the 6AG7. Each of the exciter coils includes a jumper for completing the screen-voltage circuit. These jumpers are included as a protective measure to insure that neither screen nor plate voltage will be applied to an exciter tube when a plate coil is not present in the coil socket for that tube.

If it is desired, alternatively, to feed the v.f.o. directly to the grid of the 4E27/257B, the coil arrangement shown in figure 32 may be used. Five-prong coils instead of the four-prong variety specified are required. But, through making slight changes in the screen and plate voltage circuits, a link may be added to the coil forms. Then, the system allows two alternatives. Two types of coils, one with a link for external excitation and one with-

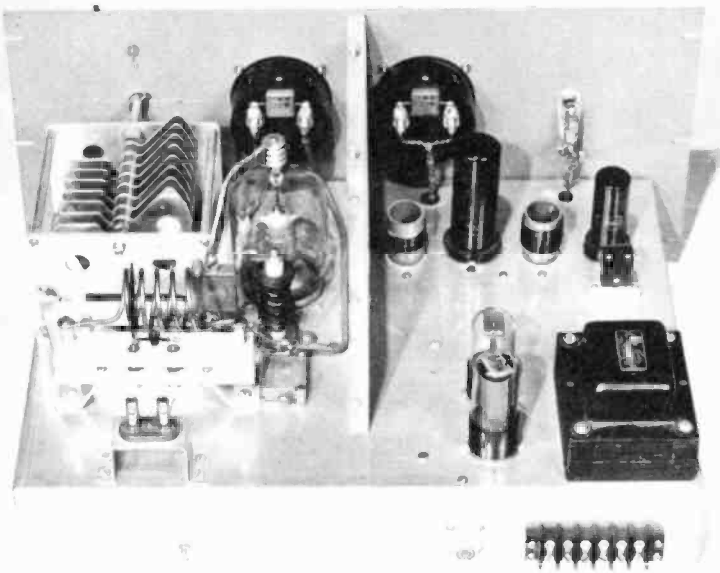
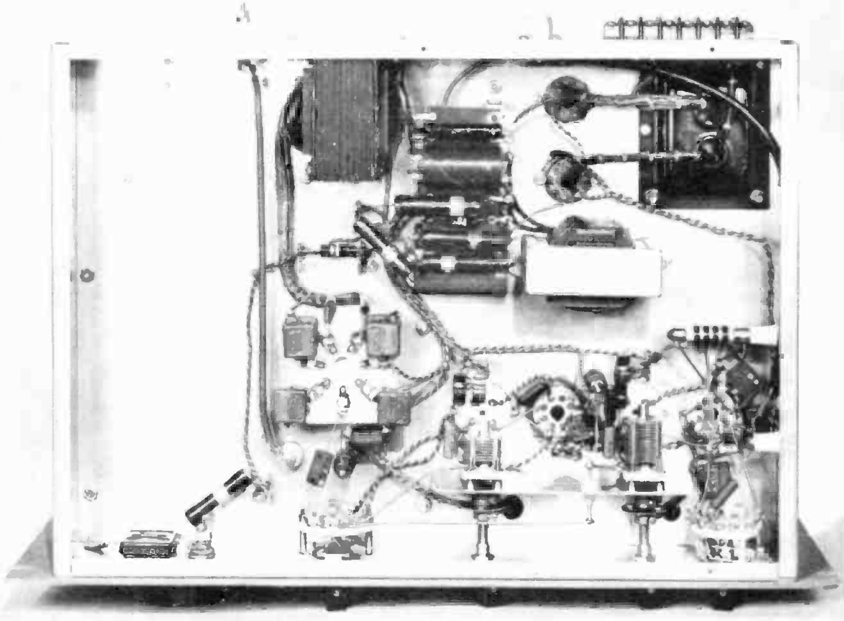


Figure 28.
REAR VIEW OF THE 4E27/257B TRANSMITTER.

Figure 29.
UNDERCHASSIS VIEW OF THE TRANSMITTER.
Panel controls are, from right to left in this photograph: S_1, v.f.o./Crystal switch; C_1, plate tank capacitor of 6AG7; C_2, plate tank capacitor of 6L6; S_2, excitation switch to final; and the key jack.



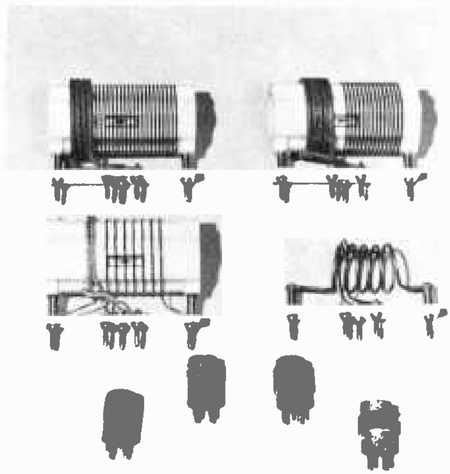


Figure 30.
COIL SET FOR THE 4E27/257B TRANSMITTER.

out link but with jumper, may be used as in figures 32 (A) and (B). With the link coils, (B), in place there is neither plate nor screen voltage applied to the oscillator stage. With the (A) coils in place the circuit operates normally. But this circuit arrangement requires two separate coils for those bands on which both types of operation are required. Figure 32 (C) shows an adaptation in which a switch has been added to remove plate and screen voltage from the oscillator tube when external v.f.o. direct to the 4E27/257B is desired. Only one coil for each band is required with this arrangement.

Power Supplies And Keying A 350-volt power supply and a 300-volt bias supply are included on the chassis. The 350-volt supply feeds the oscillator, the multiplier, and the screen of the final. In addition, the bleeder of this supply is tapped to furnish plus 40 volts for the suppressor of the 4E27/257B. The bias supply is used to cut off the plate current of the 6L6 when this tube is not being used and to furnish a smaller amount of fixed bias when the 6L6 is in the excitation lineup. The bias supply also is used to furnish grid-block keying of the 4E27/257B final amplifier. With key up the full bias-supply voltage cuts off plate current on the final. With key down one-fifth the bias supply voltage is fed to the 4E27/257B grid return as fixed bias. The placing of a capacitor from the bottom end of M_1 to ground will increase the time constant of the grid-block keying circuit and provide softer keying. A value as high as 0.1 μfd. may be desirable in some cases.

A fixed output-coupling link on the final plate coils has been included. A shielded external antenna-coupling circuit with a variable-coupling provision is suggested as a means of reducing BCI, TVI, and the radiation of the harmonic signals which are generated in the plate circuits of all class C power amplifiers.

Construction The transmitter is mounted on a 12 by 17 by 3 aluminum chassis. The 8 ¾ by 19 inch dural panel is finished with gray wrinkle enamel. The only noteworthy features from the construction aspect are the facts that the two plate-tuning capacitors in the exciter stages are mounted behind the panel on an aluminum bracket, and that the rotor and frame of the

COIL TABLE

Oscillator and multiplier coils. Only one of each needed since coils may be used in plate circuit of either tube.	
3.5 Mc.	32 turns no. 24 enam. closewound, 1-inch dia.
7.0 Mc.	17 turns no. 24 enam. closewound, 1-inch dia.
14 Mc.	10 turns no. 16 enam. spaced to 1 inch, 1-inch dia.
21-28 Mc.	4¾ turns no. 16 enam. spaced to ⅝ inch, 1-inch dia.
All coils wound on National XR-1 coil forms.	
FINAL AMPLIFIER COILS	
3.5 Mc.	27 turns no. 14 enam. Four-turn link.
7.0 Mc.	14 turns no. 14 enam. Four-turn link.
14 Mc.	7 turns no. 14 enam., double-spaced. Two-turn link.
21-28 Mc.	5 turns no. 8 bare spaced to 2". One-turn link.

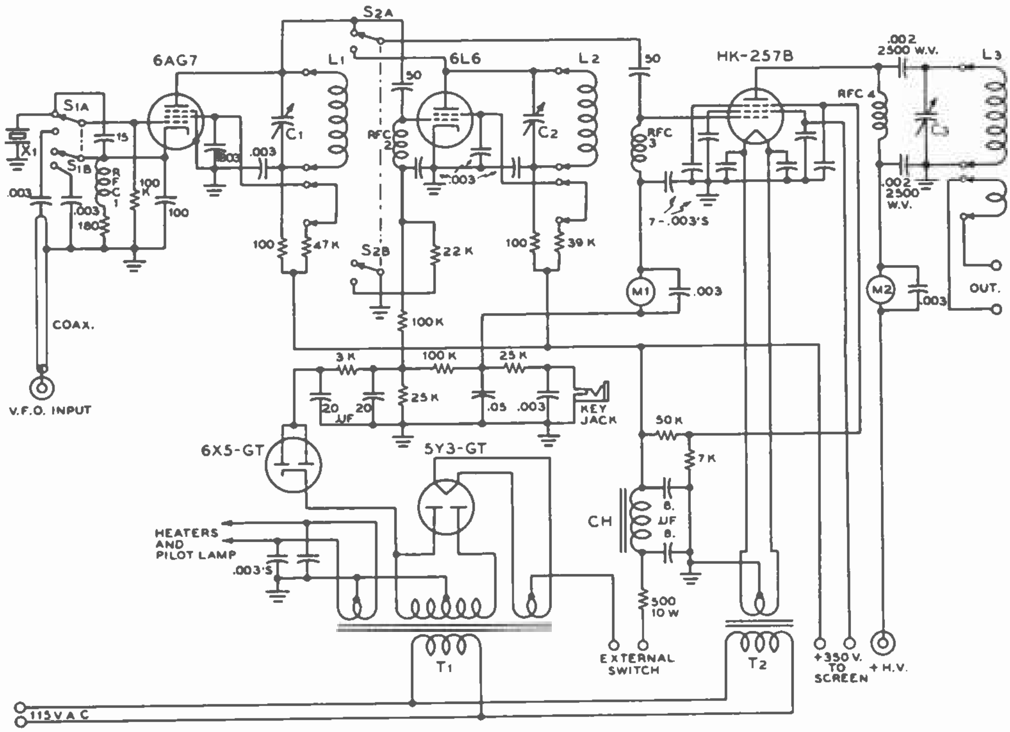


Figure 31.

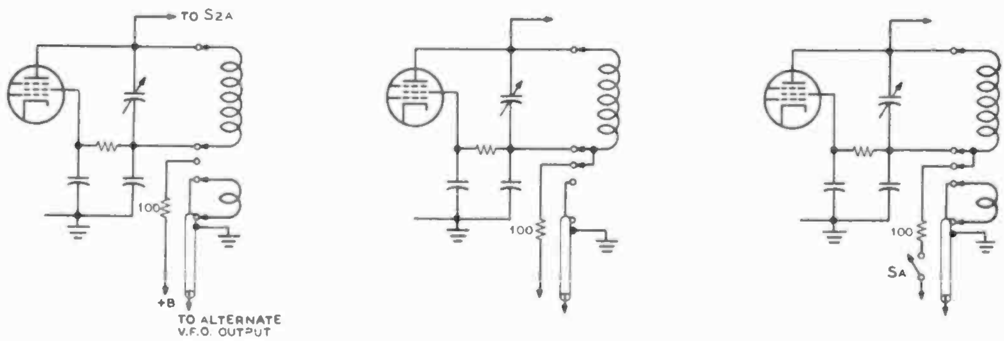
SCHEMATIC OF THE 4E27/257B TRANSMITTER.

C_1—100-μμfd. midget variable (National UM-100)
C_2—50-μμfd. midget variable (National UM-50)
C_3—100-μμfd. 6000-volt variable (National TMA-100A)
CH—10.5-hy. 110-ma. choke (Stancor C-1001)
L_1, L_2, L_3—See coil table.
M_1—0-15 d-c milliammeter (Marion 535N)
M_2—0-250 d-c milliammeter(Marion 535N)
RFC_1, 2, 3—2.5-mh. 100-ma. (National R-100U)
RFC_4—1-mh. 600-ma. choke (National R-154U)
S_1, S_2—2-pole, 2-position ceramic (Centralab 2505)
T_1—700 v. c.t. 120 ma., 5 v. 3 a., 6.3 v. 4.7 a. (Stancor P-6013)
T_2—5 volts at 10 a. (Stancor P-6135)
X_1—3.5 or 7 Mc. crystal

final plate tank capacitor are grounded. Shunt feed to the 4E27/257B plate has been used in the circuit so that the tank capacitor frame may be grounded. In constructing the amplifier it was desirable that as small a panel height as practicable be used. Since the final tank capacitor proved to be the highest item, it was possible to reduce the overall panel height to 8¾ inches by grounding the frame of this capacitor and thus dispensing with the usual standoff insulators between the frame of the tuning capacitor and the chassis.

4-65A Exciter-Transmitter

The 4-65A Exciter/Transmitter is designed primarily for use as a medium-power transmitter. It can, however, be used as an exciter for a triode kilowatt final amplifier. In fact, with 2000 volts on the plate of the 4-65A sufficient power output will be obtained to excite the 304TL grounded-grid final amplifier shown in *Chapter Five.* The unit may be operated as a c-w, or FM transmitter with up to 300 watts input with 2000 volts on the plate of the 4-65A on all the amateur bands from 3.5 through 54 Mc. For high-level plate modulation the plate voltage on the final stage will be limited to 1250 volts by the 2500-volt by-pass capacitor from the final amplifier plate tank circuit to ground. If the working-voltage rating of this capacitor is raised to 4500 or 5000 volts up to 1750 or 2000 volts may be used on the final stage with plate modulation. At these higher plate voltages the plate spacing of the tank capacitor C_1 becomes the lim-



(A) COILS FOR V.F.O. OPERATION, NO SCREEN OR PLATE VOLTAGE ON TUBE.

(B) COILS FOR NORMAL OPERATION WITH CRYSTAL OSC. OR V.F.O. TO GRID OF FIRST STAGE.

(C) COILS FOR EITHER V.F.O. OR CRYSTAL OPERATION WITH ADDED SWITCH SA.

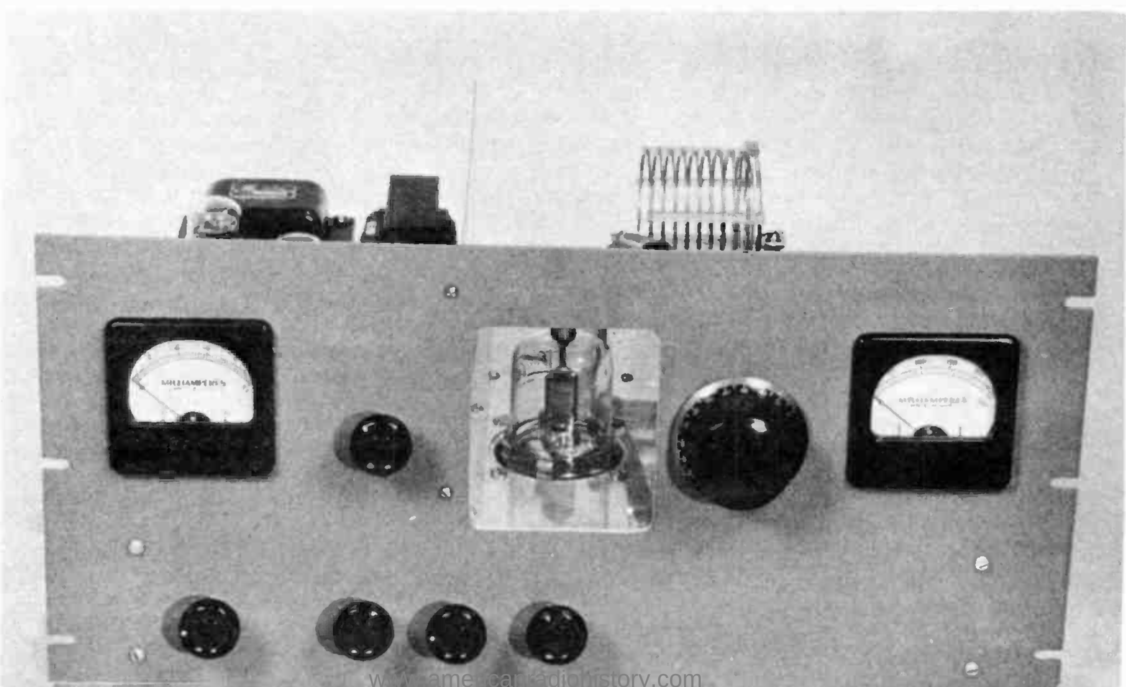
Figure 32.
ALTERNATIVE COIL ARRANGEMENT.

The use of this coil arrangement in place of that shown in figure 31 permits the feeding of an external v.f.o. directly into the grid of the 4E27/257B final stage. The circuit requires changes in the plate and screen returns of both the 6AG7 and 6L6 stages, plus the substitution of five-prong coil forms. The additional arrangement shown at (C) permits the use of links on all coils but requires the addition of a switch in series with the plate voltage supply for the 6AG7 stage.

iting factor. Normal operation of the transmitter has been with 1250 to 1500 volts on the plate of the 4-65A with 175 to 225 watts input.

Circuit Description The unit described, with an external 1250 to 1500 volt power supply capable of 150 ma. drain, can serve as a complete 200-watt c.w. transmitter on all the amateur bands below 54 Mc. Plate voltage for the exciter and screen voltage for the final amplifier are included in the unit. Also included is a "click-less" keying circuit for the final amplifier. Pro-

Figure 33.
FRONT OF THE 4-65A TRANSMITTER R-F UNIT.



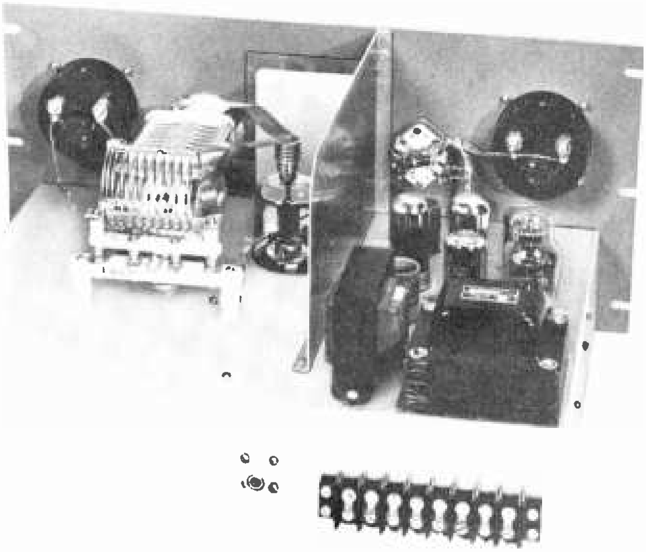


Figure 34.
REAR OF THE 4-65A TRANSMITTER UNIT.

vision has been made for exciting the final amplifier directly from the output of a 3 to 6 watt v.f.o. on all bands. Or the v.f.o. may operate only on the 3.5-Mc. band and the two exciter stages within the unit may be used to obtain excitation for the final amplifier up through 29.7 Mc.

The attainment of the degree of flexibility discussed above requires the winding of ten coils for the exciter and the use of two circuit-change switches in the exciter unit. The first 7C5 tube may be operated either as a crystal oscillator, with S_1 in the upward position, or it may be operated with S_1 thrown downward as a frequency multiplier with excitation from an external v.f.o. When operating as a crystal oscillator the plate circuit of this tube may be tuned to the crystal frequency with 3.5 and 7 Mc. crystals, or it may be tuned to a harmonic of the crystal frequency with fundamental crystals in any range. The output of this stage is always capacitively coupled to the grid of the next 7C5. However, when S_2 is in the top position the second 7C5 is inoperative and the output of the first 7C5 is link coupled to the grid circuit of the 4-65A final stage.

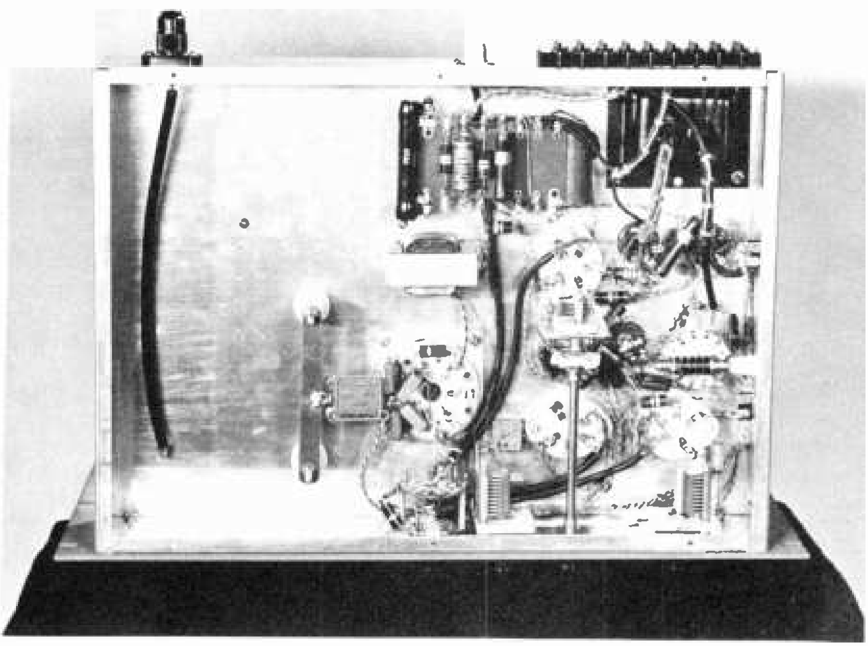
With S_2 in the center position the second 7C5 also is operative and the output of this second stage is link coupled to the grid tank circuit of the 4-65A. This arrangement is used when it is desired to operate on the fourth or higher harmonics of the crystal frequency or the frequency being fed to the first stage by the v.f.o. As an example, take the case of operation in the 50-Mc. band with an 8.4-Mc. crystal. In this case S_1 is in the upper position and S_2 is in the center position. L_1 is tuned to the third harmonic of the crystal, 25.2 Mc., and L_2 and L_3 are tuned to 50.4 Mc.

With S_2 in the lower position both 7C5 tubes are inoperative as a result of their cathode circuits having been opened. Then excitation from an external v.f.o. is coupled directly from the v-f-o coaxial socket to the grid tank of the 4-65A.

Metering Milliammeter M_1, a 0-10 d.c. instrument, can be used to measure the cathode current of either of the 7C5's or the grid current of the 4-65A by the selection of the proper circuit with S_3. When measuring current on either of the 7C5's the full-scale reading of the meter is increased to about 100 ma. by placing a 100-ohm resistor in series with the meter movement and then

4-65A TRANSMITTER/EXCITER		
	EXCITER COILS, L_1, L_2, AND L_3	
3.5 Mc.	2 coils	35 t. no. 22 enam. 1" long, link 6 to. no. 22 enam.
7.0 Mc.	1 coil	21 t. no. 22 enam. 9/16" long, 4 t. link; this coil also for 14 Mc. at coil position L_2
	1 coil	14 t. no. 22 enam. 7/16" long, 4 t. link.
14 Mc.	2 coils	8 t. no. 18 enam. ¾" long, 4 t. no. 18 enam. for link
21 and 28 Mc.	2 coils	6 t. no. 16 bare, ¾" long, 3 t. no. 18 enam. for link
50 Mc.	2 coils	2-¾ t. no. 16 bare ¾" long, 2 t. no. 18 enam. for link
All exciter coils wound on Millen 45005 forms.		
	4-65A PLATE COILS, L_4	
3.5 through 29 Mc.		B&W type BEL
50 Mc.		4 t. ¼" copper tubing 1" dia. spaced 5/16" between turns, link 1 t. no. 12 enam.

Figure 35.
UNDERCHASSIS OF THE 4-65A TRANSMITTER.
Note the use of a copper strap between the two posts of the ceramic feed-through bushings which support the tuning capacitor for the plate tank of the 4-65A. The plate by-pass capacitor runs from the center of this strap directly to the r-f ground return of the final stage.



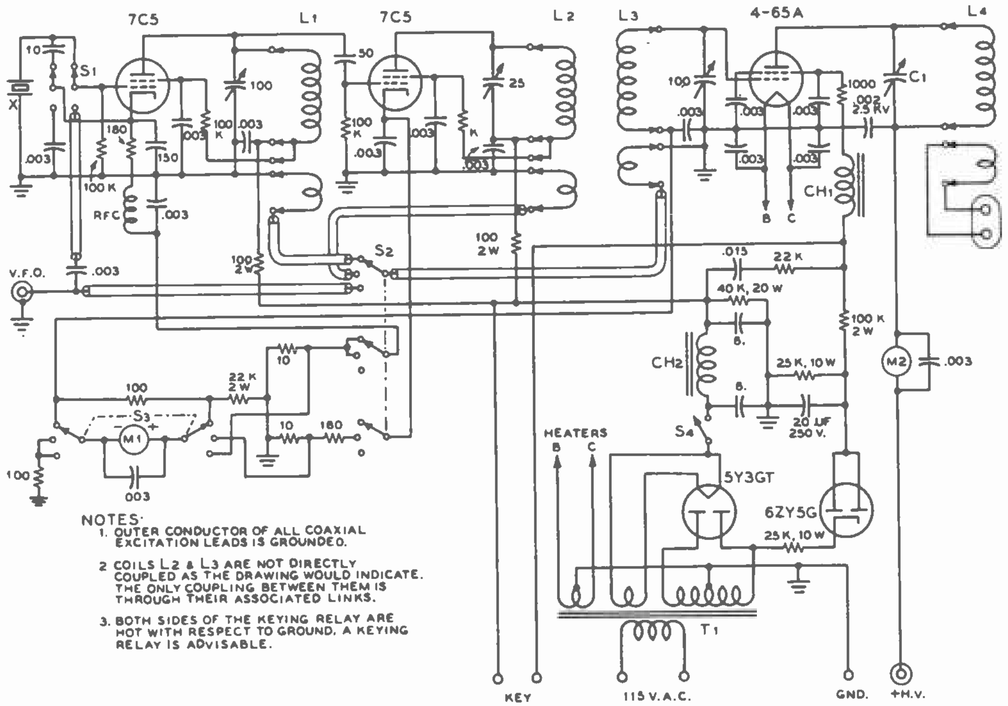


Figure 36.

SCHEMATIC DIAGRAM OF 4-65A TRANSMITTER/EXCITER.

C_1—70-μμfd., 0.125" spacing (Johnson 70E45)
CH_1—13-hy. 65-ma. choke (Stancor C-1708)
CH_2—10.5-hy. 110-ma. choke (Stancor C-1001)
L_1, L_2, L_3, L_4—See coil table
M_1—0-10 d.c. milliammeter (Marion 53SN)
M_2—0-250 d.c. milliammeter (Marion 53SN)
S_1—2-pole 2-position ceramic (Centralab 2505)
S_2—3-pole 3-position wafer (Centralab 1407)
S_3—3-pole 3-position wafer (Centralab 1407)
S_4—S.p.s.t. toggle switch (H&H)
T_1—700 c.t. 120 ma., 5 v. 3 a., 6.3 v. 4.7 a. (Stancor P-6013)

measuring the drop across a 10-ohm resistor in series with the cathode return of each of the 7C5 tubes. In the third position the meter measures the grid current of the 4-65A with about a 5 per cent error since the current through the meter is much greater than the current which flows through the 100-ohm resistor which shunts it. The 100-ohm resistor is in the circuit to carry the grid current when the meter is switched to another circuit.

Construction The unit is constructed upon a 12 by 17 by 3 inch aluminum chassis. The panel is a standard 8-¾ by 19 inch dural unit with gray wrinkle finish. The chassis is supported from the panel by means of bolts along the front and by a bent piece of aluminum which also acts as an interstage shield. Standard interstage shields of cadmium-plated steel are available from several manufacturers with the same dimensions as the fabricated one which was used. A hole was cut in the dural panel so that the plate temperature of the 4-65A could be watched. A piece of standard window glass, cut to shape in a glass shop, is supported behind the panel opening by means of two small metal brackets.

The plate tank capacitor has been mounted in a somewhat unconventional manner to minimize the effects of lead inductance. The capacitor itself is supported by means of two feed-through ceramic insulators (Johnson no. 135-40). The insulators were inverted so that the 1¼-inch portion projected downward with the ½-inch portion upward. The mounting feet of the tank capacitor were then drilled and tapped to take the 10-32 machine screw in the insulator. Copper strap was run between the studs on the two insulators below the chassis. The plate by-pass capacitor then connects directly from the center of this strap to the common ground point for the stage. Copper strap also was run from each side of the tank capacitor to the tank-coil jack bar. Somewhat thinner copper strap is run from each end of the plate tank capacitor to the plate cap of the 4-65A tube. Through this procedure, plus the use of two screen by-pass capacitors and two filament by-pass capacitors all running to the same common ground point as the plate by-pass, the amplifier is completely stable on all bands through 54 Mc. Also, through the efforts toward reducing lead inductance in the tank circuit, a fair-size tank coil can be used on the 50-Mc. band. The plate current dip in the unloaded condition on this band indicates that good tank-circuit efficiency is being obtained.

Notes on Operation Normal plate current of each of the 7C5 tubes is about 40 ma. Normal grid current to the 4-65A is 8 to 10 ma.; this value of grid current is easily attainable on all bands. Plate current to the final amplifier should be limited to 150 ma. for c-w or FM operation and to 120 ma. for high-level AM. The screen-grid keying circuit gives smooth clickless keying and completely cuts off power output from the stage when the key is up. When the key is up the screen voltage is reduced to about minus 150 volts by the 6ZY5-G auxiliary bias rectifier. With key down the exciter plate supply is fed to the 4-65A screen. Since both sides of the keying circuit are hot with respect to ground, it is suggested that a keying relay be used between the key and the keyed circuit. For plate modulation of the 4-65A it is only necessary to apply the modulated plate voltage to the "plus H.V." terminal. Since CH_1 is in the circuit at all times, the screen voltage of the tube will self-modulate as the plate voltage is modulated. This method of obtaining combined plate and screen modulation is convenient due to its simplicity. Such methods of "self modulation" are recommended by the tube manufacturer.

CHAPTER FOUR

Single-Sideband and FM Exciter Transmitters

Exciters and low-power transmitters for c-w or conventional high-level AM use are essentially similar, hence they were grouped together in the previous chapter. Similarly, exciter units for ssb and those for FM use are similar to the extent that modification of the signal being produced by the exciter usually is done at a relatively low level in the equipment. There are exceptions, of course, but due to this basic characteristic that the carrier wave itself is modified in the exciter unit, those two types of equipments have been grouped together in this chapter.

General Considerations Concerning SSB Exciters In reality, there are three systems in accordance with which a single-sideband transmitter of several hundred watts output may be operated. These systems may be listed as follows:

(1) The Filter Method
(2) The Low-Level Phasing Method
(3) The High-Level Phasing Method

It is not the function of this chapter to delve into the basic theory of single-sideband systems, but rather to describe equipment which illustrates in practical form procedures for obaining a satisfactory single-sideband signal either for direct radiation into an antenna or for feeding to the grid circuit of a high-power amplifier. However, the three systems mentioned above will be described briefly, so that the reader will have a general idea of the relative advantages of the different systems, and so that he may make up his own mind concerning the system most suited to his needs.

The filter method for obtaining a ssb signal is the classic method which has been in use by the telephone companies for many years both for land-line and radio communications. The mode of operation of the filter method is diagrammed in figure 1, in terms of components and filters which normally would be available to the amateur. The output of the speech amplifier passes through a conventional speech filter to limit the frequency range of the speech to about 200 to 3000 cycles. This signal then is fed to a balanced modulator along with a 10,000-cycle signal from a self-excited oscillator. A low-frequency balanced modulator of this type most conveniently may be made up of four diodes of the vacuum or crystal type cross connected in a balanced bridge circuit. Such a balanced modulator passes only the sideband components resulting from the sum and difference between the two signals being fed to the balanced modulator. The audio signal and the 10-kc. signal from the oscillator both cancel out in the balanced modulator so that a band of frequencies between 7 and 10 kc. and another band of frequencies between 10 and 13 kc. appear in the output.

The signals from the first balanced modulator are then fed through the most critical component in the whole system—the first sideband filter. It is the function of this first sideband filter to separate the desired 10 to 13 kc. sideband from the unneeded and undesired 7 to 10 kc. sideband. Hence this filter

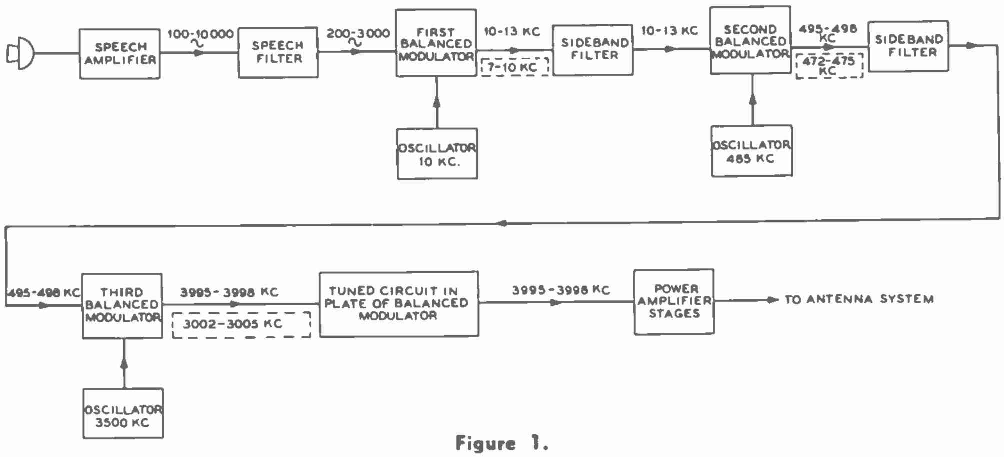


Figure 1.

BLOCK DIAGRAM OF THE "FILTER" METHOD.

The filter method of obtaining a single-sideband signal is quite satisfactory provided the first sideband filter (which in this case passes 10 to 13 kc. and rejects the sideband below 10 kc.) is purchased or constructed.

must have low attenuation in the region between 10 and 13 kc., a very rapid slope in the vicinity of 10 kc., and a very high attenuation to the sideband components falling between 7 and 10 kc. This filter may be purchased (the National Company F-22 filter has excellent characteristics) or it may be constructed and tested at home if the test equipment is available (See "An Inexpensive Sideband Filter," by David O. Mann, *QST*, March 1949, page 21, for a description of an adequate filter which may be constructed from inexpensive and easily available components).

The balance of the components in the block diagram of the ssb transmitter shown in figure 1 are readily available. Transformers of the type used in the i-f amplifier of a receiver are used in the sideband filter following the second balanced modulator, while the tuned circuit in the plate of the third balanced modulator serves to separate the desired from the undesired sideband. The construction and testing of a single-sideband transmitter using this system of sideband generation is necessarily a rather complex operation. However, constructional details on a 10-watt transmitter using the filter system have been given in *QST* (Nichols, Jan. 1948 *QST*, page 19) and elaborated upon in the article referenced in the previous paragraph.

The Phasing System There are a number of points of view from which the operation of the phasing system of ssb generation may be described. We may state that we generate two double-sideband suppressed carrier signals, each in its own balanced modulator, that both the r-f phase and the audio phase of the two signals differ by 90 degrees, and that the outputs of the two balanced modulators are added with the result that one sideband is increased in amplitude and the other one is cancelled. This, of course, is a true description of the action that takes place. But it is much easier to consider the phasing system as a method simply of adding (or of subtracting) the desired modulation frequency and the nominal carrier frequency. The carrier frequency of course is not transmitted, as is the case with all ssb transmissions, but only the sum or the difference of the modulation band from the nominal carrier is transmitted.

The phasing system has the obvious advantage that all the electrical circuits which give rise to the single sideband can operate at the nominal output frequency of the transmitter. That is to say that if we desire to produce a single sideband whose nominal carrier frequency is 3.9 Mc., the balanced modulators are fed with a 3.9-Mc. signal and with the audio signal from the phase splitters. It is not necessary to go through several frequency conversions in order to obtain a sideband at the desired output frequency, as is the case with the filter method of sideband generation.

Assuming that we feed a speech signal to the balanced modulators along with the 3900-kc. carrier (3.9 Mc.) we will obtain in the

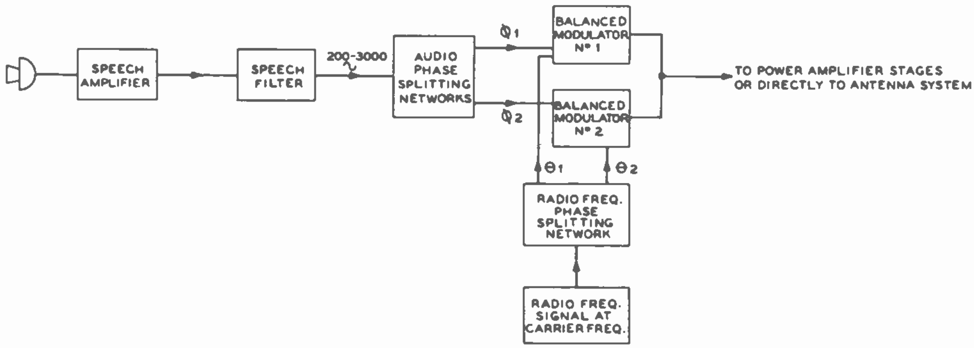


Figure 2.

BLOCK DIAGRAM OF THE "PHASING" METHOD.

The phasing method of obtaining a single-sideband signal is simpler than the filter system in regard to the number of tubes and circuits required. The system is also less expensive in regard to the components required, but is more critical in regard to adjustments for the transmission of a pure single-sideband signal.

output of the balanced modulators a signal which is either the sum of the carrier signal and the speech band, or the difference between the carrier and the speech band. Thus if our speech signal covers the band from 200 to 3000 cycles, we will obtain in the output a band of frequencies from 3900.2 to 3903 kc. (the sum of the two, or the "upper" sideband), or a band from 3897 to 3899.8 kc. (the difference between the two or the "lower" sideband). A further advantage of the phasing system of sideband generation is the fact that it is a very simple matter to select either the upper sideband or the lower sideband for transmission. A simple double-pole double-throw reversing switch in two of the four audio leads to the balanced modulators is all that is required.

High-Level Phasing Vs. Low-Level Phasing The plate-circuit efficiency of the four tubes usually used to make up the two balanced modulators of the phasing system may run as high as 50 to 55 per cent under optimum conditions of operation. Hence it is practicable to operate the double balanced modulator directly into the antenna system as the output stage of the transmitter. This can be called a high-level phasing-system ssb transmitter. Several amateur transmitters, using four tubes as large as 813's in the output stage of a kilowatt ssb transmitter have been constructed to prove the practicability of the high-level system.

The alternative arrangement is to generate the ssb signal at a lower level and then to amplify this signal to the level desired by means of class A or class B r-f power amplifiers. If the ssb signal is generated at a level of a few milliwatts it is most common to make the first stage in the amplifier chain a class A amplifier, then to use one or more class B linear amplifiers to bring the output up to the desired level.

In comparing the high-level and low-level phasing systems it seems that the high-level system offers an advantage in a transmitter which is to be used for single-sideband operation only. The arrangement requires fewer components and only one r-f stage which requires any special adjustments. On the other hand, when a transmitter is to be used for conventional AM or FM, or c.w., it is somewhat more practicable to generate the single-sideband signal at a relatively low level and to amplify to the desired power output. Then the power amplifier stage or stages may be left substantially unchanged, and only a different exciter substituted when changing from ssb to another method of transmission. Also, the phasing system may be tried in comparison to the filter method of sideband generation without the necessity of making any changes in the high-level portion of the transmitter. Transmitters using both versions of the phasing system are described later on in this chapter.

Balanced Modulator Circuits Illustrated in figure 3 are the two basic balanced modulator circuits which give good results with a radio frequency carrier and an audio modulating

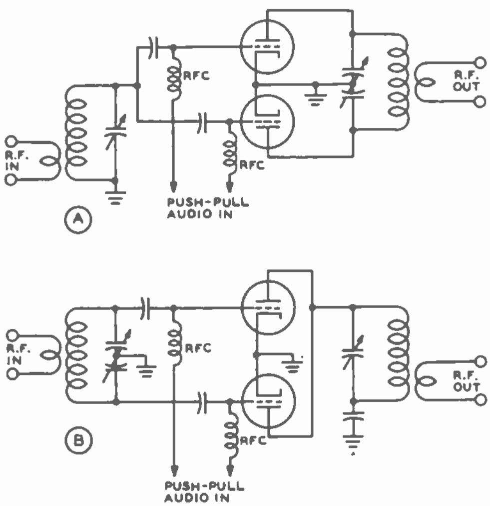


Figure 3.

SHOWING THE TWO COMMON TYPES OF BALANCED MODULATORS.

Notice that a balanced modulator changes the circuit condition from single ended to push-pull, or vice versa. Choice of circuit depends upon external circuit conditions since both the (A) and (B) arrangements can give satisfactory generation of a double-sideband suppressed-carrier signal.

signal. Note that one push-pull and one single ended tank circuit is required, but that the push-pull circuit may be placed either in the plate or the grid circuit. Also, the audio modulating voltage always is fed into the stage in push pull.

When combining two balanced modulators to make up a double balanced modulator as used in the generation of an ssb signal by the phasing sysem, only one plate circuit is required for the two balanced modulators. However, separate grid circuits are required since the grid circuits of the two balanced modulators operate at an r-f phase difference of 90 degrees. Shown in figure 4 are the two types of double balanced modulator circuits used for generation of an ssb signal. Note that the circuit of figure 4(A) is derived from the balanced modulator of figure 3(A), and similarly figure 4(B) is derived from figure 3(B).

150-Watt SSB Transmitter For 3.9 MC.

Illustrated in figures 5, 6, and 7 is an experimental single-sideband transmitter which

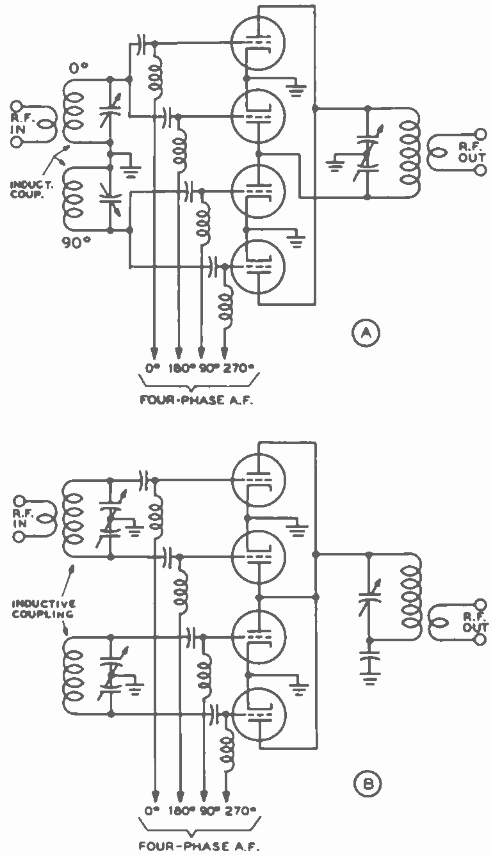


Figure 4.

TWO CIRCUITS FOR SINGLE-SIDEBAND GENERATION BY THE PHASING METHOD.

The circuit at (A) offers the advantages of simplicity in the single-ended input circuits plus a push-pull output circuit. Circuit (B) requires double-ended input circuits but allows all the plates to be connected in parallel for the output circuit.

illustrates the principle of generating the sideband by the phasing system at a low level, and then amplifying the signal through several stages. The transmitter underwent a number of changes over an extended period of operation; hence there are a number of unused holes in the 13 by 17 by 3 inch plated chassis.

Circuit Description The equipment was constructed primarily as a means of making a number of original tests concerning the practicability of amateur ssb equipment and the utility of ssb on the amateur 3.9-Mc. band. Hence no provision was made for use of the transmitter on any other amateur frequency band. The output stage normally operates with 1500 volts on the plate and 600 volts on the screen, to deliver a usable signal output of about 150 watts.

The r-f lineup of the unit begins with a 6V6 in the standard circuit as a crystal oscillator. The output of the 6V6 is link coupled to a pair of RC networks which deliver signals differing in phase by 90 degrees to the two balanced modulators. Two 6SN7-GT tubes (four triode elements) are used in class A to make up the two balanced modulators. The use of a 2000-ohm potentiometer, with slider grounded, as both cathode resistors of the pair of tube elements which make up each of the balanced modulators permits accurate balancing out of the carrier component from the output signal. Since the balanced modulators are fed in parallel with the r-f signal and in push-pull as far as the audio signal is concerned, it is necessary that the plate load circuit of the balanced modulators consist of a balanced or push-pull circuit. Each of the two balanced modulators uses the same push-pull tank circuit.

The output signal from the double balanced modulator is inductively coupled to the grid of a conventional class A r-f amplifier with a 6AG7 tube. The voltage level at the grid of the 6AG7 reaches about 3 volts on peaks. The 6AG7 amplifies this signal in a linear manner with a voltage stage gain of about 50. The output signal from the 6AG7 is capacitively coupled to the grid of the 4-65A final amplifier. The 4-65A operates as a class B linear amplifier, with swamping in the grid circuit furnished by the 10,000-ohm 2-watt resistor across the r-f choke in the grid return of the tube. A relatively large number of link turns are required on the plate tank coil of the 4-65A to obtain adequate coupling to the antenna feed line. Rather tight antenna coupling is required to obtain the degree of loading of the class B amplifier needed for linear operation.

Speech Amplifier And Phase-Shift Networks The speech amplifier uses a 6SL7-GT tube with the two sections cascaded. The 100,000-ohm resistor and 50-$\mu\mu$fd. capacitor from the plate of the second section of the 6SL7-GT back to the cathode of the first section serve to reduce the gain of the speech amplifier as the frequency increases above about 2500 cycles. The arm of the 500,000-ohm gain control feeds the grids of the two phase-shifting amplifiers. These amplifiers each consist of one section of a 6SN7-GT tube. The grids of these sections are run at a positive potential of about 25 volts to maintain adequate voltage drop across the cathode resistors of the phase-shifter tubes.

The phase-shifting RC networks in the output of these tube sections are standard. The output signal from the phase-shifting networks are fed from each channel to the second

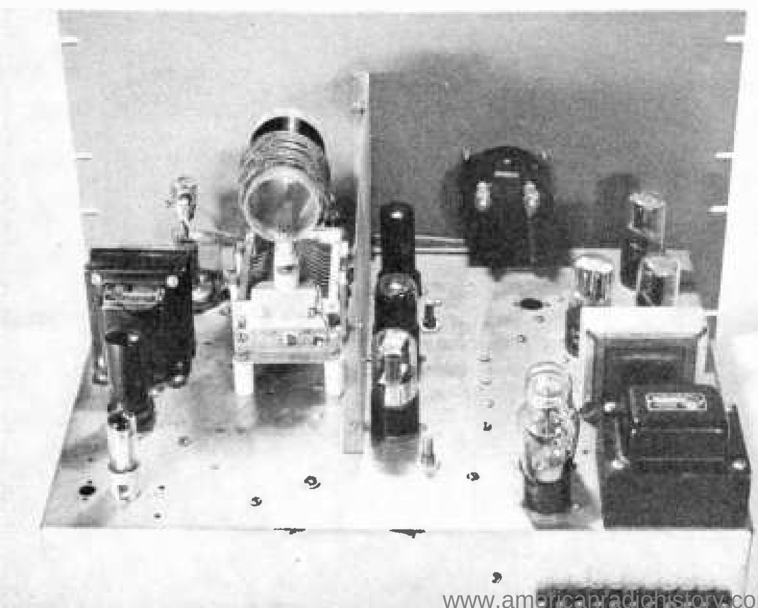


Figure 5.
REAR OF THE 4-65A SINGLE-SIDEBAND TRANSMITTER.

The speech amplifier and phase-shifter stages are on the right front of the chassis. Behind them is the power supply and just to the right of the shield baffle are the crystal oscillator tube and the two balanced modulators. The voltage regulator, the 6AG7 amplifier, and the output stage are to the left of the baffle shield.

section of the 6SN7-GT's, which in turn acts as a phase inverter. The values of the six resistors and six capacitors in the phase-shifting networks should be checked to make sure that they are within a few per cent of the values specified on the schematic.

Sideband Selector Switch Switch S_1 acts to select either the upper or the lower sideband or to provide phase-modulated output from the exciter unit. With the switch in the upper of the three positions indicated on the schematic one of the sidebands will be obtained, while the center of the switch positions will give the other sideband. The switch positions giving upper and lower sideband can quickly be determined for a particular transmitter unit by checking the output signal on a receiver. Note that changing from one sideband to the other merely requires a reversal of one of the push-pull audio pairs to the balanced modulators.

When switch S_1 is in the lower of the three positions the transmitter will deliver a phase-modulated carrier of constant amplitude. This is accomplished by leaving one of the balanced modulators unchanged, while at the same time the other "balanced" modulator is completely unbalanced by applying sufficient grid bias to cut off plate current on one of the tubes. The grid return of the other of the pair of tubes is grounded In the unit illustrated the upper half of the bottom 6SN7-GT is biased off while the return of the lower half is grounded. The lower half then acts as a straight carrier amplifier with no audio signal applied to its grid. The upper balanced modulator, which is still operating in its normal manner and at an r-f phase angle of 90 degrees with respect to the carrier amplifier below, is fed by the push-pull audio signal. The result of the addition of a double sideband signal at an r-f phase angle of 90 degrees with the carrier signal is that the carrier is phase modulated by the audio signal being fed to the input. Note, however, that the screen voltage of the 4-65A must be reduced considerably from the value used for single sideband when the tube is to be used as an amplifier for the PM signal; this is discussed in the following paragraphs.

The 4-65A Final Amplifier The output stage of the transmitter, using a 4-65A tetrode, operates as a class B amplifier. It operates as a linear amplifier for single-sideband transmission and as a class B c-w amplifier with grid-circuit limiting for phase-modulated transmission. The bias on the tube is fixed at 108 volts by the OB-2 voltage-regulator tube in the grid return. Normal plate voltage on the tube for the components illustrated is 1500 volts. But, unfortunately, the screen voltage must be changed when going from single-sideband to phase-modulated transmission.

For the best linearity in the output stage with the variable amplitude ssb signal being impressed upon its grid, it is desirable that the tube have a high power sensitivity. With high power sensitivity it is possible to obtain full output from the stage with only a very small amount of grid current being drawn on full amplitude signal peaks. High power sensitivity in a beam tetrode tube is obtained by running the screen at a relatively high value of positive potential. In the amplifier

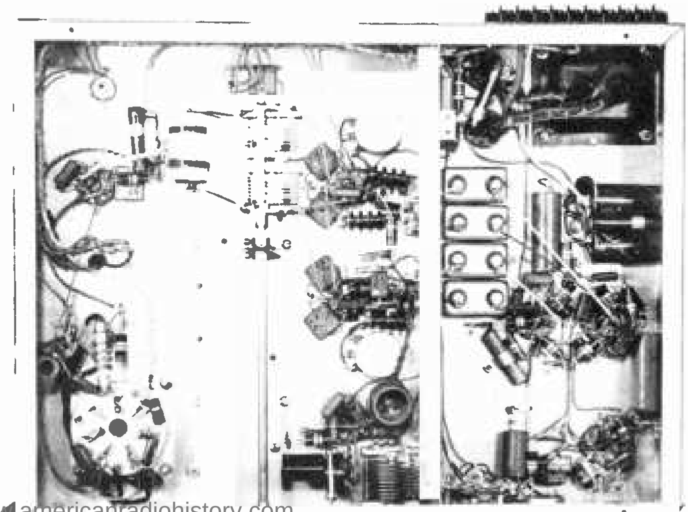


Figure 6.
UNDERCHASSIS OF THE 4-65A SSB TRANSMITTER.
A shield baffle separates the audio portion from the r-f stages of the equipment.

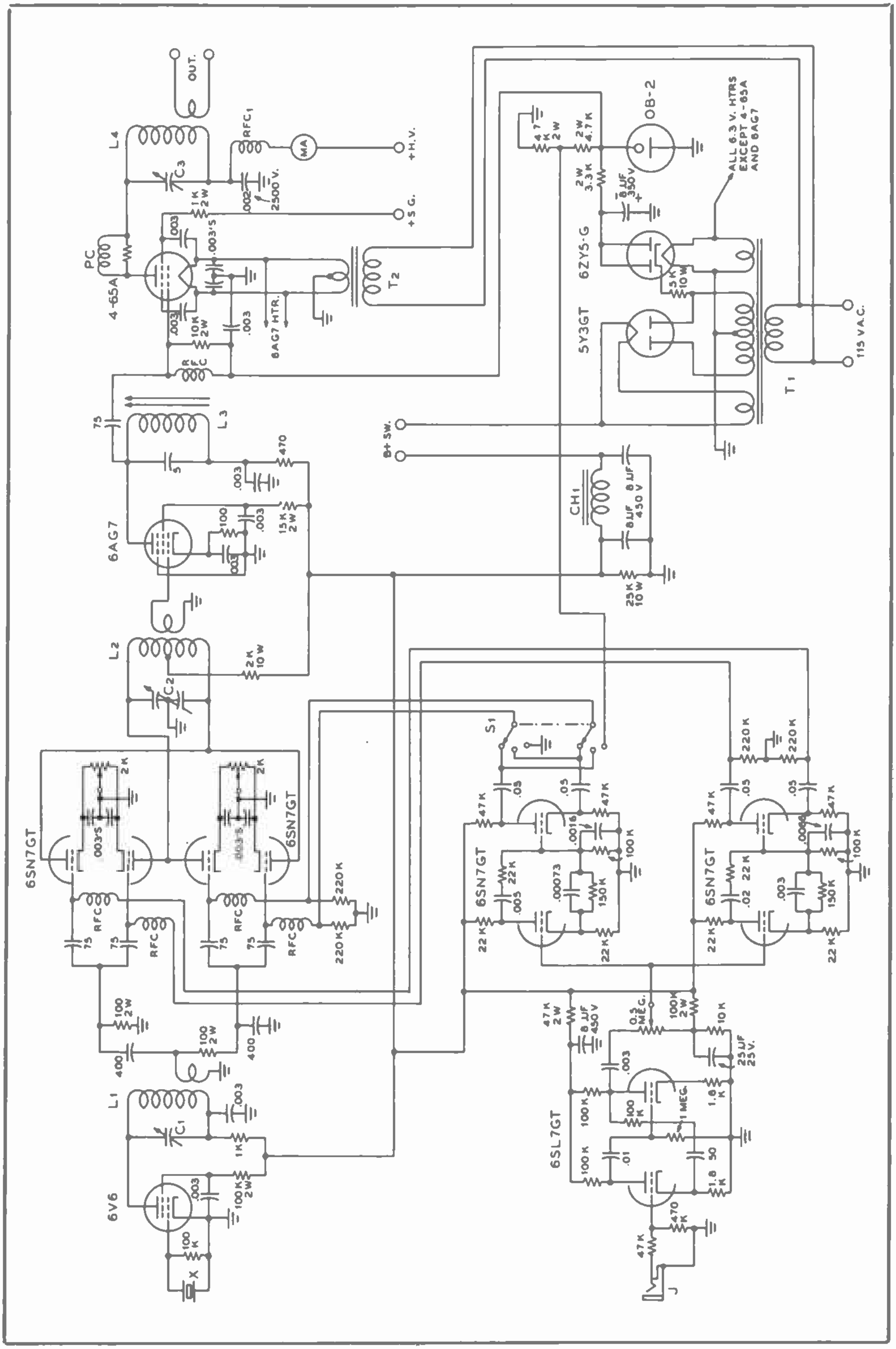

OUT.
L4
C3
RFC1
MA
+H.V.
+S.G.
PC
4-65A
T2
6AG7 HTR.
L3
6AG7
L2
C2
6SN7GT
L1
C1
6V6
X
OB-2
ALL 6.3 V. HTRS EXCEPT 4-65A AND 6AG7
6ZY5-G
5Y3GT
115 V.A.C.
T1
B+ SW.
CH1
S1
6SL7GT
J

Figure 7.
SCHEMATIC OF THE 4-65A SSB TRANSMITTER.

C_1—140-$\mu\mu$fd. small variable capacitor
C_2—Dual 100-$\mu\mu$fd. split-stator capacitor
C_3—150 $\mu\mu$fd. capacitor, 0.070" spacing
CH_1—10.5-hy. 110-ma. filter choke
T_1—700 v. c.t. 90 ma., 5 v., 3 a., 6.3 v. 3.5 a.
T_2—6.3-volt 4-ampere filament transformer
L_1—32 turns no. 22 enam. closewound on 1" dia. form with 5-turn link of hookup wire around low-potential end.
L_2—45 turns no. 22 enam. closewound on 1" dia. form with 10-turn link of hookup wire around center
L_3—National XR-50 form wound with one full layer no. 30 enam. (about 62 t.)
L_4—25 turns no. 14 enam. closewound on 1-7/8" dia. form (Millen 44001) with 9-turn link wound around low-potential end.
MA—0-250 d-c milliammeter
X—Crystal between 3850 and 4000 kc.
J—Closed-circuit phone jack for microphone
RFC—2½-mh. 125-ma. r-f chokes
RFC_1—1-mh. 300-ma. r-f choke
PC—4 turns no. 18 tinned wound around a 22-ohm 2-watt resistor

illustrated the screen voltage applied to the 4-65A for ssb operation should be 600 volts. This is the maximum screen-voltage rating of the tube and is permissible only for single-sideband transmission, where the high value of power sensitivity is desirable.

For c-w phase-modulated transmission, high power sensitivity is not required, and the screen voltage must be lowered to a maximum of 400 volts to be in accordance with the manufacturer's ratings. For actual operation with phase-modulated output from the unit, a screen voltage of 250 volts is quite adequate. So it is important that some provision be included in the screen-voltage power supply of the 4-65A for dropping the screen voltage from 600 for ssb operation to about 250 volts for phase modulated transmission.

Power Supply A small power supply for feeding all stages in the unit except for the plate and screen voltage to the 4-65A is included on the chassis. In fact, this same power supply may be used as screen supply for the 4-65A when the unit is being employed for phase-modulated transmission, although an external 600-volt supply still will be required for ssb transmission. A 6ZY5-G tube, with its cathode fed through a resistor from one side of the high-voltage secondary of the power transformer, is used as the bias rectifier in the equipment. Total bias voltage is regulated at 108 volts by the OB-2 regulator tube. A tap on the bleeder of the bias pack is used for the bias voltage to cut off one half of one of the 6SN7-GT tubes when using phase modulation.

Tuning and Aligning The audio phase-splitting portion of the equipment may best be checked with the aid of an audio oscillator and a cathode-ray oscilloscope in the normal manner. The oscilloscope used for checking, however, must have a moderate amount of gain in its voltage amplifiers both for horizontal and vertical deflection. This gain is required since the voltage output of the phase inverters is of the order of 5 volts peak. The phase shift is best checked by placing the vertical deflection lead from the amplifier in the oscilloscope onto the plate of the phase-inverter section of one of the 6SN7-GT's, while the lead for vertical deflection is placed on the plate of the phase-inverter section of the other 6SN7-GT. If the correct values of resistance and capacitance have been used in the phase splitting networks it will be found that a fairly good circle will be obtained on the 'scope with frequencies from about 150 to 2700 being fed into the microphone input of the equipment.

No adjustment is required in the r-f portion of the equipment except the adjustment of the tuned circuits to resonance. The crystal oscillator circuit is standard. A crystal in the 3850 to 4000 kc. range is plugged into the crystal socket (in the unit illustrated the crystal socket is below the chassis alongside the tuning capacitor for the crystal oscillator plate.). Capacitor C_1 is tuned to the point of slightly less capacitance than that which causes the crystal to go out of oscillation. The phase-shifting networks to the grids of the 6SN7-GT balanced modulators are fixed in value. They will be found to give a phase shift close enough to the correct 90 degrees between the two balanced modulators over the 3850 to 4000 kc. frequency range. With the number of turns specified for the link coil on L_1 the correct value of excitation voltage will be applied to the balanced modulators.

The next step in the adjustment procedure is to open the lead from the grid return of the 4-65A to the OB-2 voltage regulator. A d-c voltmeter with a 0-250 range is then connected across the 0.003-μfd. capacitor from the bottom of the r-f choke and resistor combination to ground. The d-c voltmeter, used in this manner, indicates the peak value of the r-f signal being applied to the control grid of the 4-65A.

The exciter portion of the equipment is now turned on, with no plate or screen voltage being applied to the 4-65A. The switch S_1 is placed in the phase-modulation position and the reading of the d-c voltmeter in the grid return of the 4-65A noted. Capacitor C_2 in the plates of the balanced modulators and the tuning slug of the coil L_3 should be varied for greatest peak-voltage indication. A value between 150 and 200 volts should be obtained when both circuits are at resonance.

The selector switch is now placed in one of the ssb positions. It is probable that a moderate amount of deflection still will be obtained. The 2000-ohm potentiometers in the cathodes of the balanced modulators should now be varied, one at a time, until a minimum in the peak grid voltage is obtained. It should be possible to reduce the indication down to about 3 or 4 volts. This minimum indication is due to the operation of the filament of the 4-65A on a.c.; hence the indication, or most of it, should persist when plate voltage is removed from the exciter but the filaments still are left lighted. A communications receiver, with a short pickup wire brought near to the grid of the 4-65A, will be helpful in adjusting the balanced modulators for minimum carrier output.

Checking the Single Sideband An audio tone in the vicinity of 500 cycles is now applied to the microphone input, and the gain is turned up slowly The voltage indication at the grid of the 4-65A should increase, and a strong carrier should begin to be heard in the receiver to one side or the other of the crystal frequency. The signal heard in the receiver should be quite clean, with only a small amount of modulation on it. As the gain is increased further, the voltage indication should increase to approximately 150 volts before further increase in audio gives no further indication.

The microphone may now be plugged into the input and the ssb signal monitored in the receiver by turning down the r-f gain and turning on the beat oscillator. The receiver is tuned so that the sideband falls in the center of the pass band, and the beat oscillator is varied until it is at zero beat with the residual carrier signal. Talking into the microphone should now result in a very clean and natural sounding signal. But if the receiver or the beat oscillator is detuned slightly, a very peculiar sounding gibberish in which some of the words still can be understood will be obtained. The voltmeter should indicate peak deflections of 125 to 150 volts with the voice signal.

The Linear Amplifier The grid return of the 4-65A may now be restored to its original position on the socket of the OB-2. Plate and screen voltage connections should now be made to the 4-65A, and a pair of 100-watt lamps connected in series used as the dummy load. Standing current on the 4-65A in the absence of modulation should be in the vicinity of 30 ma. Apply a small audio signal to the equipment and tune the plate tank of the output stage to resonance. Then increase the audio signal to the balanced modulators until the plate current to the 4-65A begins to flatten off with increasing signal. If the loading on the final stage is correct the flattening should begin to take place at about 150 ma. of plate current. It is not likely that it will take place at a much higher value, but if flattening takes place at a lower value it will be necessary to increase the loading upon the output tank circuit of the stage.

The signal being emitted by the complete equipment should now be checked carefully in the receiver while the equipment still is operating into the dummy load. The oscilloscope should be coupled loosely to the output link in such a manner that the carrier envelope may be viewed. The audio signal should then be applied to the input and the deflection on the oscilloscope viewed carefully. At very low audio signal levels the output signal will probably have a moderate amount of modulation on it due to residual unbalance. As the audio signal is increased, the pattern on the oscilloscope should be that of a fairly clean carrier with only a small amount of ripple. At the saturation point of the output stage it will be noted that any residual ripple on the carrier will disappear, due of course to limiting in the 4-65A stage.

If all these checks indicate that the equipment is operating correctly, the dummy load may be removed and the antenna system connected. Coupling to the antenna system should be varied until the same operating conditions as with the dummy load are obtained. If some provision for dropping the screen voltage when the selector switch is changed to the PM position is included, the equipment may be switched to phase modulation for calling, and then switched to ssb when contact has been established. If the equipment is switched to PM with the high screen voltage on the 4-65A, the high screen dissipation may damage the tube, and the 1000-ohm resistor in series with the screen return will overheat. It is probable that a combination of screen dropping resistor from the 600-volt supply, plus a large screen by-pass capacitor for audio signals, may be included in the screen circuit to drop the screen voltage for PM operation while still maintaining it essentially at the full value for ssb use.

Single-Sideband Transmitter With Four 807's

The description just ahead in this chapter discussed a single-sideband transmitter of the phasing type in which the ssb signal is generated at a low level and amplified up to a power level of about 150 watts. The transmitter illustrated in figures 8 through 11 utilizes the alternative arrangement for a single-sideband transmitter using the phasing system; the single-sideband signal is generated directly at a relatively high level—in this case the signal is generated in the output stage of the transmitter.

Circuit Description The transmitter uses only a single r-f stage with four 807 tubes operating as a double balanced modulator. The unit requires an external exciter unit capable of delivering about 5 watts. An external power supply capable of delivering 750 volts at 250 to 275 ma. is required to feed plate voltage to the 807's. Screen voltage for the 807's is supplied from within the exciter unit.

Since the generation of the sideband is accomplished by screen-grid modulation at a relatively high level, a moderate amount of audio power is required in the audio driver for the balanced-modulators. Hence the equipment includes two audio power amplifiers, each with a 6V6-GT being fed by a 6SJ7. Shunt feedback is used from the plate of each of the 6V6-GT's back to the plate of the 6SJ7 which excites it. These two audio power amplifiers operate at a phase difference of 90 degrees. Each audio power amplifier furnishes screen modulating voltage for a pair of the four 807's in the double balanced modulator.

The audio power amplifiers are fed from the outputs of the wide-band audio phase-shifting networks. These phase-shifting networks are somewhat more complex than those used in the equipment described just ahead of this unit, and the networks require three tube elements per network as compared to the single tube per network in the simpler type. But the wide-band type of network, as its name implies, covers a much wider frequency band for the same deviation from the ideal 90-degree phase shift. The networks illustrated are satisfactory over a frequency range from about 70 to 7000 cycles, while the simpler networks cover a frequency range of only about one-fifth this range for the same deviation from the 90-degree phase shift. The phase-shifting networks use three 12AU7 tubes, which provide a total of six triode sections or three per network. The phase-shifting networks are fed from a single-stage speech amplifier with a 6SJ7 tube. Ample gain is available for operation from a crystal microphone.

Grid Circuit Of the 807 Stage Each of the 807 balanced modulators which comprise the output stage of the transmitter use the circuit of figure 3A. In this circuit the grids of the

Figure 8.
LOOKING DOWN ON THE 807 SINGLE-SIDEBAND TRANSMITTER

tubes are connected in parallel, the plates are connected in push-pull, and the modulating signal is applied in push-pull. It is necessary for the generation of the single-sideband signal that the two balanced modulators be fed with r-f signals differing by 90 degrees in phase. In the equipment illustrated the 90-degree phase difference is obtained by virtue of the fact that the voltages appearing across two loosely coupled circuits at resonance will differ by 90 degrees in phase. The two coupled circuits in the equipment shown are both tuned at the same time by a single split-stator tuning capacitor. The input link from the exciter is tightly coupled to one of the tuned circuits, and inductive coupling is used to transfer energy from this tuned circuit to the second circuit. The split-stator tuning capacitor is merely a tuning convenience, since a trimmer capacitor is placed across the second of the two tuned circuits.

807 Plate Tank Circuit A National type MB-150 all-band tank circuit is used as the plate tank for the 807's. This tank circuit is capable of handling 150 watts of r-f energy and tunes continuously from 3.5 through 30 Mc. Inspection of the schematic will show that each 807 balanced-modulator pair has one 807 plate connected to each end of the tank circuit. This connection, of course, is for use of the four 807's as a double balanced modulator for the generation of ssb signals. A parasitic suppressor consisting of 7 turns of no. 18 tinned wire wound around a 47-ohm 2-watt carbon resistor is connected in series with the plate lead to each of the 807's.

A feature of the four-807 stage is that it may be operated as a push-pull parallel amplifier as well as a double balanced modulator. To operate the stage as a conventional push-pull parallel amplifier it is necessary to swap plate leads on the middle pair of 807's, throw the mode selector switch S_1 to the third position so that d-c screen voltage may be placed on the 807's, and insert a conventional coil without a center tap and with the link in the center, in the grid circuit in place of the double single-ended coil. The stage then tunes and operates as a perfectly conventional push-pull parallel amplifier.

Aligning the Phase-Shift Networks The 3900-ohm resistors in the cathode and plate circuits of the 12AU7 tubes are critical to the extent that the pair used with each tube should be carefully matched. Twelve of these resistors are required to make up the circuit. It is probable that out of twelve resistors of 5 per cent tolerance it will be possible to select six pairs which are matched within a small tolerance. Certainly, if the matching process is carried out at the dealer's counter, no difficulty will be had in obtaining the six matched pairs of resistors.

Equipment required for aligning the phase-shift networks consists of a cathode-ray oscilloscope with amplifiers for both horizonal and vertical deflection, and an audio oscillator capable of delivering a sine-wave signal over the frequency range from 30 to 10,000 cycles. Basic procedure for aligning an r-f phase-shift system of this type was discussed in the November-December, 1948, issue of the

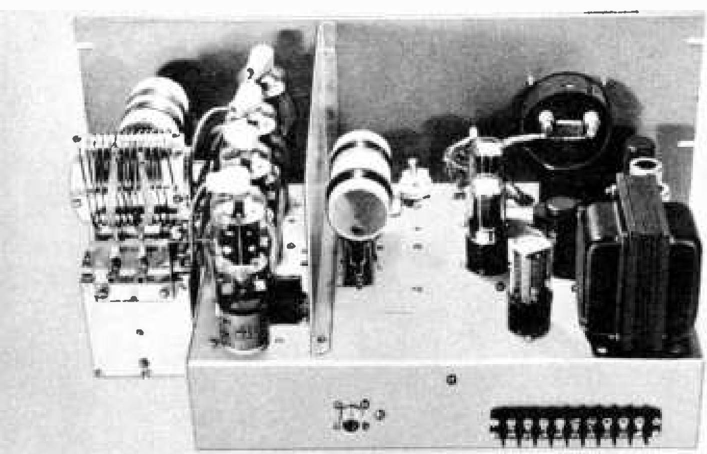


Figure 9. REAR PHOTO OF THE 807 TRANSMITTER.

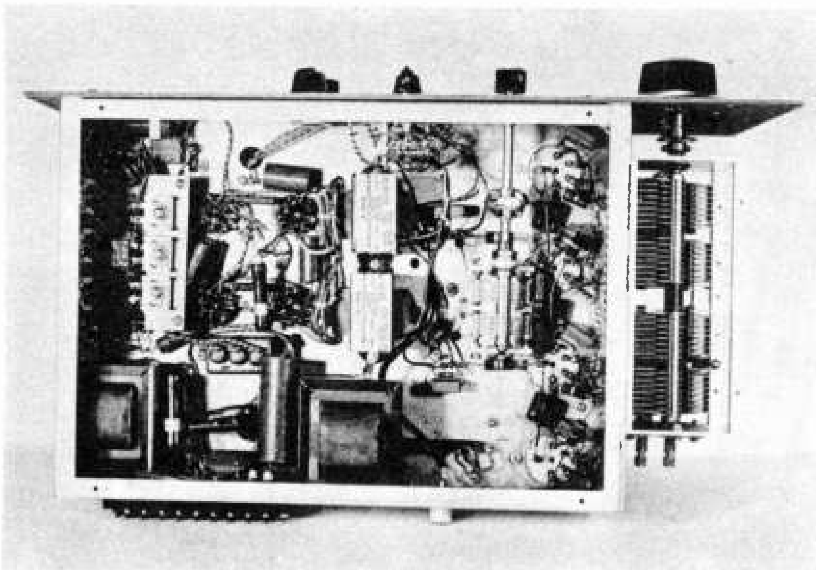


Figure 10.

UNDERCHASSIS OF THE 807 TRANSMITTER.

General Electric *Ham News*. The procedure given here is based on that given in the GE publication.

The first step in the procedure is to ground the scope to the chassis of the equipment and connect the leads from both the horizontal and vertical deflection amplifiers to point (A) on the cathode of the first half of the upper 12AU7. A small signal at 10,000 cycles is impressed on the input of the speech system through the microphone jack. Output level of the oscillator and gain of the speech system are adjusted to a point considerably above the ripple level of the system but somewhat below the overload point of the output stages of the audio system. Vertical and horizontal gain controls on the scope are now adjusted until a straight line at 45° is obtained. If the line shows a tendency to open out into an ellipse at the 45° point, connect a 50,000 variable resistor (volume-control type) in series with one scope lead or the other and adjust until the phase shift is eliminated and a thin line at 45° can be obtained through adjustment of horizontal and vertical scope gain controls.

There are six alignment frequencies for each of the six compression-type mica capacitors in the equipment. These alignment frequencies are:

Trimmer	Frequency (cycles)	Test Points
C_1	10,000	(A) - (B)
C_2	150	(B) - (C)
C_3	1000	(C) - (D)
C_4	3000	(E) - (F)
C_5	35	(F) - (G)
C_6	400	(G) - (H)

The alignment procedure involves a number of steps, but it is simple enough. The first adjustment is made at 10,000 cycles with the two scope leads connected to points (A) and (B) as listed above. Capacitor C_1 is then adjusted until a perfect circle is obtained on the face of the tube. If a perfect circle cannot be obtained, it means that proper time constant cannot be obtained in the RC network R_1-C_1; either more or less capacitance will be required, and whether the requirement is for more or less can be determined by noting whether the circle is best with maximum or with minimum capacitance setting of C_1.

After C_1 has been aligned, change the a-f oscillator frequency to 150 cycles and move

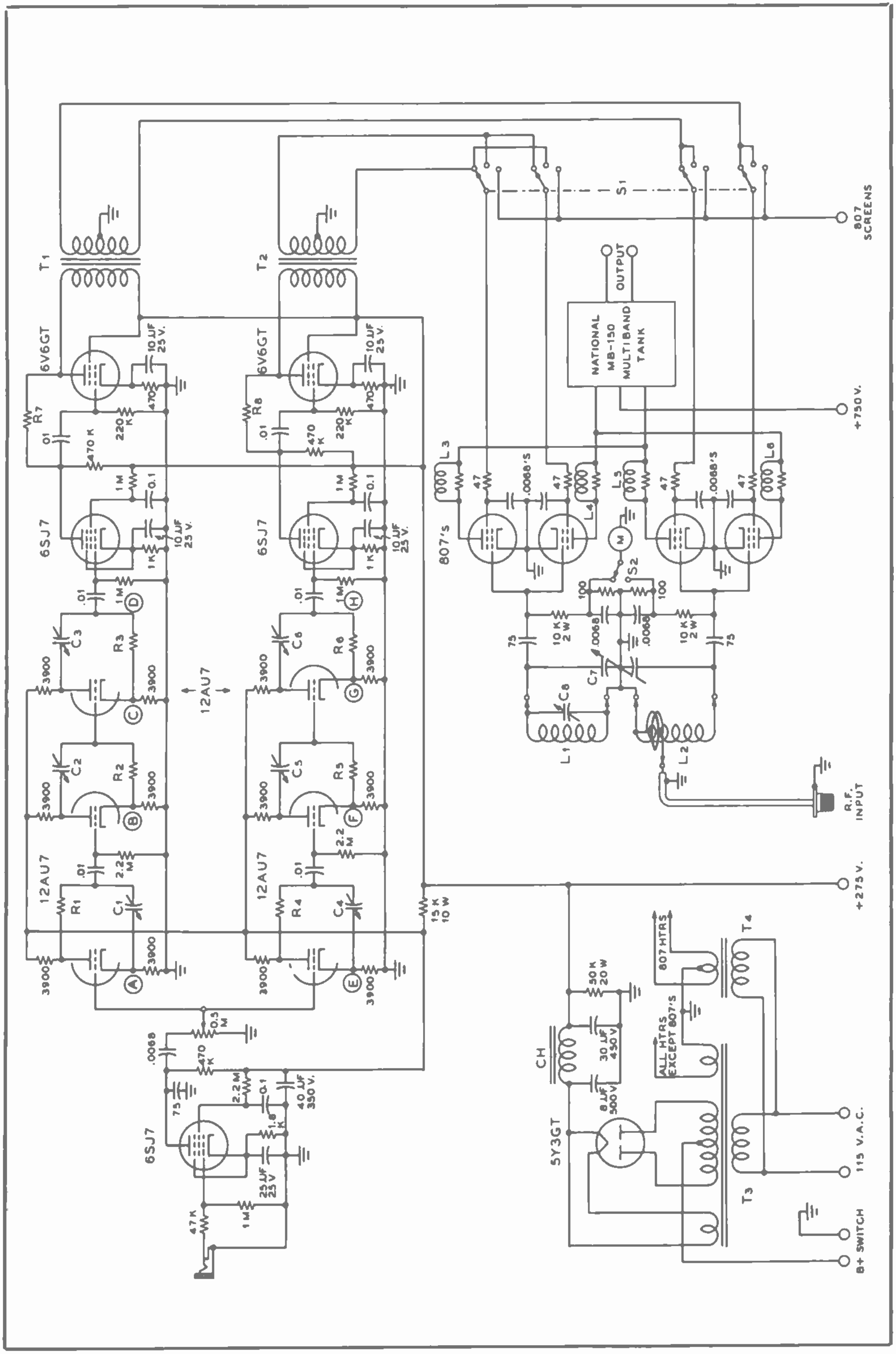

T1
T2
6V6GT
6V6GT
6SJ7
6SJ7
6SJ7
12AU7
12AU7
12AU7
807's
5Y3GT
S1
S2
807 SCREENS
OUTPUT
NATIONAL MB-150 MULTIBAND TANK
+750 V.
+275 V.
R.F. INPUT
115 V.A.C.
B+ SWITCH
807 HTRS
ALL HTRS EXCEPT 807'S
CH
T3
T4
L1
L2
L3
L4
L5
L6
C7
C8
15 K 10 W
50 K 20 W
30 µF 450 V
8 µF 500 V
40 µF 350 V

Figure 11.
SCHEMATIC OF THE 807 SINGLE-SIDEBAND TRANSMITTER.

C_1—70-350 μμfd. compression mica (ICA no. 613)
C_2—70-350 μμfd. compression mica in parallel with 0.002-μfd. mica
C_3—70-350 μμfd. compression mica in parallel with 0.0015-μfd. mica.
C_4—70-350 μμfd. compression mica in parallel with 0.000270-μfd. mica
C_5—70-350 μμfd. compression mica in parallel with 0.009-μfd. mica
C_6—70-350 μμfd. compression mica in parallel with 0.0005-μfd. mica
C_7—dual 100-μμfd. per section variable (National STHD-100)
C_x—See coil data in text
R_1—47,000 ohms ½ watt
R_2—470,000 ohms ½ watt
R_3—100,000 ohms ½ watt
R_4—100,000 ohms ½ watt
R_5—470,000 ohms ½ watt
R_6—470,000 ohms ½ watt
R_7, R_8—Values different but both between 0.5 and 1.0 megohm (See text.)
CH—15-hy. 75-ma. filter choke (Merit C-2990)
T_1, T_2—10-watt multi-tap modulation transformers (Merit A-3008). The black and white wire should be connected to B plus, and the 6V6-GT plate connected to the slate wire. On the other winding the red wire should be grounded, and the brown and blue wires connected to Switch S_1.
T_3—700 v. c.t. 70 ma., 5 v. 3 a., 6.3 v. 3 a. (Merit P-3151)
T_4—6.3-volt 6-ampere filament transformer (Merit P-2947)
S_1—4-pole 3-position wafer switch (Centralab 1415)
S_2—S.p.d.t. switch (toggle switch may be used)
L_1, L_2—See text for description
L_3, L_4, L_5, L_6—Parasitic chokes consisting of 7 turns no. 18 tinned wound around 47-ohm 2-watt carbon resistors
M—0-10 d-c milliammeter (Marion 53SN)

one scope lead from (A) over to (C). The other scope lead may remain on (B). Adjust C_2 until a perfect circle is obtained at 150 cycles. Then proceed through the frequencies listed, adjusting each of the trimmers in turn, with the scope leads connected to the test points listed above.

Now, with S_1 in one of the ssb positions and with the 807's removed from their sockets, place one of the scope leads on the secondary of T_1 and the other on the secondary of T_2. It will be necessary to reduce the gain of the scope amplifiers greatly to avoid overload of these amplifiers. Now sweep the audio oscillator over the 150 to 10,000 cycle range and note any frequencies at which the figure deviates seriously from a circle. There will be a considerable change in the diameter of the circle due to the a-f characteristics of the speech system, and there will probably be some deviation from the proper shape over some portion of the frequency range.

Slight adjustments in the phase-shift capacitor for the frequency range where the phase shift deviates from 90° (circle becomes distorted) should be made. For example, if the deviation is in the vicinity of 1000 cycles, capacitor C_3 should be changed slightly in setting. As each capacitor is changed it will become necessary to make a slight compensation in the capacitors which control adjacent frequency ranges. By making careful step-by-step adjustments in the various capacitors it will be possible to maintain the phase-shift characteristic quite close to 90° over at least the range from 200 to 7000 cycles. The audio stages have little power output below 200 cycles due to the limited inductance of the output transformers used with the 6V6-GT's. Hence the phase characteristics below this frequency will not be of too critical importance.

The relative audio output voltage from the secondaries of T_1 and T_2 should now be checked with the oscilloscope when a signal of about 1000 cycles is being fed into the input of the speech system. It probably will be found that more voltage is being obtained from one of the audio systems than from the other. Compensation, to give equal audio voltage from both channels, may be accomplished by appropriate variation in the values of the shunt feedback resistors R_7 and R_8. Install a lowered value of feedback resistor to reduce the gain of the higher gain channel.

Alignment of The 807 Stage The grid-coil arrangement for the 807's on the 3.9-Mc. band consists of 15 turns on L_1, with a 25-μμfd. APC as C_x. L_2 consists of 16 turns with a two-turn link of hookup wire closely coupled to the grounded end. Both coils are closewound of no. 22 enamelled wire. The spacing between the two coils is 1¼ inches and the coil form is a National XR-13, whose diameter is 1¾ inches. For the 14-Mc. band both coils are wound on a 1-inch diameter National XR-13A ceramic coil form. For 14 Mc., L_1 consists of 8 turns of no. 18 enamelled, closewound with a 25-μμfd. air padder capacitor connected across it. Spacing betwen coils is ⅞ inch. L_2 consists of 9 turns of no. 18 enamelled, with a two-turn link at its cold end.

To tune the stage, apply excitation on the proper band and adjust C_7 until approximately the same amount of grid current is being obtained on both pairs of 807's. The padder capacitor across L_1 should be set at about half capacitance. Connect two 60-watt lamps in series and use the series combination as a load for the 807's. Couple the vertical plates of the oscilloscope (without the vertical scope amplifier in the circuit) by means of a pickup loop to the output of the equipment. Apply about 500 volts to the 807 plates and turn up the audio gain with a signal of about 1000 cycles being fed into the audio system. The plate current on the 807's should rise from a standing current of about 30 ma. to 150 ma. or so. Dip the plate tank circuit to resonance. A fair amount of output should be observed in the load lamps.

Now vary the setting of the grid tuning capacitor C_7 while noting the envelope of the output waveform on the oscilloscope. It will be found that a relatively slight change in the setting of the grid tuning capacitor will cause a large change in the output waveform. The desirable condition is that grid current shall be the same (about 5 ma.) on both pairs of 807's, and the output waveform shall be clean and relatively free from any ripple on the envelope. It will probably be necessary to vary the coupling between L_1 and L_2, and the setting of C_4 before this condition can be obtained. The condition represents 90° phase shift in the r-f waveform being fed to the two balanced modulators, and the same amount of excitation power on the two pairs of 807 tubes, assuming that proper audio balance and phase angle already have been established as given before.

When this condition has been obtained the signal may be checked by monitoring it in a communications receiver with the a.v.c. off and the b.f.o. turned on. If all appears to be well, the output of the transmitter may be coupled to the antenna, and the plate voltage raised. Tests of the equipment with a plate potential of 1250 volts on the 807's indicated no tendency toward overloading of the output tubes. The 807's operated quite satisfactorily and without sparking or unusual heating with a plate input of 350 watts on voice peaks. Although operation at such high plate voltages is not recommended by the manufacturer for c-w service, such operation seems to be satisfactory for ssb service of this type. Each tube operates with positive screen voltage only half the time of an audio cycle, the screen voltage being negative during the balance of the audio cycle. Also, the tubes are permitted to rest during the periods beween voice peaks. Nevertheless, satisfactory operation with adequate power output will be obtained with the recommended maximum of 750 volts on the 807 tubes.

Construction It was desired to support the transmitter unit from a standard 8¾-inch relay panel. Since the MB-150 tank assembly is about 7 inches in height it was necessary to mount the tank assembly alongside the chassis rather than on top of it. So the transmitter itself is mounted on a standard 10 by 14 by 3 inch chassis displaced sufficiently to one side of the panel so that the tank assembly may be mounted on the end of the chassis. The frame of the tank assembly, as the assembly comes from the factory, is operated at plate potential. In the installation illustrated the frame of the tank assembly is bolted to the chassis of the equipment, so the r-f choke of the tank assembly is removed from the MB-150 and mounted by means of a standoff pillar to the chassis. This procedure isolates the plate voltage of the 807's from the frame of the tank circuit.

A single milliammeter for measuring grid current to the 807's is mounted on the panel of the equipment. The 750-volt plate supply for the 807's included a 0-300 d-c milliammeter which was used to measure plate current to the 807's. It would probably be desirable in many installations to include the plate milliammeter for the 807 stage on the panel of the equipment. Ample space is available between the grid milliammeter switch and the shield plate for the installation of a 0-300 or 0-500 d-c milliammeter for measuring 807 plate current.

FM TRANSMISSION

Although FM transmission is of relatively recent introduction into the field of amateur radio, it has established itself as a satisfactory means of communication under certain types of operating conditions. In fact, the use of frequency modulation for telephony on the 27-Mc. and 28-Mc. bands has become very popular in congested areas of population, where AM interference to BC and TV receivers is severe.

Wide-band FM (total deviation greater than 5 to 10 kc.) has received little use, even on the v-h-f bands due to the relatively wide bandwidth, the special receiving equipment required, and as a result of the poorer weak-signal intelligibility of wide FM as compared to a narrow-band FM signal.

An FM signal may be obtained either by the direct or the indirect method. In direct FM, the oscillator which controls the frequency of the transmitter is modulated directly by means of a reactance-tube system. The speech amplifier and reactance modulator portion of the transmitter unit to be described may be used in this manner with excellent results. However, the stability of the direct FM system is inherently poorer than that of the indirect system, since variations in power supply voltage or in the characteristics of the reactance tube will cause the average frequency of transmission to vary.

In the indirect method of generating an FM signal, the oscillator which controls the frequency of transmission is not altered, but the signal being emitted by the oscillator is phase modulated in some stage following the oscillator. A phase modulator gives zero response to zero frequency, so it cannot cause drifting or instability in the transmitted signal. A network which causes the gain of the audio channel to fall off directly in terms of frequency results in a signal having all the characteristics of an FM signal at the output of the phase-modulator stage.

A phase modulator for obtaining FM transmission has been included in the "DE-LUXE ALL-PURPOSE EXCITER UNIT" described in *Chapter Three.* This exciter unit uses a phase modulator of the type wherein a phase displacement is included in the r-f signals fed to the grids of two 6SA7 tubes. The plates of the tubes are connected in parallel and the application of a push-pull audio signal to their injection grids results in the generation of a phase-modulated signal in the common plate circuit.

A somewhat similar phase-modulator circuit is included in the exciter for the "150-WATT SSB TRANSMITTER for 3.9 MC." described earlier in this chapter. The phase modulator in the exciter unit to be described is of the type wherein a reactance tube is used as a portion of the tuned circuit in the plate of an amplifier stage. Then as a signal is applied to the grid of the reactance tube, its reactance varies with the result that the tank circuit is detuned first to one side and then to the other of resonance. This rapid detuning in accordance with the audio signal results in the generation of a phase-modulated signal, which again is converted to an FM signal through the use of an inverse-frequency network in the audio channel feeding the grid of the phase modulator.

FM Exciter for 3.9-Mc. Phone

The use of frequency modulation for radiotelephony on the 75-meter amateur band is increasing. Narrow-band FM requires less space in the band than the usual 75-meter phone signal, and the serious BCI problem on the 75-meter band can be greatly alleviated through the use of FM. But, as is well known, a narrow-band FM or phase-modulated signal of the conventional type does not have an amount of sideband energy commensurate with the power input to the output stage. Hence, the AM signal of equivalent power will be capable of greater intelligibility at a remote point.

The use of a clipper-filter system in the modulator of an AM transmitter is well known, and the improvement in performance attainable through the use of a clipper is commonly acknowledged. It has generally been overlooked, however, that the use of a clipper-filter in the audio system of an FM transmitter can give a very significant improvement in the effectiveness of an FM signal. In fact, it is quite difficult to tell the difference between a clipper-filter FM signal and a conventional AM signal on a standard communications receiver. Only when the receiver is tuned exactly to the center of the carrier of the FM signal does the modulation have a tendency to become distorted.

The unit illustrated in figures 12, 13, and 14 incorporates a clipper-filter-modulator system which may be used in several different types of FM transmitter. The audio system from the 6SJ7 through the 6SN7 and 6H6 to the 6SH7 reactance tube may be used to modulate directly the operating frequency of a v.f.o. to obtain direct FM of the carrier. Or the reactance tube may be used as a portion of the tuning inductance across a tuned circuit in the plate of an r-f amplifier stage as a method of obtaining phase modulation and thus indirect FM. When the 6SH7 is to be used as a reactance tube for obtaining direct FM of the operating frequency of a v.f.o., it is necessary that the 0.015-μfd. capacitor in the lead from the audio amplifier to the grid of the 6SH7 be removed from the circuit. This capacitor, in conjunction with the 220K resistor which feeds it, serves to impart an inverse-frequency characteristic to the audio voltage feeding the grid of the 6SH7. This inverse-frequency characteristic in the audio system converts the phase modulation obtained in a circuit such as that illustrated into FM at the output of the exciter stages. When the reactance tube is to be used for obtaining direct modulation of the frequency of an oscillator, the inverse-frequency network is not required and may be removed from the circuit. If it should be left in the circuit by mistake, the transmitted signal will have an excessively large amount of the lower audio frequencies in the output with rapidly falling level at the higher audio frequencies.

Circuit of the Clipper-Filter-Modulator Other than the use of the inverse-frequency network in the grid of the 6SH7 reactance tube, the circuit of the audio system is quite standard. The 6SJ7 operates as a high-gain pentode voltage amplifier, with its output coupled through the gain control to the grid of one half of the 6SN7. The clipper-filter circuit is quite similar to that popularized by the Collins Radio Company. The 100,000-ohm potentiometer in the grid of the second half of the 6SN7 serves as a level control for varying the signal output from the clipper-filter to the balance of the audio system.

The 6SH7 reactance tube acts as a variable inductance, since the plate current through the tube lags the a-c voltage which is appearing between plate and cathode. The phase shift in the grid voltage with respect to the voltage being impressed upon the plate by the exernal circuit is obtained by feeding r-f to the grid through a resistor from the plate of the tube. The voltage from grid to ground then lags the voltage from plate to ground as a result of the capacitance from the grid of the 6SH7 to ground. The interelectrode capacitance of the tube is sufficient to cause the desired phase shift. When the reactance tube is to be operated on a frequency different from that of the unit illustrated, it will be necessary to experiment with the value of the resistor which couples the r-f signal from the plate of the tube to the grid. The 75-$\mu\mu$fd. mica capacitor in series with the plate lead of the 6SH7 serves merely as a blocking capacitor to isolate the d-c plate voltage from the grid of the tube.

To use the clipper-filter-modulator as a reactance modulator for a v.f.o., it is necessary to connect the plate of the 6SH7 to a point of moderately high impedance in the frequency determining circuit of the oscillator. In oscillators of the e.c.o. type the plate of the 6SH7 should be capacitively coupled to the grid end of the tapped tank coil. In the case of oscillators of the Clapp type, the plate of the 6SH7 should be capacitively coupled to the junction between the tuning capacitor and the tank coil. In either event it will be necessary to feed plate voltage to the 6SH7 through an r-f choke, and screen voltage through the 100,000-ohm resistor illustrated on the schematic diagram.

When the reactance tube is to be used in conjunction with a v.f.o. to make up an FM system, it will be found that the frequency of oscillation of the v.f.o. will be altered materially when the reactance tube is connected into the circuit. This is because the reactance tube acts, true to its name, as a reactance connected across the circuit in parallel with the reactances already there. In a conventional type of oscillator, the frequency of oscillation will be raised as soon as the reactance tube is placed into operation. A separate set of calibrations may be made up for use when the reactance tube is operating, or the trimmer of the v.f.o. may be shifted to a value which will

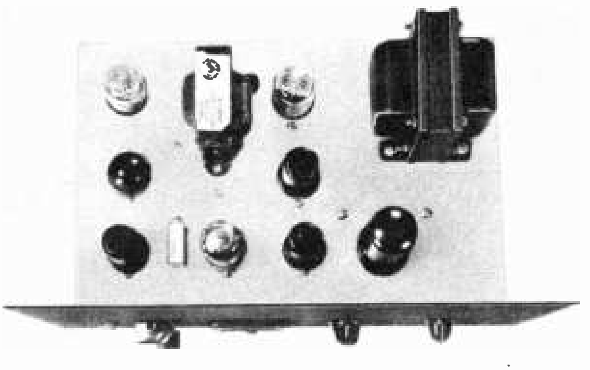


Figure 12.
LOOKING DOWN UPON THE 3.9-MC. FM EXCITER.
The operating frequency of the crystal is obtained by dividing the marked frequency of the channel (26.2 Mc. in this case) by 54.

bring the calibrations into alignment over the desired portion of the scale of the v.f.o.

R-F Portion of the Exciter Unit The r-f portion of the exciter unit illustrated in figures 12 and 13 was designed so as to provide a high-quality FM signal for use on the 3.9-Mc. phone band only. It was desired that the frequency be crystal controlled, yet a sufficient amount of deviation was desired so that conventional reception with an off-tuned AM receiver would give a signal effectiveness equivalent to a conventional AM signal. The most obvious way of accomplishing this, the procedure commonly used for FM operation on the 28-Mc. band, is to use a crystal on one-eighth the desired operating frequency. In this case, for operation in the 3.85 to 3.9 Mc. NBFM phone band, the crystal would be required to lie between 481.25 kc. and 487.5 kc. A crystal on such a frequency would be a special (and probably expensive) item if ordered directly from a crystal manufacturer. However, it so happens that a large quantity of crystals in this general frequency range is available on surplus from at least one distributor (Sun Radio of Washington D.C.). The particular crystal used in the equipment illustrated is ground for about 485.2 kc.

The 7F7 tube is a dual triode of the high-mu type. The first half of the tube operates as a Pierce crystal oscillator with the crystal operating between the grid and the plate of the tube. The second half of the tube acts as an r-f amplifier with the reactance tube operating as a portion of the tuned circuit in the plate return of the 7F7. Since the RFC is a portion of this tuned circuit, the type specified in figure 14 should be used. The 6SH7 reactance tube serves to detune from resonance the tuned circuit in the plate of the second half of the 7F7 alternately on one side of resonance and then the other side, in accordance with the audio-frequency wave being impressed on the grid of the 6SH7. This detuning in accordance with the audio wave serves to phase modulate the wave being impressed on the grid of the 6SJ7 multiplier which follows. Since there is an inverse-frequency circuit in the audio line to the grid of the 6SH7, the phase modulation action of the 6SH7 effectively results in an FM wave at the output of the transmitter.

The 6SJ7 which follows the 7F7 and the reactance modulator serves as a quadrupler. With the 485.2-kc. crystal in use the plate circuit of this tube is tuned to 1940.8 kc. The plate circuit of this tube must be moderately high C (which is to say that there must be

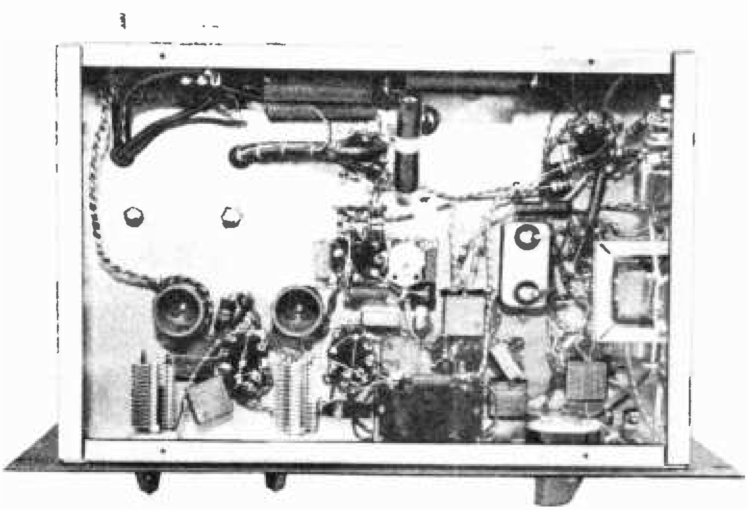


Figure 13.
UNDERCHASSIS OF THE 3.9-MC. FM EXCITER.

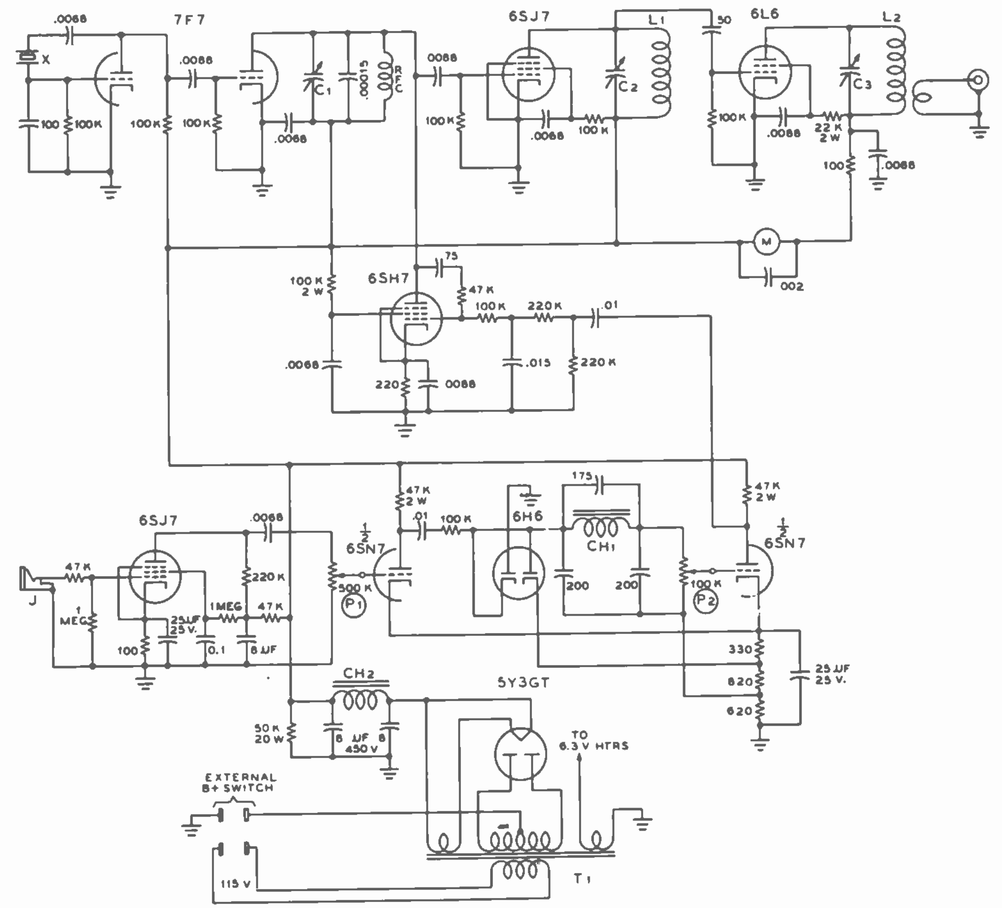


Figure 14.

SCHEMATIC OF THE FM EXCITER UNIT.

C_1—4.5-25-μμfd. ceramic trimmer
C_2, C_3—140-μμfd. air padder capacitor
CH_1—3.5-hy. miniature choke (Stancor C-1080)
CH_2—15-hy. 75-ma. filter choke (Merit C-2990)
J—Closed circuit jack for microphone
M—0-100 d-c milliammeter (Simpson model 127)
RFC—1-mh. r-f choke (National R-300U)
X—Crystal on one-eighth of desired output frequency
L_1—46 turns no. 28 enam. closewound on 1" dia. form (National XR-2)
L_2—31 turns no. 22 enam. closewound on 1" dia. form (National XR-2)
T_1—700 v. c.t. 70 ma., 5 v. 3 a., 6.3 v. 3 a. (Merit P-3151)
P_1—Clipping control (overall gain control)
P_2—Deviation control

at least 125 μμfd. from plate to ground on the tube) so that the third and fifth harmonic of the crystal frequency will be far down with respect to the fourth harmonic to which the circuit is tuned. The 6L6 output stage then acts as a doubler to deliver the output frequency of about 3881.6 kc. It probably will be of assistance in first tuning the transmitter to insert a milliammeter in series with the grid leak for the 6L6. With the exciter stages operating properly, about 1.5 ma. of grid current on 1940.8 kc. will be obtained in the 6L6 grid return. The 6L6 will draw about 60 ma. of plate and screen current with full loading, which represents about 16 watts input to the plate circuit. An output of 8 to 10 watts is obtainable from the link coupled to the plate coil of the 6L6.

Operating Notes Experience has shown that the best way of tuning a unit such as this is with the aid of an audio oscillator, a receiver, and an oscilloscope. The r-f portion of the transmitter is tuned, the output of the unit is fed to a 15-watt lamp or 25-watt lamp as a dummy load, and the signal being emitted is picked up in the receiver. Since the signal on the air probably will be received a majority of the time on a conventional AM receiver detuned to one side, the transmitter may as well be tuned in this manner using a conventional AM receiver detuned to one side or the other. The audio oscillator is then fed into the exciter unit, and the output of the receiver is fed to the oscilloscope. The operation of the gain control P_1 and the clipping level control P_2 will become obvious from inspection of their action as viewed on the oscilloscope. Capacitor C_1 in the plate circuit of the 7F7 should then be tuned for best wave form of the output signal. It will be found that this capacitor should be set to about one-half capacitance. In fact, if the complete set of test equipment is not available, capacitor C_1 may be set to about half scale and the signal emitted by the transmitter checked while talking into the microphone.

It will be found that the audio channel of the exciter unit has a reserve of gain. This reserve is obviously necessary if much clipping action is to be available. It will be found also that the clipping-level control P_2 must not be advanced past about half-scale or the deviation will become greater than can be handled by the conventional communications receiver. Hence the excessive deviation will appear as splatter on adjacent channels. So be sure that the clipping level control is set to a point where excessive deviation cannot take place. The gain control P_1 will then serve to control the number of db of clipping being introduced by the clipper. The so-called "quality" of the speech transmitted by the unit will be better with the gain control backed down so that there is only a moderate amount of clipping. But when maximum signal effectiveness is desired, the gain control may be wound "wide open" to produce 15 to 20 db of clipping in the unit. The speech will still be quite understandable with this amount of clipping, but the voice probably will no longer be recognizable. A compromise amount of clipping will be found to be best for normal all-around working of the transmitter unit.

CHAPTER FIVE

High Frequency Power Amplifiers

The trend in the design of transmitters for operation on the amateur high-frequency bands is toward the use of a single high-level stage. The most common and most flexible arrangement includes an exciter unit, with 5 to 25 watts output on all the h-f bands, and a single-stage power amplifier. In many cases the exciter unit is on the operating table, with a coaxial cable feeding excitation to the power amplifier, although many prefer to have the exciter unit included in the main transmitter housing.

This trend is a natural outgrowth of the increasing importance of v-f-o operation on the h-f bands. It simply is not practicable to make a quick change in the operating frequency of a transmitter when a whole succession of stages must be retuned to resonance following the frequency change. Another significant factor in implementing the trend has been the ready availability of high-power-gain tetrode tubes. Through the use of these tubes it is convenient and practical to excite an amplifier of 100 to 1000 watts output from an exciter unit on the operating desk having 10 to 20 watts output. A further factor is that the use of a single high-level stage eases the TVI problem.

Modern triode tubes are capable of giving a moderate power gain, so that it becomes a toss-up as to whether a triode or tetrode is used in the 100 to 250 watt power range. But for power levels above about 250 watts the beam-tetrode amplifier tube is the logical choice, unless factors outside this discussion influence the decision. Even below the 250-watt level the beam-tetrode tube often is the most desirable choice, especially when quick bandswitching is desired, limited excitation is available, or where single-ended input and output circuits are needed.

One consequence of the trend toward tetrode tubes is that the standard push-pull amplifier is losing popularity with respect to the single-ended stage. With triode tubes the most frequent choice was for a push-pull circuit, since it was necessary to balance one circuit anyway to obtain the neutralizing voltage. Hence few additional components were required to convert the stage to a push-pull amplifier and thus double the power-handling capability. Further, the better balance of the push-pull circuit reduced the number of problems associated with neutralization.

Generation of Harmonics With the trend toward the use of high-gain tetrodes, where circuit balance is not of such significance, the trend has been toward the use of a single-ended final amplifier stage. Experience with properly designed single-ended power amplifier stages has borne out the theory that the single-ended class C stage inherently is capable of affording a lower level of harmonic output than a push-pull stage of equivalent power handling characteristics. The explanation given for the reduced harmonic output from a single-ended stage as referred to a comparable push-pull class C stage lies in the fact that the plate tank circuit of the push-pull amplifier receives two kicks of plate current for every cycle at the output frequency. Hence, any impedance which is common to the plate circuits of both the amplifier tubes will have second-harmonic current flowing in it. Stated in another manner, the push-pull stage acts as a push-push frequency doubler as far as any impedance common to both tubes is concerned.

This theory of course is in direct opposition to the common assumption that a push-pull amplifier affords reduced harmonic output as compared to a push-pull stage. However, the old theory of reduced harmonic output from a push-pull amplifier was applicable to the case of a class A or class B amplifier operating into a balanced output transformer in the audio frequency range. It is not logical that this theory can be extended to the much more specific case of a class C amplifier operating with narrow plate-current pulses into an output circuit with a relatively low coefficient of coupling from one tube to the other.

In the case of push-pull class C r-f amplifiers the two amplifier tubes in the circuit operate substantially independently of each other. The tube on one side of the tank circuit delivers a pulse of energy to the tank circuit during a portion of one half cycle, then is completely inoperative during the balance of that half cycle and during the entire next half cycle. But during this next half cycle the tube on the opposite side of the tank circuit delivers its pulse of energy to the tank circuit. True, we can use a lower value of Q (equivalent to the ratio of energy stored to energy lost per cycle) in the plate tank circuit because the circuit receives two kicks of excitation energy per cycle. But it is this *two kicks of energy per cycle* which causes the push-pull amplifier to have a strong twice-frequency current flowing.

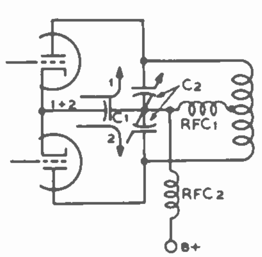


Figure 1.
SHOWING HARMONIC CURRENT FLOW IN A PUSH-PULL AMPLIFIER.

As each tube in the push-pull amplifier draws its pulse of plate current (see figure 1), this current flows through *one-half* of the split-stator tank capacitor C_2 and in addition through the plate blocking capacitor C_1. Then when the other tube draws its pulse of plate current, this current flows through the other half of the plate tank capacitor but *also* through the plate blocking capacitor. Thus we have a flow of current approximately equal to the r-m-s plate current of both tubes passing through the plate blocking capacitor and its leads to the filament center tap of the tubes. Note also that the usual plate-circuit r-f choke does not stop the flow of a portion of this second-harmonic current through the plate-voltage lead to the power supply. Hence it is necessary to add an additional r-f choke (RFC_2) in order to stop the radiation of second-harmonic energy from the plate-voltage lead between the power supply and the r-f power amplifier.

Note that the second-harmonic signal resulting from the alternate plate-current flow does not pass through the plate tank coil of the stage. The second-harmonic energy present in the tank coil is only the normal amount which results from the component of current at twice frequency in the plate circuit of each tube. Another way of stating the same thing is to say that the second-harmonic energy caused as a result of the push-push operation of the two tubes is effectively in parallel at both ends of the tank circuit. This signal can be coupled capacitively to the load, but not inductively. Hence the complete shielding of the stage, plus isolation of all leads entering the chassis, plus the use of a Faraday shield on the output link will effectively reduce the coupling of push-push second-harmonic energy into the load circuit.

Details on methods and procedures for the elimination of interference caused by harmonics of the operating frequency are given in detail in the chapter *Broadcast and Television Interference.* Additional r-f power amplifiers, and some of the amplifiers described in this chapter, are shown in conjunction with the other components which go to make up a complete transmitter in the chapter *Transmitter Construction.*

Shielded 807 Amplifier

The versatile 807 unquestionably is the transmitting tube most frequently used by amateurs. But it also is a very frequently

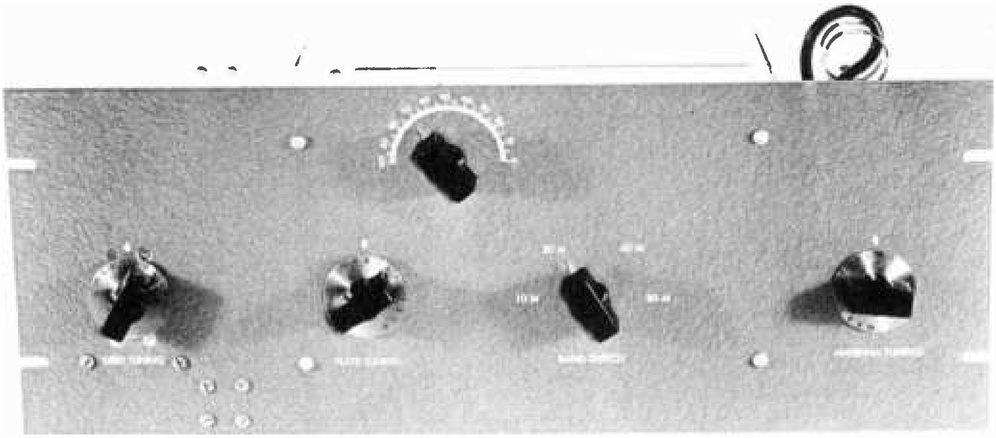


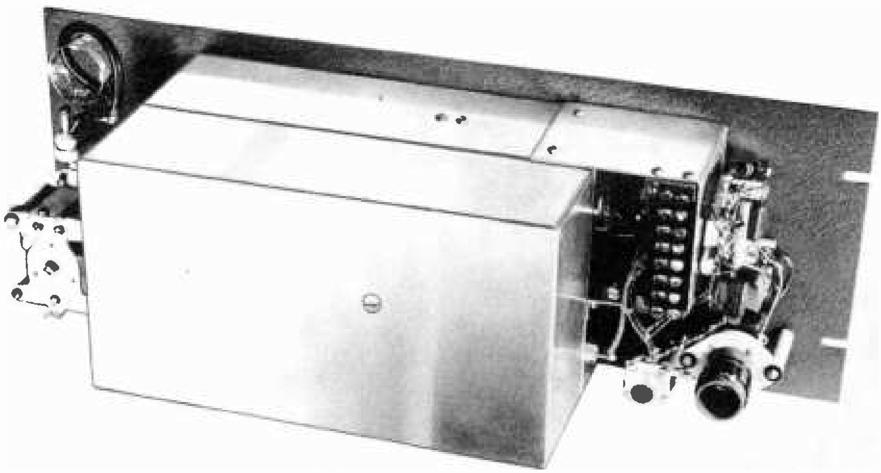
Figure 2.
PANEL VIEW OF THE SHIELDED 807 AMPLIFIER.

maligned tube due to its tendency toward spurious signal generation and parasitic oscillation. Nevertheless, the low price and unusual capabilities of the tube overweigh any misgivings about using the tube as a result of its unfortunate tendency toward self-oscillation. It has been more or less established that the 807's enthusiasm for parasitic oscillation is the result of two factors: (1) the extremely high power gain of the tube, and (2) the sizable screen-lead inductance due to the use of a rather long piece of small wire between the tube socket and the screen element within the electrode structure.

The amplifier shown in figures 2, 3, and 4 was designed and constructed with these considerations in mind. But the pre-eminent factor in the layout of this amplifier was the serious problem of TVI. A number of precautions which might lead to a reduction in the generation and radiation of harmonic signals have been taken in the layout and construction of the stage.

Theoretical analyses of the operation of a class C amplifier have shown that to obtain a high value of harmonic attenuation it is necessary to have at least two loosely coupled tank circuits of reasonable Q between the

Figure 3.
REAR OF THE 807 AMPLIFIER, WITH SHIELD COVER IN PLACE.



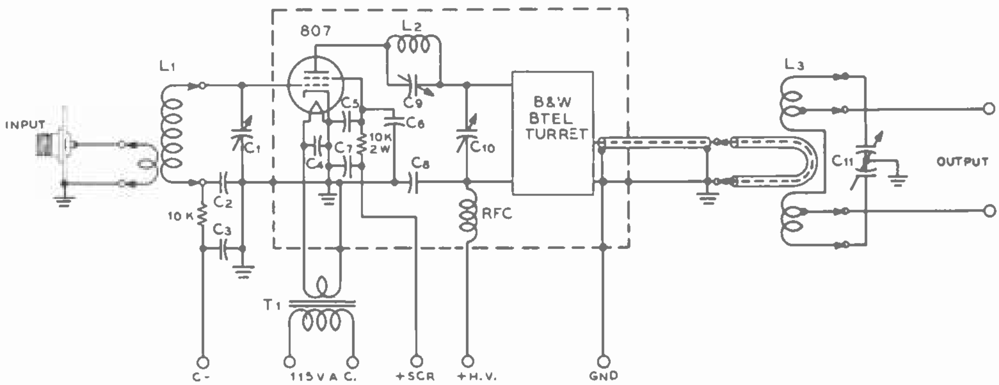


Figure 4.

SCHEMATIC OF THE SHIELDED 807 AMPLIFIER.

C_1—100-μμfd. midget variable (National UM-100)
C_2, C_3—0.003-μfd. midget mica
C_4, C_5—500-μμfd. ceramic by-pass
C_6, C_7—0.003-μfd. midget mica
C_8—0.004-μfd. 2500-volt test mica
C_9—50-μμfd. air-padder capacitor with shaft
C_{10}—50-μμfd. 3000-volt variable (Johnson 50H30)
C_{11}—Dual 100-μμfd. split-stator (National TMK-100D)
L_1—28 Mc.: 5 t. no. 14 enam. closewound, 3 t. link, 1" dia. form (Nat. XR-2)
14 Mc.: 12 t. no. 18 enam. closewound, 3 t. link, 1" dia. (Nat. XR-2)
7 Mc.: 24 t. no. 18 enam. closewound, 3 t. link, 1" dia. (Nat. XR-2)
3.5 Mc.: 38 t. no. 22 enam. closewound, 5 t. link, 1" dia. (Nat. XR-2)
L_2—4 t. no. 14 enam. ½" dia. by ½" long, air wound
L_3—50-watt plug-in coils for band in use (Nat. AR-16 series). See text for data on shielded link arrangement for 14 Mc. and 28 Mc. coils.
RFC—National R-60 v-h-f choke
T_1—6.3-volt 1.2-ampere filament transformer (UTC FT-2)

plate of the amplifier tube and the antenna transmission line. In addition, it has been shown that a trap circuit connected in series with the plate lead of the amplifier tube will, under certain conditions, afford additional harmonic reduction. Further, the amplifier stage itself should be shielded, and preferably should have a coaxial line to couple the output energy from the shielded tank to the antenna-coupling tank circuit.

All the above features have been included in the amplifier illustrated. In addition, a split-stator capacitor with grounded rotor has been used in the antenna-coupling circuit, and careful filtering of the leads which enter the amplifier compartment has been employed. The net result of all these precautions is that harmonic radiation from the amplifier itself has been reduced to a very low value. Also, harmonic radiation from the unit when coupled to a conventional three-element rotary antenna system is very low.

Circuit Description The amplifier chassis is designed to operate in conjunction with an external, shielded exciter unit and an external plate and screen-voltage supply and modulator. The grid-circuit coils for the 807 are plug-in, and are designed to be link coupled to the exciter unit. A miniature filament transformer for the 807 is mounted on the chassis. Since it was required that the plate tank circuit for the 807 be completely shielded, it was deemed desirable to use an all-band turret in this circuit position. The B&W type BTEL was found satisfactory for the application. The harmonic trap in the plate lead of the tube is insulated from all supports, and a control for the capacitor of the trap is brought out to the panel for convenience. Link coupling from the turret in the plate of the 807 to the antenna-coupling circuit on the end of the chassis is provided by a short length of coaxial cable. Plug-in coils (National AR-16 series) are used in the antenna-coupling tank circuit.

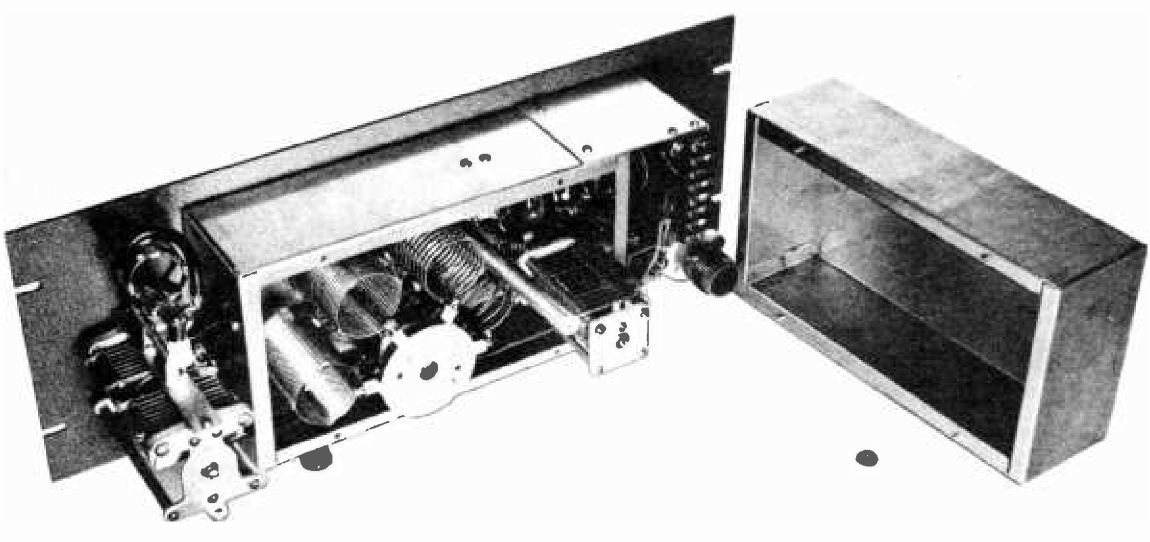
A power output of 1 to 2 watts from the external exciter unit is adequate to allow a safety factor in exciting the grid of the 807. Grid current on the 807 should run about 3.5 ma. on all bands. The grid-bias voltage for the 807 can best be obtained from a grid leak, unless excitation keying of the exciter is to be employed for c.w. In the event that excitation keying is not required as a result of some special consideration, it is suggested that screen-voltage keying of the 807 be used. The vacuum-tube keyer unit described in *Chapter One* is ideally suited to this application. A grid-leak value of 12,000 or 15,000 ohms is suggested for c-w operation of the 807, while a value of 22,000 ohms is recommended for high-level amplitude modulation of the tube.

Normal screen voltage for the 807 is 250 volts. Under normal operation with the excitation value specified and with 100 ma. of plate current the screen current will be from 5 to 7.1 ma. The full 100 ma. of plate current may be run on the 807 on phone with from 300 to 600 volts on the plate. For c-w operation the plate voltage may be increased to 750 volts.

Construction The amplifier is assembled on a standard 7 by 19 inch dural rack panel. The grid circuit components of the amplifier are at the left end of the panel while the antenna-coupling tank circuit is at the right end. Between is a 5½ by 10 by 3 inch aluminum chassis (ICA no. 29004), mounted vertically, which houses and shields the plate-circuit components of the stage. The aluminum chassis is supported from the panel by four 8-32 bolts and is separated from the panel about ⅛ inch by four metal washers of the type normally used underneath the heads of oval-head panel mounting screws. Another chassis identical to the one mounted to the panel serves to complete the shielding enclosure. The four holes on the bottom of the chassis which is mounted to the panel (these holes were intended to take the screws for holding the bottom cover of the chassis) are drilled to provide a clearance hole for 6-32 screws. Then the matching holes in the other chassis which is used for a cover are tapped to take 6-32 screws. Four ¼-inch 6-32 screws are then threaded into the tapped holes with a short screwdriver. These four screws then serve as locating pins when the two chassis are placed together. A metal post affixed by one bolt to the chassis which is mounted to the panel then serves to take a bolt at its other end for clamping the two chassis solidly together.

The placement of the components inside the shielding compartment can be seen from the photographs. All components associated with the grid circuit of the 807 are unshielded, but if difficulty is encountered as a result of harmonics generated within the exciter unit

Figure 5.
REAR OF THE 807 AMPLIFIER, SHIELD COVER REMOVED.



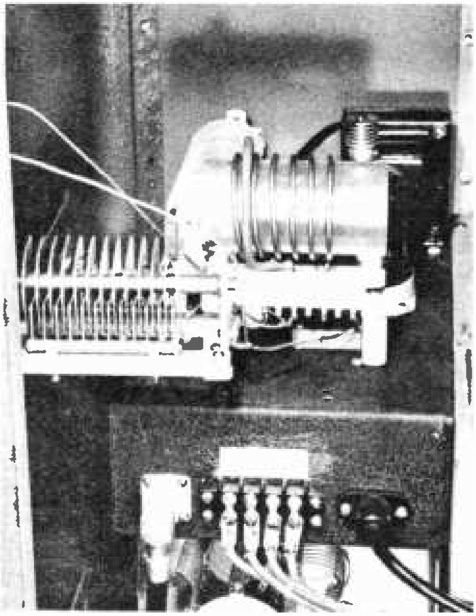


Figure 6.
SHOWING THE 4-65A AMPLIFIER INSTALLED IN THE TRANSMITTER.

for the 807, it will possibly be necessary to shield the grid-circuit components. This was not found to be necessary in the unit illustrated when operating with a completely shielded exciter.

A short length of coaxial cable is used as a link between the plate tank circuit of the 807 and the antenna-coupling tank. Note that the B&W BTEL turret assembly was modified to the extent of removing the original 28-Mc. tank coil, and then reducing the number of turns on the original 21-Mc. coil to four turns. This coil then hits both 21 Mc. and 28 Mc.—and the assembly is small enough to fit into the shielding compartment.

It was found in the testing of the amplifier that a fair amount of harmonic energy was being carried out of the shielded compartment on the coaxial coupling link. A copper strap ground from the outer conductor of the cable to the shield compartment from the link terminal on the coil socket, plus the ground inside the compartment to the outer conductor, helped afford a reduction. A further reduction was obtained through the use of a "Faraday shielded" one-turn coupling link on the 28 Mc. antenna-tank coil. The link was made from a 6-inch length of small-diameter coax. (RG-58/U) by connecting both the inner and outer conductors together at the grounded end of the link. The shield braid then extends to within one-quarter inch of the point where the inner conductor connects to the lug on the coil socket at the other end of the link loop. Thus the inner conductor is shielded throughout its length, but the shield braid does not form a shorted turn since it is open circuited at the ungrounded end of the link

4-65A Single-Ended Power Amplifier

The Eimac 4-65A tube is ideally suited for use as an r-f power amplifier in the 50-watt to 200-watt power output range. The capabilities of this tube fit in well between those of the 807 and similar types in the 50-watt range, and those of the 813, 4E27/257B, and 4-125A types in the 200-watt to 500-watt power output range. The tube will operate satsfactorily with plate voltages as low as 500 to 600 volts, and it is still practicable to use the tube at operating plate voltages of 2000 and more.

The amplifier shown in figure 6 is the same as that shown as a portion of the complete 200-WATT ALL-BAND TRANSMITTER described in the *Transmitter Construction* chapter. Since details of the operation of the amplifier with plate modulation at 1600 volts are given in that chapter, this section will be confined to a discussion of the capabilities and recommended operating conditions of the tube at other plate voltages.

In general, the plate current of the 4-65A should be limited to 150 ma. for c-w or FM operation, and it should be limited to 120 ma. for high-level AM phone. However, the plate power input should always be limited to such a value that the plate dissipation does not exceed 65 watts for c-w use and to 45 watts for high-level AM. These values of dissipation assume that a radiator-type connector is bolted firmly to the plate terminal of the tube. At 65 watts of plate dissipation the plate temperature can be described as a dull cherry red, while at 45 watts the plate shows a deep red color. Intermittent periods of high plate dissipation, such as might be encountered during tuning, will not damage the tube. Free-air cooling of the tube and plate seal normally is adequate for frequencies below 50 Mc. Above 50 Mc. some sort of forced-air cooling should be provided if the tube is to be operated with full plate voltage.

Although the maximum screen-voltage rating of the 4-65A is 400 volts for r-f amplifier service, recommended voltage for all types of r-f operation is 250 volts. The screen current will run from 30 to 40 ma. under normal operating conditions. Grid current should run between 12 and 15 ma. for all conditions of operation. Grid bias for c-w operation with 600 plate volts should be −50 volts; for high-level amplitude operation the grid bias at 600 plate volts should be about −100 volts. For c-w operation with 1000 to 2000 plate volts the grid bias should be about −75 to −80 volts and for AM over this plate-voltage range the grid bias should be about −125 volts.

For high-level amplitude modulation of the 4-65A with 600 to 2000 volts on the plate a provision should be included for applying about 175 peak volts of audio to the average positive 250 volt screen potential. This audio voltage may be obtained through the use of an audio choke in series with the screen-current lead, through a tap on the modulation transformer, or through the screen-drop resistor method.

4-125 All-Band Amplifier

Figures 7 through 10 illustrate a general-purpose beam-tetrode amplifier for operation on the amateur bands from 3.5 through 29.7 Mc. The plate voltage which may be applied to the stage is limited to 2000 volts for high-level amplitude modulation by the plate tank circuit components. Since the plate current on the tube is limited to 200 ma. on phone and 225 ma. on c.w. by the manufacturer's ratings, the input to the stage should be held to a maximum 400 watts on phone and 450 watts on c.w.

The amplifier is designed so that it may be excited by any v.f.o. or crystal oscillator having 4 to 5 watts output. Although the manufacturer's data on the tube specifies an excitation power of less than 2 watts, it is always desirable to have several times the rated excitation power available. When extra power is available it is not necessary to squeeze the last bit of power from the exciter unit to take care of tank and link losses in the coupling between it and the grid of the final amplifier. There are a number of commercial exciter units which may be used with this amplifier, and any of those described in *Chapter Three* with at least 5 watts output will be suitable.

Circuit Description To afford a high degree of convenience in operation the grid circuit of the final amplifier is completely self-contained with coils for all bands and a coil selector switch. Separate coils are used for the 80, 40 and 20 meter bands with the 10-meter coil also serving on the 15-meter band. Since the grid tuning capacitor C_1 has a maximum capacitance of only 50 μμfd. per section, it is necessary to parallel a fixed padder capacitor across the 3.5-Mc. coil to provide a satisfactory L to C ratio. Grid bias for the 4-125A is provided by a 3000-ohm grid-leak resistor plus 90 volts from the built-in bias pack. Screen voltage as well as grid bias voltage are furnished by the pack mounted on the amplifier deck. A

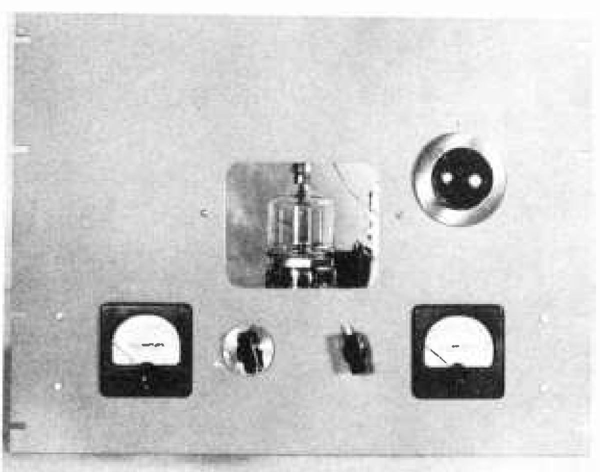


Figure 7.
PANEL VIEW OF THE 4-125A AMPLIFIER.

type VR-90 voltage regulator tube holds the grid bias voltage fixed at a minimum of −90 volts. Screen voltage is not regulated but runs at approximately 350 volts under the normal screen current of 30 to 40 ma. on the 4-125A. A 5Y3-GT is employed in the screen voltage supply. A 6X5-GT fed through a resistor from one side of the high voltage winding on the power transformer supplies the grid-bias voltage. The VR-90 bias-voltage regulator is mounted below chassis by means of a bracket to keep it out of the intense field in the vicinity of the plate circuit on the top side of the chassis.

Series feed is used for the plate tank circuit of the 4-125A. The bakelite cased, 4500-volt, 0.001 μfd. plate by-pass capacitor is returned to the same bolt to which the filament by-pass capacitors also ground. The fixed link plate tank coils are wound on National XR-10A forms in the case of the 80, 40 and 20 meter bands. The 10 and 15 meter coil is wound of no. 8 bare copper wire and is self-supporting. All plate tank coils are supported by National PB15 plug bases.

Since the amplifier is to be plate modulated, it was found desirable to connect an audio choke in series with the r-f choke which feeds plate voltage to the 4-125A. This choke consists merely of the primary winding of a medium-sized filament transformer. The secondary leads of this transformer have been cut off where they leave the coil. Note that this choke must be mounted on sizable stand-off insulators so that there will be no high voltage appearing between the coil and the core and frame of the choke. One inch insulators have been used in the unit shown, as can be seen in figure 9. The additional audio choke acts as a low-pass filter in conjunction with the 0.001-μfd. plate by-pass capacitor and an additional 0.001-μfd. capacitor in the modulator unit. Simultaneous screen-voltage modulation along with the plate-voltage modulation is obtained by connecting a choke in series with the screen current supply lead. This choke could of course be mounted in the final amplifier deck, but in the transmitter of which this unit is a portion the choke has been mounted in the modulator deck.

COIL TABLE
4-125A All-Band Amplifier

L_1—3.5 Mc., 30 turns no. 24 enam. closewound on 1" dia.

L_2—7.0 Mc., 25 turns no. 24 enam. closewound on 1" dia.

L_3—14 Mc., 10 turns no. 14 enam. closewound on 1" dia.

L_4—21 and 28 Mc., 5 turns no. 14 spaced to ¾" on 1" dia.

All grid coils wound on National XR-2 forms

L_5—3.5 Mc., 26 turns no. 14 enam. on National XR-10A form, 3 turn link.
7.0 Mc., 14 turns no. 14 enam. on National XR-10A form, 3 turn link.
14 Mc., 8 turns no. 10 double spaced on National XR-10A form, 3 t. link.
21 and 28 Mc., 6 turns no. 8 bare, 1¼" dia. 2¼" long, 2 turn link.

Construction The complete amplifier with its power supplies is mounted on an 11 by 17 by 3 inch aluminum chassis

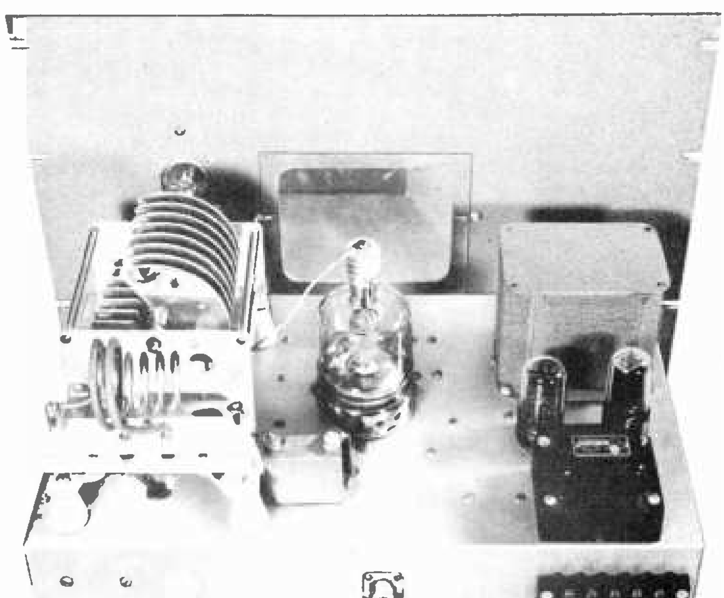


Figure 8.
REAR VIEW OF THE 4-125A AMPLIFIER.
In this photograph the plate tank circuit is on the left side and the screen, bias, and filament voltage supplies are on the right.

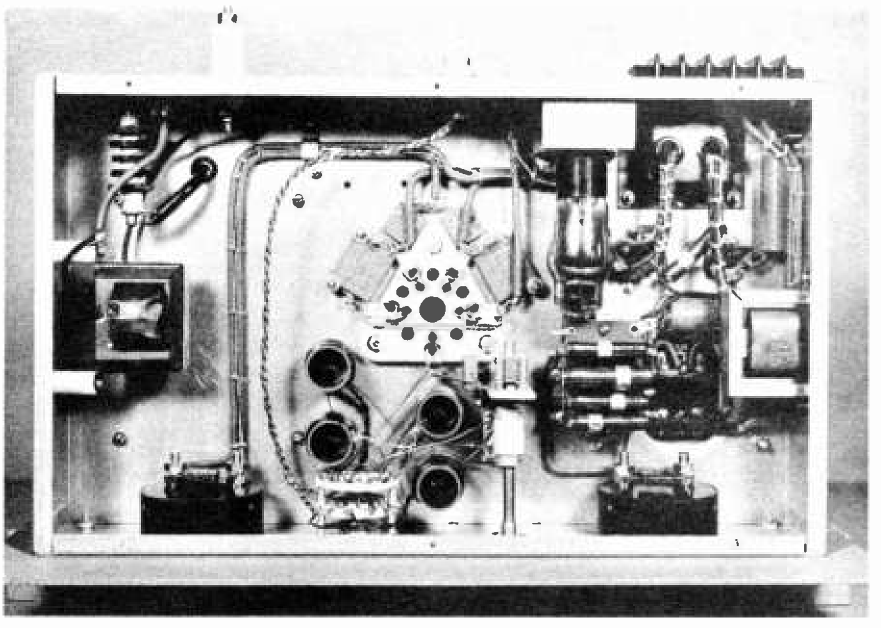


Figure 9.
UNDERCHASSIS OF THE 4-125A AMPLIFIER.
The VR-90 bias-voltage regulator can be seen underchassis mounted with the balance of the power-supply components on the right. The filament-transformer primary which acts as an audio choke can be seen mounted on standoff insulators from the left wall of the chassis.

which is supported from a standard 14 by 19 inch panel. A 3½ by 4½ inch hole has been cut in the center of the panel to permit viewing of the plate of the 4-125A while it is in operation. A small piece of window glass is mounted behind this hole and supported by a pair of solder lugs acting as brackets. The chassis for the amplifier has been mounted several inches up from the bottom surface of the panel in order that the grid and plate milliammeters could be mounted inside the chassis assembly. Consequently the meter holes run through both the panel and the chassis. After the bottom cover has been put into place all the input circuits and the meters of the 4-125A amplifier are completely shielded. The plate tuning capacitor and the plate tank coil are mounted on 1½ inch conical ceramic insulators. A coupling of the type having a long ceramic insulator and a flexible unit at each end is used to couple the National type AM dial to the National type TMA-100A tuning capacitor.

Operation Normal grid current for the 4-125A tube will be approximately 12 ma. In the event of extended testing of the final amplifier without plate voltage it will be advisable to remove the connection on the rear terminal strip which supplies screen voltage to the 4-125A. This will eliminate any possibility of excessive screen dissipation being caused by the presence of excitation without plate voltage when screen voltage is on the 4-125A tube. In all normal tuning-up operation, however, it will be sufficient if the excitation is applied only for brief periods with the screen voltage present and the plate voltage turned off.

To operate the amplifier conservatively it is suggested that the plate current be limited to 175 ma. on phone and to 200 ma. on c.w. In most cases it will be necessary to connect some type of antenna coupling network between the output terminals and the antenna system. This requirement certainly will be present if there is any number of television

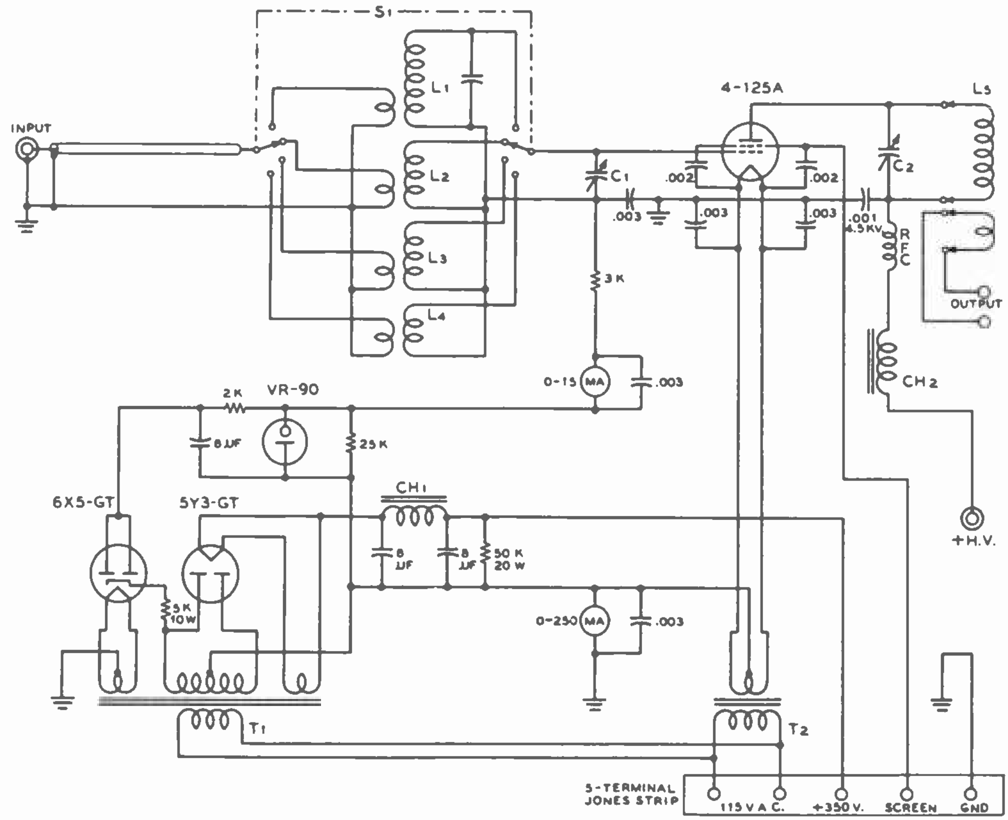


Figure 10.
SCHEMATIC OF THE 4-125A AMPLIFIER.

C_1—50-$\mu\mu$fd. midget variable (National UM-50)
C_2—100 $\mu\mu$fd., 0.171-inch spacing (National TMA-100A)
CH_1—13-hy. 65-Ma. choke (Stancor C-1708)
CH_2—Primary of 12-watt fil. trans. (Merit P-2945)
T_1—600 v. c.t. 55 ma., 5 v. 2 a., 6.3 v. 2.7 a. (Stancor P-6119)
T_2—5 v. 13 a. fil. trans. (UTC S-59)
L_1 to L_5—See coil table
Milliammeters—Marion 535N
RFC—1-mh. 600-ma. r-f choke (National R-154U)
S_1—2-pole 4-position ceramic (Centralab 2505 suitable)
Dial for plate tank capacitor—National AM

receivers in the immediate vicinity of the transmitting station. Any one of the antenna coupling systems described in *Chapter Twelve* should be suitable for this application. In installations where TVI is not a problem the coupling between the antenna transmission line and the final amplifier plate circuit may in most cases be varied over a wide range merely by connecting a variable capacitor in series with one side of the link circuit output from the amplifier.

General Purpose Amplifier

A general purpose, medium power amplifier is shown in figures 11 through 13. The schematic diagram for the amplifier is shown in figure 14. Tubes of a number of types may be used in this amplifier with few changes in the unit. Although type 812 tubes are shown, the amplifier may be used with 811, 8005, 812H, 812A, 5514, and 809 tubes. All the tubes specified have the plate out the top and the grid and filament leads brought out through a standard 4-prong base. Power outputs up to 250 watts can be handled by the plate tank circuit for the amplifier. The actual value of power input which may be used is dependent upon the particular tube type which is chosen. Appropriate changes in filament voltage of course must be made for the different tube types. Since ample room is

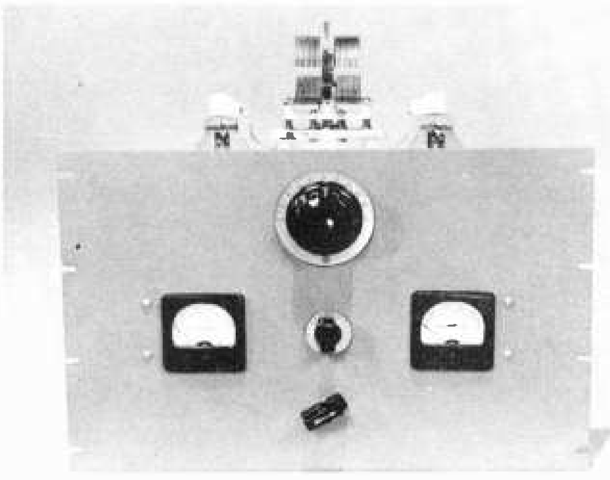


Figure 11.
PANEL VIEW OF THE GENERAL-PURPOSE AMPLIFIER.

available underneath the chassis, it is probable that it will be found desirable to mount the filament transformer directly within the unit.

A standard 19 by 12¼ inch dural panel is used to support the unit. Since a band-switching turret is used to eliminate the requirement for plug-in coils in the grid circuit of the amplifier, the main chassis of the unit is mounted just slightly below center on the panel. The two milliammeters included within the stage are mounted both through the panel and through the front drop of the 10 by 14 by 3 inch chassis. The plate tank capacitor is of the B&W medium-sized butterfly type. It is mounted above the chassis by means of 1-inch standoff insulators.

Millen connection strips for filament voltage, ground and grid bias are mounted on the left side of the rear drop of the chassis. A Millen high-voltage cable connector is

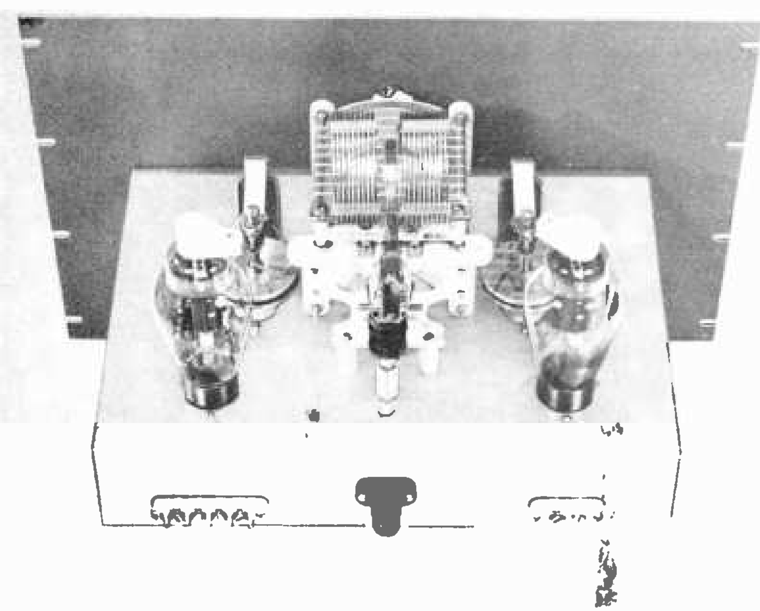


Figure 12.
PUSH-PULL GENERAL-PURPOSE AMPLIFIER, REAR VIEW.

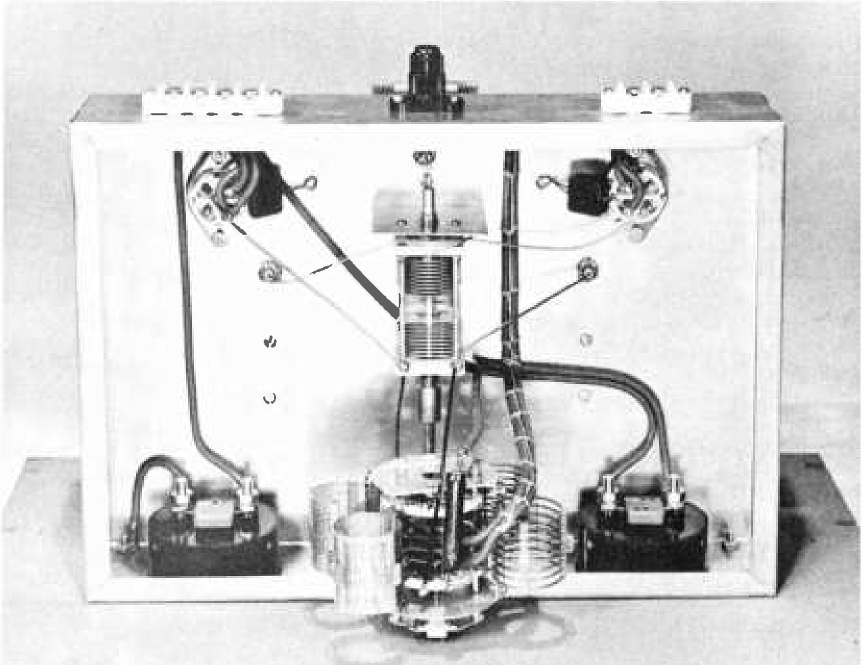


Figure 13.
PUSH-PULL GENERAL-PURPOSE AMPLIFIER, UNDERCHASSIS.

Underchassis view of the push-pull general-purpose amplifier. The leads passing through the small ceramic feed-through bushings (Millen 32150) connect to the grid side of the neutralizing capacitors above the chassis. The laced pair of wires carry excitation energy from the two-terminal strip on the right rear of the chassis to the grid coil turret.

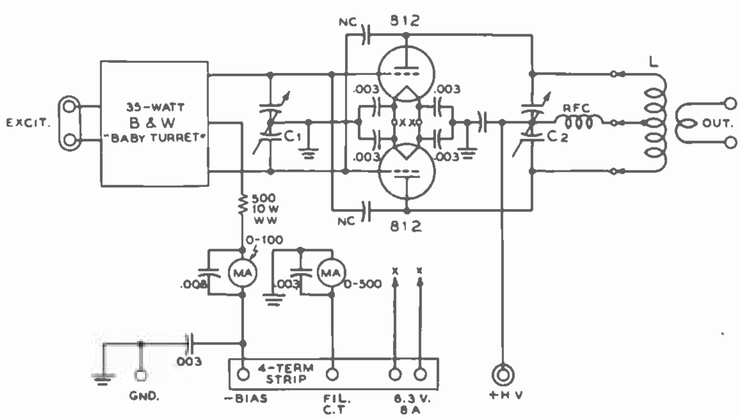


Figure 14.
PUSH-PULL GENERAL-PURPOSE AMPLIFIER, SCHEMATIC.

C_1—100-μμfd. per section, split stator (Millen 23100)
C_2—100-μμfd. per section, small butterfly (B&W JCX-100E)
RFC—500-ma. all-band r-f choke (Millen 34140)
L—Variable-link plug-in coils (B&W type BVL)
NC—Neutralizing capacitors (Millen 15011)
Milliammeters—Marion 53SN

mounted in the center of the chassis for connecting the high-voltage plate supply to the unit. Excitation to the amplifier is fed to a two-terminal ceramic strip on the right-hand edge of the rear drop of the chassis.

The two tube sockets for the amplifier are sub-mounted by means of ½-inch ceramic pillar insulators. Neutralizing capacitors are mounted directly upon the chassis alongside the plate tuning capacitor. Connections from the neutralizing capacitor to the grids of the tubes are run through the chassis in small ceramic bushings. The r-f choke for the plate circuit of the final amplifier is supported above the chassis by means of a 1-inch ceramic pillar insulator.

Tank Circuits Manufactured assemblies are used throughout for both the grid and plate tank circuits of the amplifier. A B&W type JTCL 35-watt turret is used to afford bandswitching in the grid circuit. The grid tuning capacitor is a Millen 23100. The plate tank capacitor is a B&W type JCX-100E, and B&W BVL series tank coils are used for all bands in the plate circuit.

Operating Conditions The 500-ohm 10-watt wire-wound resistor in series with the grid return of the amplifier acts to furnish a portion of the grid-leak bias required and in addition acts as a low Q r-f choke. The excitation requirements of the amplifier depend upon the particular tubes chosen for use in the stage. These requiremnts will vary from approximately 10 watts for a pair of 809's to approximately 25 watts for a pair of 8005 triodes. The amplifier may either be plate modulated or operated as a c-w stage. In the event that plate modulation is to be used, the plate voltage on the tubes should be limited to 1250 volts. For c-w or FM operation up to 1500 volts may be used on the stage.

General-Purpose 35TG Amplifier

A single-ended stage with a tube of the general class of the 35TG makes a convenient amplifier in the 125 to 200 watt range. The amplifier unit shown in figures 15 through 18 covers the frequency range from 3.5 through 54 Mc. Normal operating plate voltage is 1500. Plate current should be limited to 125 ma. on high-level AM but may be increased to 150 ma. for c-w or FM operation.

A triode tube is ordinarily quite satisfactory for use in the 150-watt power range since the power output of the average v.f.o. is usually quite adequate to furnish excitation. An excitation power of 4 to 10 watts is ample for normal operation of a single 35TG, HK-54, 8005, 809, 811, 812A, 5514, or 812H.

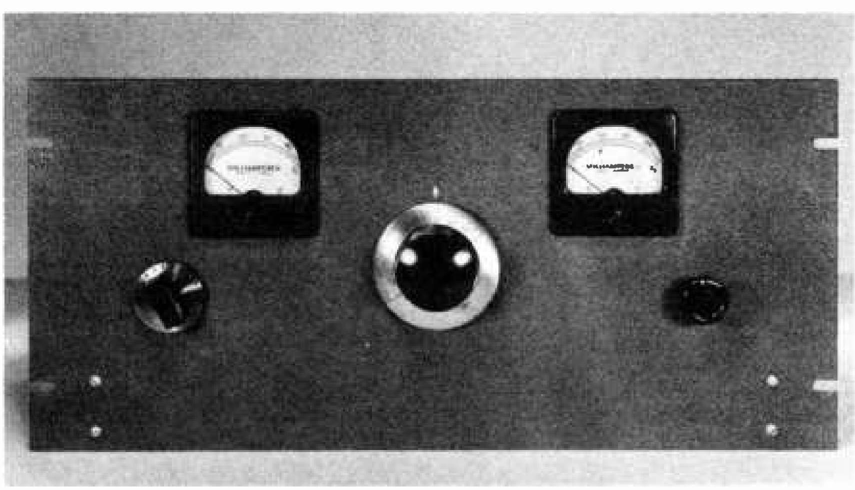


Figure 15.
PANEL VIEW OF THE 35TG AMPLIFIER.

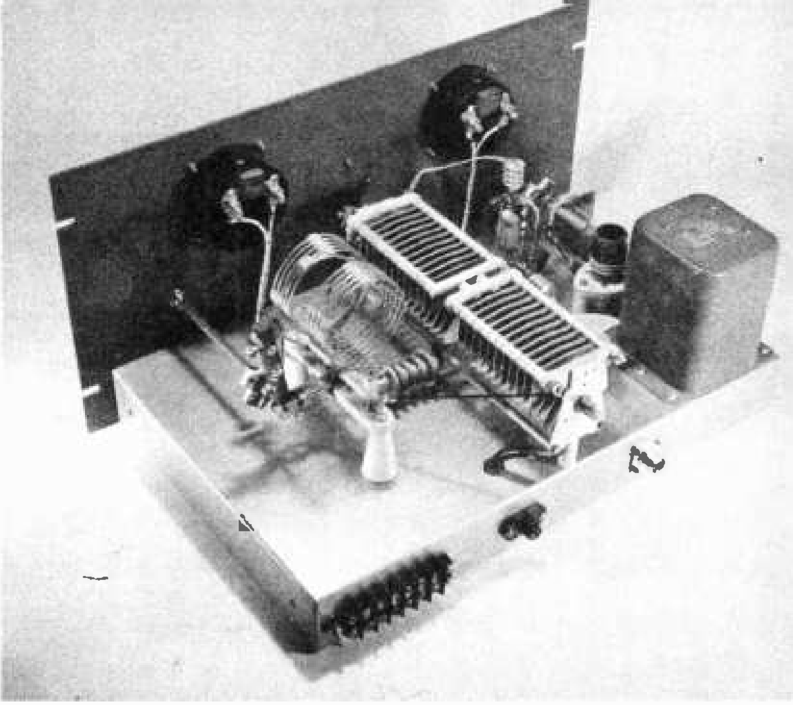


Figure 16.
REAR OF THE 35TG AMPLIFIER.
The 14-Mc. coils are in place in this photograph.

The 15-watt output of the average v.f.o. is sufficient to drive these tubes, so it is not necessary to go to the added expense and circuit complication involved in installing a beam-tetrode tube for this power range. Normal grid current of 30 to 45 ma. to the 35TG is obtained with the bias circuit shown and with about 8 watts of driving power.

The fixed-minimum bias supply for the 35TG is included on the chassis. The supply consists merely of a back-connected 6.3-volt filament transformer operating into a miniature 75 ma. selenium rectifier. The 5-volt 6-ampere filament transformer which lights the 35TG also supplies current to the 6.3-volt winding of the back-connected miniature filament transformer. The output voltage of the bias pack is about −65 volts, an amount sufficient to cut off plate current on the 35TG with plate voltages up to 2000 in the absence of excitation.

The bias supply return is made to the center tap of the filament transformer, while a 0-250 d-c milliammeter is connected between the filament center tap and ground. Through this arrangement the plate current only is indicated on the 0-250 milliammeter, while grid current indicates on the 0-50 milliammeter in the grid return. The circuit offers the advantage of having the plate mil-

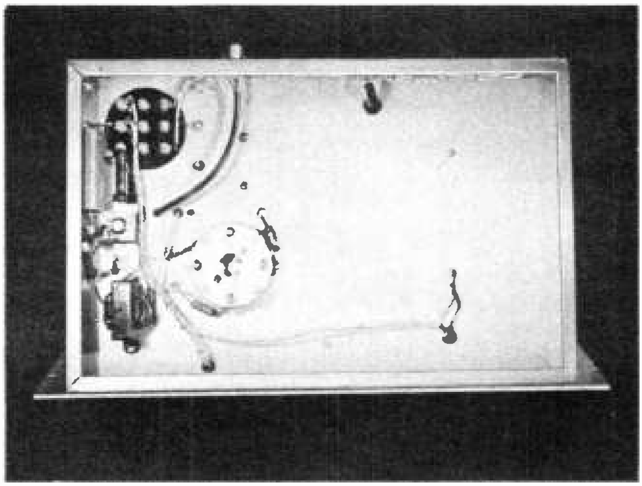


Figure 17.
35TG AMPLIFIER UNDERCHASSIS.
Note that all r-f components are mounted above the chassis.

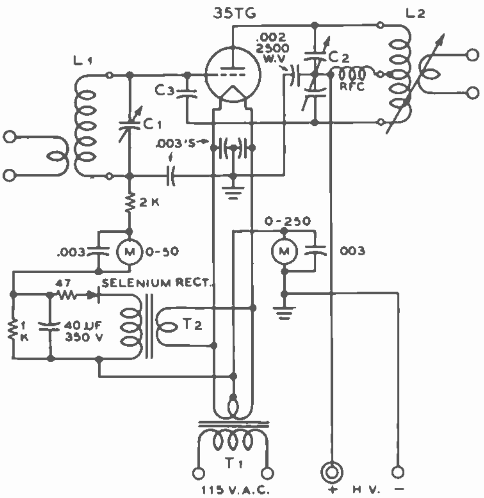


Figure 18.
SCHEMATIC OF THE 35TG AMPLIFIER STAGE.

C_1—100-μμfd. variable (Johnson 100H15)
C_2—100-μμfd. per section, 0.125" spacing (Johnson 100ED45)
C_3—Neutralizing capacitor: made of two aluminum plates approximately the same size as those in the plate tank capacitor, C_2, spaced about ¼ inch; top plate is rotatable to neutralize.
L_1—Grid coils same as those given under L_1 in figure 4, this chapter.
L_2—B&W type BVL coils for desired bands—plug into B&W stock no. 3229 swinging-link jack bar for BVL coils. A split sleeve is placed over the shaft for the swinging link so that a standard ¼" shaft coupling may be used between the link shaft and the panel control.
Milliammeters—Marion type 535N
T_1—5-volt 5-ampere filament transformer
T_2—Back connected 6.3-volt 1.2 ampere filament transformer (UTC FT-2)

liammeter at ground potential, yet the grid current of the stage does not pass through the milliammeter in the cathode.

Construction The neutralizing capacitor for the 35TG easily may be home constructed since a maximum capacitance of only 1.8 μμfd. is required. In this case it was made up of a rotor plate from a discarded variable capacitor plus a triangular piece about 2¾ inches on a side cut from aluminum sheet. The spacing between the two plates is about ¼ inch. Adjustment of neutralizing capacitance is accomplished by rotating the upper plate of the capacitor.

A provision in this amplifier which adds to its operating convenience is the fact that the control for the variable output coupling link is brought out to the front panel. The layout of components on the 10 by 17 by 3 inch chassis was juggled until the shaft for this control reached the front panel symmetrically with respect to the shaft for the grid-circuit tuning capacitor.

The plate circuit tuning capacitor is centered on the chassis, with a National AM dial controlling its rotation. Meters again are placed symmetrically with respect to the other controls on the 8¾ by 19 inch dural panel. Grid circuit coils are plug in, with the socket for these coils mounted above chassis to shorten the leads to the grid tuning capacitor and to the grid of the amplifier tube.

Grounded-Grid 304TL Amplifier

The 304TL tube is capable of operating as an r-f amplifier of the conventional type with the full kilowatt input permitted amateur stations. The tube is characterized by an enormous reserve of filament emission, resulting from the fact that about 130 watts of power is required merely to light the four filaments. Where the heavy filament drain, plus the low amplification factor of about 10, do not impose hardship in the design of the transmitter, the 304TL is quite satisfactory for amateur service.

The 304TL may, of course, be operated in the conventional manner as either a single-ended or push-pull r-f amplifier. No difficulty has been encountered by many amateurs using either one tube or a pair with full input at frequencies including the 28-Mc. band. But the 304TL offers an additional feature in that its plate-to-cathode capacitance is very low (about 0.6 μμfd.) for a tube of its size and power handling capabilities. This feature permits the tube to be operated, without neutralization, as a grounded-grid r-f power amplifier.

Characteristics of Grounded-Grid Operation The theory and design of grounded-grid r-f power amplifiers has been discussed in some detail in the chapter *Vacuum Tube Amplifiers* in the 11th edition of the RADIO HANDBOOK. Actually, a set of operating conditions is derived mathematically for a 304TL operating with one kilowatt input at a plate potential of 2700 volts. Operating grid bias is −385 volts and grid current is 58 ma. Although the excitation power of the tube is only 27.5 watts (which

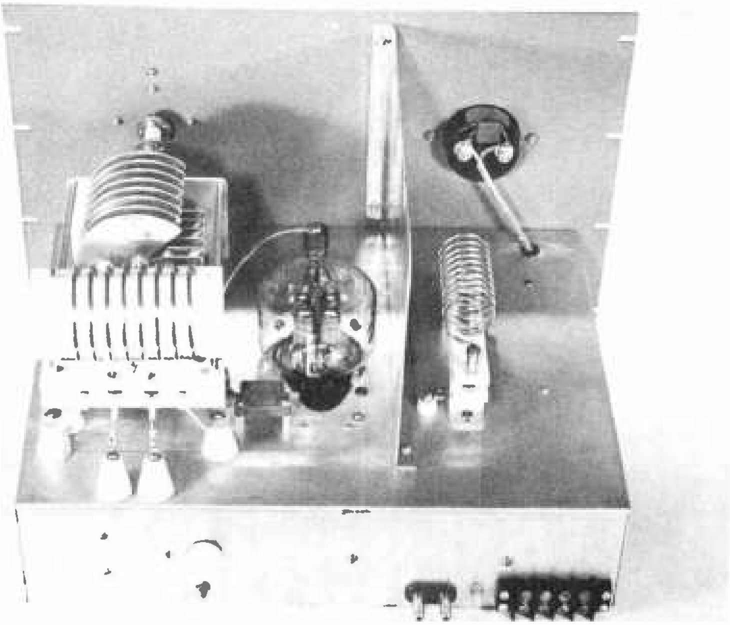


Figure 19
REAR OF THE GROUNDED-GRID AMPLIFIER.

would be the actual driving power required if the tube were operating as a neutralized amplifier) the driving power required into the cathode circuit from the exciter is about 200 watts. The extra 170 watts or so is not lost, however, since it appears directly in the output of the amplifier as additional energy. Thus while the 304TL itself will deliver about 850 watts to the load circuit, the extra 170 watts supplied by the driver over and above the 27.5 watts required to excite the 304TL appears added to the 850-watt output of the 304TL. Thus the total output of the stage would be about 1020 watts, even though the d-c input to the 304TL was only one kilowatt. Nevertheless, the tube itself operates only at its normal plate-circuit efficiency, the extra power output coming directly from the added excitation power taken from the driver.

Since 15 to 20 per cent of the output from a grounded-grid r-f stage passes directly through it from the driver, it is obvious that conventional plate modulation of the output stage only will give incomplete modulation. In fact, if the plate voltage is completely removed from the g-g (grounded-grid) stage and the plate return is grounded, the energy from the driver will pass directly through the tube and appear in the output circuit. So it becomes necessary to apply modulation to the driver tube simultaneously to that which is applied to the plate of the g-g stage. It is normal practice in commercial applications to modulate the driver stage about 60 per cent as much as the g-g stage.

For straight c-w or FM operation no special considerations are involved in the use of a g-g power amplifier—except that for c-w it obviously is necessary that the driver stage be keyed simultaneously with the final amplifier, if the installation is such that the final amplifier is to be keyed. With excitation keying the combination of the driver and output stage will operate quite normally. The g-g power amplifier is particularly well suited to use as a class B linear amplifier to build up the output of a lower powered transmitter. Operating conditions are essentially the same as those of a conventional linear amplifier, in that the plate-voltage swing on the tube under

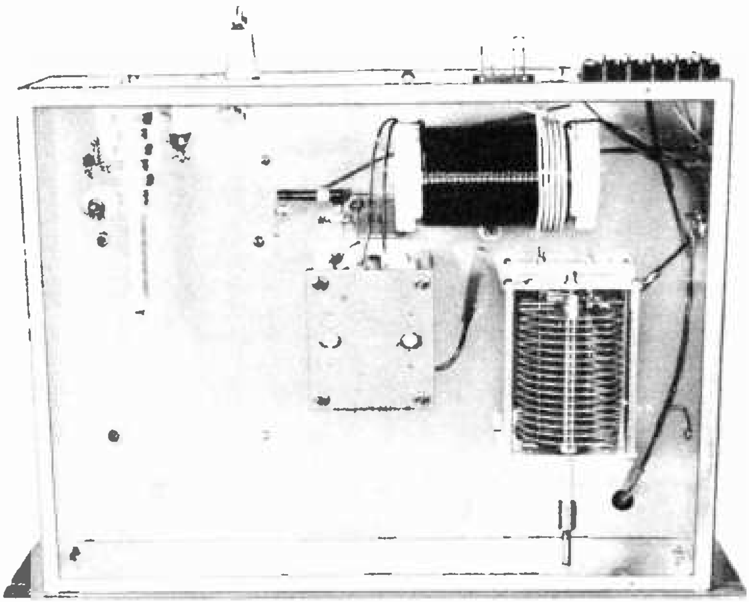


Figure 20.
UNDERCHASSIS OF THE 304TL G-G AMPLIFIER.

carrier conditions is equal to one-half the value at the positive peak of modulation. Two advantages obtained through the use of a g-g stage as a class B linear amplifier are the facts that no swamping is required in the input circuit of the g-g stage, and nearly the full output of the exciter transmitter appears in the output of the g-g stage, being added to the output of the g-g amplifier.

Circuit Description The amplifier stage shown in figures 19, 20, and 21 was constructed to exemplify the design of a grounded-grid power amplifier for use in the amateur high-frequency bands. Two features characterize the appearance of a g-g power amplifier as compared to a conventional neutralized stage. The first is the relative simplicity of the plate circuit; its appearance is essentially the same as that of a single-ended beam-tetrode amplifier circuit. The second is the relative complexity of the "grid" or cathode circuit. The plate circuit is simple since no provision is required for neutralizing the tube. The grounded (for r.f.) grid serves to shield the input from the output circuit. The cathode circuit is relatively large since it must be capable of handling about 20 per cent as much power as the plate circuit, and since the filament of the tube must be operated at a relatively high r-f voltage with respect to ground.

In the amplifier illustrated a bifilar wound coil is used to feed the filament voltage to the 304TL tube. Two parallel strands of no. 12 enameled wire are wound side-by-side for the full length of the National XR-10A coil form. Two filament sections of the 304TL were connected in series in the unit shown to reduce the filament current which must pass through the filament coil. With the filaments connected in this manner the tube requires 10 volts at 13 amperes. The loop resistance of the filament coil is about 0.05 ohms, which represents about 0.6 volts drop at the 13-ampere drain. Hence the filament transformer for the tube should deliver between 10.5 and 11 volts to insure that the 304TL will receive its rated 10 volts plus or minus 10 per cent.

Both ends of the coil are by-passed in the manner shown in figure 21 to constrain the r-f currents into the desired paths. For operation on the 3.5-Mc. band the bifilar cathode

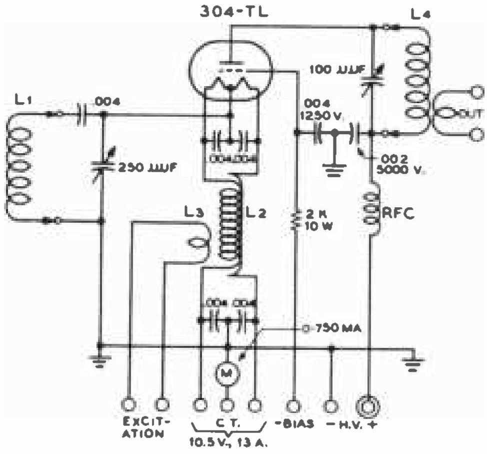


Figure 21.

SCHEMATIC OF THE 304TL G-G AMPLIFIER.

Grid tuning capacitor—National TMC-250
Plate tuning capacitor—National TMA-100A
L_1—None required for 3.5 Mc., since cathode coil L_2 tunes to 3.5 Mc.
7 Mc.—20 turns no. 14 enam., 1¼" dia. by 3" long.
14 Mc.—10 turns no. 8 bare, 1¼" dia. by 3" long
L_2—Two parallel lengths of no. 12 enam. close-wound to fill National type XR-10A coil form. 25 turns of the two wires in parallel.
L_3—5-turn link of no. 16 rubber and cotton covered wire.
L_4—3.5 Mc.: 26 turns no. 12 enam.; Nat. XR-10A form wound full, 4 t. link
7 Mc.: 14 turns no. 12 enam.; Nat. XR-10A form, 3 t. link
14 Mc.: 8 turns no. 8 bare; Nat. XR-10A form, 2 t. link
RFC—800-ma. r-f choke (National R-175)

coil serves in itself to tune to resonance with the 250 µµfd. tuning capacitor. For operation on the higher frequency bands it is necessary to parallel the filament coil with additional inductors to reduce the effective inductance. However, it was found sufficient to couple the excitation link into the cathode coil only for all bands. This is illustrated on the schematic.

The plate tank circuit for the amplifier is conventional for a stage in which provision for neutralization is not required. However, it must be remembered that the peak r-f voltage across the plate tank is greater than would be the case for a conventional amplifier operating at the same plate voltage. This is a result of the fact that the r-f cathode swing is added to the r-f plate-to-cathode swing as far as the plate tank coil is concerned. This means that the r-f peak swing across the plate tank circuit will be 10 to 20 per cent greater than the d-c plate voltage on the stage.

Tuning Procedure The tuning procedure for a grounded-grid r-f power amplifier is somewhat different and less straightforward than that of a conventional amplifier. The main difference results from the fact that the input tuned circuit is effectively in series with the output circuit as far as the output energy is concerned. Thus it is not possible to apply full excitation power to the stage unless plate current also is flowing. If full excitation were applied in the absence of plate voltage on the amplifier, the grid of the output tube would be damaged from excessive excitation.

The following tuning procedure has been found satisfactory in practice: Remove plate voltage from the g-g stage. Apply *reduced* excitation to the cathode circuit and tune to resonance as indicated by the grid milliammeter. Then tune the plate circuit to resonance by noting the change in grid current, *and in plate current,* when the plate tank is resonated. Note that a moderate amount of plate current will flow, as a result of the excitation voltage, even without plate voltage on the stage. Actually, quite high values of plate current will flow if the plate return of the final amplifier is grounded.

The procedure in the paragraph above will allow the resonant points for both the grid and plate tank circuits to be obtained and noted. Now apply a moderate amount of antenna coupling to the plate circuit of the final amplifier, apply plate voltage, and apply the excitation. It is assumed that fixed bias at least equal to cutoff is being applied to the grid of the g-g tube. The first thing that will be noticed with plate voltage and antenna coupling to the stage is that it is very difficult to excite. Where a relatively large amount of grid current might have been flowing before plate voltage and antenna coupling were applied, the grid current now will probably be very small or non-existent. Now increase the power output of the driver to the point where a moderate amount of grid current is flowing to the g-g stage. Peak the cathode circuit for maximum grid current, and peak the plate tank circuit for both maximum grid current and minimum plate current. Now make adjustments in antenna coupling and excitation coupling until normal input, output, and grid and plate currents are obtained.

It will be noticed that an increase in antenna coupling will make a moderate decrease in grid current as well as an increase in plate current.

After all the adjustments have been made, it will be found that quite good plate-circuit efficiency along with stable operation will be obtained in the amplifier. Unusually good stability and freedom from parasitics are characteristic of the grounded-grid r-f power amplifier. However, it is possible to make a g-g amplifier stage take off and oscillate on its own accord by detuning the cathode circuit considerably from resonance. When the amplifier is tuned for normal operation, however, it will be found to be quite stable and free from any tendency toward self oscillation. The comparative freedom from tendencies toward self oscillation can be attributed to the relatively low power sensitivity of the g-g amplifier. A relatively large amount of excitation power is required to excite such an amplifier; hence it is difficult for the stage to excite itself. The g-g amplifier is at the opposite end of the power-sensitivity scale from the beam-tetrode r-f amplifier.

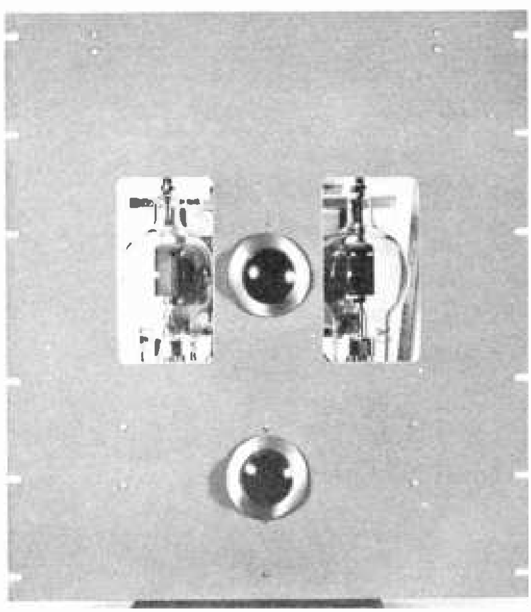
Construction Although there are several mechanical features that could be improved in the experimental amplifier illustrated, its construction does illustrate several design features which are desirable for a grounded-grid stage. First, note that the socket for the 304TL has been submounted by means of 3½-inch brackets so that the internal shield of the tube is at chassis level. This depth, in addition to the depth of the cathode tank circuit, requires the use of a chassis with a 4-inch depth. The one actually used is a standard aluminum chassis pan (ICA no. 29026) with dimensions 13 by 17 by 4 inches. Major cathode-circuit components are mounted under the chassis. For the sake of convenience, the accessory cathode-circuit tank coils for bands other than 3.5 Mc. are mounted on the top of the chassis. This top mounting of the accessory coils requires the use of a shield between the two coils mounted atop the chassis. If there is no mechanical objection to inserting the various cathode-circuit coils from below the chassis, a considerably smaller amplifier may be constructed.

One-Kilowatt 250TH Amplifier

Shown in figures 22, 23, and 24 is a one-kilowatt amplifier using a pair of 250TH tubes in push-pull. The plate tank circuit uses a B&W type CX40A-N3 butterfly tank capacitor with B&W type HDVL coils. The tank capacitor will tune the standard coils for the 10, 15, 20, and 40 meter bands without added padding. However, it is necessary to add a 25-$\mu\mu$fd. fixed vacuum capacitor across the 80-meter coil for proper tuning of the entire band. The "N3" suffix on the tank capacitor designation indicates that neutralizing capacitors suitable for use with the 250TH tubes are included as a part of the main tuning capacitor.

As is evident from the top-view photograph, figure 23, it is necessary to do some minor rebuilding of the butterfly tank capacitor in order to have the neutralizing plates at the front of the capacitor instead of at the rear. The procedure is as follows: Remove both end plates and the rotor assembly from the capacitor. Remove the neutralizing-capacitor assemblies from the rear end plate and reinstall them with the ceramic on the opposite side of the front (the one which has the sleeve bearing) end plate. Reverse the rotor end-for-end, dis-assemble it and move the spacers until its plates will fall between the stator plates, and reinstall it with the two end plates on the opposite ends of the stator assembly

Figure 22.
FRONT-PANEL VIEW
OF THE 250TH AMPLIFIER.



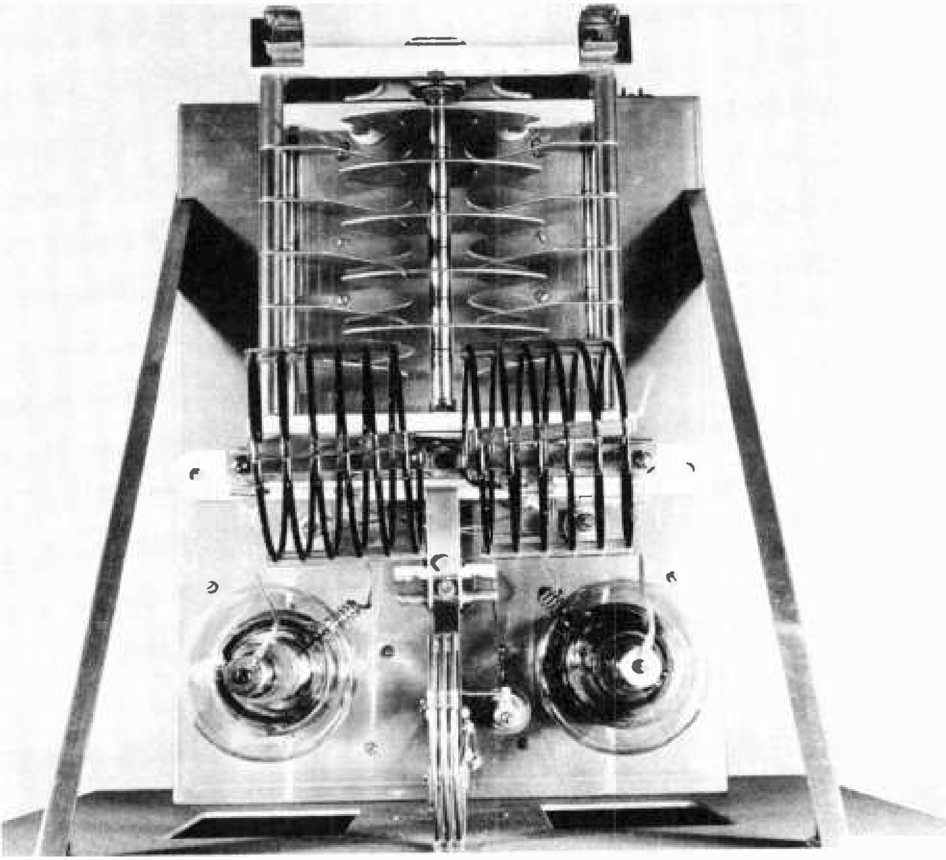


Figure 23.
LOOKING DIRECTLY DOWN ON THE 250TH AMPLIFIER.
It was necessary to dis-assemble and re-assemble the main tuning capacitor to place the neutralizing plates next to the tubes at the front. Procedure is given in the text.

from the original position. The capacitor should re-assemble quite easily. A small amount of adjustment of the thrust bearing and the thrust sleeve probably will be necessary to center the rotor plates exactly between the stator plates.

Through this dis-assembly and re-assembly procedure it is possible to install the tuning capacitor and tank assembly to the rear of the 250TH tubes and still maintain very short leads between the tube elements and the connections which the elements make to the stator and to the neutralizing plates of the main tuning capacitor. By having the amplifier tubes at the front of the amplifier chassis it is prac-t:cable to cut viewing windows in the panel so that the plate temperature of the 250TH's may be monitored. The clips for the vacuum padder capacitor can be seen on the rear of the main tuning capacitor.

The underchassis photograph shows the use of a National MB-150 all-band tank assembly as the grid tuned circuit for the amplifier tubes. Although this tank assembly originally was designed to be used in the plate circuit of an amplifier, it serves equally well as the grid tank of a high-power amplifier. The same advantages are obtained as though the tank assembly were used in the plate circuit of a smaller amplifier; it is necessary only to tune the dial on the front panel (National type AM) to resonate the grid circuit on all

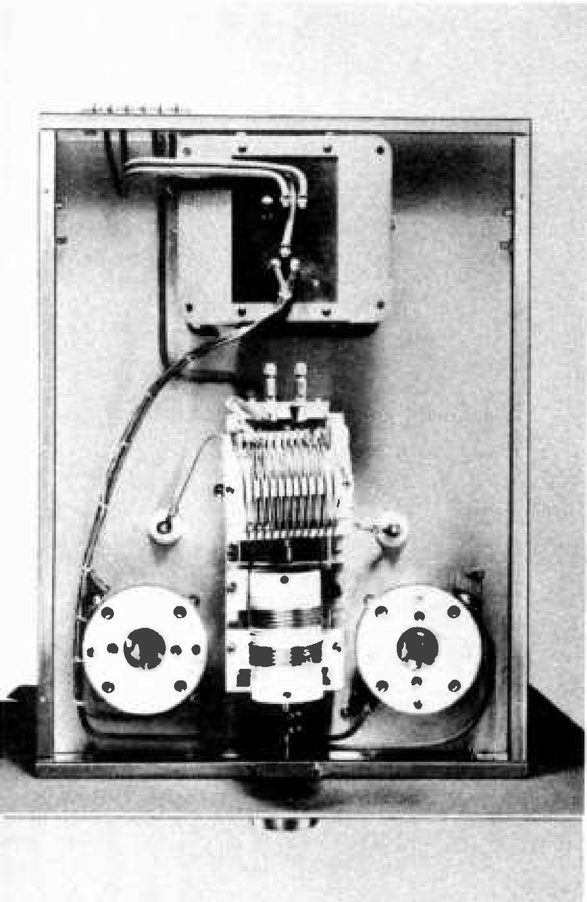


Figure 24.

250TH AMPLIFIER UNDERCHASSIS.

Note the use of a National MB-150 all-band tank assembly as the grid tuned circuit for the amplifier. The two ceramic feed-through insulators behind the tube sockets are connected to the grid leads of the tubes on the top of the chassis.

amateur bands from 3.5 through 29.7 Mc. The 150-watt rating of the National tank assembly is more than adequate to handle the amount of r-f excitation which must be supplied to the grids of the 250TH tubes. The grid-bias return for the amplifier tubes is taken off from the r-f choke on the tank assembly which serves as the plate-circuit r-f choke when the tank is used in the plate circuit of an amplifier. Note that the frame of the MB-150 tank assembly must be insulated from the chassis by the ceramic pillars supplied with it.

The filaments of the 250TH tubes are connected in parallel with the center-tap of the filament transformer brought out to the rear of the chassis for external metering of the cathode current. The grid return of the amplifier is also brought out to a terminal on the rear, for the external insertion of a grid-current milliammeter in the lead to the grid-bias source. If the return of the grid-bias source is made to the filament center-tap lead of the amplifier, rather than directly to ground, the grid current will be prevented from flowing through the milliammeter in the cathode return of the stage. When the grid return is made directly to the cathode in this manner the cathode milliammeter of the stage will indicate only the plate current flowing to the 250TH tubes. Note, from the underchassis photograph, that each filament terminal of each 250TH tube socket is by-passed to ground through a short lead to the chassis. Small mica capacitors with a capacitance of 0.0068 μfd. and a voltage rating of 500 volts are used.

The amplifier is constructed on a 13 by 17 by 3 inch aluminum chassis which is supported from a 21 by 19 inch standard dural panel. Note that the chassis is mounted so that it has the greatest depth behind the panel. This type of mounting was necessitated in order to be able to mount the components in the manner shown. Two angle struts running from approximately the top of the panel to the rear of the chassis give the complete assembly an adequate degree of rigidity. The struts are bent up in a sheet-metal shop from 0.051 inch half-hard dural sheet and are one-half inch wide by one inch deep.

It was found necessary to have the neutralizing plates retracted to a position such that the front surface of the plates was about flush with the rear surface of the ceramic stator-support bars of the stator of the capacitor. Hence it is necessary that the ceramic strips which support the neutralizing plates be mounted on the *front* side of the aluminum end plates of the capacitor. With the neutralizing plates in this position, perfect neutralization was obtained on all bands from 3.5 through 29.7 Mc. Normal grid current to the amplifier is 150 ma. with 180 volts of bias. Plate current runs 330 ma. at 3000 volts. A power output of 50 watts from the stage which is to excite the 250TH amplifier will be found adequate for c.w., FM, or high-level plate modulation. Higher values of grid bias and greater exciting power are likely to result

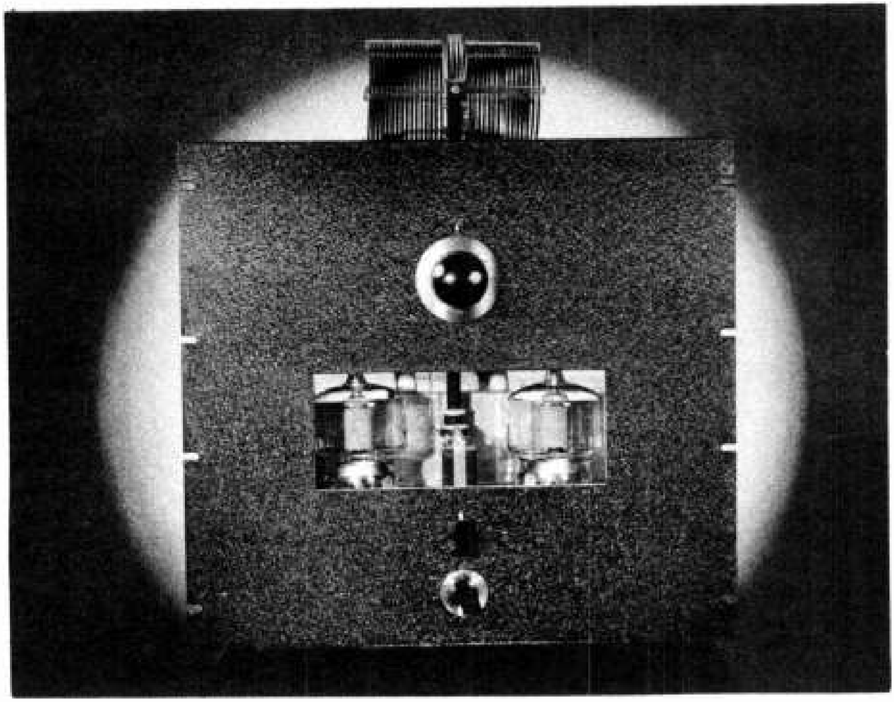


Figure 25.
FRONT OF THE PUSH-PULL 4-250A AMPLIFIER.

in the generation and radiation of an excessive amount of harmonic energy.

When operating in an area in which TVI is likely to be encountered, it will be found necessary to take extreme measures to eliminate the last amount of harmonic signal which will be generated in an amplifier of this type. Extensive discussions of procedures for the reduction of TVI have appeared in the periodicals catering to the amateur. But in any event it will be found necessary to shield completely all r-f stages of the transmitter, with particular attention being paid to the final amplifier and to the driver stage of an amplifier which requires as much driving power as the 250TH amplifier described. Then all leads entering the shielding enclosure for the transmitter must be choked and filtered where they leave the housing. Then, the output energy from the plate circuit of the final amplifier must be fed through a coaxial cable to an external tuned-circuit antenna coupler which is mounted in a shielded box. The coupling of the signal from the coaxial cable to the antenna-coupling tank circuit should be by a link coil with a carefully grounded Faraday shield to prevent capacitive coupling of harmonic energy from the inner conductor of the coaxial cable to the antenna circuit. Through the use of procedures such as these it is possible to obtain TVI-free operation beyond a reasonable radius from a high-power transmitter using an amplifier such as that just described.

Push-Pull 4-250A Kilowatt Amplifier

The low driving-power requirements of the Eimac 4-250A tetrode make possible the construction of a kilowatt transmitter in a relatively small space. The high power sensitivity of the tubes in turn makes it necessary that special precautions be taken in regard to shielding and parasitic elimination. But when these precautions have been taken into account in the construction and adjustment of an amplifier, the resulting piece of equipment can truly be a thing of pleasure and satisfaction to operate.

Figures 25, 26, and 27 illustrate a push-pull 4-250A amplifier which is the direct result of experience gained in the construction and operation of a whole series of basically similar push-pull 4-250A stages. All tendency toward parasitic oscillation in the stage has been eliminated. In fact, the amplifier was operated for a considerable period of time on both the 3.9-Mc. and 14-Mc. phone bands as a class B linear amplifier for a single-sideband phone signal. The operating conditions were such that the standing plate current on the stage was approximately 100 ma. in the absence of signal, with 3000 volts on the plates, 500 volts on the screens, and a grid bias of about −95 volts. A set of operating conditions such as this will certainly show up any tendency toward parasitic oscillation or instability in a stage. Yet completely stable operation was obtained under all types of operating conditions.

The stage normally operates on either c.w. or phone with 25 to 35 ma. of grid current. Grid bias of about −200 volts is satisfactory for c.w. or FM but −300 to −325 volts is best for plate-modulated phone. Screen voltage is 450 at about 60 ma. of screen current and plate voltage is 3000 at 330 ma. Under these operating conditions the tubes show no visible color in a brightly lighted room. In a darkened room the dull cherry red color of the plates becomes visible.

To obtain the operating conditions specified above requires about 5 to 8 watts of driving power at the grids of the 4-250A's. To allow for coupling and tank circuit losses the exciter for the stage should have a power output of about 15 watts. The 2E26 tube operating with about 400 volts on its plate is ideally suited for use in the output stage of the exciter for this amplifier.

Several commercially manufactured v-f-o exciters with this level of power output are available, or either of the v-f-o exciters with Collins 70E8 oscillator and 2E26 final amplifier shown in *Chapter Three* is suitable. In fact, the amplifier was operated for several months first with the simpler of the two ex-

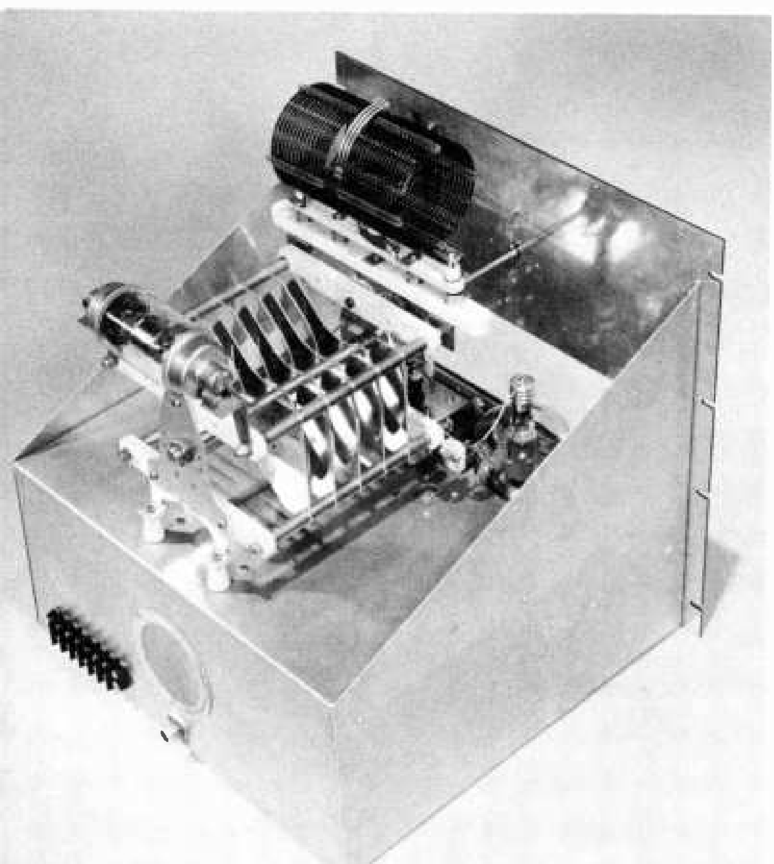


Figure 26.

THREE-QUARTER VIEW OF THE 4-250A AMPLIFIER.

The 3.5-Mc. coil and 25-μμfd. vacuum capacitor are in place in this photograph. The vacuum capacitor is not used for operation of the amplifier on the higher frequency bands.

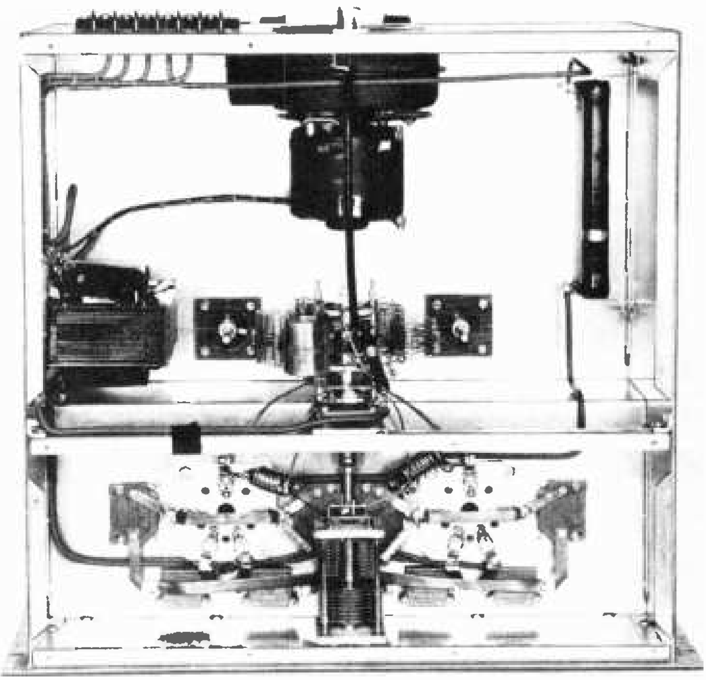


Figure 27.
UNDERCHASSIS OF THE 4-250A AMPLIFIER.
Note the use of heavy copper strap in the by-pass circuits. The Ohmite P-300 parasitic chokes in leads from the grid tuning capacitor to the grids of the tubes can be seen. Also note the feed-through type neutralizing capacitor rods on either side of the grid turret. The blower and filament transformer also are mounted below the chassis.

citers and then with the band-pass model. The final amplifier with its power supplies and power-control circuits was located in the garage, while the v.f.o. was about 50 feet away at the operating position in the house. Fifty feet of RG-8/U coaxial cable carried the excitation power from the exciter unit to the grids of the 4-250A stage. Completely satisfactory operation was obtained, with adequate grid excitation on all bands.

Circuit Description The circuit is quite conventional except in regard to the provisions used to prevent parasitic oscillation in the stage. A coaxial fitting on the rear brings the excitation through coaxial cable to the B&W BTCL bandswitching turret. The turret is modified to the extent of reducing the number of turns on the coil for the 28-Mc. band to 6 turns. The center tap on this coil is left in its original position and turns are removed from each end. A 1000-ohm, 10-watt wirewound resistor, R_1, acts to furnish a portion of the grid bias, and also serves as an r-f choke in the grid return.

The plate tank circuit is conventional with a B&W CX-40A butterfly tank capacitor and B&W HDVL coils for all bands. A 25-μμfd. vacuum capacitor is required across the 3.5-Mc. coil to hit resonance and maintain proper L to C ratio on this band. The vacuum padder capacitor plugs into a pair of standard brackets on the rear of the tank capacitor, and is needed only on the 3.5-Mc. band. It will be noted from the photograph that the brackets for mounting the jack base for the plate tank coils are mounted on the front of the butterfly capacitor instead of on the rear as is more usual. In order to obtain sufficient screw threads on the front of the capacitor it was necessary to remove the two top threaded rods which support the stator plates and to turn these rods end for end. Then the cap nuts are placed on the rear for the vacuum-capacitor brackets and the standard nuts are placed on the front on either side of the brackets for the HDVL coil-mounting base.

The screens of the 4-250A tubes are fed through a current limiting resistor. With this resistor in the circuit it is possible to apply excitation to the tubes with screen voltage present but in the absence of plate voltage and still not damage the screens of the tubes.

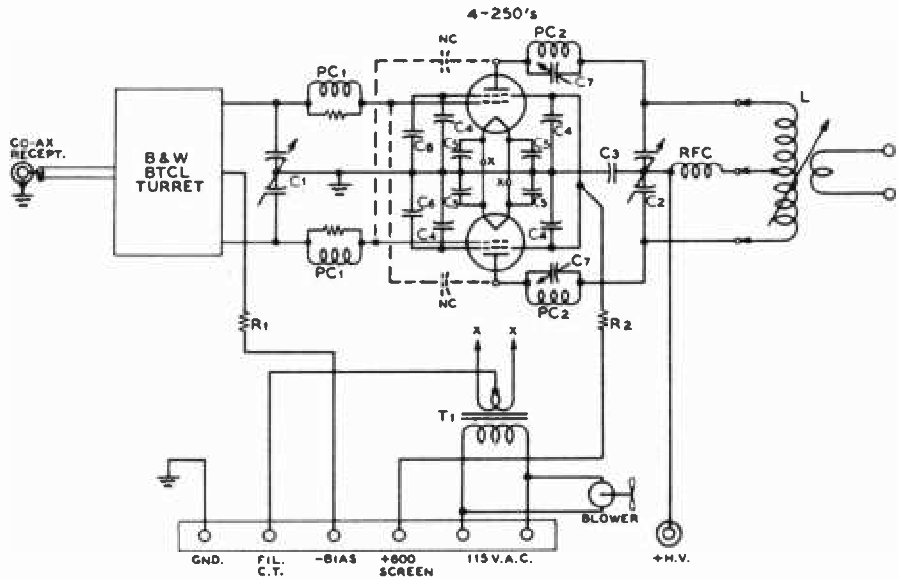


Figure 28.
SCHEMATIC OF THE 4-250A AMPLIFIER.

C_1—100-μμfd. per section split stator (Johnson 100HD15)
C_2—50-μμfd. per section, ½" gap, split stator (B&W CX-49A)
C_3—0.002-μfd. 6000-volt working mica capacitor
C_4—0.01-μfd. 1250-volt mica
C_5—0.004-μfd. 1250-volt mica
C_6—200-μμfd. ceramic by-pass
C_7—50-μμfd. APC
L—1000-watt variable-link coils (B&W HDVL series)
PC_1—Ohmite P-300 parasitic chokes (these chokes include the shunt resistors)
PC_2—6 turns no. 14 bare, ⅜" dia. by 1" long
R_1—1000 ohms 10 watts
R_2—3000 ohms 100 watts (Ohmite 0613)
RFC—800-ma. choke (National R-175)
NC—See text
T_1—5-volt 30-ampere filament transformer with primary taps

Parasitic Elimination Careful circuit layout, shielding, and wiring are necessary in an amplifier of this type in addition to the anti-parasitic provisions to attain a completely stable amplifier. The reason for this is obvious when it is considered that this amplifier is easily capable of delivering in the vicinity of one kilowatt of output with substantially no driving power. Of course the amplifier would operate with reduced efficiency with very low driving power and from 5 to 8 watts normally is used to obtain full efficiency. But the fact that the amplifier will operate with substantially no driving power points up the fact that the isolation between the output circuit and the input circuit must be extremely good to insure that the amplifier will not supply its own excitation. When it is possible for the amplifier to supply its own driving power the result, of course, is parasitic oscillation.

The most important single anti-parasitic provision is complete shielding between input and output. In the unit shown this is accomplished by placing all grid circuit components below chassis in a completely enclosed metal housing. The next consideration is that the impedance from the screen leads on the tube sockets to ground shall be very low. Four 0.01 μfd. mica by-pass capacitors from the four screen leads to the common ground point are used. Copper strip ⅜ inch in width is used in all by-pass circuits. The two screen leads of the tube socket are also strapped with this copper strip and a 200-μμfd. ceramic capacitor is connected from the closest screen terminal to the common ground point. Through this procedure the external screen inductance is minimized.

Neutralizing capacitors, cross connected in the conventional manner, are used to cancel the small residual grid-to-plate capacitance in the tube. These items are constructed by mounting clamp-type panel bearings through the center of 2 inch square pieces of dielectric material. Short lengths of ¼-inch shaft may then be pushed up and down to vary the capacitance from the ends of the shaft rod to the stators of the plate tuning capacitor. When the capacitance setting is correct there will be no reaction on grid current as the plate tank is tuned through resonance.

Connected in series with the grid lead of each 4-250A is a standard Ohmite P-300 parasitic choke. These chokes, plus the provisions described above, cured any tendency toward self-oscillation on the signal frequency. But there still was a tendency toward parasitic oscillation on about 100 Mc. This condition was completely cured by placing a small tuned circuit tuned in this range in series with the plate lead of each 4-250A. These circuits each consist of 6 turns of number 14 bare wire, wound on a ⅜ inch form and then removed from the form, and spaced to one inch. Across each coil is placed a 50-$\mu\mu$fd. APC. The setting of the APC's is not critical, any setting between about one-third and two-thirds capacitance being suitable for parasitic elimination.

Mechanical Construction The amplifier is constructed on a chassis and panel assembly which was especially designed for the job. Sets of working drawings are available for those who wish to duplicate the unit. The chassis deck has two levels; a lower level for the tubes, and a higher level upon which the tank circuit is mounted. The cooling blower, coil turret, and filament transformer are mounted below the upper chassis level. A strip of aluminum angle runs from one side of the chassis to the other to support the metal plate upon which the coil turret is mounted. The shaft for the coil turret extends through to the front panel just above the shaft for the grid tuning capacitor.

The chassis is completely enclosed by a bottom cover. The blower is mounted inside the chassis with intake on the rear and exhaust through the holes in the tube sockets and thence through the holes in the tube bases.

Shielded Kilowatt Amplifier

Figures 29 through 33 illustrate a kilowatt amplifier for the 14-Mc., 21-Mc., and 28-Mc. bands. Precautions have been taken in the

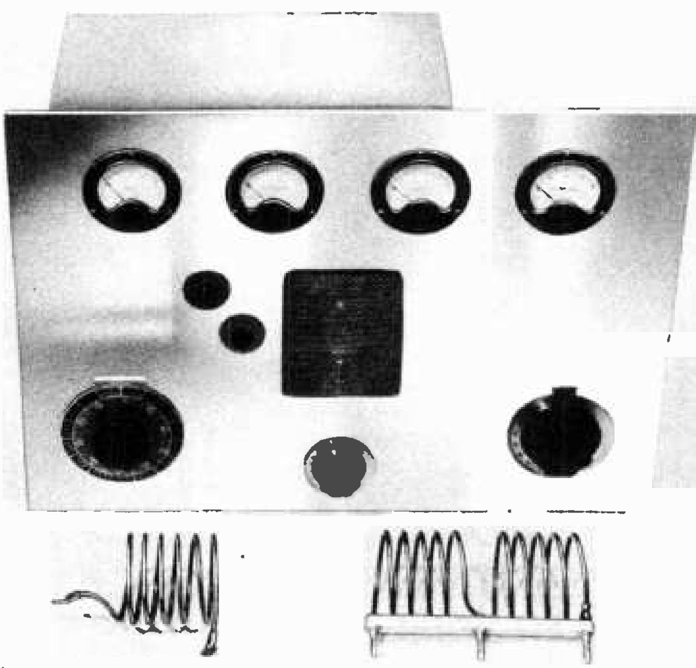


Figure 29.

FRONT VIEW OF THE SHIELDED KILOWATT AMPLIFIER.

The 14-Mc. coils for L_4 and L_7 can be seen in front of the amplifier.

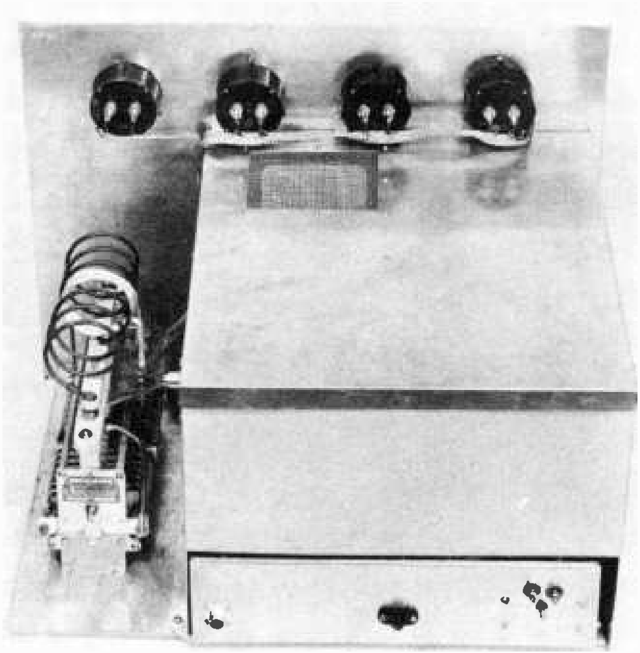


Figure 30.
REAR OF THE SHIELDED KILOWATT WITH COVER IN PLACE.

unit to afford a large reduction in the radiation of harmonics of the carrier frequency. The amplifier uses an Eimac 4-400A power tetrode in a single-ended circuit, though it also operates satisfactorily with 4-250A or 4-125A tubes. The amplifier itself is completely shielded, and especial precautions have been taken to eliminate any tendency toward the generation of parasitic oscillations. The output energy from the plate tank circuit of the 4-400A is link coupled to an external antenna-coupling tank. The energy in the link circuit is passed through a completely shielded low-pass filter, with cut-off at about 50 Mc., before the output signal leaves the shielded compartment to pass through the link which couples the energy to the antenna-coupling tank. All leads entering the shielded compartment are carefully filtered to reduce the possibility of harmonic signals leaving the amplifier by power-supply leads.

Circuit of the Amplifier The tuned grid circuit of the 4-400A tube, consisting of L_1 and C_1, is designed to be fed through a coaxial cable from an external exciter unit. The exciter should be completely shielded and should be capable of delivering an output of 10 to 15 watts on each of the desired bands of operation. By trimming the number of turns in the grid coil L_1 it was possible to have it tune over the complete frequency range from 14 to 30 Mc. Hence the 20, 15, 11, and 10 meter bands are covered by the grid circuit without coil changing or coil switching.

The coupling arrangement from the grid tank circuit to the grid of the 4-400A tube was developed as an anti-parasitic measure. With the grid of the 4-400A tube returned directly to ground through the capacitance of the grid tuning capacitor C_1 there was a strong tendency for the stage to oscillate on a frequency of about 175 Mc. This condition was cured by the insertion of C_3 in series with the grid lead to the tube; the addition of this capacitor increases the series resonant frequency of the grid circuit of the 4-400A to such a high frequency that the tendency toward self-oscillation in this mode is eliminated.

The 22,000-ohm resistor across the grid circuit of the tube serves to reduce the effective Q of the resonant circuit to such a point that the tendency for self-oscillation on the operating frequency of the amplifier is eliminated. The r-f choke across this resistor serves

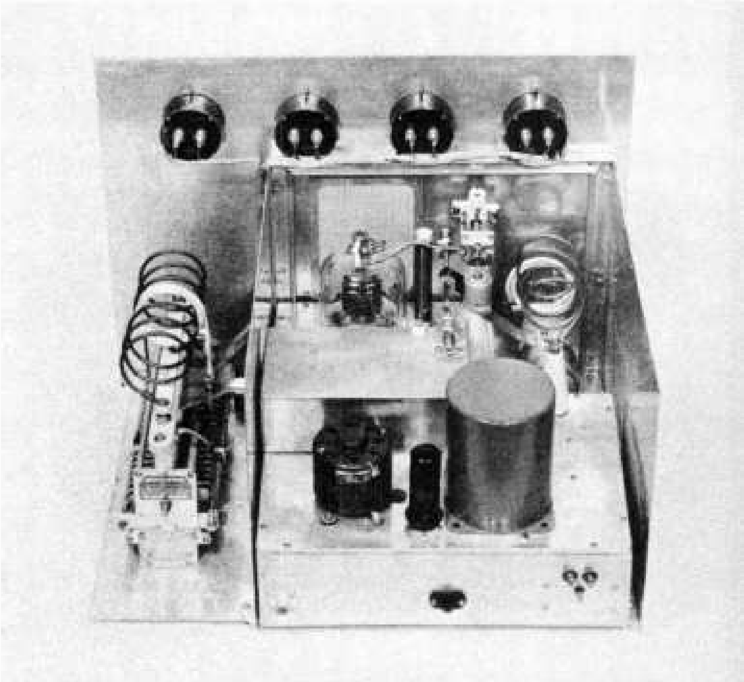


Figure 31.
REAR OF THE SHIELDED KILOWATT WITH COVER REMOVED.
The various components which go to make up the amplifier may be seen clearly in this photograph.

merely to confine all d-c voltage drop which would contribute to the bias on the 4-400A as well as on the 6L6 control tube to that which is obtained across the main 25,000-ohm grid leak. Normal grid current to the 4-400A is 9 to 12 ma. on all bands. A greater value of grid current merely increases the screen current to the tube and gives no improvement in the operating characteristics of the stage. Grid bias for the tube is obtained solely from the d-c drop across the grid leak.

Screen voltage for the 4-400A is obtained from the plate-supply voltage for the tube by means of a dropping resistor. A triode-connected 6L6 tube also is connected across the low-potential end of the screen-dropping resistor to serve as the so-called "screen-voltage puller." When excitation is removed from the grid of the 4-400A the grid bias on the 4-400A and also on the 6L6 falls to zero. The internal resistance of the 6L6 then falls to a very low value, and the drop across it falls to a value less than 50 volts. Since the screen voltage on the 4-400A also is pulled down by the action of the 6L6, plate dissipation on the 4-400A is reduced to a moderate value in the absence both of excitation and grid bias on the 4-400A. The total of plate and screen current to the 4-400A in the absence of excitation with a 3000-volt plate supply is about 110 ma., so that the dissipation of the tube is less than the maximum rated value. With normal grid current to the 4-400A, the 6L6 is biased far beyond cutoff so that it is removed from the circuit as far as any electrical effects are concerned.

One disadvantage of the method illustrated and described for obtaining screen voltage for a tetrode amplifier stage is the fact that plate voltage must never be applied to the stage until both tubes in the amplifier are up to operating temperature. If the 3000-volt plate-supply potential is applied at a time when the tubes in the stage are not heated, the full 3000 volts will appear across the 6L6 tube, the screen milliammeter, all the screen by-pass capacitors, and all the screen circuit wiring. The result of this action is almost certain to result in some sort of breakdown either in one of the components or in the wiring. Further, if plate voltage is applied to the stage in the absence of excitation and before the 6L6 has come to operating temperature, the plate current to the 4-400A will rise to an exceedingly high value. If the plate dissipation were allowed to remain at this value for more than an instant the tube could be damaged; hence it is well to have an adequate overload-protection circuit in the power supply for the final stage.

The Plate Circuit Plate voltage to the 4-400A is shunt fed by means of a single-layer r-f choke. Several chokes were tried in this position before one was found which would withstand the high peak voltage at this position over the frequency range of the amplifier. The choke is the same as is used in the plate circuit of the 813 tube in the ART-13 transmitter. It consists of 175 turns of no. 27 enamelled (chrome oxide) wire wound around a ¾-inch diameter ceramic form, with the turns spaced to a total distance of 4⅜ inches. All the other chokes tried were either of the pie-wound or sectionalized type, and one or more of the pies or sections exhibited resonance to a destructive degree either in the 14-Mc., 21-Mc., or 28-Mc. band.

The coupling capacitor from the plate of the tube to the tank circuit is a 200-$\mu\mu$fd. low-inductance ceramic capacitor with a peak-voltage rating of 7500 volts (Centralab type 851S). Connected directly to the plate cap of the tube is the small tank circuit made up of the APC C_{22} and the 3-turn coil L_2. This circuit tunes to about 125 Mc. and effectively stopped a weak tendency toward self-oscillation on about 125 Mc. with plate voltage on the stage in the absence of excitation. The trap circuit C_{23}-L_3 may be tuned over the frequency range from about 50 to 100 Mc. to assist in the quelling of harmonics in this frequency range. The shaft of the tuning capacitor for this trap circuit is brought out to the panel of the stage by means of a high-voltage flexible coupling.

The tank circuit which recives the output energy of the stage, C_{24}-L_4, uses 3/16-inch copper tubing for the coils and one of the new variable vacuum capacitors. The dial for the variable vacuum capacitor is a 15-turn unit manufactured by The Helipot Corporation of South Pasadena, California. A four-turn coil tunes both the 21-Mc. and the 28-Mc. bands while a six-turn coil tunes the 14-Mc. band. There is no reason why additional tank coils could not be constructed for operation of the amplifier on the lower-frequency amateur bands. Such a procedure, however, would require the addition of some provision for the switching into position of additional coils into the grid circuit of the 4-400A tube for the added bands.

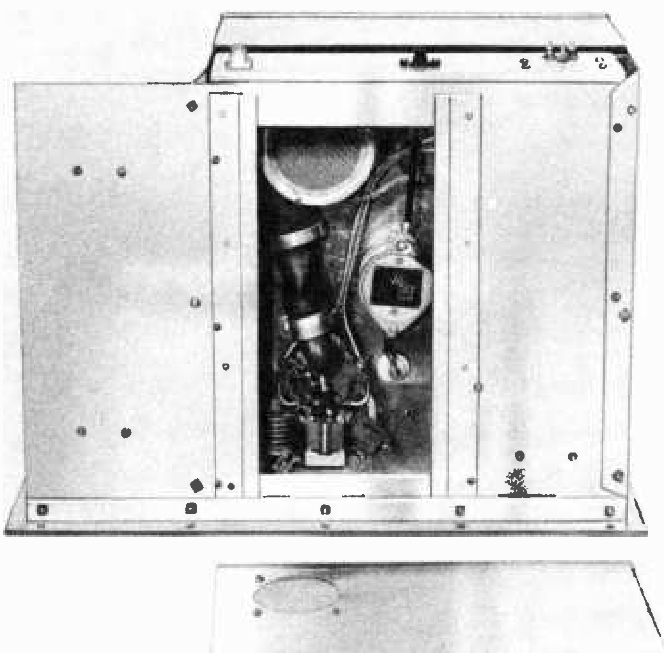


Figure 32.

UNDERSIDE OF THE AMPLIFIER WITH THE ACCESS COVER REMOVED.

The access cover can be seen in front of the amplifier. Note the mounting of the blower and the duct from it to the forced-air socket for the 4-400A tube. The 0.004-μfd. 6000-volt plate by-pass capacitor also can be seen. The grid tuned circuit is mounted on a small plate directly over the socket for the 4-400A tube.

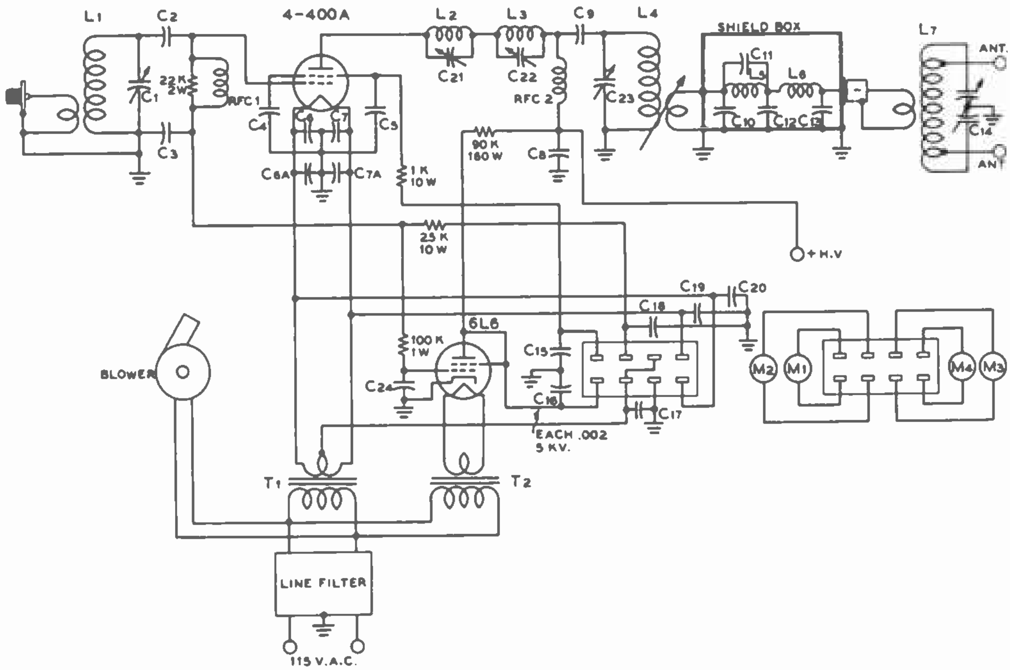


Figure 33.

SCHEMATIC OF THE SHIELDED KILOWATT AMPLIFIER.

C_1—100-μμfd. variable (Johnson 100H15)
C_2—15-μμfd. ceramic capacitor
C_3—0.001-μfd. ceramic by-pass
C_4, C_5—0.002-μufd. 5000-volt test mica
C_6, C_7—0.02-μfd. 1000-volt mica
C_6A, C_7A—0.001-μfd. ceramic by-pass
C_8—0.004-μfd. 6000-volt working mica
C_9—200-μμfd. 15,000-volt ceramic coupling capacitor. (Note: This capacitor is in the form of a cylinder 1¼" dia. by 1½" long. It may be seen mounted atop the large ceramic cone insulator in figure 31; Centralab type 851.)
C_{10}, C_{11}—40-μμfd. ceramic transmitting capacitors (Two Centralab type 853 20-μμfd. in parallel)
C_{12}—100-μμfd. ceramic transmitting type (Two Centralab type 850 50-μμfd. in parallel)
C_{13}—50-μμfd. ceramic transmitting type (Centralab type 850)
C_{14}—100-μμfd. per section 7000-volt variable (Johnson 100DD70)
C_{15}, C_{16}—0.002-μfd. 5000-volt test mica
C_{17}, C_{18}, C_{19}, C_{20}—0.001-μfd. ceramic by-pass
C_{21}—25-μμfd. APC
C_{22}—140-μμfd. small variable (Cardwell ZU-140-AS)
C_{23}—10-60 μμfd. variable vacuum capacitor (Eimac VVC-60-10)
L_1—7¼ t. no. 16 tinned, 1½" dia. by 1½" long
L_2—3 t. no. 14 bare, ½" dia. by ½" long
L_3—3 t. no. 8 bare, ⅝" dia. by 1" long
L_4—28 Mc.: 4 turns 3/16" copper tubing 2½" dia. by 4" long

14 Mc.: 6 turns 3/16" copper tubing 2½" dia. by 4" long
L_5—3 turns no. 8 bare, ¾" dia. by ¾" long
L_6—4 turns no. 8 bare, ¾" dia. by ¾" long
L_7—28 Mc.: 6 turns 3/16" copper tubing, 2-¾" dia. by 7" long

14 Mc.: 10 turns 3/16" copper tubing, 2-¾" dia. by 7" long
Link—2 turns no. 8 vinylite insulated for both.
The 90,000-ohm screen resistor is a 160-watt slider-type unit.
M_1—0-100 d-c screen milliammeter
M_2—0-15 d-c grid milliammeter
M_3—0-800 d-c cathode milliammeter
M_4—0-8 a-c filament voltmeter
T_1—5 volt 22-ampere filament transformer (UTC CG-121)
T_2—6.3-volt 1.2-ampere filament transformer (UTC FT-2)
RFC_1—2½-mh. 125-Ma. choke (National R-100U)
RFC_2—See text for discussion; special shunt-feed r-f choke
Line Filter—Solar Elim-O-Stat
Blower—1750 r-p-m centrifugal blower

Link Circuit and Filter Output from the plate circuit of the 4-400A tube is coupled into the load circuit by means of a two-turn link, with a control brought out to the front panel for physically varying the link coupling. The energy picked up by the link is fed through a low-pass filter before going to the link on the outside of the shielded compartment which couples to the antenna tank. The low-pass filter is designed to have a characteristic impedance of 50 ohms, a nominal cutoff of about 45 Mc. and a point of maximum rejection at about 56 Mc. In the event that it is particularly important that the signal on TV channel 2 be minimized, the capacitor C_{11} inside the filter box may be made up of a variable unit in parallel with a ceramic capacitor smaller than the unit specified in the schematic. It is important that ceramic capacitors of the transmitting type be used for the capacitive elements in the filter network.

Due to the particular component layout used in the amplifier, the link coil which is coupled to L_4 resonates with the distributed capacitances and the input capacitance of the filter at about 21 Mc. Hence, for use of the equipment on the 21-Mc. band it is necessary that a Centralab type 850S 50-$\mu\mu$fd. ceramic capacitor be inserted in series with the lead from the link to the input terminal of the filter, thus detuning the circuit. This is best accomplished by removing the connection from the link to the input terminal, then screwing the ceramic capacitor onto the input terminal, then attaching the lead from the link to the other end of the ceramic capacitor with a 6-32 screw. The added ceramic capacitor must be removed from the circuit for operation of the amplifier on the other two amateur bands.

Antenna Circuit The antenna-coupling circuit is simply a split-stator parallel-tuned circuit with the rotor of the tuning capacitor grounded to the frame of the amplifier. The two-turn link which couples to the coil in the antenna circuit may be varied in its coupling, but no control is brought out for varying the coupling from the front panel. The transmission line to the antenna system should be tapped onto the antenna coil if a parallel-conductor transmission line is being used. In the event that coaxial feed to the antenna system is to be employed, an additional link coil may be coupled to the center of the antenna coupling coil. The input and output links which are both coupled to the antenna circuit should be installed in such a manner that the direct coupling between them is as small as possible, so that the main coupling betwen the two coils will be that due to their mutual inductance to the large coil of the tuned tank circuit.

Metering Four meters are used to indicate the various operating conditions existing within the amplifier. The first meter on the left of the panel is a filament voltmeter for the tube. This meter has been installed so that the line voltage fed to the amplifier could be maintained at such a value that the correct value of voltage always would exist across the filament terminals of the 4-400A tube. The next instrument is a 0-15 d-c milliammeter for indicating the grid current to the tube. Next alongside is the 0-100 d-c milliammeter which indicates screen current. This meter is not a necessity for use with a high-power tetrode tube as long as the screen voltage is being fed through a dropping resistor of sufficiently large resistance. But in the amplifier illustrated, this meter is included since cathode metering of the current flow through the 4-400A is used. Although the grid current of the tube does not flow through the cathode milliammeter, the screen current does—so it is necessary to have a separate instrument for reading the screen current to the 4-400A so that the screen current may be subtracted from the cathode current to give the true plate current to the amplifier. The next instrument is the 0-800 d-c milliammeter which indicates the cathode current of the amplifier. The screen current to the amplifier will run about 25 to 35 ma., while the plate current to the tube will run about 330 ma. for the kilowatt input to the stage.

Note that the meters for the amplifier are mounted externally to the shielded compartment of the stage. This was done to minimize leakage of harmonic signals through the faces of the instruments. Meter leads pass through an 8-wire plug and cable so that the amplifier chassis may be separated from the panel and sub-base assembly without too much difficulty. Note that the meter leads are run through shield braid throughout their length and that the shield braid is grounded frequently throughout its length. Also, each of the meter leads is carefully by-passed at the cable receptacle on the main amplifier chassis.

Mechanical Notes The amplifier is entirely of aluminum construction. The panel for the stage is of 3/16-inch aluminum and has dimensions of 18 by 24 inches. The base plate for the amplifier is of 0.105-inch 24ST aluminum and has dimensions of 22 by 18 inches. The chassis of the amplifier is bent and welded of 0.062 aluminum and the top plate of the chassis is of 0.062 24ST aluminum. The sides, top, and rear of the shield box were made up in a "tin shop" of relatively thin aluminum. Ventilating holes in the panel and shield covers are shielded by ⅛-inch mesh brass "hardware cloth."

The socket for the 4-400A is a unit made by Eimac which has provision for forced-air cooling of the tube. A small blower unit mounted in the chassis has its output air stream connected to the input hole on the tube socket by a rubber adapter which was cut from a discarded inner tube, formed to shape, and cemented with tire-patch cement. The "L" at the air intake to the socket is a copper plumbing "L" for 1-inch copper pipe. The socket includes a glass chimney which is placed over the tube to direct the air flow so that maximum cooling effect on the envelope and seals of the tube will be obtained.

Access to the components inside the amplifier chassis is obtained by means of a sliding aluminum sheet which covers a large hole in the bottom plate of the amplifier. A 3-inch diameter hole, covered by brass hardware cloth, serves to admit air to the amplifier underchassis and the input of the blower when the bottom cover is in place. This hole could have been placed in the fixed portion of the bottom plate as well as in the sliding sheet which covers the access hole.

The views of the rear of the amplifier show the small number of leads which enter the chassis. On the left is the coaxial fitting for the coaxial cable from the exciter, while the fitting for the 3000-volt plate supply is in the center. On the right-hand end of the chassis can be seen the three terminals from the line filter which filters the 115-volt input to the stage. A strap holds the filter to the edge of the chassis in such a manner that the two line leads and the ground lead project from the rear of the chassis to serve as terminals for external connection.

CHAPTER SIX

Mobile Equipment and Installation

While mobile operation is permitted on certain other bands, operation at the present time is mostly confined to the 80, 10-11, and 2 meter bands, and the following discussion will be confined to operation on those bands.

The problems involved in achieving a satisfactory two-way installation vary somewhat with the band, but many of the problems are common to all bands. For instance, ignition noise is more troublesome on 10 meters than on 75 meters, but on the other hand an efficient antenna system is much more easily accomplished on 10 meters than on 75 meters. And getting a worthwhile amount of transmitter output without excessive battery drain is a problem on all bands.

The Receiver When a broadcast receiver is in the car, the most practical receiving arrangement on 75 and 10 meters involves a converter feeding into the auto set. The advantages of good selectivity with good image rejection obtainable from a double conversion superheterodyne are achieved in most cases without excessive "birdie" troubles, a common difficulty with a double conversion superheterodyne constructed as an integral receiver in one cabinet. However, it is important that the b-c receiver employ an r-f stage in order to provide adequate isolation between the converter and the high frequency oscillator in the b-c receiver. The r-f stage also is desirable from the standpoint of image rejection if the converter does not employ a tuned output circuit (tuned to the frequency of the auto set, usually about 1500 kc.). A few of the late model auto receivers, even in the better makes, do not employ an r-f stage.

For 2-meter reception the comparatively sharp i.f. of the auto set makes a more elaborate converter necessary, because of the stability problem. For this band it is about a toss up between a converter and a complete 2-meter receiver employing a somewhat wider i-f bandwidth than that of the conventional 262 or 455 kc. i-f amplifier found in auto receivers.

For 10 and/or 75 meter operation a large percentage of amateurs purchase a commercially built converter for reception and build their own transmitter. But for those who prefer to build their own, construction details for a 10-75 meter converter are given on page 147.

The usual procedure is to obtain converter plate voltage from the auto receiver. Experience has shown that if the converter does not draw more than about 15 or at most 20 ma. total plate current no damage to the auto set or loss in performance will occur other than a slight reduction in vibrator life. The converter drain can be minimized by avoiding a voltage regulator tube on the converter h-f oscillator. On 10 and 75 meters it is possible to design an oscillator with sufficient stability that no voltage regulator is required in the converter.

With some cars satisfactory 75-meter operation can be obtained without a noise clipper if resistor type spark plugs (such as those made by Autolite) are employed. However, a noise clipper is helpful if not absolutely necessary, and it is recommended that a noise clipper be installed without confirming the necessity therefor. It has been found that quiet reception sometimes may be obtained on 75 meters simply by the use of resistor type plugs, but after a few thousand miles these plugs often become less effective and no longer do a fully adequate job. Also, a noise clipper insures against ignition noise from passing trucks and "un-suppressed" cars. On 10 meters a noise clipper is a "must" in any case.

Modifying the Auto Receiver There are certain things that should be done to the auto set when it is to be used with a converter, and they might just as well be done all at the same time, because "dropping" an auto receiver and getting into the chassis to work on it takes quite a little time.

First, however, check the circuit of the auto receiver to see whether it is one of the few receivers which employ circuits which complicate connection of a noise clipper or a converter. If the receiver is yet to be purchased, it is well to investigate these points ahead of time.

If the receiver employs a motor driven tuning unit in conjunction with a d-c amplifier tied in with the second detector (such as certain model Delco receivers), major circuit revisions are necessary unless one is willing to do away with the motor driven tuner, and use only manual tuning.

If the receiver uses a separate "control tive B resistor strip for bias (as evidenced by the cathode of the audio output stage being grounded), then the additional plate current drain of the converter will upset the bias voltages on the various stages and probably cause trouble. Because the converter is not on all the time, it is not practical simply to alter the resistance of the bias strip, and major modification of the receiver probably will be required.

If the receiver uses a separate "control head" with audio wires running between the receiver and control head volume control, tone control, etc., it is possible that stray coupling will permit ignition noise to "leak around" the noise clipper and greatly reduce its effectiveness.

The best type of receiver for attachment of a converter and noise clipper uses an r-f stage; permeability tuning; single unit construction (except possibly for the speaker); push button tuning rather than a tuning motor; a high vacuum rectifier such as a 6X4 (rather than an 0Z4 or a synchronous rectifier); a 6SQ7 (or miniature or Loctal equivalent) with *grounded cathode* as second detector, first audio, and a.v.c.; power supply negative grounded directly (no common bias strip); a PM speaker (to minimize battery drain); and an internal r-f gain control (indicating plenty of built-in reserve gain which may be called upon if necessary). Several current model auto radios have all of the foregoing features, and numerous models have most of them, something to keep in mind if the set is yet to be purchased.

Noise Limiters A noise limiter either may be built into the set or purchased as a commercially manufactured unit for "outboard" connection via shielded wires. If the receiver employs a 6SQ7 (or Loctal or miniature equivalent) in a conventional circuit, it is a simple matter to build in a noise clipper by substituting a 6S8 octal, 7X7 Loctal, or a 6T8 9-pin miniature as shown in figure 1. When substituting a 6T8 for a 6AT6 or similar 7-pin miniature, the socket must be changed to a 9-pin miniature type. This requires reaming the socket hole slightly.

If the receiver employs cathode bias on the 6SQ7 (or equivalent), and perhaps delayed a.v.c., the circuit usually can be changed to the grounded-cathode circuit of figure 1 without encountering trouble.

Some receivers take the r-f excitation for the a-v-c diode from the plate of the i-f stage. In this case, leave the a.v.c. alone and ignore the a-v-c buss connection shown in figure 1 (eliminating the 1-megohm decoupling resistor). If the set uses a separate a-v-c diode which receives r-f excitation via a small capacitor connected to the detector diode, then simply change the circuit to correspond to figure 1.

In case anyone might be considering the use of a crystal diode as a noise limiter in conjunction with the tube already in the set, it might be well to point out that crystal diodes perform quite poorly in series-gate noise clippers of the type shown.

It will be observed that no tone control is shown. Multi-position tone controls tied in with the second detector circuit often permit excessive "leak through." Hence it is recommended that the tone control components be completely removed unless they are confined to the grid of the a-f output stage. If removed, the highs can be attenuated any desired amount by connecting a mica capacitor from plate to screen on the output stage. Ordinarily from .005 to .01 μfd. will provide a good compromise between fidelity and reduction of background hiss on weak signals.

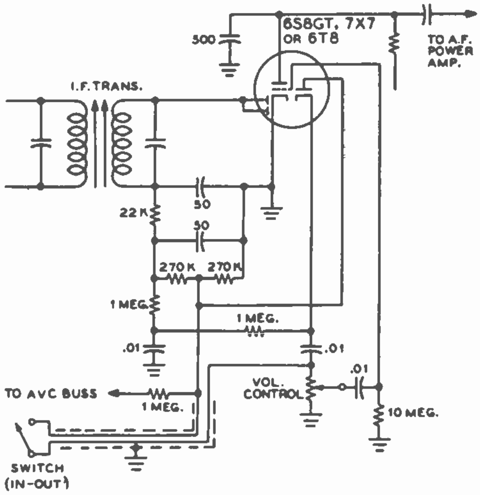


Figure 1.

SERIES-GATE NOISE LIMITER FOR AUTO RECEIVER.

Auto receivers using a 6SQ7, 7B6, 7X7, or 6AT6 as second detector and a.v.c. can be converted to the above circuit with but few wiring changes. The circuit has the advantage of not requiring an additional tube socket for the limiter diode.

Usually the switch SW will have to be mounted some distance from the noise limiter components. If the leads to the switch are over approximately 1½ inches long, a piece of shield braid should be slipped over them and grounded. The same applies to the "hot" leads to the volume control if not already shielded. Closing the switch disables the limiter. This may be desirable for reducing distortion on broadcast reception or when checking the intensity of ignition noise to determine the effectiveness of suppression measures taken on the car. The switch also permits one to check the effectiveness of the noise clipper.

The 22,000-ohm decoupling resistor at the bottom end of the i-f transformer secondary is not critical, and if some other value already is incorporated inside the shield can it may be left alone so long as it is not over 47,000 ohms, a common value. Higher values must be replaced with a lower value even if it requires a can opener, because anything over 47,000 ohms will result in excessive loss in gain. There is some loss in a-f gain inherent in this type of limiter anyhow (slightly over 6 db), and it is important to minimize any additional loss.

The switch SW is connected in such a manner that there is practically no change in gain with the limiter in or out. If the auto set does not have any reserve gain and more gain is needed on weak broadcast signals, the switch can be connected from the hot side of the volume control to the junction of the 22,000, 270,000 and 1 megohm resistors instead of as shown. This will provide approximately 6 db more gain when the clipper is switched out.

Many late model receivers are provided with an internal r-f gain control in the cathode of the r-f and/or i-f stage. This control should be advanced full on to provide better noise limiter action and make up for the loss in audio gain introduced by the noise clipper.

Installation of the noise clipper often detunes the secondary of the last i-f transformer. This should be repeaked before the set is permanently replaced in the car unless the trimmer is accessible with the set mounted in place.

Obtaining Power for the Converter While the set is on the bench for installation of the noise clipper, provision should be made for obtaining filament and plate voltage for the converter. To permit removal of either the converter or the auto set from the car without removing the other, a connector should be provided. The best method is to mount a small receptacle on the receiver cabinet or chassis, making connection via a matching plug. An Amphenol type 77-26 receptacle is compact enough to fit in a very small space and allows four connections (including ground for the shield braid). The matching plug is a type 70-26.

To avoid the possibility of vibrator hash being fed into the converter via the heater and plate voltage supply leads, it is important that the heater and plate voltages be taken from points well removed from the power supply portion of the auto receiver. If a single-ended audio output stage is employed, a safe place to obtain these voltages is at this tube socket, the high voltage for the converter being taken from the screen. In the case of a push-pull output stage, however, the screens sometimes are fed from the input side of the power supply filter. The ripple at this point, while sufficiently low for a push-pull audio output stage, is not adequate for a converter without additional filtering. If the schematic shows that the screens of a push-pull stage are connected to the input side instead of the output side of the power supply filter (usually two electrolytics straddling a resistor in an R-C filter), then follow the output of the filter over into the r-f portion of the set and

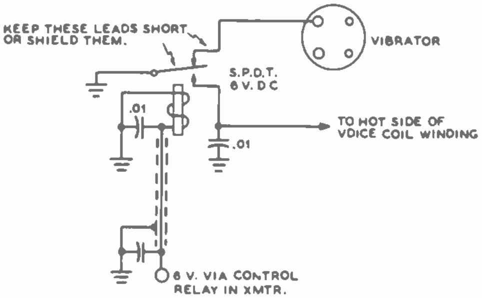


Figure 2.

METHOD OF ELIMINATING THE BATTERY DRAIN OF THE RECEIVER VIBRATOR PACK DURING TRANSMISSION.

If the receiver chassis has room for a midget s.p.d.t. relay, the above arrangement not only silences the receiver on transmit but saves several amperes battery drain.

pick it up there at a convenient point, before it goes through any additional series resistors.

The voltage at the output of the filter usually runs from 175 to 235 volts with typical converter drain and the motor not running. This will increase perhaps 10 per cent when the generator is charging. The converter drain will drop the B voltage slightly at the output of the filter, perhaps 15 to 25 volts, but this reduction is not enough to have a noticeable effect upon the operation of the receiver. If the B voltage is higher than desirable or necessary for proper operation of the converter, a 2-watt carbon resistor of suitable resistance should be inserted in series with the plate voltage lead to the power receptacle. Usually something between 2200 and 4700 ohms will be found about right.

Receiver Disabling on Transmit When the battery drain is high on transmit, as is the case when a PE-103A is run at maximum rating and other drains such as the transmitter heaters and auto headlights must be considered, it is desirable to disable the vibrator power supply in the receiver during transmissions. The vibrator power supply usually draws several amperes, and as the receiver must be disabled in some manner anyhow during transmissions, opening the 6-volt supply to the vibrator serves both purposes. It has the further advantage of introducing a slight delay in the receiver recovery, due to the inertia of the power supply filter, thus avoiding the possibility of a feedback "yoop" when switching from transmit to receive.

To avoid troubles from vibrator hash, it is best to open the ground lead from the vibrator by means of a midget s.p.d.t. 6-volt relay and thus isolate the vibrator circuit from the external control and switching circuit wires. The relay is hooked up as shown in figure 2 Standard 8-ampere contacts will be adequate for this application.

The relay should be mounted as close to the vibrator as practicable. Ground one of the coil terminals and run a shielded wire from the other coil terminal to one of the power receptacle connections, grounding the shield at both ends. By-pass each end of this wire to ground with .01 μfd., using the shortest possible leads. A lead is run from the corresponding terminal on the mating plug to the control circuits, to be discussed later.

If the normally open contact on the relay is connected to the hot side of the voice coil winding as shown in figure 2 (assuming one side of the voice coil is grounded in accordance with usual practice), the receiver will be killed instantly when switching from receive to transmit, in spite of the fact that the power supply filter in the receiver takes a moment to discharge. However, if a "slow start" power supply (such as a dynamotor or a vibrator pack with a large filter) is used with the transmitter, shorting the voice coil probably will not be required.

Using the Receiver Plate Supply On Transmit An alternative procedure is to make use of the receiver B supply on transmit, instead of disabling it. One disadvantage of the popular PE-103A dynamotor is the fact that its 450-500 volt output is too high for the low power r-f and speech stages of the transmitter. Dropping this voltage to a more suitable value of approximately 250 volts by means of dropping resistors is wasteful of power, besides causing the plate voltage on the oscillator and any buffer stages to vary widely with tuning. By means of a midget 6-volt s.p.d.t. relay mounted in the receiver, connected as shown in figure 3, the B supply of the auto set is used to power the oscillator and other low power stages (and possibly screen voltage on the modulator). On transmit the B voltage is removed from the receiver and converter, automatically silencing the receiver. When switching to "receive" the transmitter oscillator is killed instantly, thus avoiding trouble from dynamotor "carry over."

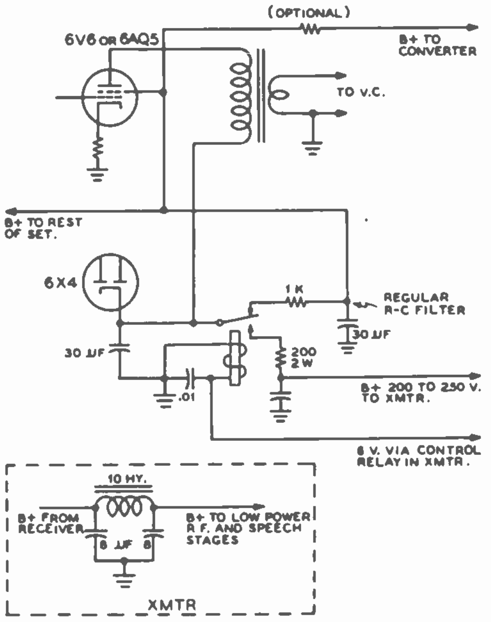


Figure 3.

USING THE RECEIVER PLATE SUPPLY FOR THE TRANSMITTER.

This circuit silences the receiver on transmit, and in addition makes it possible to use the receiver plate supply for feeding the exciter and speech amplifier stages in the transmitter.

The efficiency of this arrangement is good because the current drain on the main high voltage supply for the modulated amplifier and modulator plate(s) is reduced by the amount of current borrowed from the receiver. At least 80 ma. can be drawn from practically all auto sets, at least for a short period, without damage.

It will be noted that with the arrangement of figure 3, plate voltage is supplied to the audio output stage at all times. However, when the screen voltage is removed, the plate current drops practically to zero.

The 200-ohm resistor in series with the normally open contact is to prevent excessive sparking when the contacts close. If the relay feeds directly into a filter choke or large capacitor there will be excessive sparking at the contacts. Even with the arrangement shown, there will be considerable sparking at the contacts; but relay contacts can stand such sparking quite a while, even on d.c., before becoming worn or pitted enough to require attention. The 200-ohm resistor also serves to increase the effectiveness of the .01-μfd. r-f by-pass capacitor.

Auxiliary Antenna Trimmer One other modification of the auto receiver which may or may not be desirable depending upon the circumstances is the addition of an auxiliary antenna trimmer capacitor. If the converter uses an untuned output circuit and the antenna trimmer on the auto set is peaked with the converter cut in, then it is quite likely that the trimmer adjustment will not be optimum for broadcast-band reception when the converter is cut out. For reception of strong broadcast band signals this usually will not be serious, but where reception of weak broadcast signals is desired the loss in gain often cannot be tolerated, especially in view of the fact that the additional length of antenna cable required for the converter installation tends to reduce the strength of broadcast band signals.

If the converter has considerable reserve gain, it may be practicable to peak the antenna trimmer on the auto set for broadcast-band reception rather than resonating it to the converter output circuit. But oftentimes this results in insufficient converter gain, excessive image troubles from loud local amateur stations, or both.

The difficulty can be circumvented by incorporation of an auxiliary antenna trimmer connected from the "hot" antenna lead on the auto receiver to ground, with a switch in series for cutting it in or out. This capacitor and switch can be connected across either the converter end or the set end of the cable between the converter and receiver. This auxiliary trimmer should have a range of about 3 to 50 μμfd., and may be of the inexpensive compression mica type.

With the trimmer cut out and the converter turned off (by-passed by the "in-out" switch), peak the regular antenna trimmer on the auto set at about 1400 kc. Then turn on the converter, with the receiver tuned to 1500 kc., switch in the auxiliary trimmer, and peak this trimmer for maximum background noise. The auxiliary trimmer then can be left switched in at all times except when receiving very weak broadcast band signals.

Some auto sets, particularly certain General Motors custom receivers, employ a high-Q high-impedance input circuit which is very critical as to antenna capacitance. Unless the shunt capacitance of the antenna (including cable) approximates that of the antenna installation for which the set was designed, the antenna trimmer on the auto set cannot be made to hit resonance with the converter cut out. This is particularly true when a long antenna cable is used to reach a whip mounted at the rear of the car. Usually the condition can be corrected by unsoldering the internal connection to the antenna terminal connector on the auto set and inserting in series a 100-μμfd. mica capacitor. Alternatively an adjustable trimmer covering at least 50 to 150 μμfd. may be substituted for the 100-μμfd. fixed capacitor. Then the adjustment of this trimmer and that of the regular antenna trimmer can be juggled back and forth until a condition is achieved where the input circuit of the auto set is resonant with the converter either in or out of the circuit. This will provide maximum gain and image rejection under all conditions of use.

Reducing Battery Drain of the Receiver When the receiving installation is used frequently, and particularly when the receiver is used with the car parked, it is desirable to keep the battery drain of the receiver-converter installation at an absolute minimum. A substantial reduction in drain can be made in many receivers, without appreciably affecting their performance. The saving, of course depends upon the design of the particular receiver and upon how much trouble and expense one is willing to go to. Some receivers normally draw (without the converter connected) as much as 10 amperes. In many cases this can be cut to about 5 amperes by incorporating all practicable modifications. Each of the following modifications is applicable to many auto receivers.

If the receiver uses a speaker with a field coil, replace the speaker with an equivalent PM type.

Practically all 0.3-ampere r-f and a-f voltage amplifier tubes have 0.15-ampere equivalents. In many cases it is not even necessary to change the socket wiring. However, when substituting i-f tubes it is recommended that the i-f trimmer adjustments be checked. Generally speaking it is not wise to attempt to substitute for the converter tube or a-f power output tube.

If the a-f output tube employs conventional cathode bias, substitute a cathode resistor of twice the value originally employed, or add an identical resistor in series with the one already in the set. This will reduce the B drain of the receiver appreciably without seriously reducing the maximum undistorted output. Because the vibrator power supply is much less than 100 per cent efficient, a saving of one watt of B drain results in a saving of nearly 2 watts of battery drain. This also minimizes the overload on the B supply when the converter is switched in, assuming that the converter uses B voltage from the auto set.

If the receiver uses push-pull output and if one is willing to accept a slight reduction in the maximum volume obtainable without distortion, changing over to a single ended stage is simple if the receiver employs conventional cathode bias. Just pull out one tube, double the value of cathode bias resistance, and add a 25-μfd. by-pass capacitor across the cathode resistor if not already by-passed. In some cases it may be possible to remove a phase inverter tube along with one of the a-f output tubes.

If the receiver uses a motor driven station selector with a control tube (d-c amplifier), usually the tube can be removed without upsetting the operation of the receiver. One then must of course use manual tuning.

While the changeover is somewhat expensive, the 0.6 ampere drawn by a 6X4 or 6X5 rectifier can be eliminated by substituting six 115-volt r-m-s 50-ma. selenium rectifiers (such as Federal type 402D3200). Three in series are substituted for each half of the full-wave rectifier tube. Be sure to observe the correct polarity. The selenium rectifiers also make a good substitution for an 0Z4 or 0Z4-GT which is causing hash difficulties when using the converter.

Offsetting the total cost of nearly $4.00 is the fact that these rectifiers probably will last for the entire life of the auto set. Before purchasing the rectifiers, make sure that there is room available for mounting them. While these units are small, most of the newer auto sets employ very compact construction.

Mechanical Construction of Mobile Equipment It is recommended that the following measures be taken when constructing mobile equipment, either transmitting or receiving, to ensure trouble-free operation over long periods:

Use only a stiff, heavy chassis unless the chassis is quite small.

Use lock washers or lock nuts when mounting components by means of screws.

Use stranded hook-up wire except where r-f considerations make it inadvisable (such as for instance the plate tank circuit leads in a v-h-f amplifier). Lace and tie leads wherever necessary to keep them from vibrating or flopping around.

Unless provided with gear drive, tuning

capacitors in the large sizes will require a rotor lock.

Filamentary (quick heating) tubes should be mounted only in a vertical position.

The larger size carbon resistors and mica capacitors should not be supported from tube socket pins, particularly from miniature sockets. Use tie points and keep the resistor and capacitor "pigtails" short.

Generally speaking, rubber shock mounts are unnecessary or even undesirable with passenger car installations, or at least with full size passenger cars. The springing is sufficiently "soft" that well constructed radio equipment can be bolted directly to the vehicle without damage from shock or vibration. Unless shock mounting is properly engineered as to the stiffness and placement of the shock mounts, mechanical-resonance "amplification" effects may actually cause the equipment to be shaken more than if the equipment were bolted directly to the vehicle.

Surplus military equipment provided with shock or vibration mounts was intended for use in aircraft, jeeps, tanks, gun-firing Naval craft, small boats, and similar vehicles and craft subject to severe shock and vibration. Also, the shock mounting of such equipment is very carefully engineered in order to avoid harmful resonances.

To facilitate servicing of mobile equipment, all interconnecting cables between units should be provided with separable connectors on at least one end.

Control Circuits The send-receive control circuits of a mobile installation are dictated by the design of the equipment, and therefore will be left to the ingenuity of the reader. However, a few generalizations and suggestions are in order.

Do not attempt to control too many relays, particularly heavy duty relays with large coils, by means of an ordinary push-to-talk switch on a microphone. These contacts are not designed for heavy work, and the inductive kick will cause more sparking than the contacts on the microphone switch are designed to handle. It is better to actuate a single relay with the push-to-talk switch and then control all other relays, including the heavy duty "contactor" for the dynamotor or vibrator pack, with this relay. This procedure also permits grounding of one coil terminal on all remaining relays, making it necessary to run only one wire to each relay coil.

The heavy-duty 6-volt solenoid-type "contactor" relays such as provided on the PE-103A and used for automobile starter relays usually draw from 1.5 to 2 amperes. While somewhat more expensive, heavy-duty 6-volt relays of conventional design, capable of breaking 30 amperes at 6 volts d.c., are available with coils drawing less than 0.5 ampere. Some of the heavy duty 12-volt relays available on the surplus market can be made to work satisfactorily on 6 volts by substituting a weaker spring (or stretching the original spring) and bending the back contact or stop in such a manner as to shorten the armature throw.

When purchasing relays keep in mind that the current rating of the contacts is not a fixed value, but depends upon (1) the voltage, (2) whether it is a.c. or d.c., and (3) whether the circuit is purely resistive or is inductive. If in doubt, refer to the manufacturer's recommendations. Also keep in mind that a dynamotor presents almost a dead short until the armature starts turning, and the starting relay should be rated at considerably more than the normal dynamotor current.

Microphones and Circuits The most popular microphone for mobile work is the single button carbon. With a high-output-type microphone and a high-ratio microphone transformer, it is possible when "close talking" to drive even a pair of push pull 6L6's without resorting to a speech amplifier. However, there is a wide difference in the output of the various type single button microphones, and a wide difference in the amount of step up obtained with different type microphone transformers. So at least one speech stage usually is desirable.

One of the most satisfactory single button microphones is the standard Western Electric type F-1 unit (or Automatic Electric Co. equivalent). This microphone has very high output when operated at 6 volts, and good fidelity on speech. When used without a speech amplifier stage the microphone transformer should have a 50-ohm primary (rath-

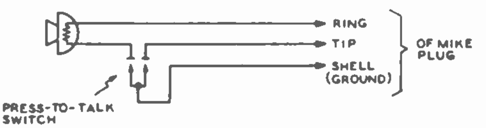


Figure 4.

STANDARD CONNECTIONS FOR PUSH-TO-TALK SWITCH ON A HAND-HELD SINGLE-BUTTON CARBON MICROPHONE.

er than 200 or 500 ohms) and a secondary of at least 150,000 ohms and preferably 250,-000 ohms.

The widely available surplus type T-17 microphone has higher resistance (200 to 500 ohms) and lower output, and usually will require a stage of speech amplification except when used with a very low power modulator stage.

Unless an F-1 unit is used in a standard housing, making contact to the button presents somewhat of a problem. No serious damage will result from soldering to the button if the connection is made to one edge and the soldering is done very rapidly with but a small amount of solder, so as to avoid heating the whole button.

A sound-powered type microphone removed from one of the chest sets available in the surplus market will deliver almost as much voltage to the grid of a modulator stage when used with a high-ratio microphone transformer as will an F-1 unit, and has the advantage of not requiring button current or a "hash filter." This is simply a dynamic microphone designed for high output rather than maximum fidelity.

The standardized connections for a single-button carbon microphone provided with push-to-talk switch are shown in figure 4. Practically all hand-held military-type single-button microphones on the surplus market use these connections.

PE-103A Dynamotor Power Unit Because of its availability on the surplus market at a low price and its suitability for use with about as powerful a mobile transmitter as can be employed in a passenger car without resorting to auxiliary batteries or a special generator, the PE-103A is probably the most widely used dynamotor for amateur work. Therefore some useful information will be given on this unit.

The nominal rating of the unit is 500 volts and 160 ma., but the output voltage will of course vary with load and is slightly higher with the generator charging. Actually the 160 ma. rating is conservative, and about 275 ma. can be drawn intermittently without overheating, and without damage or excessive brush or commutator wear. At this current the unit should not be run for more than 10 minutes at a time, and the average "on" time should not be more than half the average "off" time. The ability to deliver this amount of current means that the unit can be used to power the popular Harvey-Wells TBS-50 portable transmitter as a mobile installation.

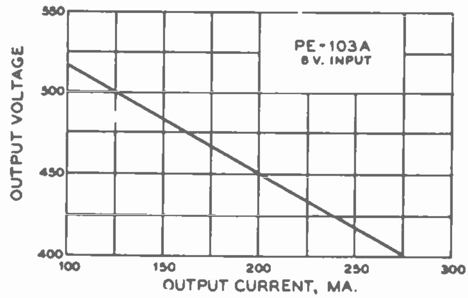


Figure 5.
OUTPUT VOLTAGE VS. LOAD CURRENT FOR A PE-103A DYNAMOTOR POWER UNIT (APPROXIMATE).

The output voltage vs. current drain is shown approximately in figure 5. The exact voltage will depend somewhat upon the loss resistance of the primary connecting cable and whether or not the battery is on charge. The primary current drain of the dynamotor proper (excluding relays) is approximately 16 amperes at 100 ma., 21 amperes at 150 ma., 26 amperes at 200 ma., and 31 amperes at 250 ma.

Only a few of the components in the base are absolutely necessary in an amateur mobile installation, and some of them can just as well be made an integral part of the transmitter if desired. The base can be removed for salvage components and hardware, or the dynamotor may be purchased without base.

To remove the base proceed as follows: Loosen the four thumb screws on the base plate and remove the cover. Remove the four screws holding the dynamotor to the base plate. Trace the four wires coming out of the dynamotor to their terminals and free the lugs. Then these four wires can be pulled through the two rubber grommets in the base plate when the dynamotor is separated from the base plate. It may be necessary to bend the eyelets in the large lugs in order to force them through the grommets

Next remove the two end housings on the dynamotor. Each is held with two screws. The high-voltage commutator is easily identified by its narrower segments and larger diameter. Next to it is the 12-volt commutator. The 6-volt commutator is at the other end of the armature. The 12-volt brushes should be removed when only 6-volt operation is planned, in order to reduce the drag.

If the dynamotor portion of the PE-103A power unit is a Pioneer type VS-25 or a Russell type 530- (most of them are), the wires to the 12-volt brush holder terminals can be cross connected to the 6-volt brush holder terminals with heavy jumper wires. One of the wires disconnected from the 12-volt brush terminals is the primary 12-volt pigtail and will come free. The other wire should be connected to the opposite terminal to form one of the jumpers.

With this arrangement it is necessary only to remove the 6-volt brushes and replace the 12-volt brushes in case the 6-volt commutator becomes excessively dirty or worn or starts throwing solder. No difference in output voltage will be noted, but as the 12-volt brushes are not as heavy as the 6-volt brushes it is not permissible to draw more than about 150 ma. except for emergency use until the 6-volt commutator can be turned down or repaired. At 150 ma. or less the 12-volt brushes will last almost as long as the 6-volt brushes.

The reason that these particular dynamotors can be operated in this fashion is that there are two 6-volt windings on the armature, and for 12-volt operation the two are used in series with both commutators working. The arrangement described above simply substitutes for the regular 6-volt winding the winding and commutator which ordinarily came into operation only on 12-volt operation.

The three wires now coming out of the dynamotor are identified as follows: The smaller wire is the positive high voltage. The heavy wire leaving the same grommet is positive 6 volts and negative high voltage. The single heavy wire leaving the other grommet is negative 6 volts. Whether the car is positive or negative ground, negative high voltage can be taken as car-frame ground. With the negative of the car battery grounded, the plate current can return through the car battery and the armature winding. This simply puts the 6 volts in series with the 500 volts and gives 6 extra volts plate voltage.

The trunk of a car gets very warm in summer, and if the transmitter and dynamotor are mounted in the trunk it is recommended that the end housings be left off the dynamotor to facilitate cooling. This is especially important in hot climates if the dynamotor is to be loaded to more than 200 ma.

When replacing brushes on a PE-103A check to see if the brushes are marked negative and positive. If so, be sure to install them accordingly, because they are not of the same material. The dynamotor will be marked to show which holder is negative.

Among the useful components in the base are the following, identified by Signal Corps symbols marked on the component:

3-E-3: A 220-ma. d-c circuit breaker (overload relay) rated at 500 volts. Contacts and coil have separate terminals. Can be shunted to trip at higher currents. Contacts will handle 115 v. a.c. at 15 amperes, making this unit useful for a home station power supply.

3-E-4: A 40-ampere d-c circuit breaker rated at 6 volts. Contacts will handle about 30 amperes at 6 volts d.c., making this relay suitable for primary protection of entire mobile transmitter. Coil and contacts have separate terminals.

3-E-5: A 7-ampere d-c circuit breaker rated at 12 volts maximum. Contacts and coil are in series, with only two terminals. This can replace the fuse on an auto radio.

3-E-6: A d-p-s-t relay operating on 6 volts d.c. and drawing very little current. Contacts good for about 5 amperes d.c. at 6 volts.

3-E-2: A heavy duty contactor of the solenoid type, designed for 6-volt d-c operation. Similar to automobile starter relay, and contacts will handle very heavy current, making a good starting relay for the PE-103A, but coil draws about 1.5 amperes.

3-E-1: A contactor similar to 3-E-2 except for a 12-volt coil.

3-C-1: A 2-μfd. 600-volt filter capacitor. A dynamotor requires a small amount of filter, and this capacitor can be mounted on the transmitter chassis to provide filtering for a PE-103A which has been removed from its base.

When using a PE-103A, or any dynamotor for that matter, it may be necessary to devote one set of contacts on one of the control relays to breaking the plate or screen voltage to the transmitter oscillator, if these are supplied by the dynamotor, because the output of a dynamotor takes a moment to fall to zero when the primary power is removed.

Simple Speech Clipper for Mobile Transmitters

Because of the limited power that can be radiated from a mobile transmitter, it is highly desirable to make the most effective use of the carrier power by incorporation of a speech clipper.

The high level clipper of figure 6 is suitable for inputs up to 500 volts and 100 ma. It requires no adjustment and, using a selenium rectifier instead of a tube rectifier, requires no filament power. The filter values are not especially critical, but it should be kept in mind that the plate by-pass capacitor

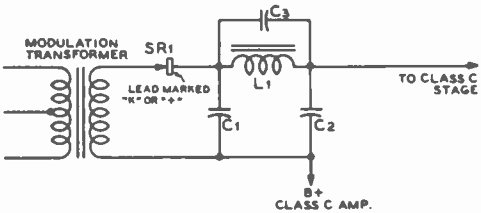


Figure 6.

HIGH LEVEL SPEECH CLIPPER FOR MOBILE WORK, USING A SELENIUM RECTIFIER.

For d-c plate voltages up to 500 volts and plate currents up to 100 ma., a rectifier of the common 130-volt r-m-s 100-ma. type (such as Federal 403D2625A) is suitable. Note polarity of the connection to the rectifier lugs. The other components are as follows:

C_1, C_2, C_3—1000-volt mica capacitors (See figure 7 for values)

L_1—Inductor capable of carrying d-c plate current to class C stage, 1000-volt insulation. (See figure 7 for value)

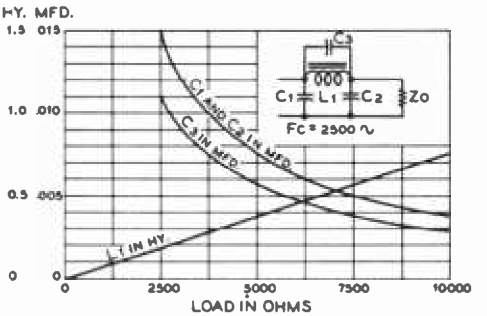


Figure 7.

DESIGN CHART FOR LOW-PASS FILTER FOR USE AFTER A SPEECH CLIPPER, BASED UPON 2500-CYCLE CUT OFF.

is in parallel with C_2. In fact the plate by pass can be made to serve as C_2 if desired, simply by making it the correct filter value.

The optimum filter values for a particular class C load may be determined by reference to figure 7. If sharper cutoff and greater attenuation of frequencies well beyond cutoff are desired, another section can be added.

Small, fractional-henry iron-core chokes with ratings of from 75 to 125 ma. suitable for use as L_1 are available on the surplus market.

10-Meter Mobile Antennas

The most popular mobile antenna for 10-meter operation is a rear-mounted whip approximately 8 feet long, fed with coaxial line. This is a highly satisfactory antenna, but a few remarks are in order on the subject of feed and coupling systems.

The feed point resistance of a resonant quarter-wave rear-mounted whip is approximately 20 to 25 ohms. While the standing wave ratio when using 50-ohm coaxial line will not be much greater than 2 to 1, it is nevertheless desirable to make the line to the transmitter exactly one quarter wavelength long electrically at the center of the band. This procedure will minimize variations in loading over the band. The physical length of RG-8/U cable, from antenna base to antenna coupling coil, should be approximately 5 feet 3 inches. The antenna changeover relay preferably should be located either at the antenna end or the transmitter end of the line, but if it is more convenient physically the line may be broken anywhere for insertion of the relay.

If the same rear-mounted whip is used for broadcast-band reception, attenuation of broadcast-band signals by the high shunt capacitance of the low impedance feed line can be minimized by locating the changeover relay right at the antenna lead in, and by running 95-ohm coax (instead of 50 or 75 ohm coax) from the relay to the converter. Ordinarily this will produce negligible effect upon the operation of the converter, but usually will make a worthwhile improvement in the strength of broadcast-band signals.

A more effective radiator and a better line match may be obtained by making the whip approximately 10½ feet long and feeding it with 75-ohm coax (such as RG-11/U) via a series capacitor, as shown in figure 8. The relay and series capacitor are mounted inside the trunk, as close to the antenna feed-through or base-mount insulator as possible. The 10½-foot length applies to the overall length from the tip of the whip to the point where the lead in passes through the car body. The leads inside the car (connecting the coaxial cable, relay, series capacitor and antenna lead) should be as short as possible. The outer conductor of both coaxial cables should be grounded to the car body at the relay end with short, heavy conductors.

A 100-μμfd. midget variable capacitor is suitable for C_1. The optimum setting should be determined experimentally at the center of the band. This setting then will be satisfactory over the whole band.

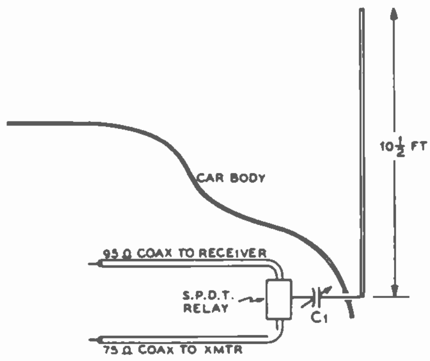


Figure 8.
5/16-WAVE WHIP RADIATOR FOR 10 METERS.
This is a more effective radiator than the common ¼-wave whip, and provides a better match to the line. The reactance is tuned out by means of C_1, which may be a 100-μμfd. midget variable.

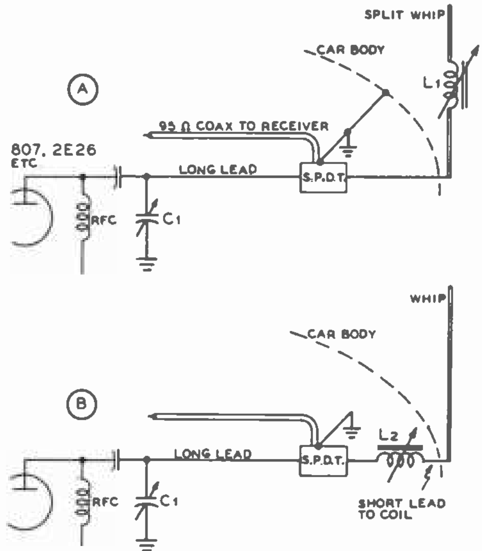


Figure 9.
CENTER-LOADED AND BOTTOM-LOADED WHIPS FOR 75-METER MOBILE OPERATION.
The center-loaded arrangement has a more favorable current distribution, but because of mechanical considerations a higher coil Q is possible with the bottom-loaded arrangement. The performance of the two arrangements is about equal. The whip should be at least 8 feet long, preferably longer.

The most practical coupling arrangement for either a ¼-wave or 5/16-wave whip on 10 meters is to use a conventional tank circuit, inductively coupled to a "variable link" coupling loop which feeds the coaxial line. If the input impedance of the line is very low and the tank circuit has a low C/L ratio, it may be necessary to resonate the coupling loop with series capacitance in order to obtain sufficient coupling. This condition often is encountered with a ¼-wave whip when the line length approximates an electrical half wavelength.

75-Meter Mobile Antennas

The main problem on 75 meters is to radiate the transmitter output power. At this frequency an 8 or 10 foot whip has such low radiation resistance and presents such a high reactive impedance that the overall efficiency of the matching network and antenna may be less than one per cent, even when care is taken to obtain the highest possible efficiency.

Without going into detail as to the theory involved, two of the most effective methods of using a short whip on 75 meters are shown in figure 9. At A is shown a "top loaded" or "center loaded" arrangement, and at B a "bottom loaded" arrangement. There is not much difference in performance between the two for the following reason.

The center loaded arrangement at A, with the coil approximately half way up the whip, has a slightly higher radiation resistance and a slightly better current distribution. However, mechanical and weather problems make it difficult to construct a coil having extremely high Q. The arrangement at B, with the coil just inside the car body, permits use of a coil of large physical size, with considerably higher Q. The lower coil losses of the B arrangement just about offset the better current distribution of the A arrangement.

Both arrangements look to the final r-f amplifier like a pi network terminated in an extremely high resistance. The capacitance between the car body and that portion of the antenna *beyond the coil* serves as the output capacitance of the pi network. Because of the extremely high impedance step up, normal loading will be obtained with a high ratio of input capacitance (C_1) to output capacitance. Under these conditions C_1 will have little effect upon the resonant frequency; it is useful only as a loading adjustment.

Because the effective output capacitance of the network is fixed, the most practical way to vary the resonant frequency without sacrificing efficiency is by variation of the coil inductance. The effective Q of the overall system will be high with either the A or B arrangement, and tuning will be quite sharp. Therefore the inductance of the coil will have to be changed when the operating frequency is changed more than a very few kilocycles. However, only a small variation in inductance is required in order to cover the 75-meter phone band.

A convenient method of varying the inductance over the required range with a B arrangement is by means of a powdered iron ring of the type on which toroidal coils are wound. With the B arrangement it is desirable that the coil be space wound with no. 12 wire on a large ceramic form (such as are used in certain BC-375 tuning units) in order to obtain maximum Q. The coil should be mounted as close to the lead-in as possible. The powdered iron ring is used as a slug, rather than a sleeve.

With the B arrangement it is desirable (though not essential) that the slug be adjustable from outside the car, because opening and closing the trunk will have considerable effect upon the resonant frequency of the overall system. Usually one adjustment of C_1 will serve for the whole 75-meter phone band. A jack mounted on the bumper apron can be used to read cathode current to the final r-f range, and permit resonance adjustments without opening the trunk.

The required inductance for L_1 or L_2 will vary considerably with the particular installation. Usually it will be necessary to prune the coil experimentally in order to arrive at a condition where the band can be covered by adjustment of the slug or ring. As a rough approximation from which to start, the inductance of L_2 should be made such that it will resonate at 4000 kc. with about 50 $\mu\mu$fd. of capacitance, as determined from a coil calculator or chart. For the A arrangement, the experimental coil should be calculated on the basis of approximately 25 $\mu\mu$fd. of capacitance. A grid-dip meter loosely coupled to L_1 or L_2 will be found helpful in pruning the experimental coil.

The coil for a type A arrangement usually is close wound on a form from 1 to 1½ inches in diameter with no. 16 to 20 wire. A conventional iron slug of at least ½-inch diameter and at least 1½ inches long can be used to trim this coil, or an iron ring can be used as an adjustable sleeve.

Powdered iron rings, and adjustable slugs of sufficient size, are manufactured by numerous concerns but are not widely stocked by radio parts stores. However, they can be located in the larger cities by "shopping around." Be sure the slug or ring uses an "r-f powder" and not an "a-f powder." As an alternative to slug or ring tuning, the last 10 or 20 turns of the coil (L_1 or L_2) can be tapped every turn or two and adjustments made by means of a clip or selector switch.

With the B arrangement the whip is very "hot" at the bottom, and good insulation is required for the base mount and lead-in to avoid dielectric losses or flashover.

Capacitor C_1 should have a voltage rating of at least twice the d-c plate voltage used on the final amplifier, and preferably somewhat more. The greater the capacitance, the greater the loading on the amplifier. In many cases it may be necessary to use a 500 $\mu\mu$fd. per section split-stator capacitor with the sections in parallel in order to obtain sufficient loading. A three-gang "t-r-f" type receiving capacitor with sections connected in parallel usually will be satisfactory for a final stage running at 300 volts. The capacitor may be placed either at the transmitter or near the lead-in. The connecting lead may be several feet long without harmful effects. Plastic-insulated no. 12 house wire is suitable.

If either antenna is used with a factory-built transmitter employing a conventional pi network, the transmitter coil can be shorted out and the two capacitors used in parallel as C_1.

Vehicular Noise Suppression

Satisfactory reception on frequencies above the broadcast band usually requires greater attention to "suppression" measures. The required measures vary with the particular vehicle and the frequency range involved.

Most of the various types of noise that may be present in a vehicle may be broken down into the following main categories:

(1) Ignition noise

(2) Wheel static (tire static, brake static, and intermittent ground via front wheel bearings)

(3) "Hash" from voltage regulator contacts

(4) "Whine" from generator commutator segment make and break

(5) Static from scraping connections between various parts of the car

There is no need to suppress ignition noise completely, because at the higher frequencies ignition noise from passing vehicles makes the use of a noise limiter mandatory anyway. However, the limiter should not be given too much work to do, because at high engine speeds a noisy ignition system will tend to mask weak signals, even though with the limiter working, ignition "pops" may appear to be completely eliminated.

Ignition Noise The following procedure should be found adequate for reducing the ignition noise of practically any passenger car to a level which the clipper can handle satisfactorily at any engine speed at any frequency from 500 kc. to 148 Mc. Some of the measures may already have been taken when the auto receiver was installed.

First either install a spark plug suppressor on each plug, or else substitute Autolite "resistor" plugs. The latter are more effective than suppressors, and on some cars ignition noise is reduced to a satisfactory level simply by installing them. However, they may not do an adequate job alone after they have been in use for a while, and it is a good idea to take the following additional measures.

Check all high tension connections for gaps, particularly the "pinch fit" terminal connectors widely used. Replace old high tension wiring that may have become leaky.

Check to see if any of the high tension wiring is cabled with low tension wiring, or run in the same conduit. If so, reroute the low tension wiring to provide as much separation as practicable.

By-pass to ground the 6-volt wire from the ignition coil to the ignition switch at each end with a 0.1-μfd. molded case paper capacitor in parallel with a .001-μfd. mica or ceramic, using the shortest possible leads.

Check to see that the hood makes a good ground contact to the car body at several points. Special grounding contactors are available for attachment to the hood lacings on cars that otherwise would present a grounding problem.

If the high-tension coil is mounted on the dash, it may be necessary to shield the high tension wire as far as the bulkhead, unless it already is shielded with armored "flex."

Wheel Static Wheel static is either static electricity generated by rotation of the tires and brake drums, or is noise generated by poor contact between the front wheels and the axles (due to the grease in the bearings). The latter type of noise seldom is caused by the rear wheels, but tire static may of course be generated by all four tires.

Wheel static can be eliminated by insertion of grounding springs under the front hub caps, and by inserting "tire powder" in all inner tubes. Both items are available at radio parts stores and from most auto radio dealers.

Voltage Regulator Hash Certain voltage regulators generate an objectionable amount of "hash" at the higher frequencies, particularly in the v-h-f range. A large by-pass will affect the operation of the regulator and possibly damage the points. A small by-pass can be used, however, without causing trouble. At frequencies above the frequency at which the hash becomes objectionable (approximately 20 Mc. or so) a small by-pass is quite effective. A 0.001-μfd. mica capacitor placed from the field terminal of the regulator to ground with the shortest possible leads often will produce sufficient improvement. If not, a choke consisting of about 60 turns of no. 18 d.c.c. or bell wire wound on a ¾-inch form can be added. This should be placed right at the regulator terminal, and the 0.001-μfd. by-pass placed from the generator side of the choke to ground.

Generator Whine Generator "whine" also known as generator "howl" or "growl," often can be satisfactorily suppressed from 550 kc. to 148 Mc. simply by by-passing the armature terminal to ground with a special "auto radio" by-pass of 0.25 or 0.5 μfd in parallel with a 0.001-μfd. mica or ceramic capacitor. The former usually is placed on the generator when an auto radio is installed, but must be augmented by a mica or ceramic capacitor with short leads in order to be effective at the higher frequencies as well as on the broadcast band.

When more drastic measures are required, special filters can be obtained which are designed for the purpose. These are recommended for stubborn cases when a wide frequency range is involved. For reception only over a comparatively narrow band of frequencies, such as the 10-meter amateur band, a highly effective filter can be improvised by connecting between the previously described parallel by-pass capacitors and the generator armature terminal a resonant choke. This may consist of no. 10 enamelled wire wound on a suitable form and shunted with an adjustable trimmer capacitor to permit resonating the combination to the center of the frequency band involved. For the 10-meter band 11 turns close wound on a one-inch form and shunted by a 3-30 μμfd. compression-type mica trimmer is suitable. The trimmer should be adjusted experimentally at the center frequency.

When generator whine shows up after once being satisfactorily suppressed, the condition of the brushes and commutator should be checked. Unless a by-pass capacitor has opened up, excessive whine usually indicates that the brushes or commutator are in need of attention in order to prevent damage to the generator.

Body Static Loose linkages or body or frame joints anywhere in the car are potential static producers when the car is in motion, particularly over a rough road. Locating the source of such noise is difficult, and the simplest procedure is to give the car a thorough tightening up in the hope that the offending poor contacts will be caught by the procedure. The use of braided bonding straps between the various sections of the body of the car also may prove helpful.

Miscellaneous There are several other potential noise sources on a passenger vehicle, but they do not necessarily give trouble and therefore require attention only in some cases.

The heat, oil pressure, and gas gauges can cause a rasping or scraping noise. The gas gauge is the most likely offender. It will cause trouble only when the car is rocked or is in motion. The gauge units and panel indicators should both be by-passed with the 0.1-μfd. paper and 0.001-μfd. mica or ceramic combination previously described.

At high car speeds under certain atmospheric conditions "corona" static or "velocity" static may be encountered unless means is taken to prevent it. The receiving-type auto whips which employ a plastic ball tip are so provided in order to minimize this type of noise, which is simply a discharge of the frictional static built up on the car. A whip which ends in a relatively sharp metal point makes an ideal discharge point for the static charge, and will cause corona trouble at a much lower voltage than if the tip were hooded with insulation. A piece of Vinylite sleeving slipped over the top portion of the whip and wrapped tightly with heavy thread will prevent this type of static discharge under practically all conditions. An alternative arrangement is to wrap the top portion of the whip with "Scotch" brand *electrical* tape.

Generally speaking it is undesirable from the standpoint of engine performance to use both spark-plug suppressors *and* a distributor suppressor. Unless the distributor rotor clearance is excessive, noise caused by sparking of the distributor rotor will not be so bad but what it can be handled satisfactorily by a noise limiter. If not, it is preferable to shield the hot lead between ignition coil and distributor rather than use a distributor suppressor.

In many cases the control rods, speedometer cable, etc., will pick up high-tension noise under the hood and "pipe" it up under the dash where it causes trouble. If so, all control rods and cables should be bonded to the fire wall (bulkhead) where they pass through, using a short piece of heavy flexible braid of the type used for shielding.

In some cases it may be necessary to bond the engine to the frame at each rubber engine mount in a similar manner. If a rear mounted whip is employed the exhaust "tail pipe" also should be bonded to the frame if supported by rubber mounts.

Locating Noise Sources Determining the source of certain types of noise is made difficult when several things are contributing to the noise, because elimination of one source often will make little or no apparent difference in the total noise. The following procedure will help to isolate and identify various types of noise.

Ignition noise will be present only when the ignition is on, even though the engine is turning over.

Generator noise will be present when the motor is turning over, regardless of whether the ignition switch is on. Slipping the drive belt off will kill it.

Gauge noise usually will be present only when the ignition switch is on or in the "left" position provided on some cars.

Wheel static when present will persist when the car clutch is disengaged and the ignition switch turned off (or to the left position), with the car coasting.

Body noise will be noticeably worse on a bumpy road than on a smooth road, particularly at low speeds.

One-Tube Mobile Converter For 10 and 75

The simple converter shown in figures 10 through 13 provides reception over the frequency ranges from 26.5 through 30 Mc. and 3500 through 4000 kc. when operated into a standard broadcast-band auto radio receiver. The converter uses a single tube, a single-ended loctal type 7S7, and operates

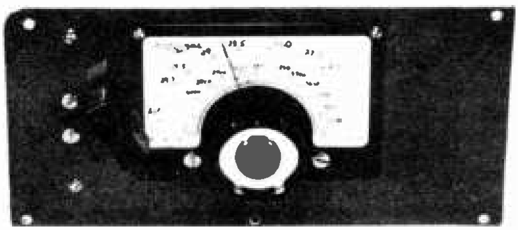


Figure 10. FRONT OF THE TWO-BAND MOBILE CONVERTER.

into an intermediate frequency of 1500 to 1600 kc. Power supply requirements for the converter are low enough so that power may be furnished by the auto receiver.

Circuit of the Converter A type 7S7 tube was chosen for use in the converter primarily as a result of its relatively high conversion conductance of 525 micromhos. This value of conductance results in a slightly higher overall gain in the converter than could be obtained with the more standard types of tube such as the 6K8 or the 6SA7. Also, the single-ended loctal construction of the tube contributes to circuit layout and to stability with respect to the mechanical vibration encountered.

The 7S7 tube is a triode-heptode converter with internal injection between the triode grid and the number 3 grid of the heptode. Seriesed tank circuits are employed both in the oscillator portion of the circuit and in the antenna circuit. Through the use of the series-tank arrangement a lower value of loss is obtainable since the high-potential end of the tank circuit for the high-frequency band is effectively isolated from the selector switch. Then, when the switch is placed in the position for the low-frequency band, the high-frequency tank is in series with the low-frequency tank circuit. The effect of having the high-frequency tank in series with that for the low-frequency band is :elatively minor. Reference to the schematic diagram of figure 13 will indicate the circuit details of the bandswitching method.

The oscillator tank circuits, L_1 and L_2, must be solidly constructed and rigidly mounted. All components must be firmly held in place in such a manner that they cannot vibrate when the car is in motion. This requirement is particularly important in regard to the components for the 28-Mc. band. Any vibration in the oscillator tank circuit will show up as severe frequency modulation of an incoming signal when the car is in motion. Even a small amount of vibration of the components can result in a degree of frequency modulation which will make it completely impossible to read an incoming signal with the car moving. This effect will disappear, of course, as soon as the car is stopped.

The Antenna Circuit It will be noted that two tank circuits are connected in series in the antenna circuit the same as in the oscillator circuit. The tank circuit for the 3.5-Mc. band is at the low-potential end, and is shorted out when the selector switch is in the 28-Mc. position. The main tuning capacitor C_1B, is connected permanently to a tap on the 28-Mc. coil. The negligible impedance of this tuned circuit on the 3.5-Mc. band results in the tuning capacitor being effectively connected to the top end of the tank coil on the lower frequency 3.5-Mc. band.

Conventional inductive coupling from the antenna transmission line to the tank coil is used on the 28-Mc. band. Completely satisfactory results will be obtained with a conventional whip, 6 to 11 feet in length, as the receiving antenna on the 28-Mc. band. However, a quite different condition exists on the 3.5-Mc. band. Any conventional whip antenna will appear as a moderate value of capacitance with a negligible value of radiation resistance to the end of the antenna transmission line. The matter of the antenna for mobile operation on the 3.5-Mc. band has been discussed in some detail at the beginning of this chapter. But suffice to say that if a conventional unloaded whip is to be used for receiving, results will certainly not be very satisfactory as only the loudest signals on the band will be heard. Also, the feed line from the antenna terminal of the converter to the base of the antenna should be as short as possible and should be of the lowest capacitance cable obtainable. Even then, the entire feed line and antenna system must be treated as a capacitance with a small amount of signal pickup. Hence the tuning system indicated for the 3.5-Mc. band on the schematic diagram of figure 13.

If a good antenna is to be installed on the car for 3.5-Mc. mobile work (such as some type of loaded affair) it is important that its feed-point impedance be matched as closely as possible to that of the antenna transmission line. Then inductive coupling from the feed line to the antenna coil L_4 may be used, the same as has been done for the 28-Mc. band on L_3. The bottom end of capacitor C_4 should be grounded with this type of antenna coupling so that this capacitor may act as the trimmer for the antenna tank circuit. Much improved reception will be obtained with this type of antenna and the inductive method of antenna coupling. But as has been said before, any short loaded antenna for the 3.5-Mc. band will necessarily be rather sharp in its tuning characteristics. So only a selected portion of the amateur band will be received with maximum signal pickup for any given set of tuning conditions at the antenna loading circuit.

Output Circuit of the 7S7 The output tank in the plate circuit of the 7S7 converter stage may be any i-f transformer with a primary winding capa-

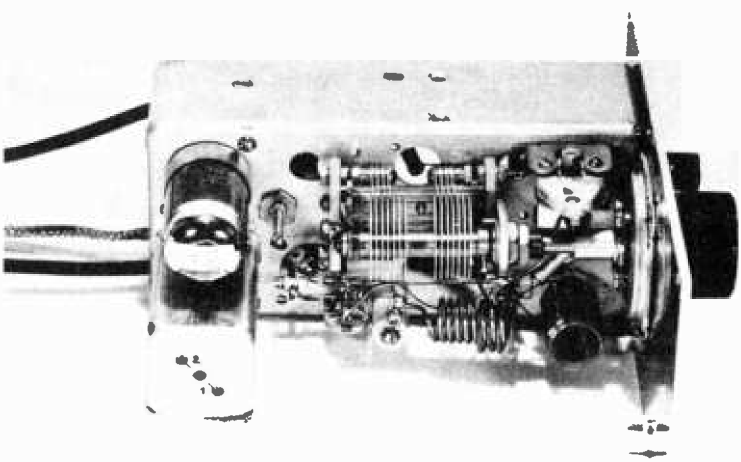


Figure 11.
SIDE VIEW OF THE CONVERTER.

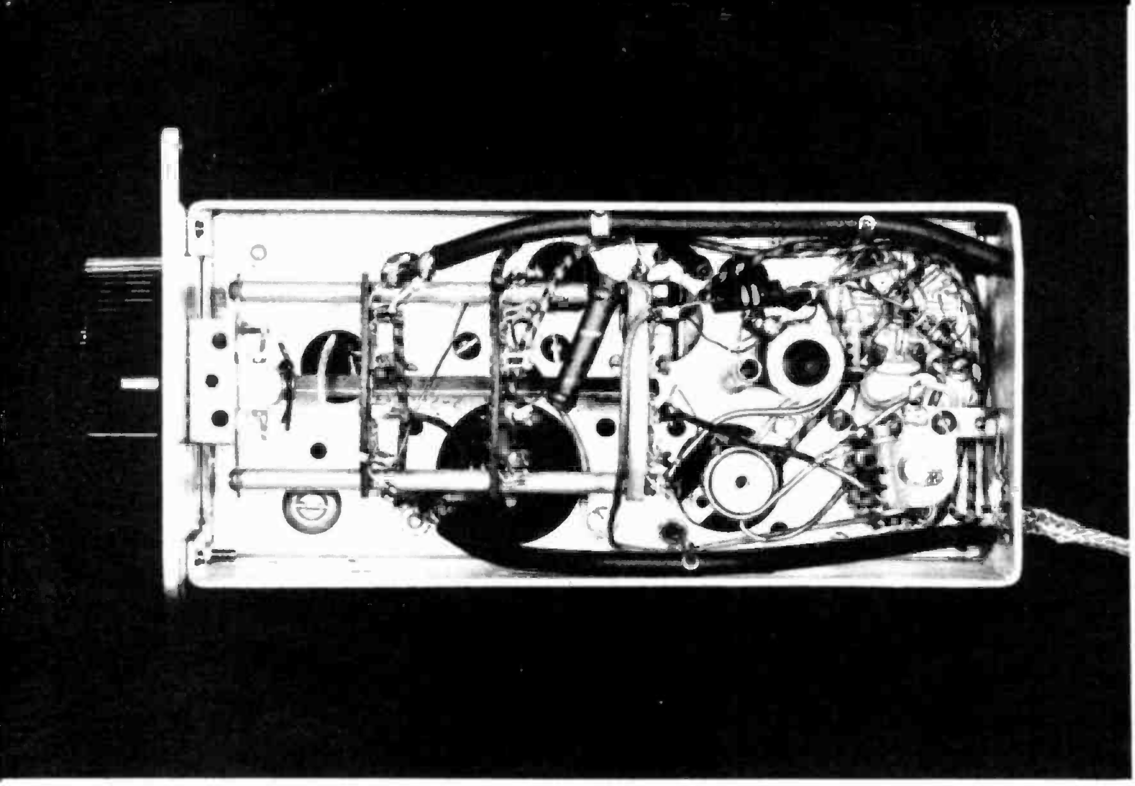


Figure 12.
UNDERCHASSIS OF THE CONVERTER.

ble of tuning to 1500 kc. Some experiment will be required in determining the number of turns on the secondary of L_5. The input circuit of most broadcast auto receivers is quite high in impedance, and is designed to operate from a signal source with a moderate amount of capacitance to ground. Hence the first test might be made with a conventional 1500-kc. double-tuned i-f transformer with the primary unchanged and with the tuning capacitance removed from the secondary. It will probably be found that there is too much circuit capacitance for resonance in the secondary winding under these conditions so some turns will have to be removed from the secondary. The actual tuning procedure of the installation will be described in the following paragraphs.

Alignment of the Converter The alignment procedure for the converter is relatively simple, but it can carried out much more conveniently and successfully on a table in the operating room rather than with the converter installed in the car. Connect power supply voltages to the converter, and bring a short lead from the antenna post of the station receiver into the vicinity of the oscillator circuits of the converter. The intermediate frequency to be used with the converter should now be established. It is merely necessary to choose some frequency between 1450 and 1550 kc. which is not in use by some local broadcast station, and which can be tuned by the receiver in the car. If we assume that 1500 kc. is to be used, this value should be added to the frequency coverage of the oscillator in the converter. The oscillator is on the high side for both bands. This means that the oscillator must cover 5000 to 5500 kc. with some leeway at each end for the 3.5 to 4.0 Mc. band; and the oscillator must cover from about 28.0 to 31.5 Mc. to give reception from 26.5 Mc. through 30 Mc.

Adjustment of the oscillator coverage should be accomplished first on the 28-Mc. range. Only a variation in the setting of the zero-coefficient ceramic trimmer C_2 will be required if the oscillator coil has been made and tapped as specified. Then the bandswitch should be placed in the 3.5-Mc. position and the tuning slug in L_2 varied until coverage from about 4950 to 5550 kc. is obtained.

The output coaxial cable from the converter is now connected to the input of the communications receiver and the receiver tuned to the frequency which has been chosen as the i.f.—

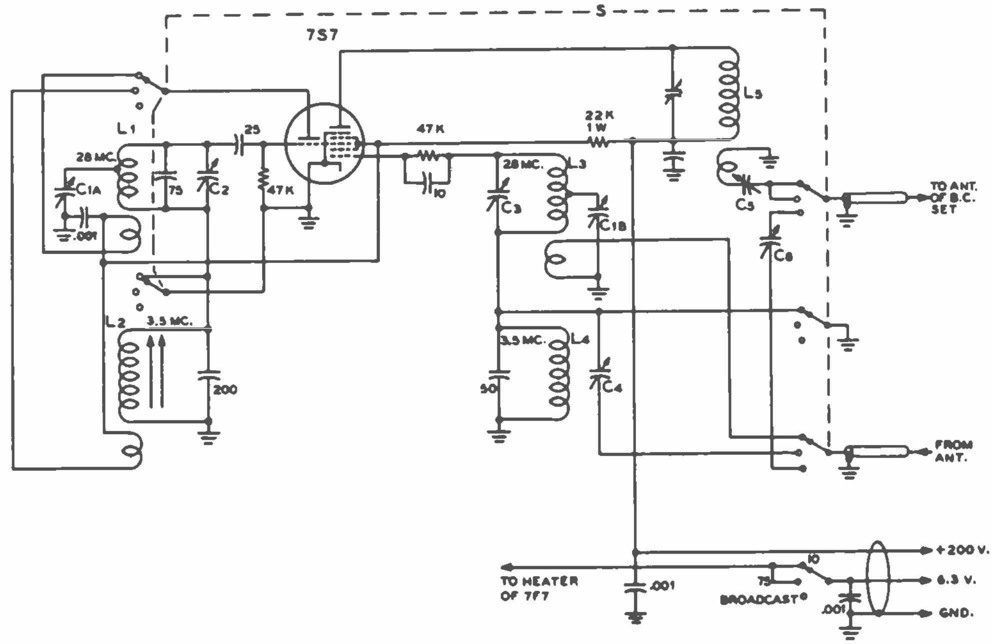


Figure 13.

SCHEMATIC OF THE TWO-BAND CONVERTER.

$C_{1}A$, $C_{1}B$—Dual 100-μμfd. variable (National STHD-100) with three plates removed from each stator section

C_2—4.5-25 μμfd. zero-coefficient ceramic trimmer (Centralab 822AZ)

C_3—7-35 μμfd. ceramic trimmer (Centralab 820C)

C_4—10-100 μμfd. ceramic trimmer (Centralab 823BN)

C_5—20-125 μμfd. ceramic trimmer (Centralab 823 AN)

C_6—Omit when whip antenna used—10-100 μμfd. ceramic trimmer

L_1—5 turns no. 14 tinned on ½-inch insulator spaced to ½", tapped at 3½ turns, with 4 turns no. 22 enam. on bottom for tickler

L_2—20 turns no. 22 enam. closewound on National XR-50 slug-tuned form

L_3—9 turns no. 14 tinned, air wound, ½" dia. by 1" long, tapped 4 turns from ground end, 4-turn link for antenna coupling

L_4—38 turns no. 22 enam. closewound on ¾-inch dia. form (Amphenol no. 24)

L_5—1500-kc. i-f transformer with trimmer removed from secondary. A 1415-kc. transformer of the type removed from a BC-454 command set was used in the model illustrated.

S—5-pole 3-position switch made up from Centralab "Switchkit." Ceramic deck used for coil switching; other decks are wafer type.

1500 kc. in the example mentioned. The tuned circuit in the plate of the 7S7 is peaked for maximum noise output. The bandswitch is now placed in the 28-Mc. position and capacitor C_3 peaked for maximum noise level on the 28-Mc. band. If a signal generator is available it may be used to check the tracking of the converter over the 28-Mc. band and to give an idea as to the relative sensitivity of the converter. If a signal generator is not available, the converter may be peaked with the aid of signals received in the 27 to 29.7 Mc. range.

Alignment of the 3.5-Mc. range of the converter must be accomplished with the equipment installed in the automobile, if the antenna input circuit of figure 13 has been used. However, if the feed line from the antenna to the converter actually is operating as a matched line instead of as a capacitance (as discussed in a previous paragraph) the inductive input circuit may be used. With this type of input circuit the converter may be tracked and aligned on the bench before installation in the car. With the type of input circuit shown in figure 13 the converter should be installed and capacitor C_4 peaked for maximum noise level in the center of the desired band, probably about 3925 kc., with the antenna extended the normal amount.

Matching the Converter to the Broadcast Receiver Automobile broadcast receivers are designed to operate from an antenna with a specified capacitance range to ground. A trimmer is provided on these receivers to compensate for variations in the capacitance to ground of the actual antenna in use. With the receiver tuned for a particular capacitance to ground, a large deterioration in performance will be encountered when the value of this capacitance is changed without a compensating change in the setting of the trimmer in the receiver. Consequently it is important that the input of the broadcast receiver see the same value of capacitance whether the converter is in operation or the receiver is being fed directly from the antenna.

After the converter is installed, with plate and heater voltage taken from within the broadcast receiver by means of a shielded cable and plug, the switch on the front of the converter is placed in the position which allows broadcast reception. If a whip antenna is being used for reception it will be possible to vary the trimmer in the front end of the broadcast receiver until maximum sensitivity on the broadcast band is obtained. If a low-impedance transmission line from an antenna on the rear of the car is to be used it probably will be necessary to install an additional capacitor, C_4, in series with the lead between the two switch sections. This capacitor is in series with the feed line on the broadcast band; variation in this capacitance about a value in the vicinity of 75 $\mu\mu$fd. will allow the car receiver to be peaked in spite of the rather large feed-line capacitance to the rear of the car. Further information on this problem has been given earlier under "Auxiliary Antenna Trimmer."

After the installation has been peaked for maximum sensitivity on the broadcast band with the existing antenna and feed line combination, the converter should be switched to the 28-Mc. position. The trimmer across L_3 should be peaked for maximum noise level on the 28-Mc. band or for maximum strength of a received signal. It is quite likely that insufficient overall gain will be obtained as a result of the detuning of the input circuit of the broadcast receiver. With step-by-step variation in the number of turns on the link winding of L_4 and in the capacitance of C_5 it will be possible to obtain optimum coupling of the signal from the converter into the broadcast receiver, and at the same time peak up the first tuned circuit in the broadcast set for maximum overall gain.

Construction The unit illustrated was constructed on a 3 by 6½ by 2 inch chassis of the type used in a surplus marker-beacon receiver. The case for the original receiver also serves as the shield cover for the converter. A moderate amount of variation in layout is permissible since only one tube is used and internal shielding is not critical. The form factor of the equipment can be varied considerably it it is necessary to fit the completed converter into the glove compartment, below the dash, or onto the steering column. The most important consideration is that the unit be completely shielded by a cover that completely encloses the assembly. Next most important is that the leads which supply plate and heater voltage to the equipment be properly shielded throughout their length from the car receiver to the converter, and that these leads be by-passed by low-inductance ceramic by-pass capacitors at each end. Also, make sure that the shield cover for the unit is securely fixed to the panel at the front and to the chassis at the rear. If the cover is permited to vibrate with respect to the chassis it is probable that serious frequency modulation of incoming signals will occur whenever the automobile is in motion.

The factors involved in the installation of a noise limiter and in the deriving of plate and heater voltage for the converter from the broadcast receiver have been discussed earlier in this chapter.

12-Watt 3.9-Mc. and 28-Mc. Mobile Transmitter

With the opening of the 75-meter band to mobile radiophone operation, a large number of amateurs have had to revise their thinking about mobile operation. All previous operation had been on the 28-Mc. band and on the v.h.f.'s. The little transmitter shown in figures 14, 15, and 16 was designed to assist the average amateur in giving mobile operation a fling without too much capital investment. Both the component requirements and the power drain of this small transmitter are modest; yet it runs 12 watts input to the final stage and is capable of instant change from the 10-meter band to the 75-meter band at the flick of a switch.

The transmitter is designed for operation from a single 300-volt 100-ma. power supply. Two power units which have proven satisfactory for use with the transmitter are the Mallory VP-552 Vibrapack and the *9-volt* dynamotor from a Model ABK or SCR-595 IFF transpondor. The 9-volt dynamotor was designed to deliver 450 volts, but when operated from a 6-volt supply it delivers about 280 volts at a 100-ma. load. A photograph of the separate power unit for this transmitter is shown in figure 17, while the schematic diagram is shown in figure 18. Note that an inexpensive automobile-horn relay is used as the contactor to control the dynamotor.

Circuit Design A unique feature of this transmitter which adds greatly to operating convenience is the fact that it can be completely pre-tuned for operation on both the 75-meter phone band and on either the 10-meter or the 11-meter bands. The selector switch, S_1, selects the crystal and the pre-tuned tank circuits for either band of operation. A 6AQ5 tube is used as a conventional crystal oscillator with a 3.9-Mc. crystal for the 75-meter band, while this same tube acts as a harmonic oscillator with a crystal in the 13.5 to 14.85 Mc. range to give excitation to the 6AQ5 final amplifier in the 27 to 29.7 range. Tank circuit C_1L_1 tunes to the 10-meter band while C_2L_2 tunes to the 3.9-Mc. band.

Shunt feed is used to the plate of the 6AQ5 final amplifier so that different types of output circuits may be used between the plate of the tube and the antenna circuit. Tank L_3C_3 for the 10-meter range is a conventional parallel-tuned circuit with a link wound over the low-potential end of the coil for antenna coupling. It may be found desirable to insert a 75-$\mu\mu$fd. APC capacitor (C_7) in series with the lead from the link coil to the antenna-selector portion of S_1. Through the use of this capacitor the power input to the final amplifier of the transmitter may be varied by varying the antenna coupling. This capacitor also can serve to tune out any reactance which may exist in the antenna circuit on the 28-Mc. band. This capacitor is shown dotted in figure 16. A conventional 8-foot to 12-foot whip antenna will be found best for operation on the 10-meter band. Coaxial cable such as RG-8/U, RG-58/U, or RG-11/U will prove satisfactory for the lead from the base of the antenna to the transmitter. If the same antenna is to be used for the 75-meter band the length of the lead should be as short as is practicable, and it should be possible to switch a loading coil in series with the base of the antenna for 75-meter operation.

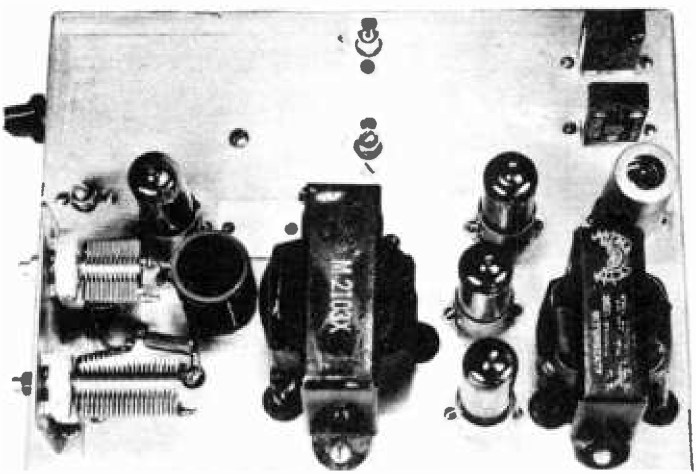


Figure 14.
TOP OF THE 12-WATT TWO-BAND MOBILE TRANSMITTER.

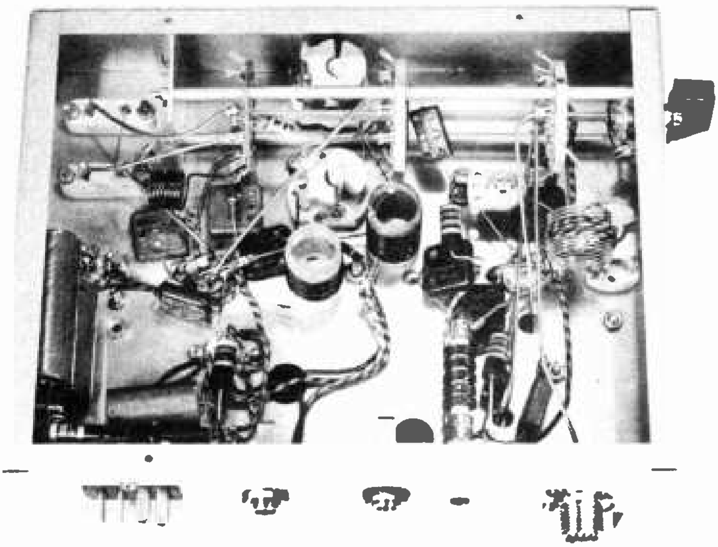


Figure 15.
UNDERCHASSIS OF THE 12-WATT MOBILE TRANSMITTER.

A conventional pi network is switched in as a coupler when the transmitter is changed over for operation on the 75-meter band. This type of coupler has been used since it allows a wide degree of flexibility in the value of antenna impedance which may be matched to the plate of the final-amplifier tube. Antennas for 75-meter mobile operation have been discussed earlier in this chapter. The tuning and matching system illustrated in figure 9 may be substituted for the 75-meter output network illustrated in figure 16.

The modulator for the transmitter is quite conventional, except in one respect; the carbon microphone is connected in the cathode circuit of the first speech tube. The 6C4 tube is operated as a grounded-grid amplifier, with its plate circuit driving the grids of the 6AQ5 modulator tubes through a push-pull input transformer. The 6C4 cathode current provides the microphone current for the carbon button. Surplus microphone type T-17B has proven quite adequate for use in this circuit. The circuit eliminates the microphone transformer and the microphone-voltage filter which is almost invariably required when the microphone is operated from the 6-volt line. The 6AQ5 tubes operate into a plate-to-plate load impedance of about 10,000 ohms, while the final amplifier presents a load of about 7500 ohms to the secondary when it is running at 40 ma. with 300 volts on the plate. The 6AQ5's have more than adequate power output to modulate the 12 watts input to the final amplifier.

The transmitter is constructed on a 7 by 9 by 2 inch aluminum chassis. Steel can of course be used, but aluminum is capable of lower losses from the fields around the tank coils, and the aluminum is much easier to work. The construction of the unit is apparent from the photograph. The switch and tank circuits occupy more than one half of the chassis, while the modulator and tubes take up the balance.

Wiring is accomplished with conventional stranded hookup wire for all the d-c and audio circuits and with no. 14 tinned wire for all the r-f circuits. Coil L_6 is self-supporting, while L_1 and L_2 are wound on Amphenol no. 24 polystyrene coil forms. L_3 is a portion of a B&W no. 3010 Miniductor, while L_4 is wound on a National XR-2 coil form.

Tuning Procedure Two closed-circuit jacks are included on the

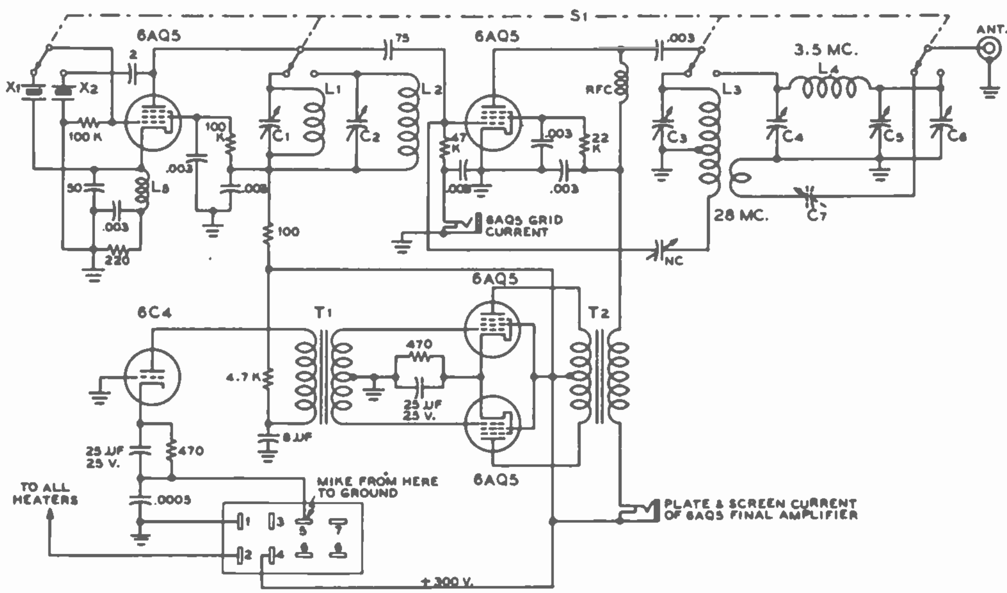


Figure 16.
SCHEMATIC DIAGRAM OF THE 10/75 METER MOBILE TRANSMITTER.

C_1—50-μμfd. APC capacitor
C_2—100-μμfd. APC capacitor
C_3—25-μμfd. APC capacitor
C_4—75-μμfd. APC capacitor
C_5—140-μμfd. APC capacitor
C_6—Ceramic padding capacitor (see text)
L_1—6 turns no. 18, ¾" dia., spaced to ¾"
L_2—42 turns no. 24, ¾" dia., closewound
L_3—6 turns no. 18, ¾" dia., ¾" long, with 3-turn link (B&W 3010 Miniductor)
L_4—38 turns no. 22 enam., 1" dia., 1" long (National XR-2 form)
L_5—9 turns no. 18, ½" dia., closewound
X_1—14-Mc. crystal (James Knights type H-73)
X_2—3.9-Mc. crystal (James Knights type H-73)
T_1—10,000-ohm plate to p-p grids driver (Stancor A-4734)
T_2—10-watt mod. trans. 10,000 ohm pri. to 8000 ohms (Peerless M-2103X)
RFC—2.5 mh. (National R-100U)
S_1—3-deck 4-pole double-throw ceramic (Made from Centralab Switchkit)
Power connector—Jones P-308AB

chassis of the transmitter unit. One jack is used to measure grid current to the 6AQ5 amplifier, while the other jack is used to measure the sum of the plate and screen current to the same tube. A 0-50 d-c milliammeter may be plugged into either jack for measurement of the appropriate currents while tuning the transmitter. When tuning the antenna system it will probably be found most satisfactory to mount an insulated jack on the bumper apron at the rear of the car. Then a plug from this jack may be plugged into the plate-current jack on the transmitter. Through this arrangement the trunk may be closed for tuning the antenna system, yet plate current to the final amplifier may be measured by a milliammeter plugged into the external jack.

Normal grid current to the 6AQ5 final amplifier will run about 3 ma., although 2 to 2.5 ma. is adequate for satisfactory operation of the stage. On the 3.9-Mc. band, where the crystal stage operates as a conventional tuned-plate oscillator, it will be found necessary to detune C_2 on the plate tank of the oscillator slightly on the low-capacitance side of maximum output. This procedure is standard for a straight crystal oscillator to insure that the crystal will start reliably. On the 28-Mc. band the tank circuit in the plate of the crystal oscillator is peaked for maximum grid current to the final amplifier. It will be found best to listen to the output frequency of the transmitter in a 28-Mc. receiver, to insure that the correct harmonic of the crystal oscillator is being tuned.

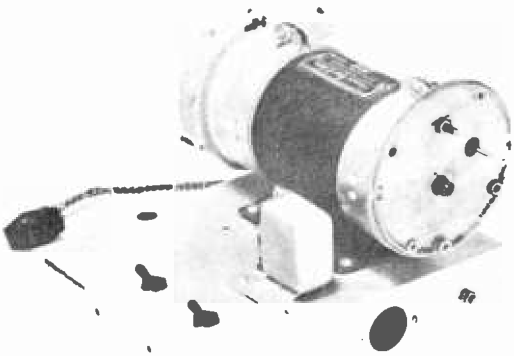


Figure 17.
SHOWING THE DYNAMOTOR UNIT FOR THE 12-WATT TRANSMITTER.

The dynamotor is a 9-volt to 450-volt unit removed from a surplus IFF transpondor. The blower assembly has been removed from the far end, although half the blower housing still remains. The reduction-gear assembly has been removed from the near end of the dynamotor. The plug and cable in the rear connect the dynamotor to the 12-watt mobile transmitter.

Neutralization of the Final Amplifier After excitation to the final amplifier has been obtained on both bands, the next procedure is to neutralize the 6AQ5 stage on the 28-Mc. band. Neutralization is not required on the 3.9-Mc. band.

The neutralizing procedure is as follows: Plug an *open-circuited* phone plug into the plate-current jack. Plug the milliammeter into the grid-current jack. Then apply plate voltage to the transmitter and tune for maximum grid current to the 6AQ5 on the 28-Mc. band. Now vary the adjustment of the 28-Mc. plate tank capacitor, C_3, while noting the indication on the grid milliammeter. It probably will be noticed that there is a considerable kick in the grid current as the plate tank circuit is tuned through resonance. Now change the setting of NC and retune C_1 again for maximum grid current. Again tune C_3 through resonance and see if the kick in grid current has been reduced. If the kick has been reduced, advance NC further in the same direction; if the kick was increased, move NC in the opposite direction. After a few tries, a setting for NC will be found where the tuning of C_3 through resonance will cause no change in the grid current of the 6AQ5. The final amplifier stage has been neutralized when this condition is reached.

Tuning the Output Circuit The loading procedure for the final amplifier on the 28-Mc. band is standard. The plate tank is dipped to resonance without the antenna connected. Then the antenna is connected, the tank tuned slightly to make sure that it is at resonance, and the plate current is noted. The number of link turns on L_3 and the setting of the series capacitor C_7 are varied until the indication on the plate-and-screen milliammeter is about 45 ma. at resonance.

A pi network of the type indicated in figure 16 for use on the 3.9-Mc. band is satisfactory for feeding an antenna system which has a relatively low value of feed-point impedance. Such an antenna might consist of a center-loaded radiator with the value of loading inductance varied until the impedance at the base of the antenna is an approximate match for a coaxial feed line.

An alternative antenna and loading circuit is illustrated in figure 9B. With this type of coupling arrangement the coil at L_4 can be eliminated. Then the two capacitors C_4 and C_5 can be operated in parallel as the plate end of the network which matches this type of antenna arrangement.

If the pi-network loading arrangement shown in figure 16 is used in conjunction with an antenna system which presents a relatively low value of load impedance, it will be found necessary to experiment with the value of capacitor used at C_6. For a first test it is best to place a 250-$\mu\mu$fd. zero-coefficient ceramic capacitor at this position. Then, with the load connected, dip C_4 to resonance and note the minimum plate current. The objective of the tuning procedure is to obtain the rated value of about 45 ma. of plate current plus screen current to the 6AQ5 with the largest possible value of total capacitance at C_5 plus C_6. If the minimum dip in plate current is too low, decrease the setting of C_5 and again dip C_4. If the plate current dip is still too low, assuming that the out-of-resonance plate current exceeds the desired value, de-

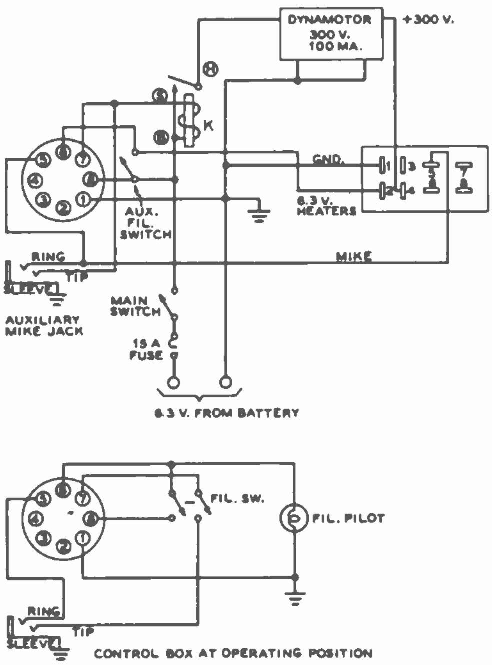


Figure 18.

SCHEMATIC OF THE DYNAMOTOR AND TRANSMITTER CONTROL CIRCUIT.

Although the main control for the transmitter is at the operating position, provision is made for alignment at the transmitter by closing the auxiliary filament switch and plugging the microphone into the auxiliary mike jack. The two-circuit filament switch at the operating position prevents turning on the dynamotor unless the filaments are lighted. An inexpensive automotive horn relay is used at K to control the dynamotor. The three connections to the usual type of horn relay are indicated by the three letters encircled on the drawing. The filament pilot lamp will light whether the heaters have been turned on at the transmitter or at the operating position.

crease the value of the shunting capacitor C_6. If the antenna is presenting a very low value of load impedance to the transmitter it may be found necessary to reduce the number of turns in L_4 to obtain proper loading. When the transmitter is loaded properly it will be found that the plate current at resonance is only about 10 per cent less than the out-of-resonance plate current.

No difficulty should be encountered in getting the modulator to operate properly. However, it will be found that close talking is required to obtain full modulation with a T-17 microphone. Other single-button carbon microphones, including the "F-1 unit" and the military "lip mike" type will give greater modulation for the same voice level. A suggested control circuit for the transmitter is indicated in the schematic of figure 18.

807 Mobile Transmitter For 3.9 and 28 Mc.

With the prevalence of the PE-103A dynamotor on the surplus market, many amateurs have desired to construct mobile transmitters which make use of the 500-volt 160-ma output of this excellent machine. The unit shown in figures 19 through 22 has been designed to fill this need. The transmitter is capable of running 40 watts input to the final amplifier on both the 3.9-Mc. and the 28-Mc. bands. The modulator has sufficient power output capability to give full modulation of the input to the final stage with a conventional carbon microphone at the input of the speech amplifier.

The combination of the mobile transmitter described and a PE-103A dynamotor makes an ideal mobile installation. However, one must not overlook the fact that such an installation will draw about 25 amperes from the car battery while transmitting plus the 5 to 8 ampere drain of the receiver. This is more power drain than the average automobile electrical system is capable of handling continuously in addition to other loads which already exist in the automobile. However, for the intermittent type of drain imposed by mobile operation, no trouble with overheating of present types of automobile generators should be encountered.

Circuit Description The circuit design of the 807 mobile transmitter is essentially similar to that of the 12-watt mobile transmitter which has just been described. The equipment is designed to be completely pretuned for operation on both the 75-meter phone band and on either the 10-meter or the 11-meter phone bands. The selector switch S_1 selects the crystal and the pretuned tank circuits for either band of operation. A 7C5 tube is used as a conventional crystal oscillator with a 3.9-Mc. crystal for the 75 meter band. With the switch in the alternate position this same tube acts as a harmonic oscillator with a crystal in the 13.5 to 14.85 Mc. range to give excitation to the 807 final amplifier in the 27 to 29.7 Mc. range.

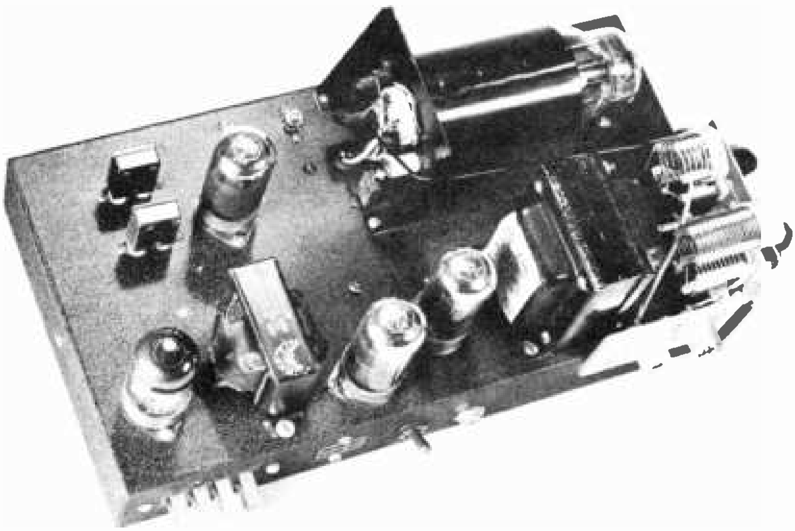


Figure 19.

TOP OF THE 807 MOBILE TRANSMITTER.

Along the front drop of the chassis are, from left to right, receptacle for cable to dynamotor, receptacle for cable to the control panel at the operating position, test switch, meter jack, and the two coaxial receptacles for the antenna feed lines.

A pair of 7C5 tubes operating class AB_1 serve as modulators for the 807. Experience with the tubes has shown that they operate satisfactorily with the full 500 volts on the plates so long as the screen voltage is held to about 275 volts and a high value of cathode resistor is employed. The 7C5's are capable of modulating fully an input of 40 watts to the 807 output stage, with a conventional carbon microphone of the T-17 type in the cathode of the 7A4 speech amplifier. The 7A4 tube operates as a grounded-grid amplifier stage with the driver transformer for the 7C5's in its plate circuit.

Metering Provision has been made for the use of a single 0-100 d-c milliammeter in the cathode return of the 807 stage. With switch S_2 in the open position the screen circuit of the 807 is opened. Since opening of the screen circuit reduces the screen current to zero and the plate current to a very low value, a satisfactory indication of grid current to the 807 is obtained with this switch in the open position. Hence the exciter stage may be tuned for maximum grid current to the 807 on both bands of operation. Then when the switch S_2 is closed the milliammeter in the cathode of the 807 indicates the sum of grid, screen, and plate current to the tube.

The grid current indication will be rather small on a 0-100 milliammeter, since the normal grid current will be from 3 to 4 ma. However, the indication on such a milliammeter is sufficient to allow the exciter stage to be tuned, even though the actual value of the grid current cannot be read with accuracy. An alternative metering method would be to use a double-pole single-throw switch at S_2, with a 0-10 d-c milliammeter in the cathode circuit. When both sections of S_2 were open, grid current would be read on the 0-10 scale. When the two sections of S_2 were closed, a shunt would be connected across the milliammeter jack for increasing the full-scale deflection to 100 ma. With a procedure such as this both the grid current and the plate current could be read with a satisfactory meter deflection.

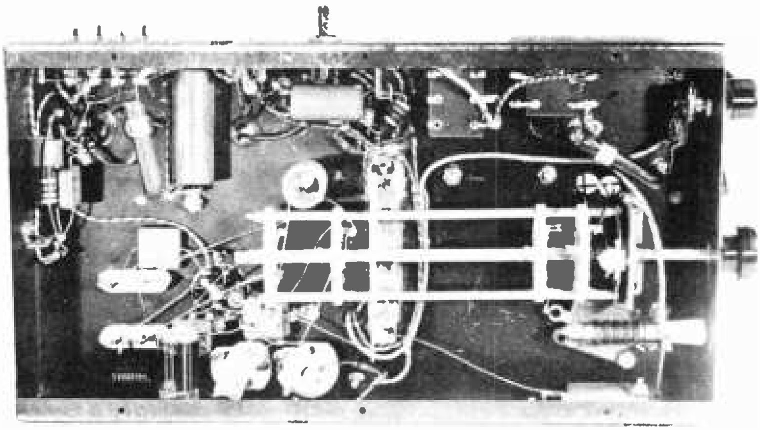


Figure 20.
807 MOBILE TRANSMITTER UNDERCHASSIS.
The band-selector switch can be seen along the center of the chassis. The second section from the front of the bandswitch is not in use, but could be connected into the antenna circuit so that a single coaxial output connector could be used.

The 807 Output Circuit The 10-ohm resistor in the grid circuit of the 807, plus the small parasitic choke in series with the plate lead, result in stable operation of the tube on both the 28-Mc. and the 3.9-Mc. bands. Plate voltage to the tube is shunt fed, with the appropriate output circuit selected by the bandswitch S_1. The tank circuit for the 28-Mc. band is conventional with a link for coupling to the coaxial antenna feed line. Variation in the loading of the antenna upon the amplifier may be obtained by changing the number of turns on the coupling link. It often will be found desirable to include a variable capacitor of 75 to 100 $\mu\mu$fd. in series with the link, or in series at the base of the antenna as shown in figure 7. The series capacitor can best be installed at the base of the antenna if the whip is longer than one-quarter wave, but it can be mounted at the transmitter if the antenna is between 8 and 8.5 feet in length.

The problem of matching the transmitter to the antenna on the 3.9-Mc. band is a much more difficult problem. Certain aspects of the problem have been discussed in some detail earlier in this chapter. If an antenna system such as shown in figure 8 is used, the tank circuit C_2-L_4 may be eliminated and the components discussed in connection with figure 8 installed at the 3.9-Mc. switch position in the plate of the 807. With a loaded-whip antenna tuned so that it presents an impedance approximately equal to the characteristic impedance of the coaxial feed line, the tank and link arrangement of C_3 and L_5 may be used to couple power from the plate of the 807 to the antenna system.

One of the problems associated with a trunk-mounted transmitter is that of tuning the antenna system and the transmitter. In many cases it will be found that an antenna tuned with the trunk open will be seriously detuned when the trunk is closed. This condition is almost certain to be encountered in the case of the relatively sharp tuning antennas which must be used on the 3.9-Mc. band. One way of alleviating, though not necessarily eliminating the problem, is to use an insulated jack mounted on the bumper apron of the

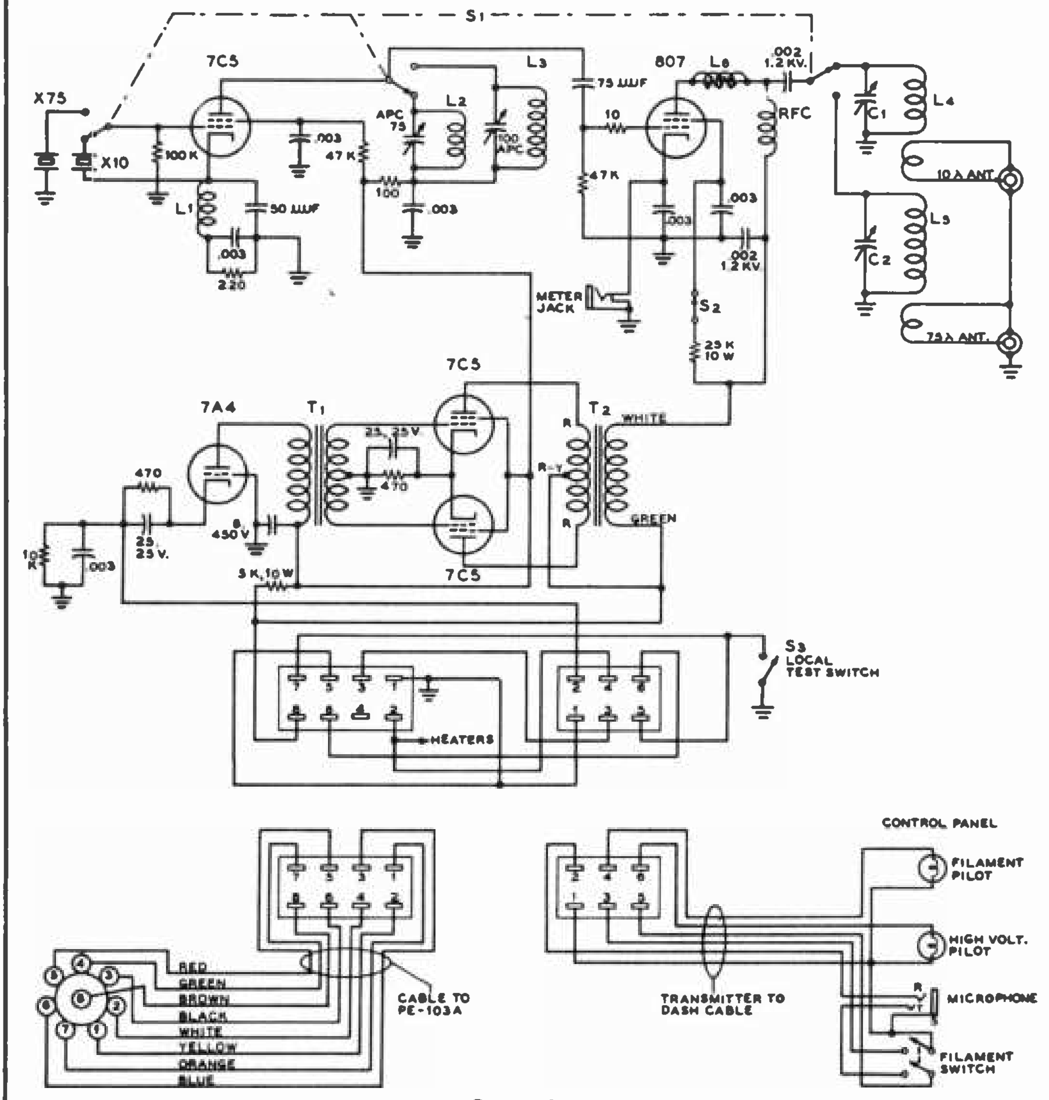


Figure 21.

SCHEMATIC OF THE 807 MOBILE TRANSMITTER.

Shown also in this drawing are the connections for the control circuits and the cabling details for the cables to the dynamotor and to the control panel. The color code for the dynamotor cable is as follows: yellow, heaters; white, 6.3 volts from battery (unused); black, 6.3 volts to plate-voltage pilot lamp; green, control lead for dynamotor relay; red, ground and common for control circuits; blue, control lead for filament relay; orange, ground; brown, positive 500 volts.

L_1—9 t. no. 14 enam. ½" I.d. closewound
L_2—6 t. no. 18 tinned on ¾" dia. Amphenol no. 24 form spaced to ¾"
L_3—35 t. no. 22 enam. closewound on ¾" Amphenol no. 24 form
L_4—8 t. B&W ¾" dia. no. 3010 Miniductor, 3 t. link
L_5—30 t. B&W ¾" dia. no. 3011 Miniductor, 7 t. link
L_6—Parasitic choke; 6 t. no. 18 tinned on Ohmite 47-ohm 2-watt carbon
S_1—Made up from Centralab Switchkit with 7" support screws. Four no. XX 90-degree single-pole four-position ceramic decks used.
S_2—S.p.s.t. wafer switch for opening screen circuit
S_3—S.p.s.t. toggle switch
T_1—3:1 ratio push-pull input (Merit no. A-2912 with 7A4 on whole pri.)
T_2—25-watt modulation trans. (Merit no. A-3109)
RFC—2.5-mh. 125-ma. r-f choke (National R-100U)
X75—Crystal in 3.9-Mc. range
X10—Crystal in 14-Mc. range for operation in 10-11 meter band

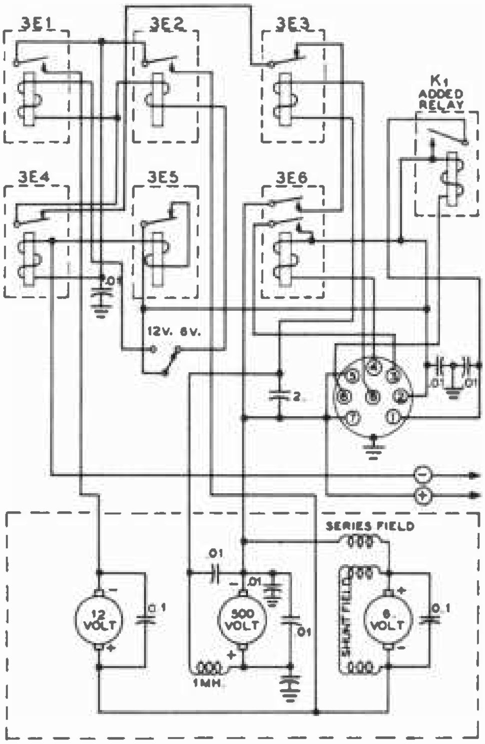


Figure 22.

SCHEMATIC OF THE MODIFIED PE-103A DYNAMOTOR.

All components except those indicated on this schematic may be removed. Resistor 3R3 is rather difficult to remove so it may simply be by-passed. The brushes for the 12-volt commutator (adjacent to the 500-volt commutator) are removed to reduce drag. The added relay, K₁, may be any small 6-volt relay capable of carrying the heater current of the tubes in the transmitter.

rear of the car. A plug connected to this external jack may be inserted into the meter jack on the transmitter, and the meter inserted into the external jack after the trunk is closed. Through a series of approximations and trunk openings and closings the antenna system may be tuned and properly coupled to the transmitter. Alternatively, the transmitter might be mounted in such a position that the dials may be reached and the meter readings noted with the trunk opened only a few inches. But a transmitter installed in such a position would in most cases interfere seriously with the use of the trunk compartment for its normal function—and the transmitter would be quite vulnerable to shifting luggage.

Operation of the Control Circuits The entire primary supply for the transmitter comes through the two heavy cables which run from the PE-103A to the battery. It is assumed throughout this discussion that the positive post of the automobile battery is grounded to the frame of the automobile. The dynamotor may be left connected across the battery at all times since there is no drain unless the filament switch on the control panel at the operating position is turned on. Also, with the specified rewiring of the connections inside the PE-103A, it is not necessary to turn off the circuit breakers on the front of the PE-103A when a period of operation has been completed. The removal of relay 3E7 in the changeover eliminates all power drain with the equipment inoperative. Note that the equipment always must be operated from a 6-volt battery and that the 6-volt/12-volt switch always is left in the 6-volt position.

When the filament switch on the control panel at the operating position is closed, the added relay K_1 inside the base of the dynamotor closes. The closing of this relay applies heater voltage to the tubes in the transmitter and lights the filament pilot on the control panel. Also, it will be noted that the closing of the filament switch on the control panel completes the high-voltage control circuit to the tip connection of the microphone jack. Then when the switch on the side of the microphone is closed the relay 3E6 in the dynamotor closes. The closing of 3E6 lights the high-voltage pilot lamp at the control panel and completes the circuit for the closing of relay 3E2 in the dynamotor. With the closing of 3E2 the dynamotor starts and high voltage is applied to the transmitter.

Protective Circuits The three automatic circuit breakers included within the bottom compartment of the PE-103A are still operative in the circuit of the equipment. In the event of an overload on the heater or control lines of the installation, circuit breaker 3E5 (the one on the left) will open. Opening of this circuit breaker completely disables the equipment. Circuit breaker 3E5 opens on a current of 7.5 amperes through the filament circuit or control lines. If the high-voltage supply should become shorted, or if the total plate current drain of the transmitter should exceed 220 ma., the center circuit breaker (3E3) will open and shut down the dynamotor The circuit breaker on the right (3E4), with an opening current of 40 amperes, is not likely to open unless there is a short or some other serious trouble inside the dynamotor itself.

Modification of the PE-103A Dynamotor The PE-103A dynamotor used with the transmitter has been modified so as to eliminate the standby drain with the equipment inoperative, and to allow for remote control of the application of heater voltage to the tubes of the transmitter. The first step is to remove completely the over-voltage relay 3E7 and all four of the resistors included within the base assembly. It actually is not necessary to remove resistor 3R3 since this resistor is shorted out by one set of contacts of switch $3S_1$ when this switch is in the 6-volt position. The filament-control relay K_1 is then installed in the position formerly occupied by relay 3E7. Any small 6-volt relay capable of carrying about 3 amperes through its contacts may be used. The rewiring of the control circuits of the dynamotor in accordance with the circuit of figure 22 may be accomplished without the addition of any wires to those already present in the main cable of the equipment. However, the functions of several of the wires in the main cable must be changed.

832A Transmitter For 144 Mc.

The transmitter illustrated in figures 23 and 24 may be used with a dynamotor or vibrator-pack supply for mobile use, or with an a-c operated power pack for use at the home station. In either event a power supply capable of delivering 300 volts at about 160 ma. will be required. The unit is crystal controlled with an 832A in the output stage which runs at about 20 watts input—65 to 70 ma. at 300 volts. Provision is included within the unit for operation with a single-button carbon microphone, with the 6C4 plate current acting as microphone current. If desired, a 6AU6 pentode amplifier stage may be included ahead of the 6C4 for operation of the unit from a ceramic or a dynamic mike.

Circuit Details The transmitter is crystal controlled, with output

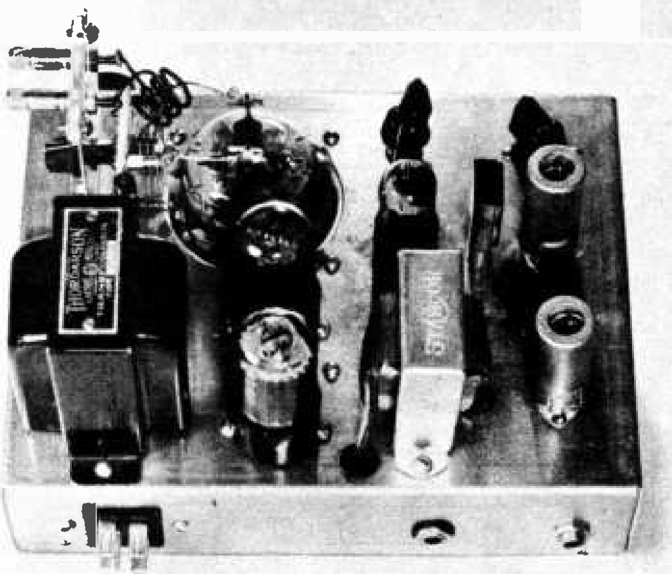


Figure 23.
TOP VIEW OF THE 144-MC. TRANSMITTER.
The 8-Mc. crystal is mounted between the 6J6 and 12AU7 tubes, while the audio channel is mounted along the front of the chassis.

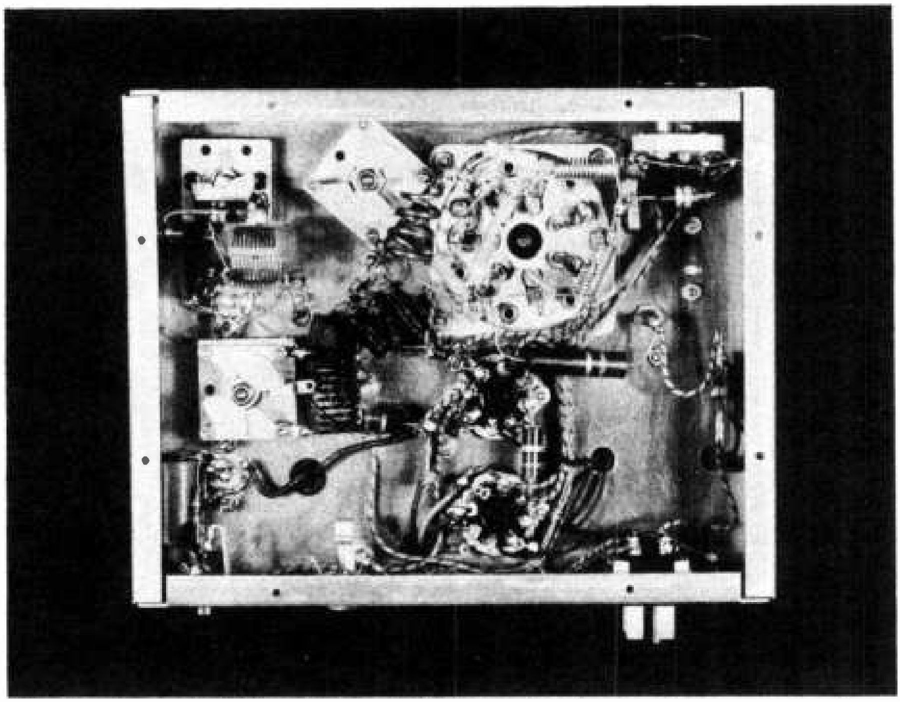


Figure 24.

UNDERCHASSIS OF THE 832A 144-MC. TRANSMITTER.

from the crystal stage on about 24 Mc. If a 24-Mc. crystal is available, it may be used in the equipment. However, 8-Mc. crystals of the surplus variety are much more readily available, and they may be used with equal facility. The oscillator actually operates on the third mechanical harmonic of the crystal frequency. This "third overtone" mode of operation gives an output frequency which is not exactly equal to three times the calibrated frequency of the crystal. So when using a crystal whose output frequency would be close to the band limit, it will be wise to make an accurate check on the output frequency of the transmitter.

The data given for the oscillator coil, L_1, has proven to be satisfactory for use with the normal run of surplus 8-Mc. crystals for third-overtone use. However, if a high-frequency crystal designed for 24-Mc. operation (such as the James Knights H-173, Standard Piezo HF-20, or Bliley AX-3) is to be used, the number of turns on the grid end of the coil should be reduced to the amount which is just sufficient to sustain oscillation.

The second section of the 6J6 is capacitively coupled to the output of the crystal oscillator stage. This section of the tube acts as a frequency tripler with output at some frequency between 72 and 74 Mc., depending upon the frequency of the crystal used. A split-stator capacitor is used in the plate circuit, with capacitive coupling to the grids of the 12AU7 doubler.

The 144-Mc. Multiplier Those who have worked with low-power crystal-controlled transmitters on the 144-Mc. band already know, or soon will discover, that the main problem is to obtain adequate output from the stage which multiplies frequency to 144 Mc. A variety of tubes and circuit combinations were tried in the transmitter illustrated The first arrangement used a 6J6 as a push-pull tripler, with the output of the 6J6 oscillator-multiplier on 48 Mc. This circuit arrangement simply would not deliver sufficient output to the 832A. Also tried were 6AQ5, 6C4, and 12AU7, both as doublers and triplers. The 6AQ5 was completely un-

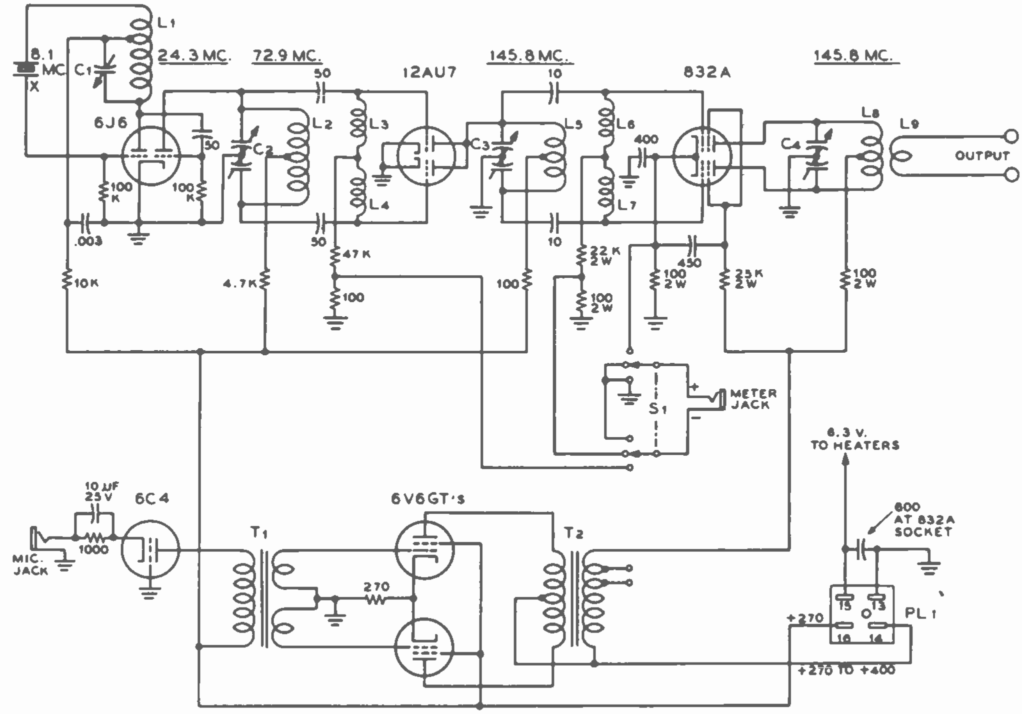


Figure 25.

SCHEMATIC OF THE 832A 144-MC. TRANSMITTER.

C_1—50-μμfd. miniature variable (Millen 20050)
C_2, C_3, C_4—7-μμfd. midget butterfly (Cardwell ER-8-BF/S)
Note—All by-pass capacitors on 832A are Centralab ceramic
L_1—10 turns no. 20, 3/4" dia. by 5/8" long (B&W no. 3011 Miniductor) tapped 3 turns from the crystal end
L_2—10 turns no. 16 enam. 1/2" i.d. spaced to 1-1/8"
L_4, L_7—22 turns no. 22 enam. 5/16" i.d. closewound self-supporting, secured with polystyrene cement
L_5—4 turns no. 14 bare 1/2" i.d., spaced to fit lugs on C_3
L_6, L_7—14 turns no. 18 tinned 1/4" i.d. spaced to 7/8"
L_8—Same as L_5
L_9—One turn pickup link, no. 14 enam.
S_1—2-pole 3-position wafer switch (Centralab 1405)
T_1—Push-pull input, 3:1 ratio (Stancor A-4750)
T_2—10-watt mod. trans. 10,000-ohm pri. to 5000-ohm sec.
PL_1—4-contact plug (Jones P-404-AB)

satisfactory, the 6C4 was marginal in output even at excessive plate input power, and the 12AU7 as a push-pull tripler was almost satisfactory.

Since the 6C4 as a doubler came closest to delivering the desired output, the 12AU7 was then tried as a push-push doubler. Sufficient output was obtained with a plate input less than the maximum rated value. An effort was made to eliminate grid-chokes L_6 and L_7 by using shunt feed to the plates of the 12AU7 and series feed to the 832A grids; this arrangement did not give satisfactory output. So the circuit shown in figure 25 was wired in final form in the completed version. Approximately 3.5 ma. of grid current is delivered to the 832A by the exciter arrangement illustrated.

The 832A final amplifier is plate modulated by a pair of 6V6-GT tubes operating as a class AB_1 amplifier. The 832A stage is conventional, with the plate tank and antenna coupling coil on top of the chassis. A coaxial fitting may be mounted in place of the two-terminal output fitting if it is desired to feed the antenna system by means of coaxial cable. A miniature butterfly capacitor is used in the plate circuit of the 832A as well as in the plate circuits of both multiplier stages of the exciter.

Metering Provision is included for checking the cathode current of the 832A final amplifier, and for measuring the grid currents of the 12AU7 144-Mc. doubler and the 832A final amplifier. A 0-75 or 0-100 d-c milliammeter will be suitable for metering all three circuits. The indication in the two grid-current positions will be rather small (from 1.5 to 4 ma.) but the deflection is sufficiently great to permit tuning.

144-Mc. Mobile Antennas The most satisfactory antenna system for mobile operation on the 144-Mc. band has been found to be a ground-plane vertical. The most satisfactory antenna installation, if there is no objection to cutting a hole in the roof of a metal-top car, is that which uses a vertical rod operating against the car roof as a ground plane. A variety of such antennas designed for police car use are available, or one of the military surplus antenna bases designed for installation through the skin of an airplane may be used. In any event the length of the radiating rod should be about 20 inches. The tapered rods furnished with the surplus aircraft-type antennas usually are several inches shorter than 20 inches. But in most cases an extension may be machined to fit between the large base of the tapered rod and the antenna mounting unit. Coaxial feed, either with RG-8/U or RG-58/U cable should be used between the base of the antenna and the coaxial antenna changeover relay.

If it is desired not to cut a hole in the roof of the car for installation of the antenna at this point, the ground-plane vertical may be mounted atop a steel tube supported from the rear bumper. The height of the vertical radiator, when installed in this manner, should be at least as great as the car top to avoid strong directional effects.

CHAPTER SEVEN

Speech and Amplitude Modulation Equipment

Amplitude modulation of the output of a transmitter for radiotelephony may be accomplished either at the plate circuit of the final amplifier, commonly called high-level AM or simply plate modulation of the final stage, or it may be accomplished at a lower level. Low-level modulation is accompanied by a plate-circuit efficiency in the final stage of 30 to 45 per cent, while the efficiency obtainable with high-level AM is about twice as great, running from 60 to 80 per cent. Intermediate values of efficiency may be obtained by a combination of low-level and high-level modulation; cathode modulation of the final stage is a common way of obtaining combined low-level and high-level modulation.

High-level AM is characterized by a requirement for an amount of audio power approximately equal to one-half the d-c input to the plate circuit of the final stage. Low-level modulation, as for example grid-bias modulation of the final stage, requires only a few watts of audio power for a medium power transmitter and 10 to 15 watts for modulation of a stage with one kilowatt input. Cathode modulation of a stage normally is accomplished with an audio power capability of about 20 per cent of the d-c input to the final stage. A detailed discussion of the relative advantages of the different methods for accomplishing amplitude modulation of the output of a transmitter is given in the chapter *Amplitude Modulation* of the RADIO HANDBOOK, eleventh edition.

Two trends may be noted in the design of systems for obtaining high-level AM of the final stage of amateur transmitters. The first is toward the use of tetrodes in the output stage of the high-power audio amplifier which is used as the modulator for a transmitter. The second trend is toward the use of a "high-level splatter suppressor" in the high-voltage circuit between the secondary of the modulation transformer and the plate circuit of the modulated stage.

Tetrode Modulators In regard to the use of tetrodes, the advantages of these tubes have long been noted for use in modulators having from 10 to 100 watts output. The 6V6, 6L6, and 807 tubes have served well in providing audio power outputs in this range. Recently the higher power tetrodes such as the 4-65A, 813, 4-125A, and 4-250A have come into more general use as high-level audio amplifiers. The beam tetrodes offer the advantages of low driving power (even down to zero driving power for many applications) as compared to the usual triode tubes having equivalent power-output capabilities.

On the other hand, beam tetrode tubes require both a screen-voltage power supply and a grid-bias source. So it still is expedient in many cases to use zero-bias triodes or even low-mu triodes such as the 304TL in many modulators for the medium-power and high-power range. A short list of suggested modulator combinations for a range of power output capabilities is given in conjunction with several of the modulators to be described.

Increasing the Effective Modulation Percentage It has long been known that the effective modulation percentage of a transmitter carrying unaltered speech waves was necessarily limited to a rather low value by the frequent high-amplitude peaks which occur in a speech waveform. Many methods for increasing the effective modulation percentage in terms of the peak modulation percentage have been suggested in various publications and subsequently tried in the field by the amateur fraternity. Two of the first methods suggested were Automatic Modulation Control and Volume Compression. Both these methods were given extensive trials by operating amateurs; the systems do give a degree of improvement as evidenced by the fact that such arrangements still are used in many amateur stations. But these systems fall far short of the optimum because there is no essential modification of the speech waveform. Some method of actually modifying the speech waveform to improve the ratio of peak amplitude to average amplitude must be used before significant improvement is obtained.

It has been proven that the most serious effect on the radiated signal accompanying overmodulation is the strong spurious-sideband radiation which accompanies negative-peak clipping. Modulation in excess of 100 per cent in the positive direction is accompanied by no undesirable effects as far as the radiated signal is concerned, at least so long as the linear modulation capability of the final amplifier is not exceeded. So the problem becomes mainly one of constructing a modulator-final amplifier combination such that negative-peak clipping (modulation in excess of 100 per cent in a negative direction) cannot normally take place regardless of any reasonable speech input level.

The speech waveform of the normal male voice is characterized, as was stated before, by high-amplitude peaks of short duration. But it is also a significant characteristic of this wave that these high-amplitude peaks all are poled in one direction with respect to the average amplitude of the wave. This is the "lopsided" or assymetrical speech which has frequently been discussed and illustrated in the literature. Thus the highest possible average level of modulation which is attainable without negative peak clipping may be had merely by insuring that these high-amplitude peaks always are poled in a positive direction at the secondary of the modulation transformer. This adjustment may be achieved in the following manner: Couple a cathode-ray oscilloscope to the output of the transmitter in such a manner that the carrier and its modulation envelope may be viewed on the scope. Speak into the microphone and note whether the sharp peaks of modulation are poled upward or whether these peaks tend to cut the base-line with the "bright spot" in the center of the trace which denotes negative-peak clipping. If it is not obvious whether or not the existing polarity is correct, reverse the polarity of the modulating signal and again look at the envelope. Since a push-pull modulator almost invariably is used, the easiest way of reversing signal polarity is to reverse either the leads which go to the grids or the leads to the plates of the modulator tubes.

When the correct adjustment of signal polarity is obtained through the above procedure, it is necessarily correct only for the specific microphone which was used while making the tests. The substitution of another microphone may make it necessary that the polarity be reversed, since the new microphone may be connected internally in the opposite polarity to that of the original one.

Low-Level Speech Clipping The low-level speech clipper is, in the ideal case, a very neat method for obtaining an improved ratio of average-to-peak amplitude. Such systems, used in conjunction with a voice-frequency filter, can give a very worthwhile improvement in the effective modulation percentage. But in the normal amateur transmitter their operation is less than ideal. The excessive phase shift between the low-level clipper and the plate circuit of the final amplifier in the normal transmitter results in a severe alteration in the square-wave output of the clipper-filter which results from a high degree of clipping. The square-wave output of the clipper ends up essentially as a double saw-tooth wave by the time this wave reaches the plate of the modulated amplifier. The net result of the rather complex action of the clipper, filter, and the phase shift in the succeeding stages is that the low-level speech clipper system *does* provide an improvement in the effective modulation percentage, but it *does not* insure against overmodulation. An extensive discussion of these factors, along with representative waveforms, is given in the *Amplitude Modulation* chapter of the RADIO HANDBOOK, eleventh edition. Circuits for some recommended clipper-filter systems will also be found in the abovementioned chapter.

The clipper-filter system is capable of delivering essentially ideal performance, however, when used with FM telephony. The reason is simple; no significant amount of audio phase shift would normally take place between the output of the clipper-filter and the r-f output stage of the transmitter. The application of the clipper-filter to FM radiotelephony is discussed in detail in the chapter *FM and Single-Sideband Equipment.*

High-Level Splatter Suppressor The only practicable method disclosed to date for the substantial elimination of negative-peak clipping in a high-level AM transmitter is the so-called "high-level splatter suppressor." As figure 1 shows, it is only necessary to add a high-vacuum rectifier tube, a tube socket, and a filament transformer to an existing modulator-final amplifier combination to provide high-level splatter suppression. And the additional tube and transformer may just as well be placed down in the high-voltage power supply for the final stage.

The tube, V_1, serves to act as a switch to cut off the circuit from the high-voltage power supply to the plate circuit of the final amplifier as soon as the peak a-c voltage across the secondary of the modulation transformer has become equal and opposite to the d-c voltage being applied to the plate of the final amplifier stage. A single-section filter, made up of the capacitance-to-ground of the filament transformer, the inductance of the secondary of the modulation transformer, and the plate-voltage by-pass capacitor for the final modulated amplifier, serves to filter out any high-frequency components resulting from the "switch opening" or clipping action.

Tube V_1 may be a receiver rectifier with a 5-volt filament for any but the highest power transmitters. The 5Y3-GT is good for 125 ma. plate current to the final stage, the 5R4-GY and the 5U4-G are satisfactory for up to 250 ma. For high-power high-voltage transmitters the best tube is the high-vacuum transmitting tube type 836. This tube is equivalent in shape, filament requirements, and average-current capabilities to the 866A. However, it is a vacuum rectifier and utilizes a large-size heater-type dual cathode requiring a warm-up time of at least 40 seconds before current should be passed. The tube is rated at an average current of 250 ma. For greater current drain by the final amplifier, two or more 836 tubes may be placed in parallel.

The filament transformer for the cathode of the splatter-suppressor tube must be in-

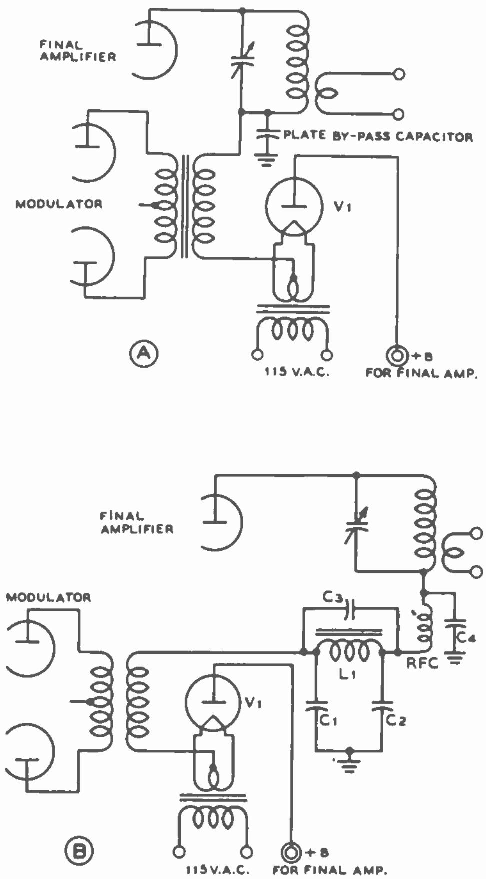


Figure 1.

"HIGH-LEVEL SPLATTER SUPPRESSOR."

This simplified version, (A) above, of the "splatter suppressor" requires fewer components than the original circuit described in the RADIO HANDBOOK. However, the circuit acts as a splatter suppressor only insofar as that splatter which would be generated as a result of negative-peak clipping. No attenuation to high-frequency harmonic distortion generated in the modulator is added to that already resulting from the presence of the plate by-pass capacitor. A combination of the features of the simplified circuit and the original circuit is shown at (B). Normal attenuation to modulator harmonics is offered by the circuit at (B), yet the filament transformer for the rectifier tube need not withstand the high audio peaks at the secondary of the modulation transformer. Chokes suitable for use at L_1 are manufactured by Thordarson. The correct values for C_1, C_2, C_3, and C_4 for use with the Thordarson chokes are specified on the installation sheet for a wide range of operating conditions.

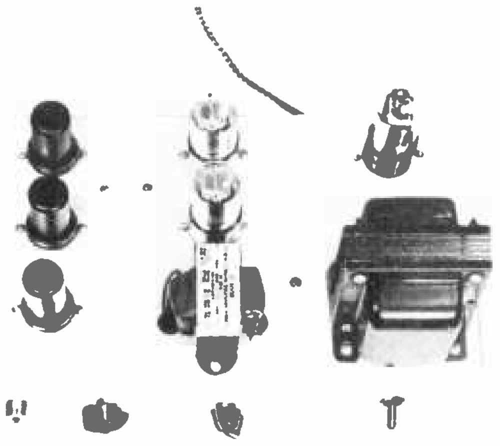


Figure 2.
TOP OF THE 10-WATT 6V6-GT MODULATOR

sulated only for the operating plate voltage of the final amplifier, plus a reasonable safety factor. Insulation of the filament transformer for the voltages at the secondary of the modulation transformer on modulation peaks is not required since the splatter-suppressor tube is at the low-potential end of the secondary of the modulation transformer.

12-Watt Modulator With 6V6 Tubes

The modulator shown in figures 2 and 3 is capable of delivering about 12 watts at the secondary of the modulation transformer. This level of power output is convenient for use in modulating a class C amplifier with a d-c plate input of 15 to 25 watts. The unit also may be used as a grid modulator for a high-power transmitter, or as a cathode modulator for a transmitter with up to about 100 watts input to the modulated stage. Type 6V6 tubes operating class AB_1 are used in the output stage with resistance-capacitance coupling to them from the phase inverter. Ample gain is provided to deliver full output from the modulator when it is driven from a conventional crystal microphone.

Circuit Description The 6SJ7 first stage is excited directly from the output of the crystal microphone. The output of this tube is fed through the gain-control potentiometer into the input grid of the phase inverter stage. A pair of 6SJ7 tubes operating as a "common-return" type of phase inverter in turn feed the grids of the 6V6-GT output stage. Note that no by-pass capacitor is used in conjunction with the common cathode resistor and the common screen resistor of the two 6SJ7 tubes in the phase inverter. Since the signal is fed only to the grid of the first tube of the phase inverter, and the grid of the second tube is grounded, the signal voltage which produces the output from the second tube of the phase inverter is that which is developed across the common cathode and screen resistors. Since this procedure always would result in slightly less voltage output from the second tube as compared to the tube which is fed directly by the signal, degenerative feedback from the plates of the 6V6-GT tubes is coupled back to the plates of the two 6SJ7 tubes in the phase inverter. The feedback resistor for the second tube of the phase inverter is greater in value than that connected to the plate of the first tube by an amount sufficient to permit both tubes to deliver the same signal voltage to the grids of the 6V6-GT's.

In addition to equalizing the output voltages from each side of the phase inverter, the feedback serves to improve the linearity of frequency response of the amplifier within the audio range, and affords a considerable reduction in the harmonic distortion generated within the output stage. Also, since the effective internal impedance of the 6V6-GT output stage is reduced materially by the

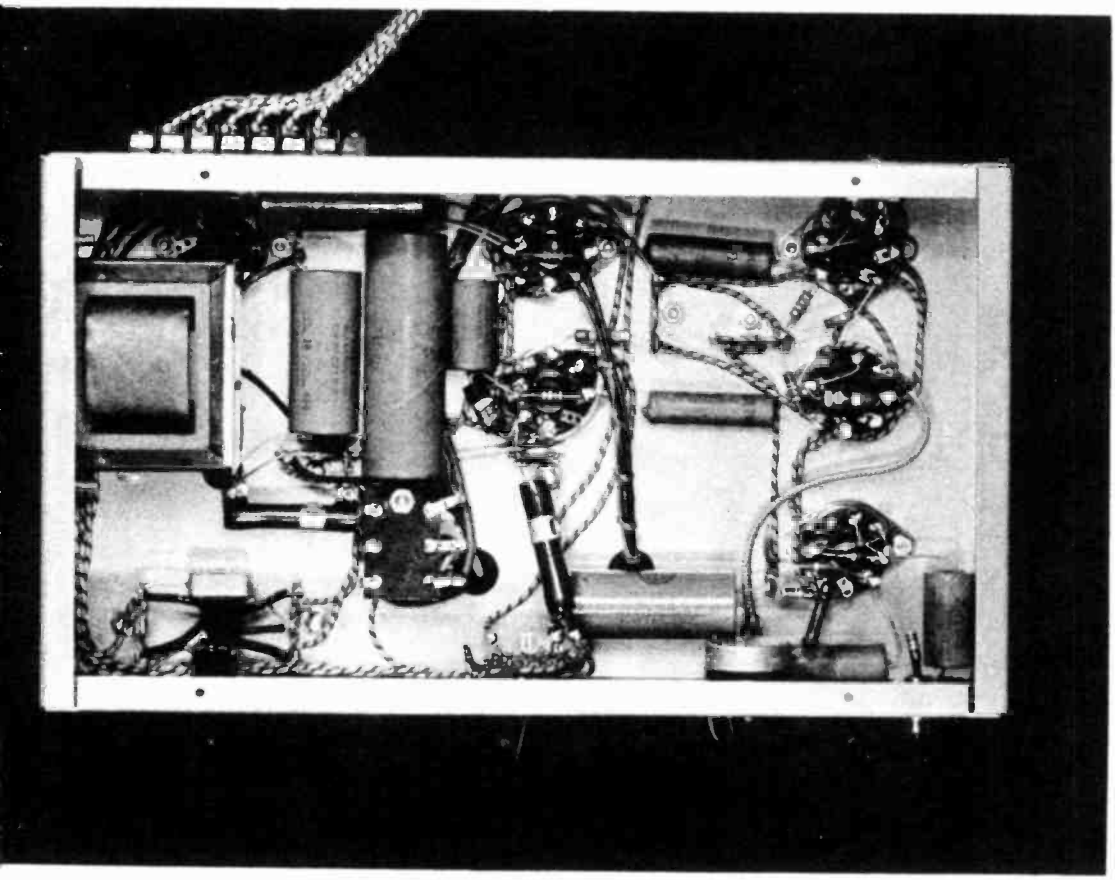


Figure 3.
UNDERCHASSIS OF THE 6V6-GT MODULATOR.

degenerative feedback, the output voltage regulation with varying load is improved. This feature is of considerable value in the event that the 6V6-GT tubes are to be used as drivers for a high-power class B audio stage, with the modulation transformer replaced by a driver transformer in the pate circuit of the 6V6-GT's.

The plate-to-plate load impedance for the 6V6-GT tubes should be 12,500 ohms for the operating conditions of this amplifier. The other operating conditions of the 6V6-GT tubes are: plate voltage, 325; screen voltage, 300; and grid bias about 21. Semi-fixed bias on the output tubes is obtained by passing the bleeder current through the cathode resistor for the stage.

Construction The complete modulator is mounted, along with its power supply, on a 7 by 12 by 3 inch aluminum chassis (ICA type 29008). Terminals (Jones 4-141) are mounted on the rear of the chassis for connection to the a-c line cord and to the amplifier which will be modulated by the unit. Also included on the rear of the chassis is a 4-wire connector (Jones S-304-AB and P-304-FHT) for bringing out the 6.3 volts and high-voltage d.c. for operation of an external unit such as a converter or standby receiver. An additional switch on the front of the chassis can be connected to cut out the modulator (by removing screen voltage from the 6V6-GT's) when plate voltage is applied to the external unit.

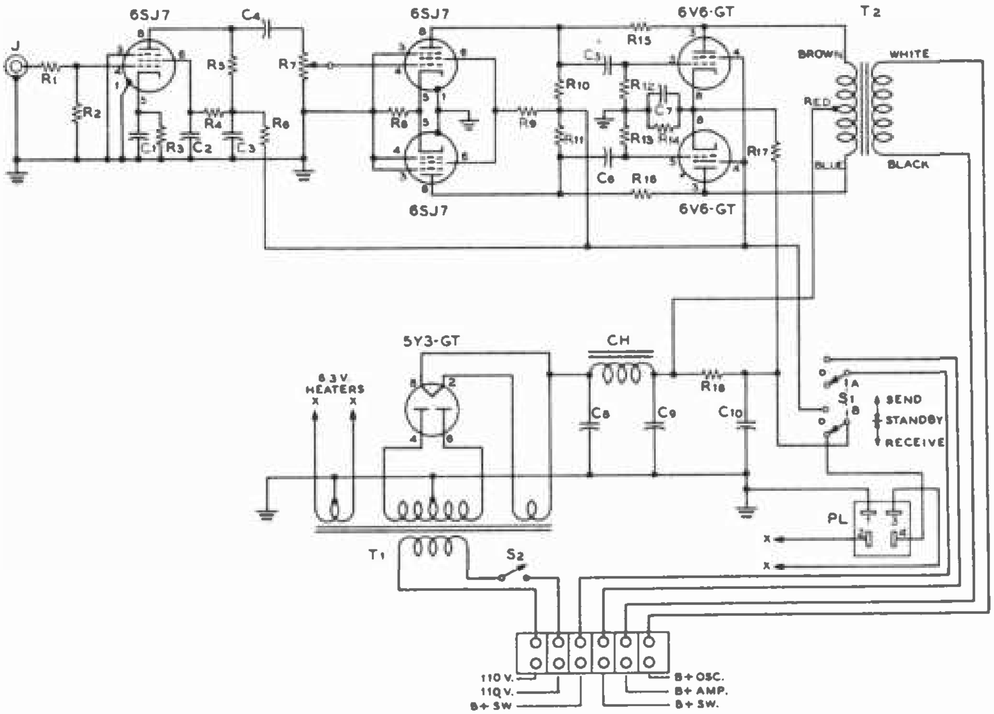


Figure 4.

SCHEMATIC OF THE 10-WATT 6V6-GT MODULATOR.

C_1—25-µfd. 25-volt electrolytic
C_2—0.1-µfd. 400-volt tubular
C_3—12-µfd. 450-volt elect.
C_4—0.001-µfd. ceramic or mica
C_5, C_6—0.05-µfd. 400-volt tubular
C_7—25-µfd. 25-volt elect.
C_8, C_9—10-µfd. 450-volt elect.
C_{10}—30-µfd. 450-volt elect.
CH—15-hy. 75-ma. filter choke (Merit C-2990)
PL—4-contact Jones S-304-AB receptacle
R_1—47,000 ohms, ½ watt
R_2—1.0 megohm, ½ watt
R_3—1000 ohms, ½ watt
R_4—2.2 megohms, ½ watt
R_5—470,000 ohms, ½ watt
R_6—47,000 ohms, ½ watt
R_7—500,000-ohm potentiometer
R_8—680 ohms, 1 watt
R_9—1.0 megohm, ½ watt
R_{10}, R_{11}, R_{12}, R_{13}—470,000 ohms ½ watt
R_{14}—270 ohms, 2 watts
R_{15}—1.0 megohm, ½ watt
R_{16}—1.5 megohms, ½ watt
R_{17}—22,500 ohms 10 watts
R_{18}—3000 ohms 10 watts
S_1—2-pole 3-position wafer switch (Centralab no. 1473)
S_2—S.p.s.t. toggle switch
T_1—700 v. c.t. 70 ma., 5 v. 3 a., 6.3 v. 3 a. (Merit P-3151)
T_2—Small 10-watt modulation transformer (Merit A-3008)

50-Watt Modulator With 6L6 Tubes

It is difficult to surpass the capabilities of the reliable 6L6 tube when an audio power output of 25 to 50 watts is required of a modulator. A pair of 6L6 tubes operating in such a modulator will deliver good plate circuit efficiency, require only a very small amount of driving power, and they impose no serious grid-bias problems.

Circuit Description Included on the chassis of the modulator shown in figures 5 and 6 are the speech amplifier, the driver and modulation transformers for the output tubes, and a plate current milliammeter.

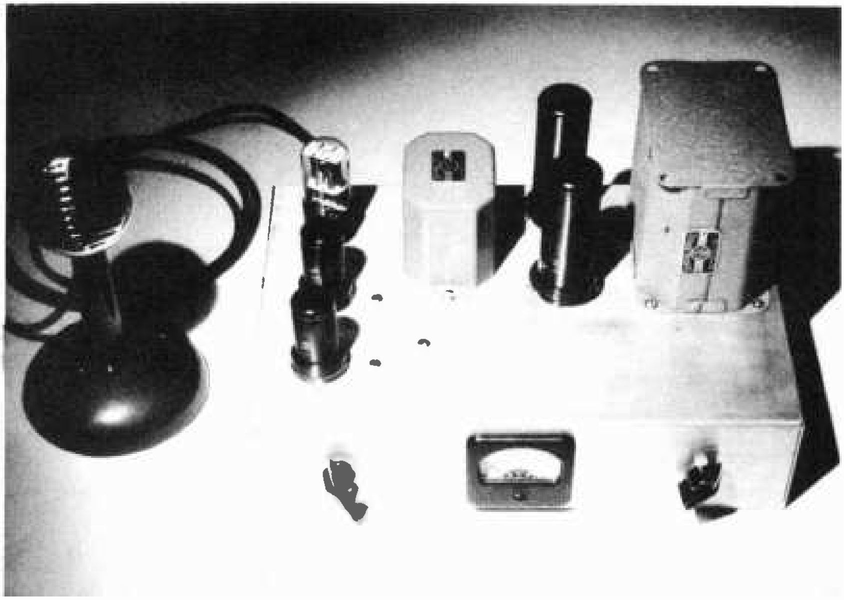


Figure 5.
TOP VIEW OF THE 6L6 MODULATOR.

The power supply has not been included. The 6SJ7 pentode first stage is coupled through the volume control to the grid of a 6J5 phase inverter. The output of the phase inverter is capacitively coupled to the grids of a 6SN7-GT which acts as a push-pull driver for the output tubes. Transformer coupling is used between the driver stage and the grids of the output tubes so that the output stage may be operated either as a class AB_1 or class AB_2 amplifier.

The Output Stage Either 6L6, 6L6-G or 1614 tubes may be used in the output stage of the modulator. As a matter of fact, either 6V6-GT or 6F6-G tubes could be used in the output stage if somewhat less power output is required. The 1614 tube is the transmitting-tube counterpart of the 6L6 and carries the same ratings and recommended operating conditions as the 6L6 within the ratings of the 6L6. But the 1614 does have somewhat greater maximum ratings when the tube is to be used for ICAS (Intermittent Commercial and Amateur Service) operation. The 6L6 and 1614 retail to the amateur for essentially the same price, although the 1614 is available only from transmitting tube distributors. The 6L6-G tube retails for a somewhat lower price; hence it is expedient to purchase 6L6-G tubes if 360 to 400 volts is the maximum to be used on the output stage, or to purchase 1614 tubes if up to 550 volts will be applied.

Tabulated below are a group of recommended operating conditions for different tube types in the output stage of the modulator. In certain sets of operating conditions the tubes will be operated class AB_1, that is with increased plate current with signal but with no grid current. Other operating conditions specify class AB_2, operation, in which the plate current increases with signal and grid current flows on peaks. Either type of operation is quite satisfactory for communication work. All operating conditions for 50 watts output and less are suitable for use with the output transformer specified. The operating conditions for power outputs greater than 50 watts are shown to illustrate the fact that the driver stages are capable of exciting the specified tubes to the greater power outputs; however, an output transformer with a power-handling rating greater than the unit specified (see caption to figure 7) will be required.

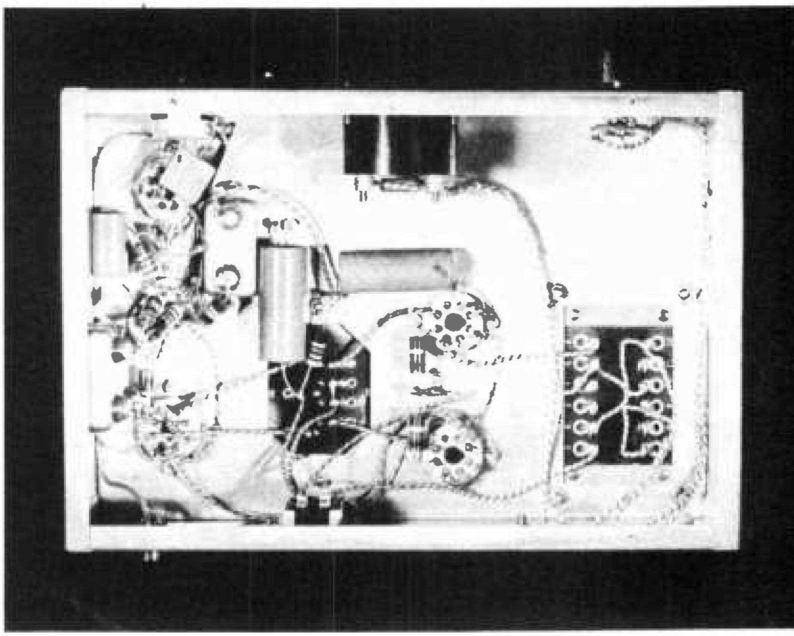


Figure 6.
UNDERCHASSIS OF THE 6L6 MODULATOR.
A 4-connector plug is used for filaments and plate voltage to the speech amplifier, while a 6-wire terminal strip is used for the high-voltage connections and the transmitter-control switch.

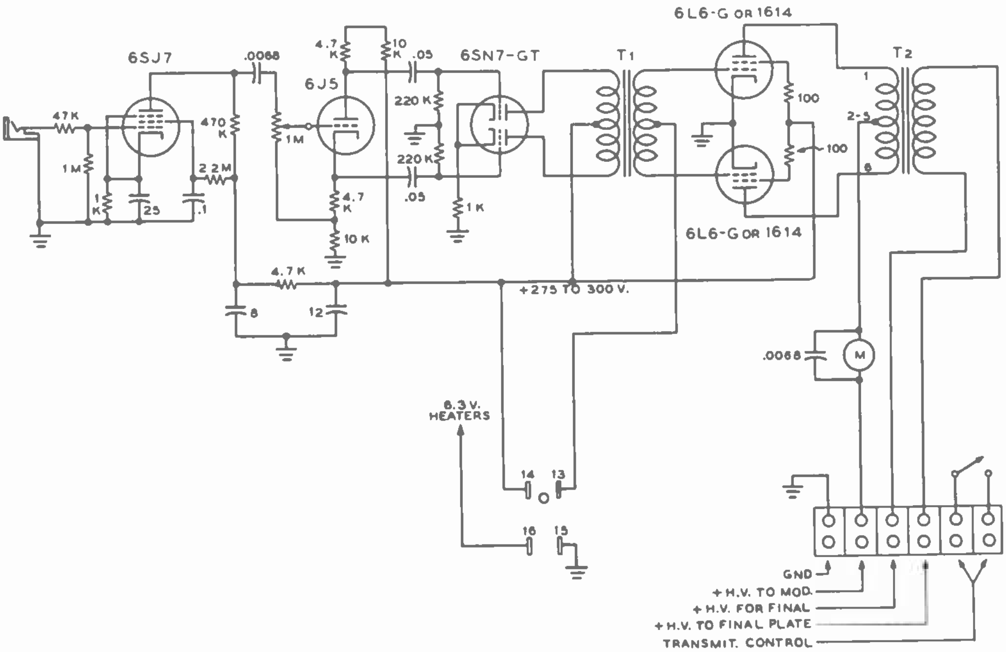


Figure 7.
SCHEMATIC OF THE 6L6 MODULATOR.

M—0-250 d-c milliammeter (Simpson model 127)
T_1—Driver transformer to 6L6 grids (UTC S-10)
T_2—60-watt modulation transformer (UTC S-20)

Tubes	Class	Plate Voltage	Screen Voltage	Grid Bias	Plate-to-Plate Load	Zero-Sig. Plate Cur.	Max.-Sig. Plate Cur.	Power Output
6V6-GT	AB_1	285	285	-19	8000	70	92	14
6F6-G	AB_2	375	250	-26	10000	34	82	20
6L6-G	AB_1	360	270	-22.5	6600	88	132	26.5
6L6-G	AB_2	400	275	-22.5	3800	90	210	50
1614	AB_1	530	340	-36	7200	60	160	50
1614 or 807	AB_2	500	300	-30	4250	60	240	75
807	AB_2	750	300	-32	6950	60	240	120

50-Watt Modulator With 815

The 815 tube is satisfactory for use in a modulator in the 50-watt power range for operation from a 500-volt power supply. The cost of an 815 tube is slightly more than the pair of 807's which could have been used, but the 815 requires considerably less space than a pair of 807's and requires less filament current. A modulator using an 815 is particularly well suited to operation in conjunction with a 300 to 350 ma. power supply for modulating a transmitter with an 829B in the final stage.

Figure 8 shows an 815 modulator operating in conjunction with a Millen 90810 r-f section for the 10, 6 and 2 meter bands. This transmitter uses an 829B in the final and in this installation both the r-f section and the 815 modulator run from a single 500-volt. 300-ma. power supply. An additional 250-volt power supply furnishes plate voltage for the speech amplifier portion of the modulator and screen voltage for the 815.

Circuit Description The speech amplifier portion of the modulator utilizes the popular 6SJ7/6V6-GT combination with feedback from the plate of the 6V6-GT to the plate of the 6SJ7. A conventional step-down driver transformer couples the output of the 6V6-GT to the grids of the 815 tube. This speech amplifier arrangement gives ample gain for operation of the modulator from a conventional diaphragm-type crystal microphone. Since it is not practicable to include a gain control within the feedback loop, a 1-megohm potentiometer is placed directly across the output of the crystal microphone with the slider arm feeding through

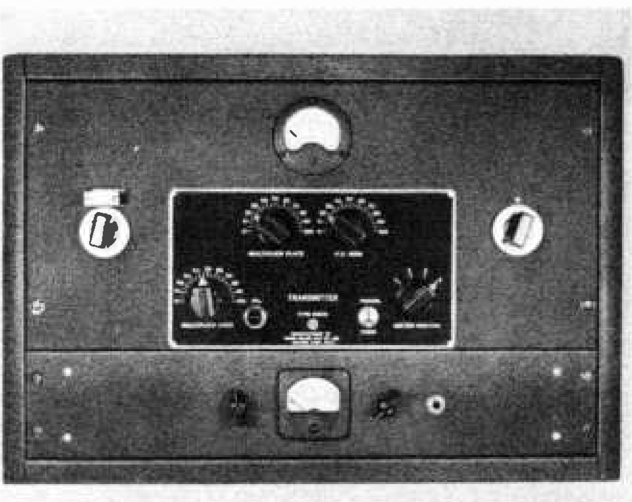


Figure 8.
SHOWING THE MODULATOR-TRANSMITTER COMBINATION.

The 815 modulator is shown installed in a 12¼-inch standard cabinet along with a Millen no. 90810 v-h-f transmitter. The power supply control switch, which acts as the transmit-receive switch, is mounted on the front panel of the modulator on the opposite side of the plate milliammeter from the audio gain control.

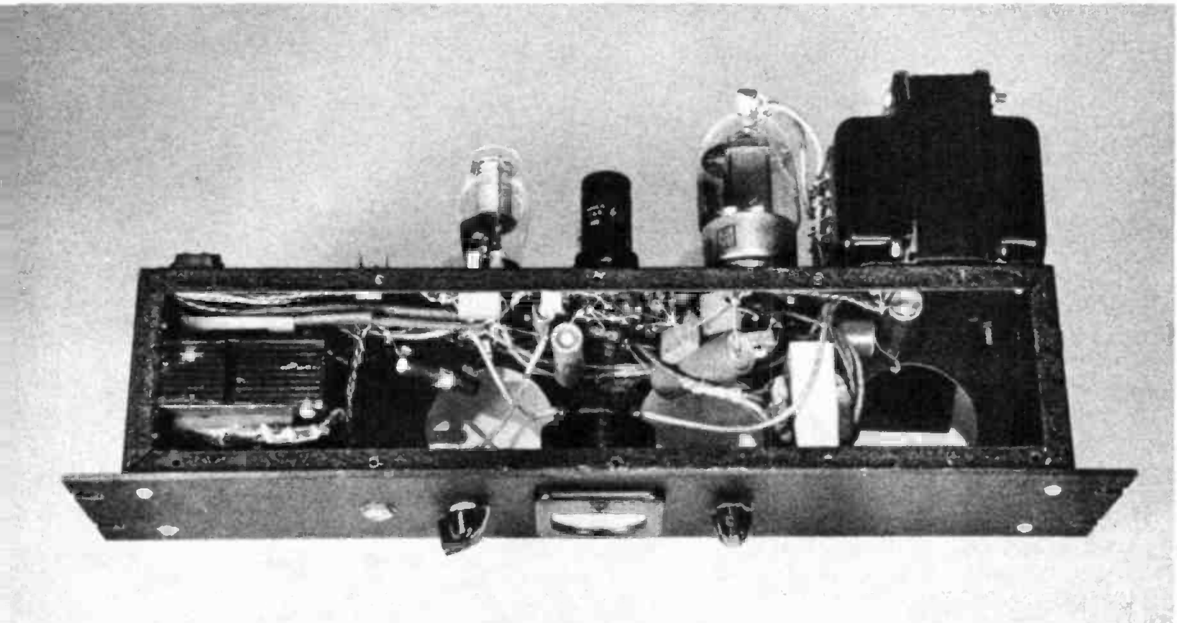


Figure 9.

LOOKING INSIDE THE MODULATOR CHASSIS.

The chassis has been removed from the cabinet and inverted for this photograph. Note the heavy-duty filament transformer for all tubes mounted inside the chassis and attached to the left end in this view.

an r-f filter circuit to the grid of the 6SJ7. In the event that more or less gain is required from the speech amplifier, a moderate variation may be obtained by varying the value of the feedback resistor between the plates of the two speech-amplifier tubes. Lowering the value of this resistor will increase the feedback and decrease the overall gain. An increase in the value of this resistor will reduce the feedback with a consequent increase in stage gain but with increased distortion from the speech amplifier portion of the modulator.

Fixed bias is used on the grids of the 815 tube. In this particular equipment it was found most practicable to obtain this bias from a tapped 22½-volt C battery. The 16-volt tap on the battery is run to the grid return of the 815 tube. Screen voltage on the 815 is held at 150 volts by a VR-150 voltage regulator tube. The regulator tube is fed from the 250-volt power supply which also feeds the two speech amplifier stages. A 0-200 d-c milliammeter is mounted in the center of the modulator to measure the plate current on the 815 tube. The normal standing plate current on the 815 with −16 volts of bias and 150 volts on the screen will be about 40 ma. with 500 volts applied to the tube. With full signal being applied to the modulator the plate current on the 815 will kick to full scale on the meter on voice peaks. The correct value of plate-to-plate load impedance for the 815 is 8000 ohms.

The modulator unit was designed to operate in conjunction with a surplus model PE-110B power supply and to be mounted in the same case as the 90810 r-f unit. Hence the modulator unit includes a filament transformer with sufficient capacity to run both the modulator and the r-f unit. Also mounted in the modulator unit is a send-receive switch for controlling the operation of the external power supply. The control circuits within the modulator are such that operation with the PE-110B is obtained merely by throwing the one switch. Equally satisfactory operation can be obtained of course with any other 500-volt, 300-ma. power supply with a power relay controlled by the send-receive switch. The

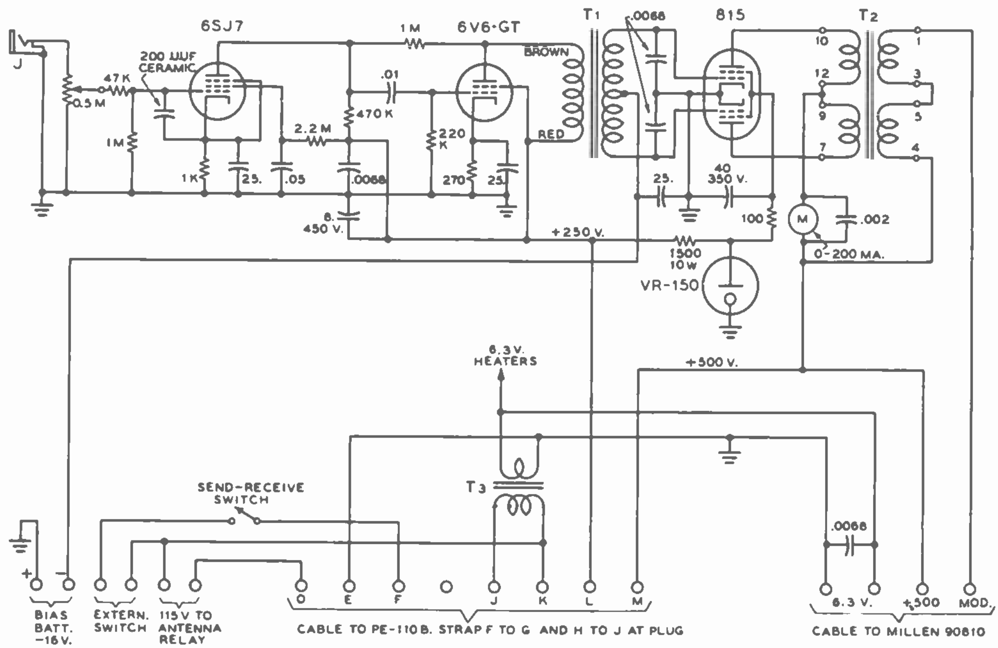


Figure 10.
SCHEMATIC OF THE 815 MODULATOR.

J—Closed-circuit microphone jack
M—0-200 d-c milliammeter (Simpson 2 inch)
T_1—10,000-ohm driver plate to p-p grids (Stancor A-4752)
T_2—60-watt multi-tap modulation trans. (Stancor A-3893)
T_3—6.3 v. 6 amperes, filament trans. (Stancor P-3064)

power supply unit should include an additional receiver-type power supply capable of delivering 250 volts at approximately 70 ma.

Construction The mounting of the components is such that all may be supported behind a single 3½ by 19 inch standard panel. To accomplish this the modulation transformer, all tubes, and the connectors for the power cables are mounted on the rear of a 4 by 3 by 17 inch chassis. The filament transformer, inter-stage transformer and all minor components are mounted inside the chassis proper. All connections from the modulator unit to the remote power supply terminate in an 8-wire Jones plug. Connections from the modulator unit to the r-f amplifier with which it operates terminate in a 4-wire Jones plug. External leads to the bias battery and to the antenna change-over relay are brought out to a 6-terminal Jones strip on the rear of the chassis.

100-Watt Modulator With 807 Tubes

Type 807 tubes are convenient for use in modulators with 75 to 120 watts of audio power output. The tubes are inexpensive, easy to drive, and the regulation required of the plate, screen, and bias voltage supplies is not critical. Figure 11 shows a block diagram of an 807 modulator designed to deliver 100 watts output at the secondary of the modulation transformer. This modulator is a component of the 200-WATT ALL-BAND TRANSMITTER described in detail in the *Transmitter Construction* chapter. Photographs and the detailed schematic diagram of the modulator are given in the description of the complete equipment in that chapter. In the case of the transmitter described in *Chapter Nine,* the 807 modulator feeds audio to the plate circuit of a single-ended 4-65A final amplifier.

6-Watt Amplifier With the 6AS7-G

The 6AS7-G tube is a low-mu dual triode with quite unusual characteristics. Each section has an amplification factor of 2.1, a transconductance of 7500 micromhos, and the unusually low plate resistance of 280 ohms. The very low plate resistance makes the tube particularly effective for several tube applications where other more common tubes leave something to be desired. Two of these applications are: (1) As a regulator tube in a voltage-regulated plate-voltage or bias supply Use of the 6AS7-G in this application is described in the *Power Supply* chapter. (2) As an output tube in a push-pull audio power amplifier which must feed a load whose impedance varies over the audio cycle. The most common example of the second application is, of course, the driver stage which feeds the grids of a class B audio power amplifier or modulator.

The audio amplifier shown in figures 12, 13, and 14 was designed and constructed to use the characteristics of the 6AS7-G either to feed a speaker system as a high-fidelity amplifier, or to feed the grids of a class B power amplifier as a driver unit. The tube delivers about 6 watts of audio power at the secondary of the output transformer when operating under the conditions specified on the schematic diagram. This amount of audio power is delivered at a signal level slightly below that which causes overloading of any of the stages in the amplifier chain. Considerably more power output may be obtained if a slight degree of flattening on the tops of the audio waves can be tolerated. The tube actually delivers somewhat more output than the 6 watts specified, but losses in the output transformer bring the measured output down to the value stated.

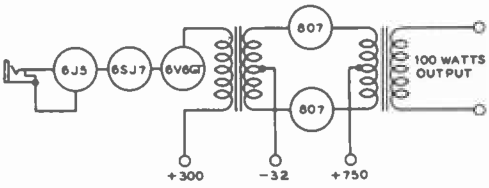


Figure 11.
SIMPLIFIED BLOCK DIAGRAM OF THE 807 MODULATOR.

Circuit Description The 6AS7-G tube is used as a push-pull tri-

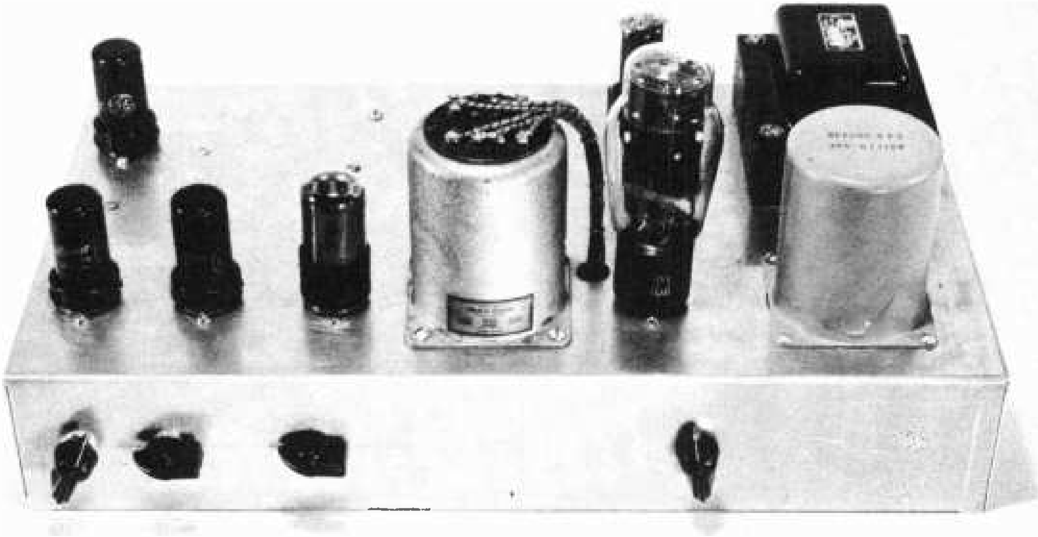


Figure 12.
TOP VIEW OF THE 6AS7-G AMPLIFIER.

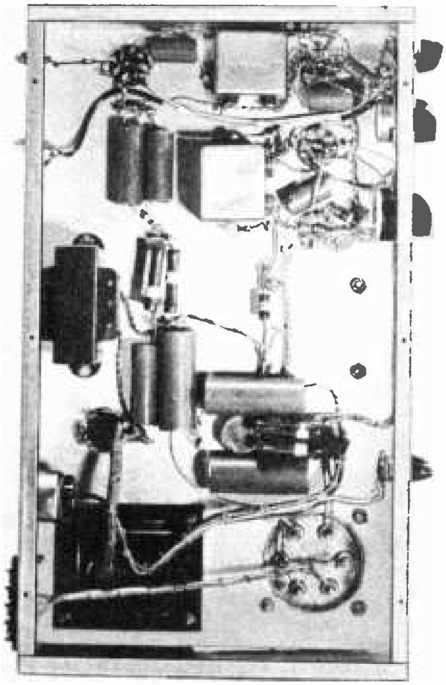


Figure 13.
UNDERCHASSIS OF THE 6AS7-G AMPLIFIER.

ode output amplifier with transformer input and output. Separate cathode bias resistors are used on the two tubes included within the 6AS7-G envelope, with individual by-pass capacitors from each cathode to ground. A linear-taper 1000-ohm potentiometer, with the movable arm grounded, serves to balance the plate currents to the two tube sections. The tube operates with a plate-to-cathode potential of about 195 volts, a plate current of about 125 ma. for both sections, and a cathode bias of about 95 volts for both sections. The proper plate-to-plate load resistance for these operating conditions is 4000 ohms. With these conditions the tube will deliver about 8.5 watts to the primary of the output transformer, and about 6 to 7 watts will be available at the secondary.

An alternative set of operating conditions for a total plate supply voltage of about 375 volts also has been specified by the tube manufacturer. The conditions are as follows: plate-to-cathode voltage—250 volts, cathode bias (2500-ohm resistor for each tube section)—125 volts, total plate current for the tube—100 ma., plate-to-plate load impedance—6000 ohms, and rated power output at the primary of the output transformer—13 watts.

Grid Drive Requirements With the use of either of the sets of operating conditions which have been specified it is necessary to supply an unusually high value of peak audio frequency grid-to-grid voltage. This requirement is one of the main disadvantages of the tube, but is a natural consequence of the very low amplification factor and plate resistance which the tube features. A peak a-f grid-to-grid voltage of about 200 volts is needed for the amplifier illustrated, while the alternate set of operating conditions specified require about 255 volts peak to peak.

It is not practicable with conventional voltage-amplifier circuits to obtain an a-f peak output voltage of 100 to 125 volts (200 to 250 volts peak to peak) with low distortion when the plate supply voltage is only 300 to 400 volts. Hence it becomes necessary to use a step-up interstage transformer between the last audio stage and the grids of the 6AS7-G tube. Experience with several 6AS7-G audio amplifiers has shown, also, that it is much preferable to use a push-pull stage to feed the primary of the step-up interstage transformer. These points should be kept in mind since the limitation upon undistorted output from a 6AS7-G amplifier usually will be found to be the driver stage rather than the output stage unless the driver is carefully designed.

The 6N7-GT Driver Stage Through the use of a 6N7-GT (Note that this tube is not a 6SN7-GT) tube as a combined phase inverter and push-pull driver for the primary of the interstage transformer an ample amount of undistorted excitation voltage is available for the grids of the 6AS7-G. The 6N7-GT acts as a cathode-coupled phase inverter through the use of the circuit arrangement shown. The cathode bias resistor is unbypassed, exciting signal is fed to one grid, and the other grid is grounded. Although the output current from each half of the phase-inverter tube is not the same with this circuit arrangement, the tight coupling between the two halves of the primary of the interstage transformer allows the two a-c output

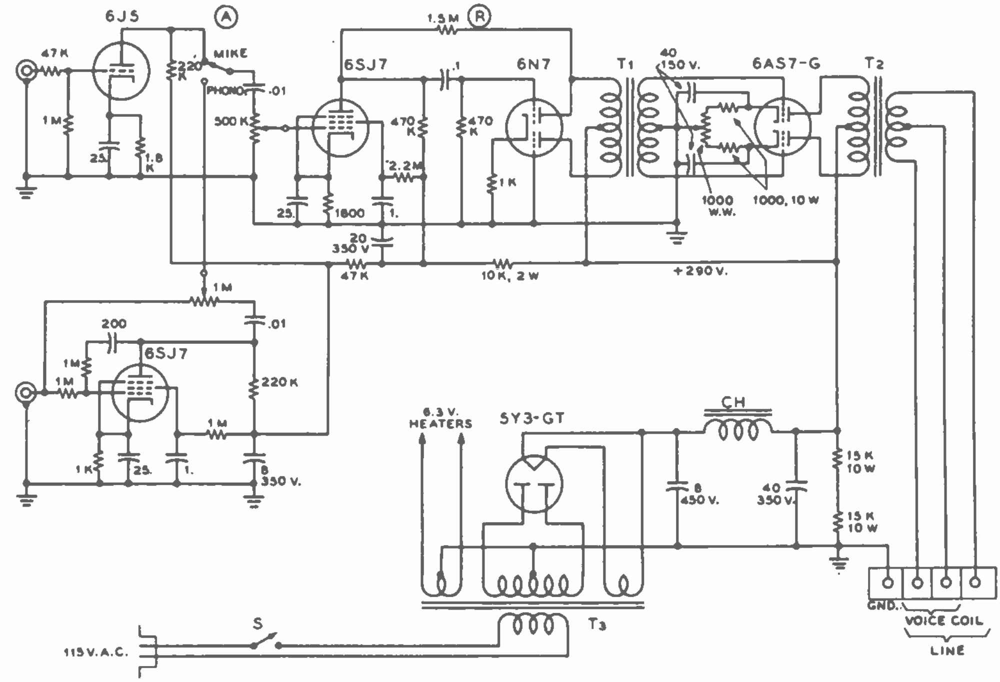


Figure 14.
SCHEMATIC OF THE 6AS7-G AMPLIFIER.

A—See text.
CH—7-hy. 150-ma. choke (Stancor C-1710)
R—Feedback resistor; see text.
T_1—Push-pull interstage transformer; see text.
T_2—Output transformer: see text.
T_3—580 v. c.t., 125 ma.; 5 v. 3 a., 6.3 v. 4.5 a. (Stancor P-6313) Transformer with higher secondary voltage may be used for greater power output from the amplifier as discussed in the text.

currents effectively to be added as far as the resulting voltage appearing across the secondary is concerned. Simple shunt voltage feedback from the first plate of the 6N7-GT to the plate of the 6SJ7 which drives it serves to improve the linearity of the phase inverter. Through adjustment of this resistor (R) it is possible to obtain a considerable variation in the overall gain of the amplifier. Lowering the value of (R) will decrease the gain, while about 10 db of additional gain may be obtained by eliminating the resistor. Moderate increase in gain may be obtained by increasing the value of (R) to a value greater than 1.5 megohms.

Both the interstage and the output transformer shown in the amplifier are non-standard units, the source of which is obscure. But the interstage transformer has a measured step-up turns ratio of total primary to total secondary of 3 to 1. Suitable substitutes are the Stancor A-4155, Merit A-2912, and Thordarson T-20A24 for communications and public address work; for high-quality radio or phonograph reproduction the UTC LS-22 or HA-107, or the ADC 214J may be used with a slight decrease in overall gain. Any output transformer which presents a 3800-ohm to 4000-ohm load to the plates of the tube with the desired load on the secondary will be satisfactory. When the amplifier is to be used as a driver for a high-power class B modulator, an output transformer designed to couple a pair of 2A3 tubes to the grids of the class B tubes will be satisfactory.

Frequency Range Limitation Provision has been made in the amplifier by the switch at (A) for the selection of two input arrangements for feeding the balance of the amplifier. With the selector switch in the upper position the amplifier may

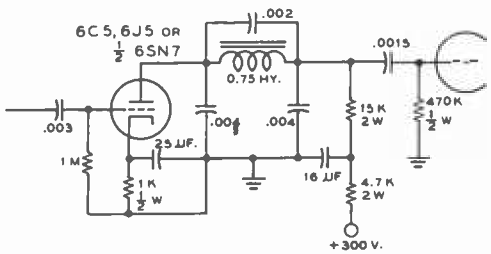


Figure 15.

SCHEMATIC OF THE VOICE-FREQUENCY FILTER.

The filter may be inserted into any speech amplifier having a triode voltage amplifier stage using a tube of the general type of those listed on the schematic above. The filter should be inserted to form the plate load impedance of the voltage amplifier stage. The output of the filter may be coupled into a resistor in the grid of the next stage, as indicated above, or a standard ½-megohm potentiometer may be substituted. The filter shows substantially flat response between 250 and 2500 cycles, with a gradual drop-off below 200 cycles and a sharp drop-off above 3000 cycles. Suitable chokes for use in the filter are the inexpensive Thordarson T-20C58 and the more expensively constructed Chicago Transformer type NSI-1.

be fed through the 6J5 pre-amplifier from a standard crystal microphone or high-impedance dynamic. In the event that the amplifier is to be used to drive a recording head the circuit as shown will be quite satisfactory. However, if the amplifier is to be used as a driver for a class B modulator in a communication transmitter it is suggested that some type of band-pass filter be used between the plate of the 6J5 and the volume control. The filter circuit arrangement shown in figure 15 has proven to be quite satisfactory for speech work. This filter introduces a gradual cutoff to all frequencies below 200 cycles, and introduces a sharp cutoff to all frequencies above 3000 cycles. The components for the filter section are inexpensive and relatively easily available.

An alternative arrangement is to include additional positions on the selector switch at (A) so that signals from additional sources may be fed into the gain control of the amplifier. A signal of about 50 millivolts at (A) will provide full output from the amplifier. Hence, a crystal pickup or the audio output of a radio or TV tuner may be fed directly to the top of the volume control at the grid of the 6SJ7.

The Equalized Phono Input The second input to the amplifier shown on figure 14 is for use with a phono pickup of the dynamic type such as the GE variable reluctance. A 6SJ7 tube is used as an equalizer amplifier to give a 6 db per octave increase in gain below the turnover frequency of 500 cycles. This equalization which compensates for the drop-off below 500 cycles obtained when using a magnetic pickup with standard recordings, is obtained by controlled degenerative feedback from the plate of the 6SJ7 back to its own control grid. The 1.0-megohm potentiometer in the plate circuit of the 6SJ7 serves as an equalization control; with this control in the top position on the schematic, full equalization is obtained. With the control at the bottom the equalization is eliminated. When the control is placed in intermediate positions a variable amount of equalization can be obtained.

The power supply for the amplifier, which is included on the chassis, is conventional, except that the supply delivers a secondary voltage which is somewhat lower than is usual (290 volts each side of center). If a conventional power transformer, with 350 to 375 volts each side of center, is used it will be necessary to raise the value of the 1000-ohm resistors in series with each cathode of the 6AS7-G to 2000 ohms. Then the alternate operating conditions specified for the 6AS7-G at the beginning of this section should be used. The most significant change is the increase in the rated load resistance from 4000 to 6000 ohms plate to plate. The power output will be increased materially.

Class B 809 Modulator

The modulator unit shown in figures 16 and 17 uses a pair of 809 tubes in conjunction with a line-input driver transformer and an 85-watt output transformer. Type 809 tubes are capable of an output power up to about 145 watts, but in the application for which this modulator was constructed a power output of 85 watts was sufficient to modulate the 170 watts input to the final amplifier.

Only the bare essentials of the class B modulator stage have been mounted upon the chassis and its associated panel. These components include the filament transformer, the input and output transformers, and the plate milliammeter for the 809 tubes. The modulator was designed to be driven from a 5 to 10 watt speech amplifier at the operating table. A 500-ohm line from the output of the speech

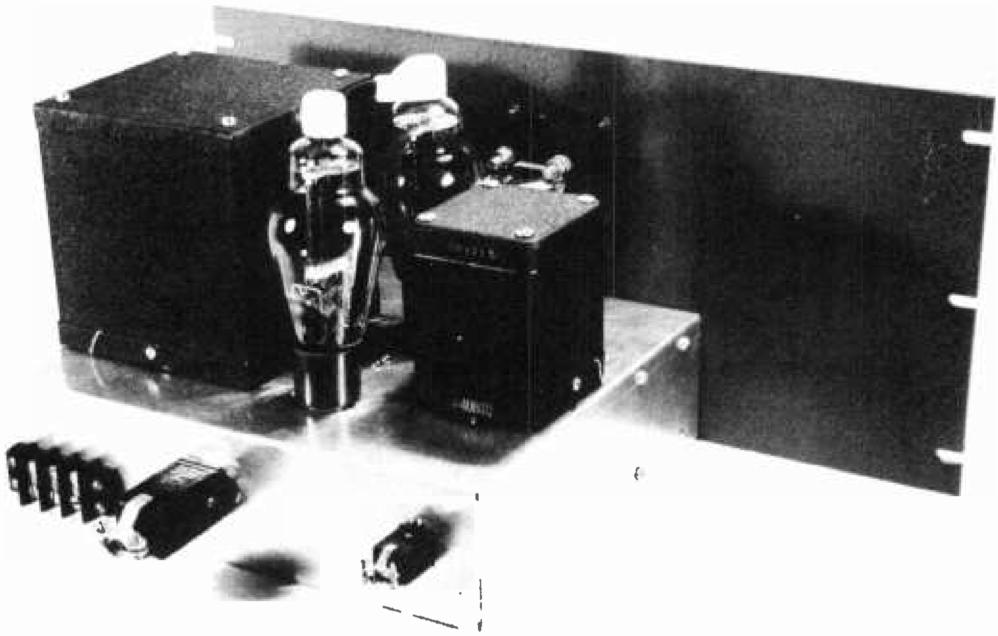


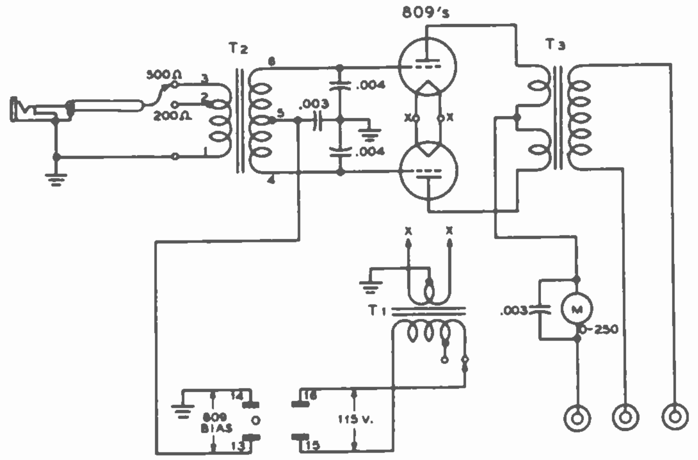
Figure 16.
REAR VIEW OF THE 809 MODULATOR.

amplifier to the primary of the line driver transformer T_2 serves to couple the audio signal from the output of the speech amplifier to the grids of the 809's. However, it was considered that at a later date the speech amplifier might be mounted alongside the 809 output stage and supported from the same panel. Hence the 10 by 12 inch chassis which supports the modulator was offset by an amount sufficient to permit the mounting of a 5 by 12 by 3 inch speech amplifier/driver chassis alongside. The panel is a standard 8¾ by 19 inch dural unit. The plates of the 809 tubes project slightly above the height of the panel which was used, but the short panel height was required and the tops of the tubes do not interfere with the components below the deck of the unit mounted above. If desired, the 809 tubes may be lowered with respect to the top edge of the panel by sub-mounting the tube sockets.

Type 809 tubes are practicable for use in class B audio amplifiers and modulators at plate voltages from 500 to 1000 volts. The tubes may be operated at zero grid bias with plate voltages as high as 700 volts. Above this value of plate voltage a small amount of grid bias, such as can be obtained from one or two 4½-volt C batteries, is sufficient to limit the zero-signal plate current to a

SUGGESTED 809 OPERATING CONDITIONS

Plate Voltage	Grid Bias	Zero-Sig. Plate Cur.	Max.-Sig. Plate Cur.	Plate-to Plate Load	Power Output
500	0	40	250	3750	85
600	0	55	210	6000	85
700	0	70	250	6200	120
750	-4.5	40	200	8400	105
1000	-9	40	200	11,600	145



T₁—6.3 volts at 10 amps (Stancor P-6308)
T₂—Line to Class B grids (Peerless A-4086Q)
T₃—85-watt modulation trans. (Peerless M-2105Q)
M—0-250 d-c milliammeter (Marion 53SN)

Figure 17.
SCHEMATIC OF THE 809 MODULATOR.

value which will keep the plate dissipation of each tube within the 30-watt maximum specified for ICAS operation.

Under ordinary conditions the procedure of driving a class B modulator stage through two transformers (the plate-to-line transformer at the driver and the line-to-grid transformer at the modulator) will be found to be satisfactory. However, the procedure will not be found satisfactory when: (1) Either of the paired transformers has a high insertion loss or high leakage reactance. (2) The driver stage would be working at its maximum capability to excite the grids of the modulator stage with only one transformer in the circuit. From one-third to one-half the power output of the driver will be lost (at the peak of the exciting-voltage cycle when the power is needed most) in passing through two cascaded transformers. (3) The tubes being driven show a sharp discontinuity in grid impedance at a certain signal amplitude. Zero-bias tubes do not exhibit this characteristic, but most conventional triodes which operate with a fair value of grid bias will show this discontinuity. This condition will result in the generation of an excessive amount of odd-harmonic distortion in the output of the modulator as a result of distortion of the driving wave. The driving-wave distortion is a result of leakage reactance and winding resistance in the two cascaded transformers. (4) The distance from the driver to the modulator is such that the resistance of the line between the two units becomes an appreciable fraction of the nominal line impedance. The net result of each of these undesirable conditions is that increased third-harmonic distortion will appear in the output of the class B modulator. Also, it may not be possible to obtain adequate drive to the grids of the class B stage Viewed on an oscilloscope, these effects make themselves apparent as a serious flattening of the peaks of the wave being fed to the modulator grids. Hence, a test made with an oscilloscope and an audio oscillator will quickly show whether a projected arrangement of transformers between the driver and modulator grids will prove to be satisfactory.

100-Watt 811 Modulator

Type 811 tubes have become more or less standard for use in communication modulators in the 100-watt to 200-watt range. This statement applies both to commercial and to amateur equipment. In fact, the audio components used in this modulator, shown in figures 18, 19, and 20, are surplus items which originally were manufactured for use in the Collins Model ART-13 equipment. Obviously, the commercial counterparts of these components could be used with equal facility; in fact, commercial equivalents for each of the transformers used have been given in the parts list which accompanies figure 20.

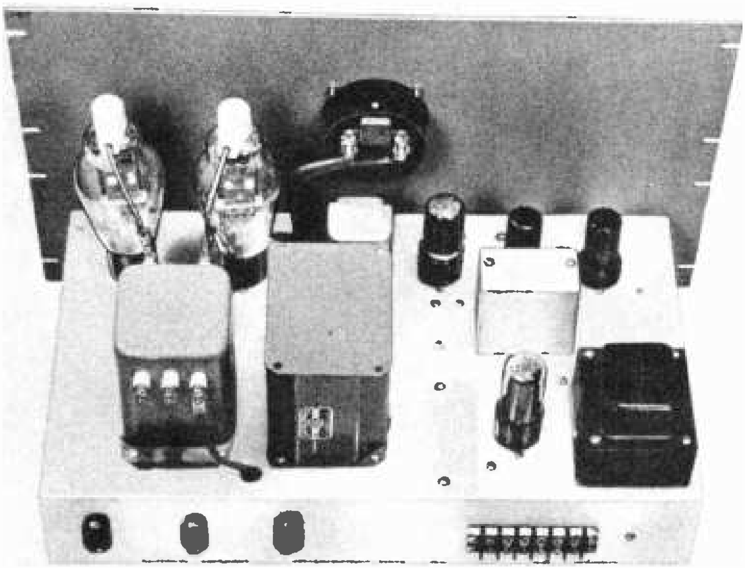


Figure 18.
REAR VIEW OF THE 100-WATT 811 MODULATOR.
The driver transformer can be seen between the 6V6-GT and the first 811 tube. The output transformer is toward the rear from the two 811's. Filament transformer and the speech-amplifier power supply are on the rear of the chassis to the right of the modulation transformer.

All the speech amplifier components from the grid of the 6SJ7 to the grids of the 811's have been obtained from a surplus 26S-1 speech amplifier unit. The components used for the 6J5 first speech amplifier stage and for the speech-amplifier power supply are quite standard. The output transformer for the 811's has been widely available on surplus, and is used in the ART-13 to modulate an 813 with a pair of 811's.

The modulator should be operated with 1250 volts, or less, on the plates of the 811's. The unit has ample gain for operation from a crystal microphone, and it is capable of about 110 watts output at the secondary of the modulation transformer. The standing plate current on the 811's will be about 40 ma. for the pair. This current will kick up to 125 to 150 ma. on voice peaks for full output from the unit. The speech quality of the modulator is excellent, being essentially flat from about 250 to 4000 cycles, with a drop off at either end. Harmonic distortion within the modulator is low enough to be negligible for speech work, and hum and internally generated noise are also negligible.

Construction The unit is built upon a standard 10 by 17 by 3 inch chassis with a standard 10½ by 19 inch dural panel. If a 26S-1 speech amplifier unit is available it is only necessary to disassemble the unit and remount the components to be used upon the chassis. The 6V6-GT sidetone amplifier with its associated components, which is included within the 26S-1 amplifier, has not been included in this unit. But these components can just as well be remounted on the chassis if a sidetone channel is desired. The metal shield can on the chassis between the 5Y3-GT rectifier and the 6SJ7 stage contains the 20-μfd. cathode by-pass capacitors used in the amplifier. If one of the surplus speech amplifiers is not available, the cathode

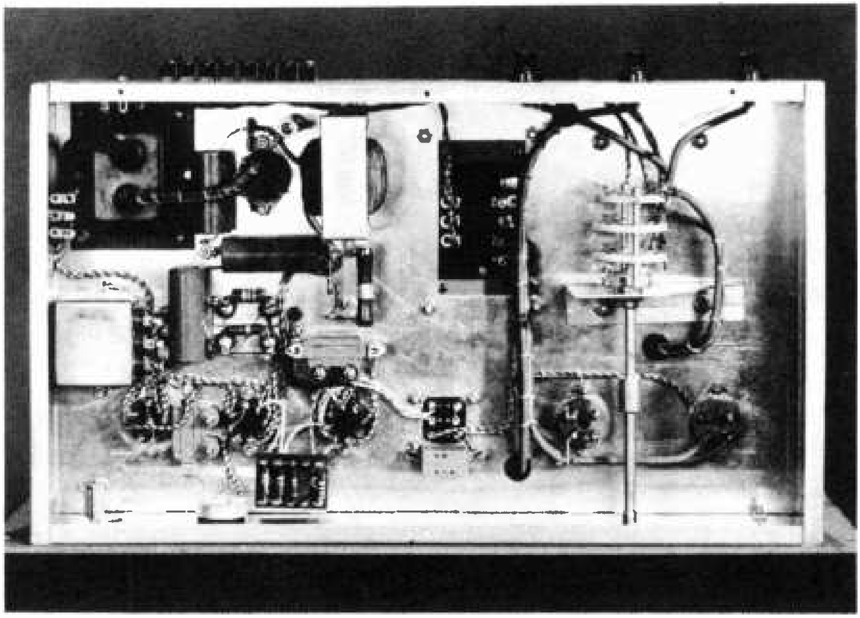


Figure 19.
UNDERCHASSIS VIEW OF THE 811 MODULATOR.

by-pass capacitors can be mounted beneath the chassis in the conventional manner.

The Output Transformer The surplus output transformer is designed to present a plate-to-plate load of 15,000 ohms to the 811's when the secondary load impedance is 7300 ohms. This value of secondary load is presented by a class C amplifier operating at 1250 volts and 170 ma. This represents an input to the class C stage of 212.5 watts, which is capable of being fully modulated by the output of the 811's. Terminals 4 and 5 on the modulation transformer were provided for simultaneous modulation of the screen of the 813 along with the plate in the ART-13 transmitter. If the modulator is to be used to plate modulate a beam tetrode tube in the final stage, this winding may be used to obtain the screen modulation. If a triode stage is to be modulated, or if another means is to be used to obtain the simultaneous screen modulation of a tetrode amplifier, this winding need not be used. The output transformer is quite compact in terms of its power handling capability. This compactness has been attained through the use of special core materials. However, it is the output transformer which imposes the limitation upon the power output of the modulator. With the use of –9 volts bias on the 811's, 1500 volts on their plates, and an output transformer of ample rating, it is possible to obtain 220 watts from the tubes.

The phone-c.w. switch incorporated within the unit can be seen clearly in the underchassis view. A Centralab ceramic switch of the 90-degree indexing type has been used. When the switch is in the PHONE position the filaments and speech-amplifier power supply in the modulator unit are energized, the short is removed from the secondary of the modulation transformer, and the external circuit which is keyed for c.w. is shorted. In the c-w position the 115-volt supply is cut off from the modulator, the secondary of the modulation transformer is shorted to eliminate keying surges which might be developed across the transformer, and the short across the key is removed. Note that the moving contact of the switch deck which shorts the modulation transformer is connected to plus 1250 while the fixed contact is connected to the modulated plate voltage. This has been done since the voltage insulation to ground is somewhat better for the stationary contact.

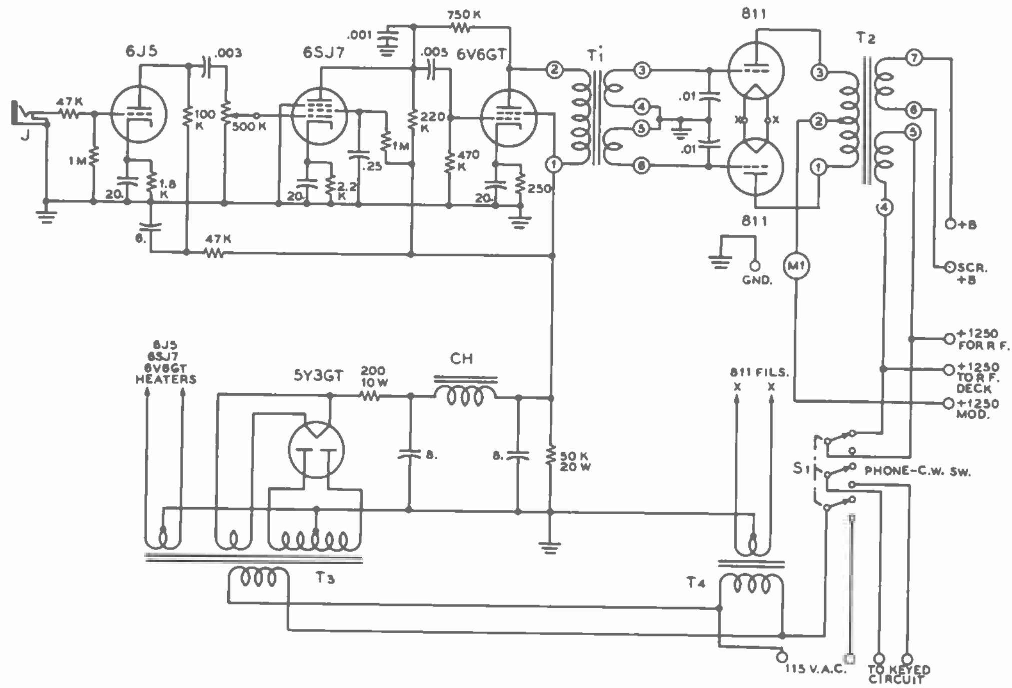


Figure 20.

SCHEMATIC DIAGRAM OF THE 811 MODULATOR.

CH—15-hy. 75-ma. filter choke (Stancor C-1002)
S_1—Ceramic "Phone-C.W." switch (Centralab 2544)
T_1—Driver transformer, 3:1 primary to half secondary (Stancor A-4210, UTC S-8, Merit A-3124 may be used in place of Collins T-202 shown.)
T_2—Modulation transformer, 125 to 250 w., 15,000-ohm primary to desired secondary load (UTC CVM-3, Merit A-3107, Stancor A-3894 may be used in place of the unit shown.)
T_3—700 v. c.t. 90 ma., 5 v. 3 a., 6.3 v. 3.5 a. (Stancor P-6012)
T_4—6.3 v. 8 a. (UTC S-61)

300-Watt Class B Modulator For 8005 or 5514 Tubes

The 300-watt modulator shown in figures 21 and 22 has been designed for use with type 8005 tubes. Type 5514 tubes may be substituted for the 8005's with appropriate changes in operating conditions. Either tube type is capable of 300 watts output when operating within the manufacturer's ratings. The limitation on output for the modulator unit shown is imposed by the manufacturer's rating on the output transformer.

Circuit Description The modulator unit is complete as diagrammed in figure 23 except for the high-voltage power supply which feeds the modulator tubes. A speech amplifier driver, suitable for operation from a crystal microphone, is included on the chassis along with its power supply. The 6SJ7 pre-amplifier stage feeds a 6N7-GT phase inverter which in turns supplies signal to the grids of the push-pull 6B4-G drivers. The driver stage is coupled to the grids of the modulator tubes through a conventional multi-purpose driver transformer.

The modulator chassis includes a filament transformer for the modulator tubes, a plate voltage supply for the speech amplifier, and a bias supply for the 8005's. Recommended bias for the 8005's with 1500 volts of plate potential is 67 to 70 volts. Since none of the standard voltage-regulator tubes are rated for this value of bias voltage, an 0A4-G gas triode tube is used as a bias regulator in the unit shown. By connecting the starter anode

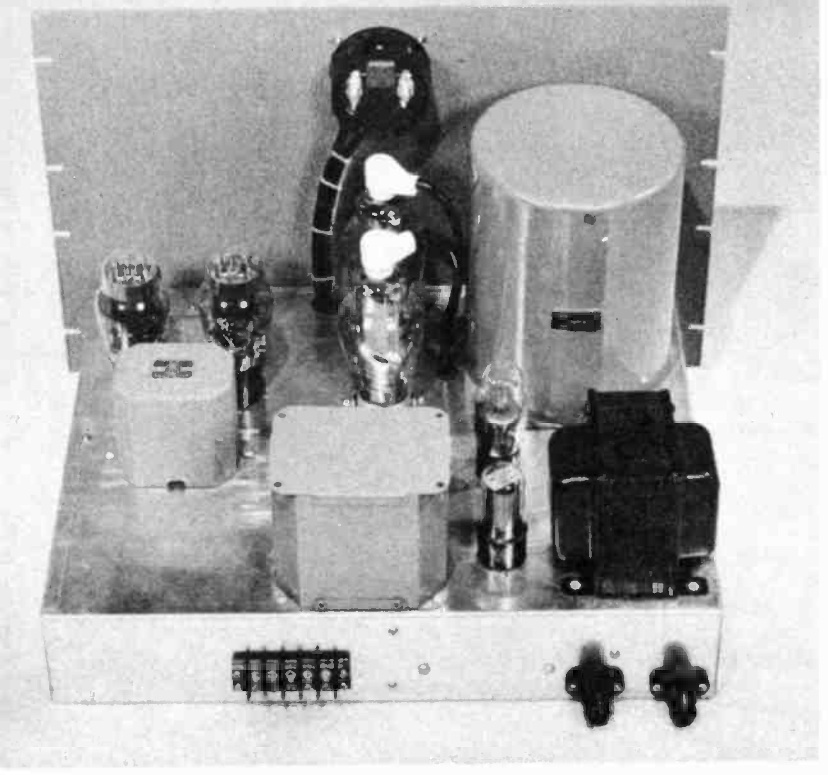
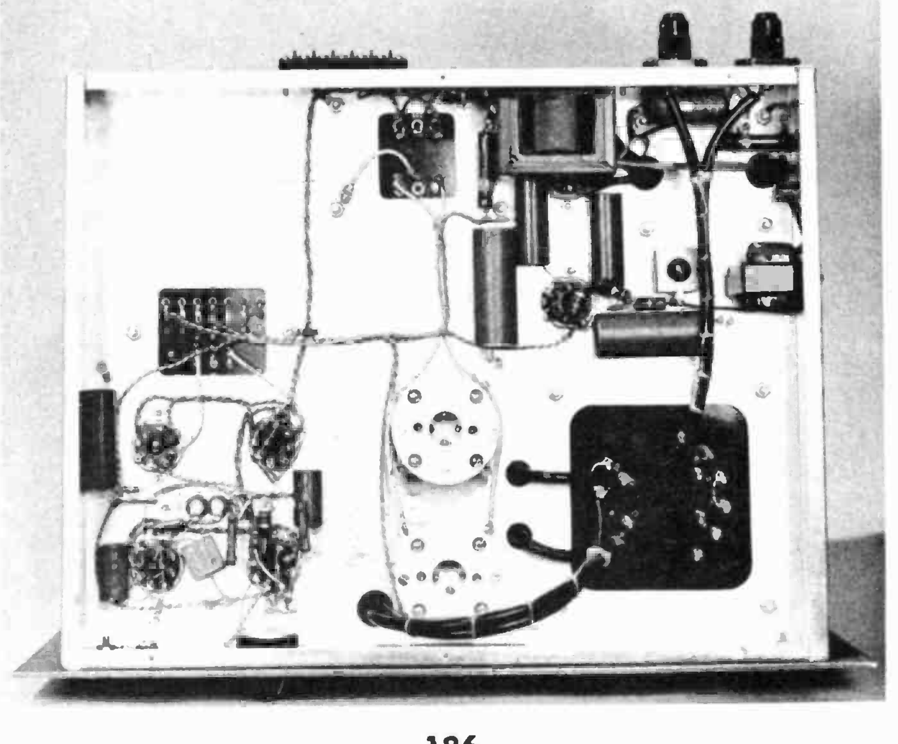


Figure 21.
REAR VIEW OF THE MODULATOR CHASSIS.

Figure 22.



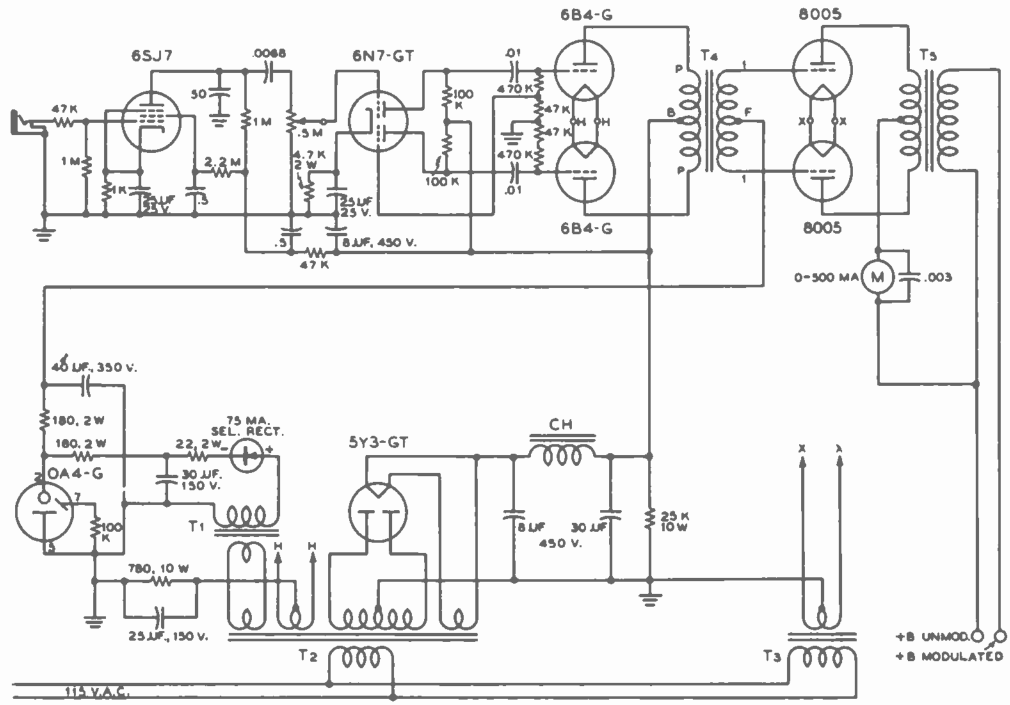


Figure 23.

SCHEMATIC OF THE 300-WATT CLASS B MODULATOR.

CH—14-hy. 100-ma. choke (UTC R-19)
T1—6.3-volt 1.2 a. trans. (UTC FT-2)
T2—750 v. c.t., 100 ma., 5 v. 3 a., 6.3 v. 4 a., 6.3 v. 2 a. (UTC R-12)
T3—10-volt 10-a. transformer (UTC S-62)
T4—Push-Pull drivers to class B grids (UTC S-9)
T5—300-watt multiple match modulation transformer (UTC CVM-4)

to the positive lead through a 100,000-ohm resistor, the 0A4-G acts as a regulator to hold the bias at about 70 volts for the modulator grids. Striking voltage for the 0A4-G is supplied by the conventional arrangement with a back-connected filament transformer and a miniature 75-ma. selenium rectifier. The filament transformer on the chassis supplies 10 volts at 6.5 amperes for the 8005 tubes. A 10-ampere filament transformer actually was used to provide a safety factor.

Operating Conditions for the 8005 Tubes The 8005's operate at a fixed bias of −70 volts with a plate potential of 1500, although they may be operated at 1250 volts with −55 volts of bias. The driver transformer (UTC S-9) is connected so that terminals 1 and 1 go to the grids of the 8005's. These tubes take a rather high grid-to-grid voltage for full output (320 volts peak grid-to-grid) so that the lowest amount of step-down available from the transformer is used. The correct value of plate-to-plate load resistance for the 8005's under these operating conditions is 10,000 ohms. The standing plate current of 35 ma. on the tubes will kick to approximately 300 ma. for a sine-wave output of 300 watts. On voice peaks the milliammeter will kick to 250 ma.

Operating Conditions for the 5514 Tubes If Hytron 5514 modulator tubes are used in place of the 8005's, it is possible to eliminate all the components of the bias supply. A single 4.5-volt C battery will then serve as fixed bias on the tubes. The C battery will give a life of many months under these operating conditions before it deteriorates due to the grid current which passes through it on audio peaks. A filament transformer capable of delivering 7.5

volts at 6 amperes should be substituted for the 10-volt transformer used with the 8005's. Also the grid leads on the driver transformer should be connected to terminals 3 and 3 to obtain greater step-down between the plates of the driver tubes and the grids of the modulators. The 5514's require only 130 volts peak grid-to-grid for full output as contrasted to the 320 volts required by the 8005's. The proper value of plate to plate load resistance for these tubes is 12,500 ohms for 300 watts output from the secondary of the modulation transformer. The standing plate current of 50 ma. on the 5514's will kick to about 300 ma. on sine wave and to 200 to 250 ma. on voice for full output.

Construction The complete modulator unit is built upon a 13 by 3 inch steel chassis. The steel panel used on the front of the modulator is a standard 19 by 14 inch unit. Since the modulator unit shown was constructed for use as the bottom unit in a rack, it was not necessary to attach support brackets between the chassis and the panel. However, if the whole weight of the unit is to be supported from the panel, as would be the case when the unit is not mounted in the bottom of a rack, angle brackets should be used on each side of the chassis. If the plate milliammeter for the modulator tubes is placed to one side of the panel rather than being installed in the center as shown, the unit may be supported by a 12¼-inch standard panel in place of the 14-inch one shown.

Circuit Alternatives Both the final amplifier and the modulator unit in the case of the equipment shown are operated from a single remote 1500-volt power supply. In many applications it will be more convenient to operate the final amplifier from a separate power supply so that the full 600 watts input may be obtained at higher voltage and lower current. In this event it is only necessary to add an additional terminal on the rear of the chassis for modulator plate voltage.

The plate milliammeter for the modulator tubes is connected in series with the high voltage lead in the unit shown. An alternative connection, which in many cases will prove more desirable from the safety standpoint, is to place the plate milliammeter in the lead from the center tap of the filament transformer to ground. In this event the return from the bias pack, which is shown as being grounded in figure 23, should be connected to the filament center tap. This change in the bias pack return will prevent grid current from showing on the plate milliammeter. Only the actual plate current to the modulators will be indicated by the milliammeter.

200-Watt Modulator With 813 Tubes

In recent years there has been a strong trend toward the use of beam tetrode tubes

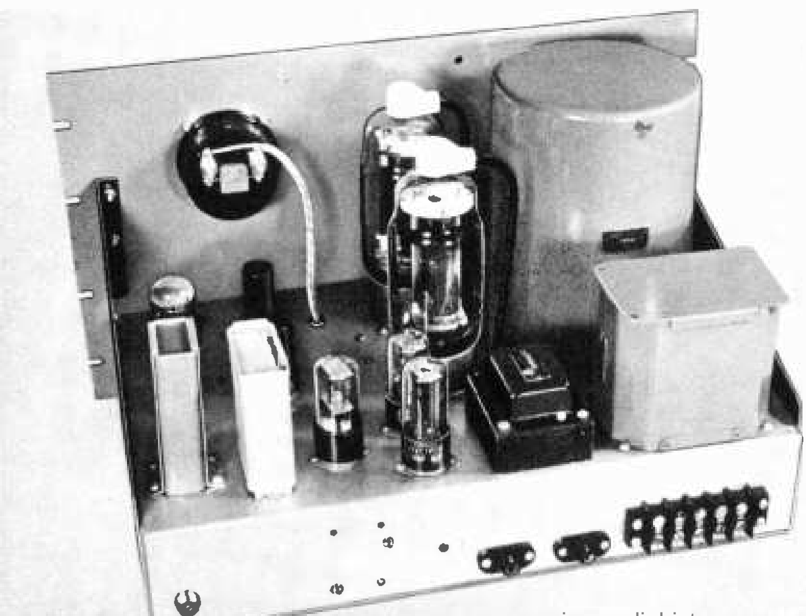


Figure 24. REAR VIEW OF THE 200-WATT 813 MODULATOR.

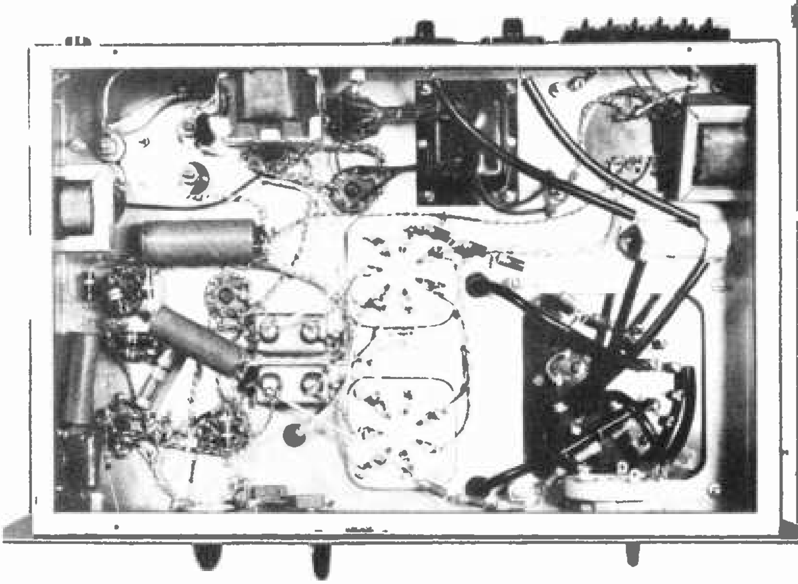


Figure 25.
UNDERCHASSIS VIEW OF THE 200-WATT 813 MODULATOR.

Note the series string of six half-meg. (470K) 1-watt resistors running from the plate lead of each 813 back to the plate of the 6SJ7 driver for that tube.

for the generation of relatively high levels of audio power. This trend is reasonable and economic for several reasons: (1) Beam tetrode tubes are only slightly more expensive in initial cost than equivalent triode types. (2) Beam tetrodes, due to their high power sensitivity, require far less driving power than equivalent triodes. (3) The bias-regulation problem encountered in a high-power class B triode amplifier is greatly reduced with class AB_2 tetrodes, and substantially eliminated with class AB_1 tetrodes. On the other side of the picture, however, it must be stated that high-level beam-tetrode audio power amplifiers require a rather high value of screen voltage which must have at least moderately good regulation.

The least expensive tube in this class which can deliver from 200 watts to 600 watts of audio power output is the standard 813. The tubes may be operated effectively either as class AB_1 or class AB_2 amplifiers. That is to say that they may be operated either without grid current but with swinging average plate current (class AB_1), or with grid current on peaks and with swinging average plate current (class AB_2). The modulator illustrated in figures 24 and 25 and diagrammed in figure 26 uses 813 tubes operated in class AB_1. On the succeeding pages a similar modulator for greater power output is described using 813 tubes in class AB_2.

Circuit Description On the face of it there might seem to be little justification for using 813 tubes in a modulator with a power output of only 200 watts. It is certainly true that the same amount of output power may be obtained with less expensive tubes such as Hytron 5514's or 811's operated in class B. However, this modulator has been designed for the case where it is desired to operate both the modulator and the modulated amplifier from a single 2000-volt power supply. Actually this modulator is used to plate modulate an amplifier with a single 4-125A operating also at 2000 volts with an input of 375 to 400 watts. Nearly all other modulator tubes with this range of power capability are not capable of operating at a plate voltage of 2000.

The first stage of the modulator is quite conventional, using a 6SJ7 pentode. S_1 was included so that the modulator could be fed from a line alternatively to operating from a crystal microphone plugged into the front panel. The gain control is operative from either signal-input source. The next stage of the amplifier is somewhat unconventional. Two 6SJ7 tubes operate as a self-balanced

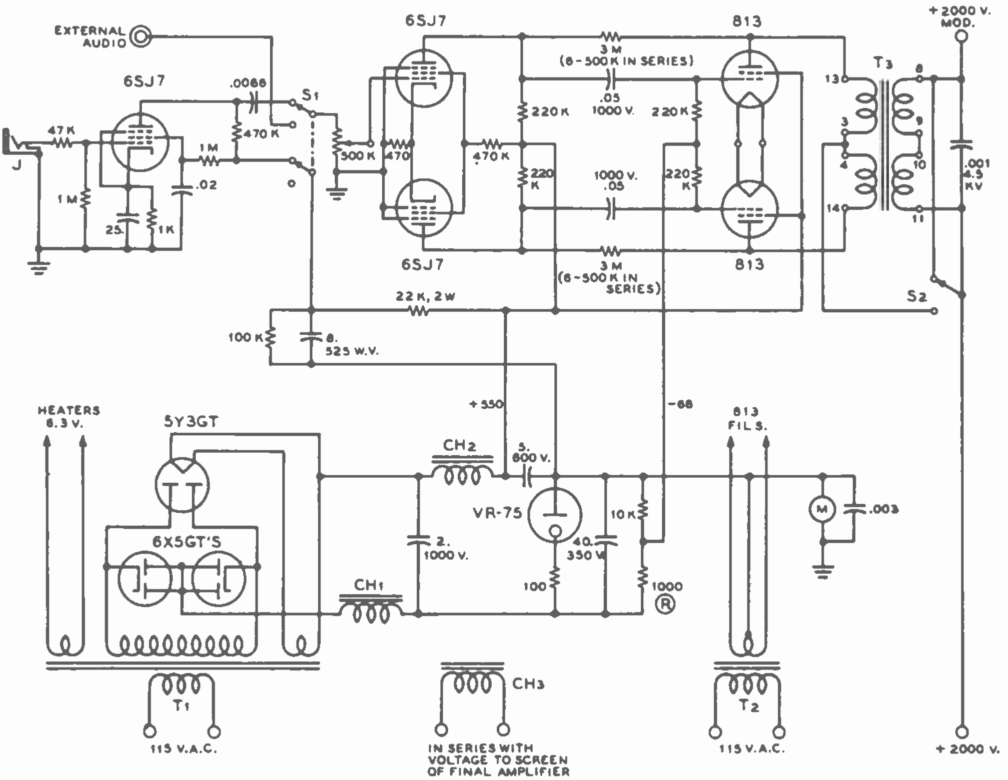


Figure 26.

SCHEMATIC OF THE 200-WATT 813 MODULATOR.

CH1—3.5-hy. 50-ma. choke (Stancor C-1080)
CH2—16-hy. 50-ma. choke (Stancor C-1003)
CH3—13-hy. 65-ma. choke (Stancor C-1708)
(R)—Portion of bias voltage divider. See text.
M—0-250 d-c milliammeter (Marion 53SN)
T1—600 v. c.t., 55 ma.; 5 v. 2 a., 6.3 v. 2.7 a. Stancor P-6119)
T2—10 v. c.t., 10 a. (UTC S-62)
T3—300-watt modulation transformer (UTC CVM-4)
J—Microphone jack, shorting type.

phase inverter to feed the grids of the two 813's. This type of phase inverter is quite convenient for an application of this type where additional gain is not needed between the phase inverter and the stage which is driven by it. The stage gives phase inverting action by virtue of the fact that both the cathode resistor and the series screen resistor are unby-passed. The only assymmetry about the stage is that the grid of one tube is grounded while the input signal is fed to the grid of the other tube. The plates of the phase-inverter tubes are capacitively coupled to the grids of the 813's.

Since the 813 output stage is operating class AB1 and requires no driving power, the 6SJ7 tubes provide ample signal to excite the 813 grids. In fact, effective limiting action on the input signal takes place at the point on the signal cycle where the peak positive voltage on each 813 grid equals the operating bias on the tubes. This limiting action gives the same net result as the clipper sometimes installed in one of the earlier stages of a speech amplifier. Note also that shunt feedback is employed from the plates of the 813's back to the plates of the 6SJ7 drivers. Six 500,000-ohm 1-watt resistors connected in series on each side go to make up the 3-megohm feedback resistors. The addition of the feedback network improves the linearity of the 813 stage with a consequent reduction in harmonic distortion.

The power supply system for the screens

of the 813's and the speech amplifier is somewhat unconventional in that a bridge rectifier is used. The power transformer is a conventional receiving type designed for a 55-ma. load at about 300 volts. However, the high-voltage secondary of this transformer is bridge rectified by means of a pair of 6X5-GT's and a 5Y3-GT. The output voltage under the normal load of about 22 ma. is about 625 volts. A VR-75 in series with the negative return of the power supply serves to regulate the bias voltage fed to the control grids of the 813's. A voltage divider across the 75 volts of the bias supply feeds about 68 volts to the 813 grid returns. The subtraction of the voltage drop across the bias supply leaves about 550 volts for the screen supply for the 813's.

Note that the plate and bias supply is returned to the filament center tap of the 813's. Through this procedure the milliammeter in the filament center tap of the 813 filament transformer reads only the plate current to the 813's. Actually the small amount of current taken by the three 6SJ7 tubes passes through the cathode meter. This small current causes the meter to indicate a small amount of current in a negative direction when plate voltage is not applied to the 813's.

Normal standing plate current on the 813's should be between 40 and 60 ma. This current will vary with variations in line voltage since the grid bias is regulated while the screen voltage for the 813's will vary with line-voltage variations. The value of the resistor (R) in the bleeder for the bias pack should be varied until the standing plate current for the 813's under normal operating conditions is about 50 ma. The 1000-ohm resistor shown on the schematic diagram will serve as a satisfactory starting value for (R). With full voice modulation the plate current on the 813's will kick from about 50 ma. to a value of 140 to 160 ma. At 180 ma. with 2000 volts on the plates of the 813's a power output of 200 watts at the secondary of the modulation transformer can be obtained with a sine-wave signal. Optimum value of plate-to-plate load impedance for the 813's is about 23,000 ohms.

Construction The modulator is built upon an 11 by 17 by 3 inch plated steel chassis with a 10½ by 19 inch dural panel. Although a steel panel would have been better from the standpoint of strength, there are two good reasons for using dural: (1) It is far easier to cut the large hole for the milliammeter in a dural panel with a standard circle cutter. (2) The mounting of the instrument in a dural panel does not change the calibration as is the case when a steel panel is used. Through the use of chassis-support brackets at each end of the unit an ample amount of rigidity is obtained. A chassis bottom cover is used to complete the shielding of the modulator.

500-Watt 813 Modulator

Illustrated in figures 27, 28, and 29 is a modulator unit capable of high-level ampli-

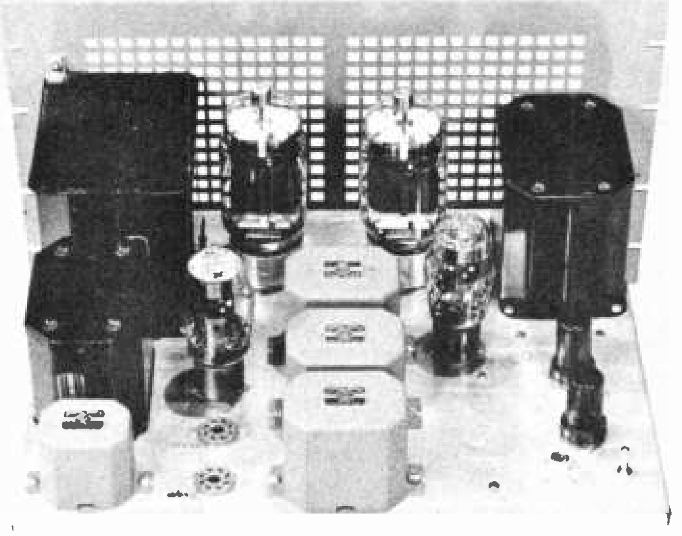


Figure 27.
REAR VIEW OF THE 500-WATT 813 MODULATOR.

The output transformer for the 813's is mounted externally so does not show in this photograph. The coaxial fitting to the right rear of the chassis in this photograph is for external audio input. Switch S_1, which selects either the microphone input on the front panel or the external audio input, is mounted just to the right of the coaxial fitting.

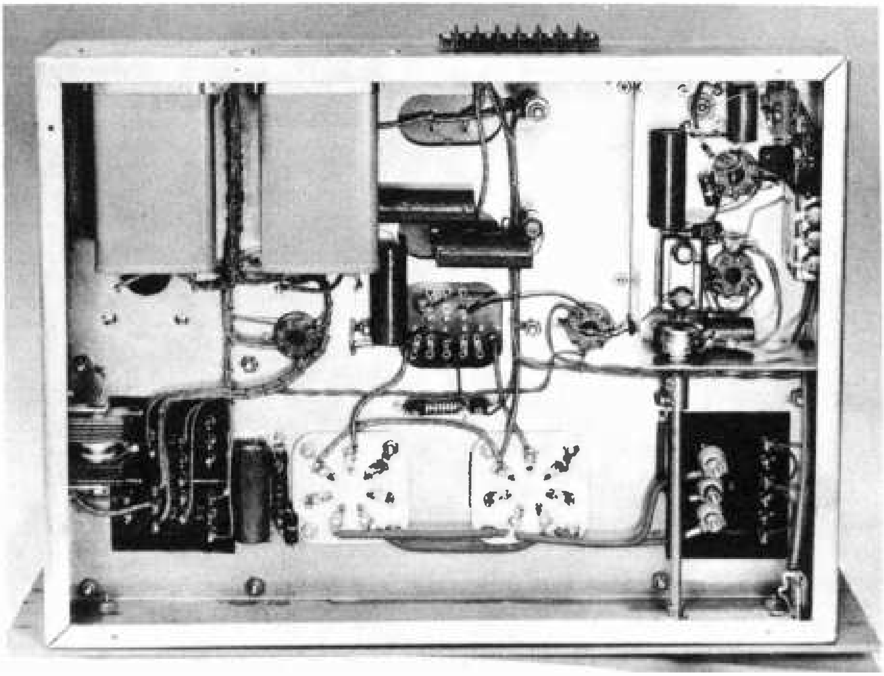


Figure 28.

UNDERCHASSIS VIEW OF THE 500-WATT 813 MODULATOR.

The two selenium bias rectifiers can be seen in the lower left hand corner of this photograph. The two high-voltage filter capacitors are sub-chassis mounted from the rear wall. Note the shield around the low-level audio stages in the upper right corner of the photo. A chassis bottom cover completes the shielding of the Unit.

tude modulating one kilowatt input to the final amplifier stage of a transmitter. It is self-contained except for the plate supply for the 813 and the modulation transformer. The modulator is capable of delivering 500 watts of audio at the secondary of the modulation transformer with 2000 volts on the plates of the 813's, and will deliver up to 650 watts output with 2500 volts on the modulator tubes. The screen supply, bias pack, and the speech amplifier with its power supply all are included within the chassis. Since the modulation transformer for this high a power level is a very large and heavy item, no provision for mounting the transformer has been made in this unit. In most cases it will be suitable either to mount the modulation transformer on a separate panel by itself, or to mount it at the bottom of the transmitter along with the heavy power-supply components.

Circuit Description The modulator uses a conventional speech amplifier with a 6SJ7 first stage followed by a 6J5, with a 6B4-G triode as driver for the 813's. Provision is made for the selection either of an external audio signal or the signal from a microphone plugged into the front panel. A coaxial connector is fitted to permit the use of coaxial cable from the external audio source into the speech amplifier. The 6SJ7 first speech stage is cut out of the circuit when the external audio input is in use. A minimum signal of about 4 volts peak is required at the "external audio" terminals to obtain full output from the modulator. Ample gain is available through the 6SJ7 stage for operation of the modulator from the output of a standard crystal microphone.

The driving power required at the grids of the 813's is somewhat less than one watt.

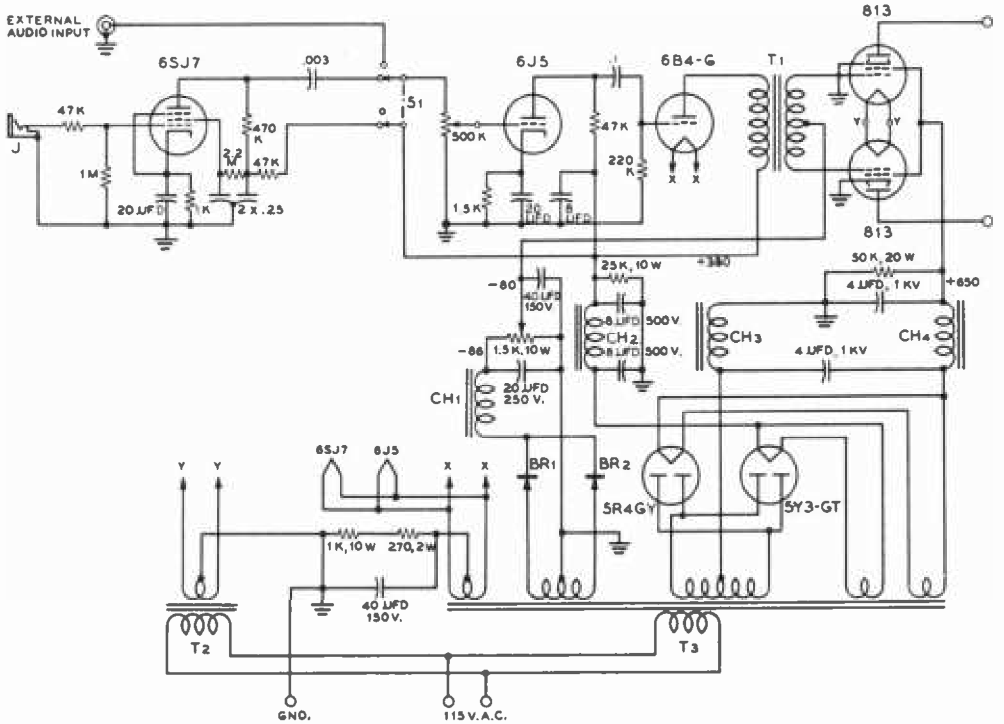


Figure 29.

SCHEMATIC OF THE 500-WATT 813 MODULATOR.

CH_1—15-hy. 60-ma. choke (UTC S-27)
CH_2—30-hy. 75-ma. choke (UTC S-27)
CH_3—10-hy. 200-ma. choke (UTC PA-40 or CG-40)
CH_4—20-hy. 100-ma. choke (UTC S-28)
T_1—Push-pull drivers to class B grids (UTC S-9)
T_2—10 v. 10 a. (UTC PA-124 or CG-124)
T_3—500 v. ea. side 250 ma., 80 v. ea. side 100 ma., 5 v. 3 a., 5 v. 2 a., 6.3 v. 4 a., 6.3 v. 3 a. (UTC PA-428 or CG-428)
500-Watt modulation transformer—UTC CVM-5
J—Microphone jack on front panel
S_1—D.p.d.t. toggle switch

Hence, the 6B4-G is capable of delivering this amount of driving power with a very low amount of loading. A conventional "push-pull plates to class B grids" driver transformer is used between the 6B4-G and the 813 grids. The whole primary winding is used for the plate circuit of the 6B4-G tube. Cathode bias is used on all the tubes in the speech amplifier/driver, while fixed bias is used on the 813's. The 813 grid bias is obtained from a low-resistance slider-type bleeder across the bias pack. Two miniature 75-ma. selenium rectifiers of the type designed for use in a.c.-d.c. receivers are used to rectify the 160-volt center-tapped bias winding on the power transformer.

Two rectifier and filter systems are operated from the single high-voltage secondary of the power transformer. The low-voltage supply, which delivers 380 volts for the speech amplifier and driver uses a 5Y3-GT rectifier with CH_3 acting as the input choke for the filter system. The high-voltage supply, which delivers 650 volts to the screens of the 813's, uses a 5R4-GY with a 4-μfd. 1000-volt input capacitor. Both CH_3 and CH_4 contribute to the filtering action in the 650-volt power supply.

Construction The modulator unit is constructed on a 13 by 17 by 3 inch chassis with a 19 by 12¼ inch steel panel. The panel is of the type having a grille in its upper portion as can be seen from the photograph. The two heavy transformers are mounted toward the front of the chassis so that their weight will exert the least torque upon the panel. In addition, a small bracket is bolted to the top of the larger transformer and to the panel to assist in supporting the weight of the chassis.

Operating Conditions For the 813's The 813's are capable of a power output of at least 500 watts at a plate voltage of 2000, 2250, or 2500 volts. The choice of the actual operating plate voltage will depend upon considerations other than the power output required from the 813 tubes. With 2000 volts on the 813's the plate-to-plate load impedance should be about 12,000 ohms. With 2250 volts the load for the tubes should be about 17,000 ohms and with 2500 volts a load of 19,000 ohms will give 500 watts output. Since the plate current of the 813's is substantially independent of the instantaneous plate voltage, the a-c voltage across the primary of the modulation transformer is directly affected by the inductance of the primary at low frequencies. Consequently, serious distortion and reduced power output at the lower voice frequencies will be obtained when using an output transformer which has inadequate primary inductance. This statement is, of course, generally true in the case of any audio system which uses pentode or beam tetrode tubes in the power output stage. Hence, always use the highest quality output transformer available for the application. The use of an output transformer with limited primary inductance will have a more deleterious effect upon the operation of a modulator with tetrodes or pentodes in the output than it will upon a triode class B modulator. Triode tubes, in spite of their disadvantages as class B modulators, are more tolerant of the output transformer into which they operate.

500-Watt 304TL Modulator

Ordinarily, few amateurs would be inclined to design the high-level stages of their transmitters around type 304TL tubes. Although the 304TL unquestionably is an excellent tube, with its extremely high transconductance and power sensitivity, its price and capabilities are in excess of those required even for a kilowatt amateur transmitter. But with enormous supplies of these tubes available at a very low price on the surplus market it becomes economic to consider their use in high-power amateur transmitters. In fact, with the use of these 304TL's the cost of heating power for filaments becomes a much more significant figure than the cost of the tubes.

The 304TL is ideally suited for use as a modulator for a high-power amateur transmitter. In fact, due to the relatively low amplification factor of the tube (about 10) the 304TL may even be used as a class A triode Heising modulator. Such an arrangement is practicable for modulating a medium-power transmitter when a 1500 to 2000 volt plate supply is available.

But the 304TL really comes into its own as a high-power class AB or class B modulator. Since a pair of the tubes are rated at 1400 watts output at only 2000 volts on the plates (plate current, 1 ampere) the problem becomes one of choosing a set of operating conditions which will allow the production of about 550 watts of audio (to allow for 10 per cent loss in the modulation transformer) at good plate circuit efficiency.

We may arrive at three general sets of operating conditions which will deliver the 550 watt power output at full signal on the tubes. These sets of operating conditions will be called Conditions 1, 2, and 3.

Condition 1: Full class B operation, optimum plate load.

Under condition 1, the full 550 watts of audio may be obtained at a plate potential as low as 1250 volts without requiring excessive grid drive. Recommended operating conditions for 550 watts output are:

Plate Voltage Volts	Grid Bias Volts	Plate-to-Plate Load Ohms	Max. Plate Current Ma.	Peak A-F Grid-to-Grid Volts
1250	-100	4,400	650	360
1500	-105	6,600	525	360
2000	-160	12,500	375	440
2500	-220	18,500	300	530
3000	-260	27,000	260	580

Full class B operation provides the highest plate circuit efficiency, but requires high driving power and means that both halves of each 304TL must be lighted at all times.

Condition 2: Full class B operation, one-half of each 304TL used.

Under condition 2, only one-half of each 304TL is used at a time. The filaments of the other half of each tube are not lighted. This procedure reduces the filament drain of the stage from 260 to 130 watts, as a result of running only one pair of filaments in each tube. When operated in this manner, the tubes are equivalent to 152TL tubes, except that interelectrode capacitances are the same as the 304TL. When operated in this manner it is suggested that changeover from one set of filaments to the other be made at periodic intervals of a month or so. Recommended operating conditions for 550 watts output are:

Plate Voltage Volts	Grid Bias Volts	Plate-to-Plate Load Ohms	Max. Plate Current Ma.	Peak A-F Grid-to-Grid Volts
1500	-105	5500	570	500
2000	-160	12,400	380	540
2500	-220	18,000	310	600
3000	-260	26,000	270	660

From the two tabulations above it can be seen that the only significant change when using one-half of each 304TL as compared to using the entire element structure is that the grid drive is increased for the half-tube system. This means that both the driving-voltage and the driving-power requirements are greater for half-tube operation.

Condition 3: Class AB_1 (no grid current) operation, complete tube used.

With class AB_1 operation no driving power is required of the stage which excites the grids of the 304TL tubes. This means that a relatively small tube, or pair of tubes, may be used to excite the grids of the modulators. The push-pull 6B4-G driver shown in the modulator to be described may be used, of course, but the full power-output capabilities of the driver will not be required. An alternative driver would be an arrangement similar to that shown for exciting the grids of the 6AS7-G amplifier already described in this chapter. It would be necessary, however, to increase the plate voltage on the driver tube so that it would be enabled to deliver sufficient voltage at the secondary of the interstage transformer to excite the grids of the 304TL's. Two sets of recommended operating conditions are listed on page 196.

It can quickly be seen by inspection of the table that class AB_1 operation of the tubes is much less efficient in the ratio of power input required for a given power output. But for special applications where low driving power is a requirement, these operating conditions may prove useful.

Figure 30.
REAR VIEW OF THE 304TL MODULATOR.

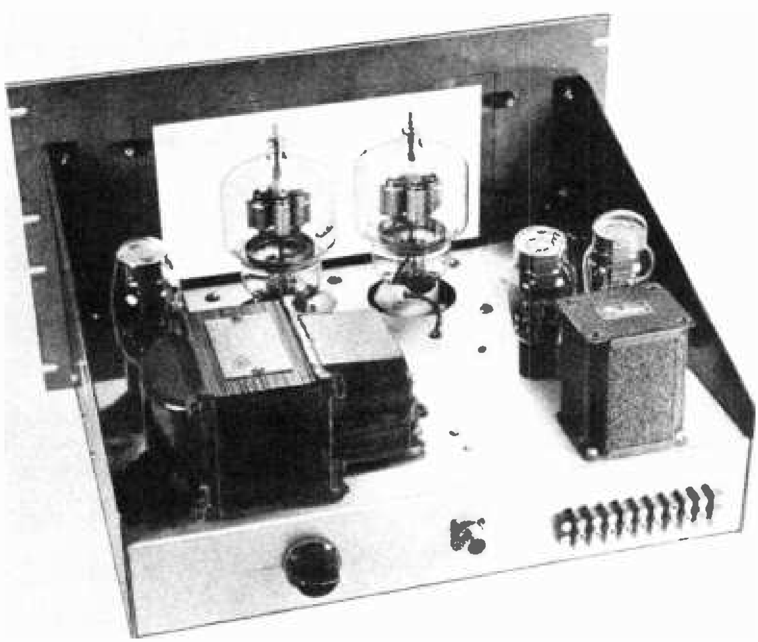
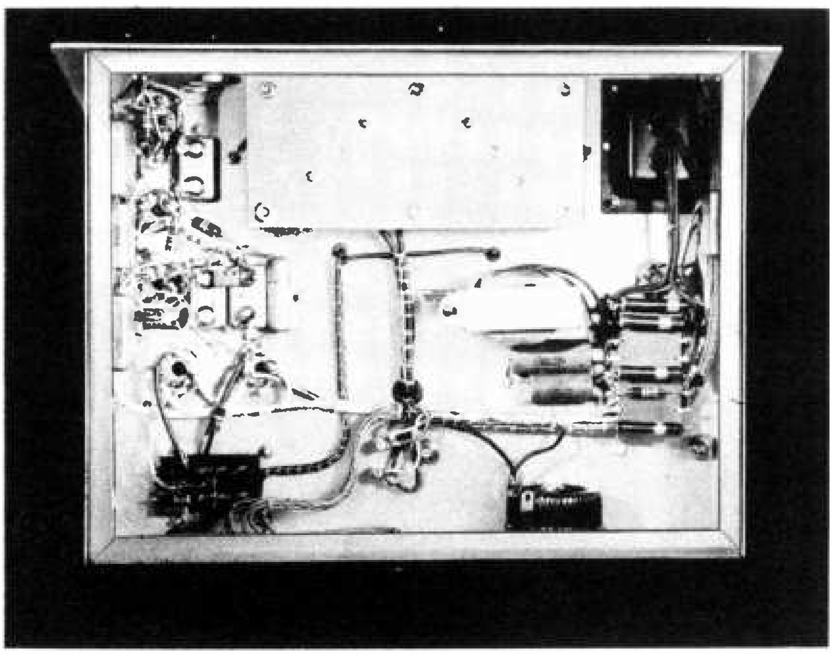


Plate Voltage Volts	Grid Bias Volts	Plate-to-Plate Load Ohms	Max. Plate Current Ma.	Peak A-F Grid-to-Grid Volts	Power Output Watts
2000	-160	5300	550	320	490
2500	-220	8000	500	440	550
3000	-260	12,000	450	520	730

Description of the Modulator Illustrated Figures 30 and 31 illustrate a 304TL modulator unit which may be used under a variety of the alternative operating conditions already described. Included on the chassis are the speech amplifier, the push-pull 6B4-G driver, the power supply for the speech amplifier and driver, the output tubes and a filament supply for the tubes. Grid bias for the 304TL's, plate voltage for them, the modulation transformer and the plate milliammeter are external. The two filament groups for each 304TL are connected in series so that the two tubes require 10 volts at 26 amperes. This connection permitted the use of an ancient 11-volt 30-ampere transformer for lighting the filaments, with a 3-ohm 50-watt rheostat in the primary so that the filament voltage could be adjusted to 10 volts. The tubes could just as well be operated with filaments in parallel if a transformer capable of delivering 5 volts at 52 amperes were available. A transformer often advertised on the surplus market is rated at 5 volts at 60 amperes; this transformer was designed for use with a pair of 304TL's and will serve well in this modu-

Figure 31.
UNDERCHASSIS OF THE 304TL MODULATOR.
The large rheostat on the rear of the chassis controls the filament voltage on the tubes by varying the primary voltage. Note the metal plate upon which the sockets for the 304TL tubes are mounted.



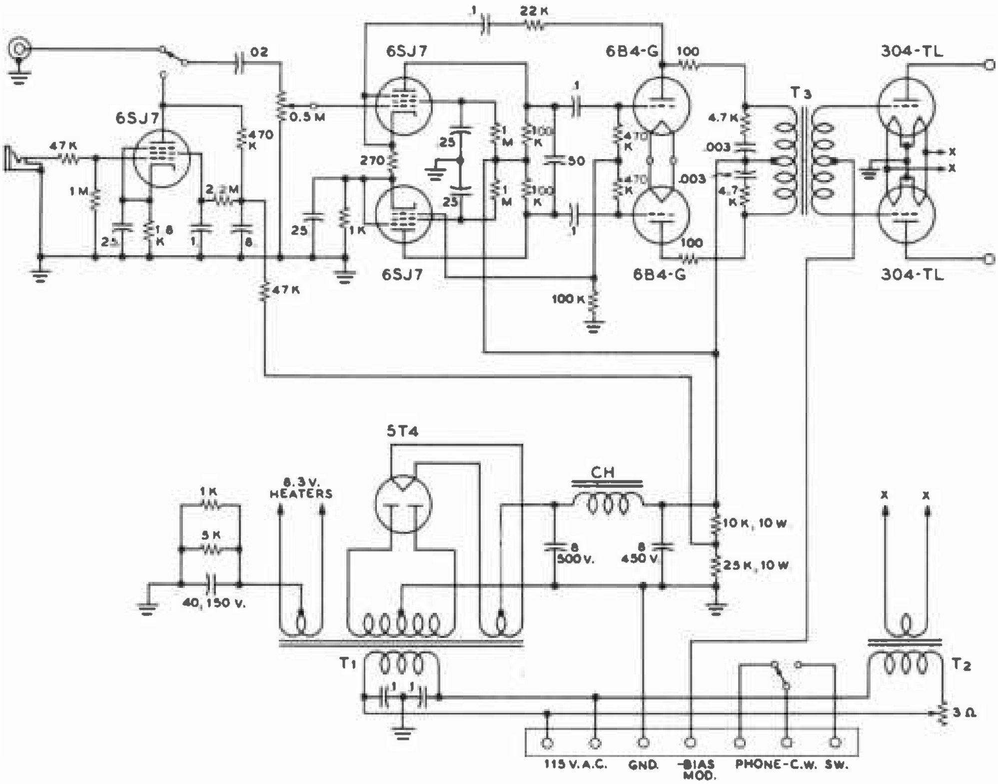


Figure 32.

SCHEMATIC OF THE HIGH-POWER MODULATOR.

CH—10.5-hy. 110-ma. choke (Stancor C-1001)
T_1—700 v. c.t. 120 ma., 5.0 v. 3 a., 6.3 v. 4.7 a. (Stancor P-6013)
T_2—10-volt 26-ampere filament transformer (see text)
T_3—2A3 or 6B4-G to class B grids driver transformer. Multiple-ratio type with selection from about 1.25:1 to 2.5:1 turns ratio (such as Stancor A-4761) is desirable. Unit illustrated is surplus driver transformer from BC-610 (type 55B030).

lator. If the tubes are to be operated with only one-half in service at a time, a standard transformer of the type designed for use with a pair of 4-250A tubes (5 volts at 30 amperes) will serve to deliver filament power.

The speech amplifier portion of the modulator is more or less conventional, with alternate inputs either for a crystal microphone or from an external source through a coaxial connector on the rear. A moderate amount of feedback is used from the plate of one of the driver tubes to the cathode of the first 6SJ7 of the phase inverter. The use of feedback improves the linearity and regulation of the driver stage. The PHONE-C.W. switch mounted on the panel is connected to an external relay which shorts the secondary of the modulation transformer, removes plate voltage from the 304TL's, and removes the short from the keying circuit when the switch on the modulator chassis is moved to the position for c-w transmission.

CHAPTER EIGHT

Power Supply Construction

The combination of a number of factors in the post-war period has produced a condition where transmitting tubes and radio-frequency components are relatively inexpensive and easily obtainable. On the other hand, iron-cored power supply components have felt the full impact of price increases. Many amateurs have acquired tubes and r-f components for a projected high-power transmitter, only to find that the cost of the iron-core power-supply and high-level audio components for completing the transmitter would be prohibitive. So it behooves the person designing a projected transmitter to consider carefully and in detail the power supply requirements of the projected transmitter in terms of alternative modulation and keying systems.

Although low-level modulation systems for obtaining amplitude modulation of the transmitter have been little used by amateurs, the fact that plate dissipation in the final r-f stage of the transmitter can be obtained relatively inexpensively makes low-level AM systems well worth serious consideration. It is almost certainly true that a carrier power output from the transmitter of 300 to 400 watts can be obtained least expensively in the amateur transmitter through the use of a pair of high-plate-dissipation tubes such as 304TL's in the final stage operating either as a linear amplifier or as a grid-bias modulated or cathode-modulated stage.

If TVI is a serious problem in the locality of the transmitter, the lowest possible amount of harmonic generation in the final stage certainly can be obtained through the operation of the final as a class B amplifier; that is to say that the amplifier will be operated with a grid-bias value approximately equal to the cutoff value for the tubes. The only type of operation for which a class B amplifier may not be used is high-level plate modulation. The class B amplifier in the final may be used as a c-w amplifier, an FM amplifier, an amplifier of a single-sideband signal, or as a linear amplifier for amplitude modulation. If class B linear operation is desired, the stage which precedes the final may be plate modulated in the normal manner. In fact, it will not be necessary even to include a swamping resistor on the grid circuit of the final stage if that stage is operated as a grounded-grid r-f amplifier with cutoff bias on the grounded-grid tube. A high-power grounded-grid amplifier is described in some detail in *Chapter Five.*

All the above may seem somewhat irrelevant to a chapter concerned with the construction of power supplies, but actually it is of considerable importance. The above paragraphs bear out the fact that, with the increased availability of high-power transmitting tubes and components, it becomes economically most practicable to use systems for obtaining modulation other than the long-standard plate-modulation system applied to the final stage. Then only one power supply of any size is required: a single high-voltage power supply for the final stage. All modulation, whether AM, FM, or SSB may be attained at receiving-tube power level or perhaps with 807's.

Establishing the Requirements for a Power Supply A power supply for a transmitter or for a unit of station equipment should be designed in such a manner that it is capable of delivering the required current at a specified voltage, that it has a degree of regulation consistent with the requirements of the application, that its ripple level at full current is sufficiently low for the load which will be fed, that its internal impedance is sufficiently low for the job, and that none of the components shall be overloaded with the type of operation contemplated.

The meeting of all the requirements of the previous paragraph is not always a straightforward and simple problem. In many cases compromises will be involved, particularly when the power supply is for an amateur station and a number of components already on hand must be fitted into the plan. As much thought and planning should be devoted to the power-supply complement of an amateur station as usually is allocated to the r-f and a-f components of the station.

The arrival at the design for the power supply for use in a particular application may best be accomplished through the use of a series of steps, with reference to the data in this chapter in arriving at the values of components to be used. The first step is to establish the operating requirements of the power supply. In general these are:

1. Output voltage required under full load.
2. Minimum, normal, and peak output current.
3. Voltage regulation required over the current range.
4. Ripple voltage limit.
5. Rectifier circuit to be used.

The output voltage required of the power supply is more or less established by the operating conditions of the tubes which it will supply. The current rating of the supply, however, is not necessarily tied down by a particular tube combination. It is always best to design a power supply in such a manner that it will have the greatest degree of flexibility; this procedure will in many cases allow an existing power supply to be used without change as a portion of a new transmitter or other item of station equipment. So the current rating of a new power supply should be established by taking into consideration not only the requirements of the tubes which it immediately will feed, but also with full consideration of the best matching of power supply components in the most economical current range which still will meet the requirements of the tubes. It is often long-run economy, however, to allow for any likely additional equipment to be added in the near future.

Current-Rating Considerations The minimum current drain which will be taken from a power supply will be, in most cases, merely the bleeder current. There are many cases where a particular power supply will always be used with a moderate or heavy load upon it, but when the supply is a portion of a transmitter it is best to consider the minimum drain as that of the bleeder. The minimum current drain from a power supply is of importance since it, in conjunction with the nominal voltage of the supply determines the minimum value of inductance which the input choke must have to keep the voltage from soaring when the external load is removed.

The normal current rating of a power supply usually is a round-number value chosen on the basis of the transformers and chokes on hand or available from the catalog of a reliable manufacturer. The current rating of a supply to feed a steady load such as a receiver, a speech amplifier, or a continuously-operating r-f stage should be at least equal to the steady drain of the load. However, other considerations come into play in choosing the current rating for a keyed amplifier, an amplifier of SSB signals, or a class B modulator. In the case of a supply which will feed an intermittent load such as these, the current ratings of the transformers and chokes may be *less* than the maximum current which will be taken; but the current ratings of the rectifier tubes to be used should be at least equal to the maximum current which will be taken. That is to say that 300-ma. transformers and chokes may be used in the supply for a modulator whose resting current is 100 ma. but whose maximum current at full signal will kick to 500 ma. However, the rectifier tubes should be capable of handling the full 500 ma.

The iron-core components of a power supply which feeds an intermittent load may be chosen on the basis of the current as averaged over a period of several minutes, since it is the *heating* effect of the current which is of greatest importance in establishing the ratings of such components. Since iron-core components have a relatively large amount of thermal inertia, the effect of an intermittent heavy current is offset to an extent by a key-up period or a period of low modulation in the case of a modulator. However, the current rating of a rectifier tube is established by the magnitude of the emission available from the filament of the tube; the maximum emission must not be exceeded even for a short period or the rectifier tube will be damaged. The above considerations are predicated, however, on the assumption that none of the iron-core components will become saturated due to the high intermittent current drain. If good-quality components of generous weight are chosen, saturation will not be encountered.

Voltage Regulation The general subject of voltage regulation can really be divided into two sub-problems, which differ greatly in degree. The first, and more common, problem is the case of the normal power supply for a transmitter modulator, where the current drain from the supply may vary over a ratio of four or five to one. In this case we desire to keep the voltage change under this varying load to a matter of 10 or 15 per cent of the operating voltage under full load. This is a quite different problem from the design of a power supply to deliver some voltage in the vicinity of 250 volts to an oscillator which requires two or three milliamperes of plate current; but in this latter case the voltage delivered to the oscillator must be constant within a few volts with small variations in oscillator current and with large variations in the a-c line voltage which feeds the oscillator power supply. An additional voltage regulation problem, intermediate in degree between the other two, is the case where a load must be fed with 10 to 100 watts of power at a voltage below 500 volts, and still the voltage variation with changes in load and changes in a-c line voltage must be held to a few volts at the output terminals.

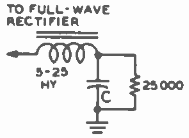
These three problems are solved in the normal type of installation in quite different manners. The high-power case where output voltage must be held to within 10 to 20 per cent is normally solved by using the proper value of inductance for the input choke and proper value of bleeder at the output of the power supply. The calculations are simple: the inductance of the power-supply input choke at minimum current drain from the supply should be equal in henries to the load resistance on the supply (at minimum load current) divided by 1000. This value of inductance is called the *critical* inductance and it is the minimum value of inductance which will keep the output voltage from soaring in a choke-input power supply with minimum load upon the output. The minimum load current may be that due to the bleeder resistor alone, or it may be due to the bleeder plus the minimum drain of the modulator or amplifier to which the supply is connected.

The low-voltage .low-current supply, such as would be used for a v.f.o. or the high-frequency oscillator in a receiver, usually is regulated with the aid of glow-discharge gaseous-regulator tubes. These regulators are usually called "VR tubes." Their use in various types of power supplies is discussed in RADIO HANDBOOK, eleventh edition. The electronically-regulated power supply, such as is used in the 20 to 100 watts power output range, is also discussed later on in this chapter and an example is given.

Ripple Considerations The ripple-voltage limitation imposed upon a power supply is determined by the load which will be fed by the supply. The tolerable ripple voltage from a supply may vary from perhaps 5 per cent for a class B or class C amplifier which is to be used for a c-w stage or an amplifier of an FM signal down to a few hundredths of one per cent for the plate-voltage supply to a low-level voltage amplifier in a speech amplifier. The usual value of ripple voltage which may be tolerated in the supply for the majority of stages of a phone transmitter is between 0.1 and 2.0 per cent.

In general it may be stated that, with 60-cycle line voltage and a single-phase rectifier circuit, a power supply for the usual stages in the amateur transmitter will be of the choke-input type with a single pi-section filter following the input choke. A c-w amplifier or other stage which will tolerate up to 5 per cent ripple may be fed from a power supply whose filter consists merely of an adequate-size input choke and a single filter capacitor.

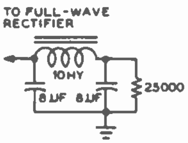
A power supply with input choke and a single capacitor also will serve in most cases to feed a class B modulator, provided the output capacitor in the supply is sufficiently large. The output capacitor in this case must be capable of storing enough energy to supply the peak-current requirement of the class B tubes on modulation peaks. The output capacitor for such a supply normally should be between 4 μfd. and 10 μfd. Capacitances larger than 10 μfd. involve a high initial charging current when the supply is first turned on, so that an unusually large input choke should be used ahead of the capacitor to limit the peak-current surge through the rectifier tubes. A capacitance of less than 4 μfd. may reduce the power output capability of a class B modulator when it is passing the lower audio frequencies, and in addition may superimpose a low-frequency "growl" on the output signal. This growl will be apparent only when the supply is delivering a relatively high power output; it will not be present when modulation is at a low level.



RIPPLE IN TERMS OF C AT FULL LOAD

CAPACITANCE, C	PERCENT RIPPLE
2 µF	13.1
3 µF	8.5
4 µF	6.2
6 µF	4.0

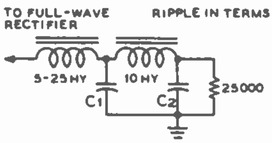
Figure 1.



RIPPLE IN TERMS OF LOAD RESISTANCE

LOAD, OHMS	PERCENT RIPPLE
25000 (BLEEDER ONLY)	0.02
15000	0.04
10000	0.06
5000	0.1
3000	0.17
2000	0.25

Figure 2.



RIPPLE IN TERMS OF C1 AND C2 AT FULL LOAD

C1	C2	PERCENT RIPPLE
2	2	1.2
3	2	0.7
4	4	0.25
8	8	0.06

Figure 3.

When a stage such as a low-level audio amplifier requires an extremely low value of ripple voltage, but when regulation is not of importance to the operation of the stage, the high degree of filtering usually is obtained through the use of a resistance-capacitance filter. This filter usually is employed in addition to the choke-capacitor filter in the power supply for the higher-level stages, but in some cases when the supply is to be used only to feed low-current stages the entire filter of the power supply will be of the resistance-capacitance type. Design data for resistance-capacitance filters is given in a following paragraph.

When a low-current stage requires very low ripple in addition to excellent voltage regulation, the power supply filter often will end with one or more gaseous-type voltage-regulator tubes. These VR tubes give a high degree of filtering in addition to their voltage-regulating action, as is obvious from the fact that the tubes tend to hold the voltage drop across their elements to a very constant value regardless of the current passing through the tube. The VR tube is quite satisfactory for improving both the regulation and ripple characteristics of a supply when the current drain will not exceed 25 to 35 ma. depending upon the type of VR tube. Some types are rated at a maximum current drain of 30 ma. while others are capable of passing up to 40 ma. without damage. In any event the minimum current through the VR tube will occur when the associated circuit is taking maximum current. This minimum current requirement is 5 ma. for all types of gaseous-type voltage-regulator tubes.

Other types of voltage-regulation systems, in addition to VR tubes, exhibit the added characteristic of offering a low value of ripple across their output terminals. The electronic-type of voltage-regulated power supply is capable of delivering an extremely small value of ripple across its output terminals, even though the rectifier-filter system ahead of the regulator delivers a relatively high value of ripple, such as in the vicinity of 5 to 10 per cent. In fact, it is more or less self evident that the better the regulation of such a supply, the better will be its ripple characteristic. The electronically regulated supply described later on in this chapter has an exceedingly low value of ripple in its output as a result of its very good regulation. It must be remembered, however, that the ripple output of a voltage-regulated power supply of any type will rise rapidly when the load upon the supply is so high that the regulator begins to lose control. This will occur in a supply of the electronic type when the voltage ahead of the series regulator tube falls below a value equal to the sum of the minimum drop across the tube at that value of current and the output voltage. In the case of a shunt regulator of the VR-tube type, the regulating effect will fail when the current through the VR tube falls below the usual minimum value of about 5 ma.

Calculation of Ripple Although figures 1, 2 and 3 give the value of ripple voltage for several more or less standard types of filter systems, it is often of value to be able to calculate the value of ripple voltage to be expected with a particular set of filter components. Fortunately, the ripple percentage may be calculated with the aid of rather simple formulas. In the two formulas to follow it is assumed that the line frequency is 60 cycles and that a full wave or a full-wave bridge rectifier is being used. For the case of a single-section choke-input filter as illustrated in figure 1, or for the ripple at the output of the first section of a two-section choke input filter the equation is as follows:

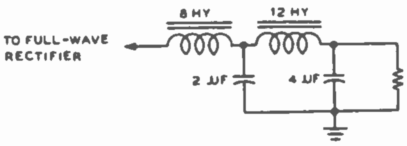


Figure 4.
FILTER CIRCUIT FOR CALCULATION OF RIPPLE.

$$\text{Per cent ripple} \quad \frac{118}{LC-1}$$

Where LC is the product of the input choke inductance in henrys (at the operating current to be used) and the capacitance which follows this choke expressed in microfarads.

In the case of a two-section filter, the per cent ripple at the output of the first section is determined by the above formula. Then this percentage is multiplied by the filter reduction factor of the following section of filter. This reduction factor is determined through the use of the following formula:

$$\text{Filter reduction factor} \quad \frac{1.76}{LC-1}$$

Where LC is the same as in the preceding equation. The reduction factor will turn out to be a decimal value, which is then multiplied by the percentage ripple obtained from the use of the preceding formula.

As an example, take the case of the filter diagrammed in figure 4. The LC product of the first section is 16. So the ripple to be expected at the output of the first section will be: 118/(16–1) or 118/15, which gives 7.87 per cent. Then the second section, with an LC product of 48, will give a reduction factor of: 1.76/(48–1) or 1.76/47 or 0.037. Then the ripple percentage at the output of the total filter will be: 7.87 times 0.037 or slightly greater than 0.29 per cent ripple.

Resistance-Capacitance Filters In many applications where the current drain is relatively small, so that the voltage drop across the series resistors would not be excessive, a filter system made up of resistors and capacitors only may be used to advantage. In the normal case, where the reactance of the shunting capacitor is very much smaller than the resistance of the load fed by the filter system, the ripple reduction per section is equal to $1/(2\pi RC)$. In terms of the 120-cycle ripple from a full-wave rectifier the expression becomes: 1.33/RC where R is expressed in thousands of ohms and C in microfarads. For 60-cycle ripple the expression is: 2.66/RC with R and C in the same quantities as above.

Filter System Resonance Many persons have noticed, particularly when using an input choke followed by a 2-μfd. first filter capacitor, that at some value of load current the power supply will begin to hum excessively and the rectifier tubes will tend to flicker or one tube will seem to take all the load while the other tube dims out. If the power supply is shut off and then again started, it may be the other tube which takes the load; or first one tube and then the other will take the load as the current drain is varied. This condition as well as other less obvious phenomena such as a tendency for the first filter capacitor to break down regardless of its voltage rating or for rectifier tubes to have short life, results from resonance in the filter system following the high-voltage rectifier.

The condition of resonance is seldom encountered in low-voltage power supplies since the capacitors used are usually high enough so that resonance does not occur. But in high-voltage power supplies, where both choke inductance and filter capacitance are more expensive, the condition of resonance happens frequently. The product of inductance and capacitance which resonates at 120 cycles is 1.77. Thus a 1-μfd. capacitor and a 1.77-henry choke will resonate at 120 cycles. In almost any normal case the LC product of any section in the filter system will be somewhat greater than 1.77, so that resonance at 120 cycles will seldom take place. But the LC product for resonance at 60 cycles is about 7.1. This is a value frequently encountered in the input section of a high-voltage power supply. It occurs with a 2-μfd. capacitor and a choke which has 3.55 henrys of inductance at some current value. With a 2-μfd. filter capacitor following this choke, resonance will occur at the current value which causes the inductance of the choke to be 3.55 henrys. When this resonance does occur, the condition where one rectifier tube (assuming mercury-vapor types) will dim and the other will become much brighter will take place.

Thus we see that we must avoid the LC products of 1.77 and 7.1. With a swinging-type input choke, whose inductance varies over a 5-to-1 range, we see that it is possible for resonance to occur at 60 cycles at a low value of current drain, and then for resonance to occur at 120 cycles at approximately full load on the power supply. Since the LC product must certainly be greater than 1.77 for satisfactory filtering along with peak-current limitation on the rectifier tubes, we see that with a swinging-type input choke the LC product must still be greater than 7.1 at maximum current drain from the power supply. To allow a reasonable factor of safety, it will be well to keep the LC product at maximum current drain above the value 10.

From the above we see that we can just get by with a 2-μfd. first capacitor following the input choke when this choke is of the more-or-less standard 5-25 henry swinging variety. Some of the less expensive types of chokes swing from about 3 to 12 henrys, so we see that the first capacitor must be greater than 2 μfd. to avoid resonance with these chokes. A 3-μfd. capacitor may be used if available, but a standard 4-μfd. unit will give a greater safety factor.

Rectifier Circuits There are a large number of rectifier circuits that may be used in the power supplies for station equipment. But the simpler circuits are more satisfactory for the power levels up to the maximum permitted the radio amateur. Figure 5 shows the three most common circuits used in power supplies for amateur equipment. Choke input is shown for all three rectifier circuits, since choke input gives the best utilization of rectifier-tube and power transformer capability, and in addition gives much better regulation. Where greater output voltage is a requirement, where the load is relatively constant so that regulation is not of great significance, and where the rectifier tubes will be operated well within their peak-current ratings, the capacitor-input type of filter may be used.

The capacitor-input filter gives a no-load output voltage equal approximately to the peak voltage being applied to the rectifier tubes. At full load, the output voltage is only slightly above the voltage obtainable with a choke-input filter, with the normal values of capacitance at the input to the filter. With large values of input capacitance, the output voltage will run somewhat higher than the r-m-s secondary voltage applied to the tubes, but the peak current flowing through the rectifier tubes will be many times as great as the d-c output current of the power supply. The circuit of figure 5A is commonly used with capacitor input and resistance-capacitance filter as a high-voltage supply for a cathode-ray tube. In this case the current drain is very small so that the peak-current

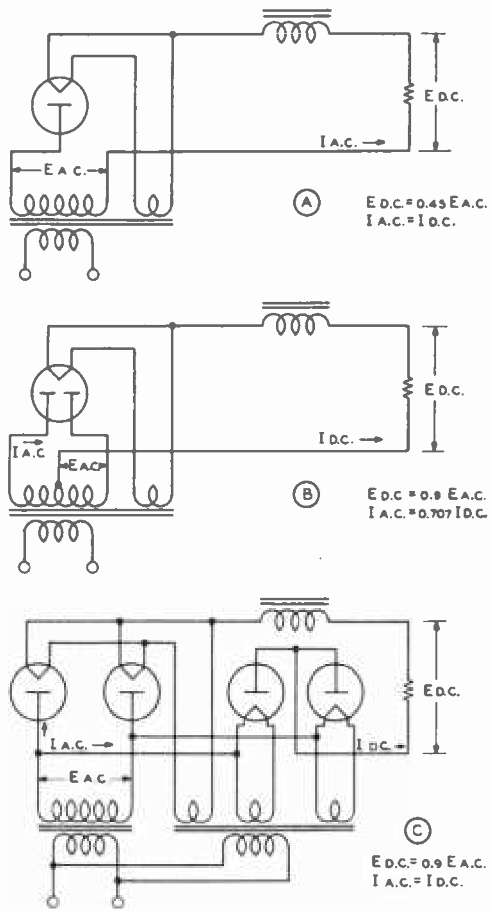


Figure 5.

MOST COMMON RECTIFIER CIRCUITS.

(A) shows a half-wave rectifier circuit, (B) is the standard full-wave rectifier, and (C) is the bridge rectifier circuit.

rating of the rectifier tube seldom will be exceeded.

The circuit of figure 5B is most commonly used in medium-voltage power supplies since this circuit is the most economical of filament transformers, rectifier tubes and sockets, and space. But the circuit of figure 5C, commonly called the "bridge" rectifier, gives better "transformer utilization" so that the circuit is most commonly used in higher powered supplies. The circuit has the advantage that the entire secondary of the transformer is in use at all times, instead of each side being used alternately as in the case of the full-wave rectifier.

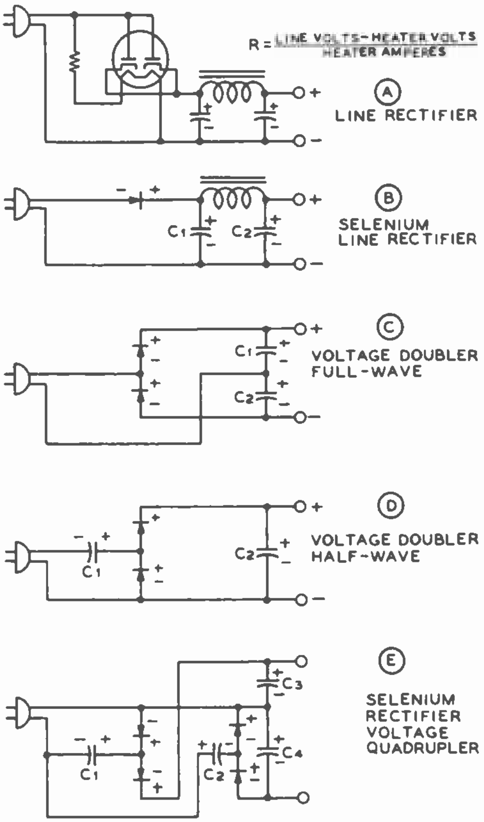


Figure 6.
LINE-RECTIFIER CIRCUITS.

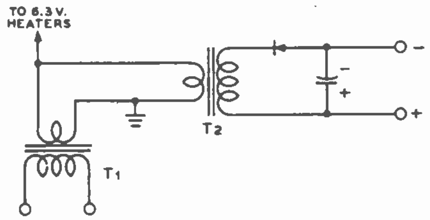


Figure 7.
POWER SUPPLY WITH FILAMENT TRANSFORMERS AND SELENIUM RECTIFIER.

A simple power supply of this type may be used to deliver either positive or negative voltage at a relatively low current drain with output voltage in the vicinity of 100 volts. An example of such a miniature power supply is illustrated in the Test Equipment chapter. Transformers T_1 and T_2 are 6.3-volt filament transformers, T_2 being back connected with respect to T_1.

Also, as a point of interest, the current flow through the secondary of the plate transformer is a substantially pure a-c wave, instead of the pulsating d-c wave through each half of the power transformer secondary in the case of the full-wave rectifier.

The circuit of figure 5C will give the greatest value of output power for a given transformer weight and cost in a single-phase power supply as illustrated. But in attempting to bridge rectify the whole secondary of a transformer designed for a full-wave rectifier, in order to obtain doubled output voltage, make sure that the insulation rating of the transformer to be used is adequate. In the bridge rectifier circuit the center of the high-voltage winding is at a d-c potential of one-half the total voltage output from the rectifier. In a normal full-wave rectifier the center of the high-voltage winding is grounded. So in the bridge rectifier the entire high-voltage secondary of the transformer is subjected to twice the peak-voltage stress that would exist if the same transformer were used in a full-wave rectifier. High-quality full-wave transformers will withstand bridge operation quite satisfactorily so long as the total output voltage from the supply is less than perhaps 4500 volts. But inexpensive transformers, whose insulation is just sufficient for full-wave operation, will break down when bridge rectification of the entire secondary is attempted.

Line Rectifiers and Voltage Doublers Line rectifiers and voltage doublers, usually using miniature selenium rectifier units instead of vacuum tubes, are quite satisfactory for certain applications, particularly when the rectifier is isolated from the power-line ground by means of a 1-to-1 transformer or a pair of back-to-back filament transformers. Figure 7 shows two filament transformers operating back-to-back so as to offer isolation of the selenium-rectifier power supply from the a-c line. The more complex circuits of figure 6 may be used with the back-to-back transformers of figure 7. However, the output power available from the back-to-back filament transformers will be limited by the leakage inductance and current capability of the filament transformers. A miniature power supply of this type is described in *Chapter Ten*. If more power output is required than is available

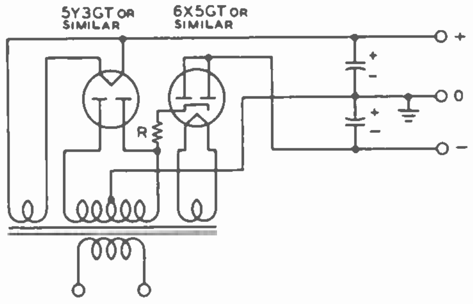


Figure 8.

AUXILIARY BIAS SUPPLY OPERATING FROM PLATE TRANSFORMER.

This arrangement may be used to deliver a negative voltage up to the magnitude of the positive voltage output, but at a lower current drain. The value of the negative voltage may be varied by varying resistor R.

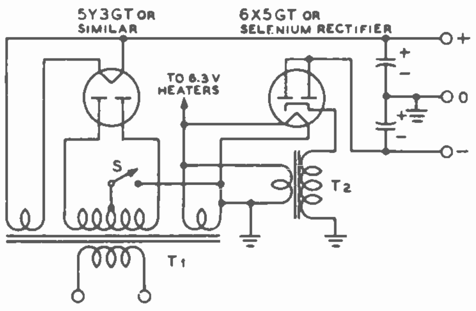


Figure 9.

AUXILIARY BIAS SUPPLY.

An auxiliary bias supply of this type may use either a selenium or a vacuum-tube rectifier. A back-connected filament transformer furnishes voltage for the bias rectifier. Output voltage is approximately 100 volts at a relatively small current drain.

from the miniature power supply described, larger filament transformers will be required.

Grid-Bias Power Supplies In the construction of a transmitter, an exciter, or other item of station equipment the operating conditions of one of the stages often require a low-current source of negative potential at from perhaps 50 to 300 volts. In many cases this value of voltage may be obtained without the installation of another transformer though the use of the circuit arrangement of figure 8. In this circuit the 6X5-GT has its heater lighted from the 6.3-volt winding on the power transformer, and due to the heater-cathode rating of 450 volts the cathode may be connected to one side of the secondary of the high-voltage winding. If a negative-voltage output approximately equal to the voltage output of the positive supply is required, the cathode may be connected directly to one side of the secondary. If a lower value of output voltage is required of the negative supply, a resistor of 1000 to 10,000 ohms (10-watt rating) may be connected in series with the lead from the secondary winding to the cathode of the 6X5-GT. The 6X5-GT tube requires 0.6 ampere of heater current at 6.3 volts. If the 6.3-volt winding on the transformer is not capable of supplying this additional current, a type 6ZY5-G rectifier may be used in place of the 6X5-GT. The 6ZY5-G requires only 0.3 ampere of heater current at 6.3 volts.

In a normal application only a few milliamperes of current will be taken from the bias supply; hence the 40-ma. rating of the 6ZY5-G as compared to the 70-ma. rating of the 6X5-GT will not be of consequence. If, however, an appreciable amount of current is to be taken from the negative-voltage supply, this value of current must be added to the current to be taken from the positive-voltage supply in determining the rating of the secondary of the power transformer. If a moderate amount of current is to be taken from the negative supply, in addition to the current from the positive supply, it would be desirable to use a full-wave rectifier instead of the half-wave rectifier illustrated. Two 6X5-GT's or 6ZY5-G's will be required for the full-wave rectifier, with the cathodes of the two tubes being connected to the opposite ends of the high-voltage secondary. With the two added rectifier tubes operating in this manner, it can easily be seen that the secondary winding of the power transformer is being bridge rectified, with the center-tap of the high-voltage being grounded so that equal positive and negative voltages will be obtained.

In figure 9 is shown an alternative circuit which has proven convenient when a negative voltage of less than 100 volts is required. A miniature 1.5-ampere 6.3-volt filament transformer is back connected so that its 6.3-volt winding is connected to the 6.3-volt winding on the power transformer. In most cases it

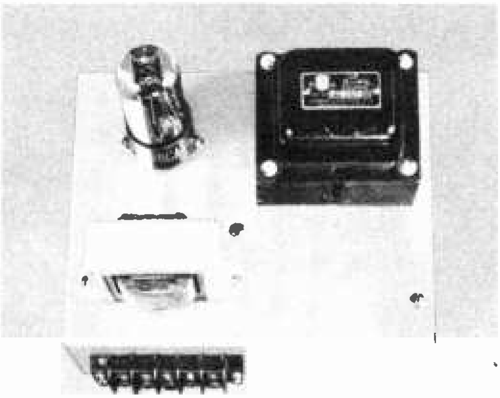


Figure 10.

TOP VIEW OF THE LOW-DRAIN POWER SUPPLY.

A 5Y3-GT tube is used instead of a 6X5-GT rectifier in the unit illustrated.

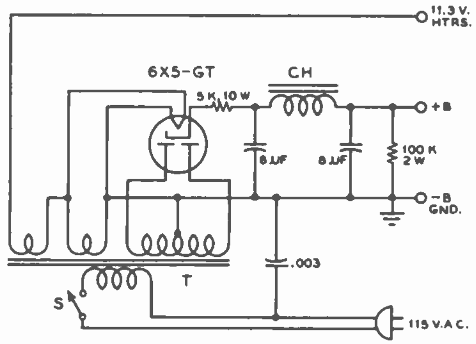


Figure 11.

SCHEMATIC OF THE LOW-DRAIN POWER SUPPLY.

The supply is shown connected for supplying heater voltage to a 12.6-volt heater string. For use with a 6.3-volt heater string the lead to the external heaters should be connected to the ungrounded side of the heater for the 6X5-GT rectifier tube. CH—16-hy. 50 ma. choke (Stancor C-1003). T—600 v. c.t., 55 ma.; 5 v. 2 a., 6.3 v. 2.7 a. (Stancor P-6119)

will be found convenient to use a miniature 115-volt selenium rectifier in this circuit instead of a rectifier tube.

Low-Drain Power Supply

There are many applications in the laboratory and amateur station for a simple low-drain power supply. The most common application in the amateur station for such a supply is for items of test equipment such as the LM and BC-221 frequency meters, for frequency converters to be operated in conjunction with the station receiver, and for high-selectivity i-f channels such as the BC-453A, the Millen 92105, and the Silver 805. Items of equipment such as these may be operated from a plate supply delivering 200 to 250 volts at up to 50 ma. of plate current. Heater supply either is already 6.3 or 12.6 volts, or the heaters in the equipment may be rewired to either of these voltages with relatively little difficulty.

The simple supply illustrated in figures 10 and 11 is capable of meeting the requirements discussed in the paragraph above. Figure 11 shows the schematic diagram of the supply, with the 5-volt and 6.3-volt windings connected in series so as to deliver 11.3 volts (nominal) to the heaters of the unit fed by the supply. The 11.3-volt output of the supply will be found to be adequate for operation of 12.6-volt tubes or for operation of a string consisting of two 6.3-volt tubes in series. The 11.3-volt heater supply is just about at the lower limit of the permissible plus or minus 10 per cent variation in heater voltage for conventional tube types.

If it is desired to operate an equipment which is wired for operation from a 6.3-volt heater winding on the power transformer rath- "hot" heater lead from the other side of the heater winding on the power transformer rather than from the series connected 5-volt winding. Where ample current is available on the 6.3-volt winding for operation of a 6X5-GT rectifier in addition to the heater drain of the equipment being fed by the supply, it is recommended that a 6X5 rectifier be used in place of the more common 5Y3-GT type. This is particularly to be recommended when the power supply is to be installed in some space with limited ventilation such as the bottom compartment of a frequency meter. The 6X5-GT rectifier requires about one-third as much heater power as the 5Y3-GT, and in addition the 6X5-GT has less internal drop than the 5Y3-GT. The 6X4 miniature type may be used alternatively to the 6X5-GT when the reduced space requirements of the miniature tube envelope would be important. Further, where heater power and dissipation must be held to a minimum, the 6ZY5-G with its 6.3-volt 0.3 ampere heater may be used in place of the 6X5-GT if the output current is limited to 40 ma.

Some variation in the loaded output voltage of the power supply may be had by varying the value of the resistor from the rectifier tube to the first filter capacitor. The 5000-ohm 10-watt resistor shown in figure 11 will be found adequate for most limited-drain applications. For an application where less output voltage is required, this resistor may be increased in value; for increased voltage the resistor may be reduced in value, or eliminated entirely. When reduced output voltage from the power supply is required, as is normally the case with accessory test equipment, it is best to place the drop resistor in the position shown in the schematic of figure 11; when the drop resistor is used in this circuit position it serves additionally as a filter element to reduce the ripple-voltage output of the power supply, and it reduces the peak-emission requirement imposed on the cathode of the rectifier tube.

350-Volt 110-Ma. Power Supply

Figures 12, 13, and 14 illustrate a general-purpose power supply suitable for operating a good size receiver, a low-power transmitter, or the exciter stages of a larger transmitter. The power supply is perfectly conventional, with a 5Y3-GT rectifier and a single-section capacitor-input filter. The two switches mounted on the front of the chassis are, respectively, the plate-voltage switch in the center-tap of the power transformer high-voltage secondary,

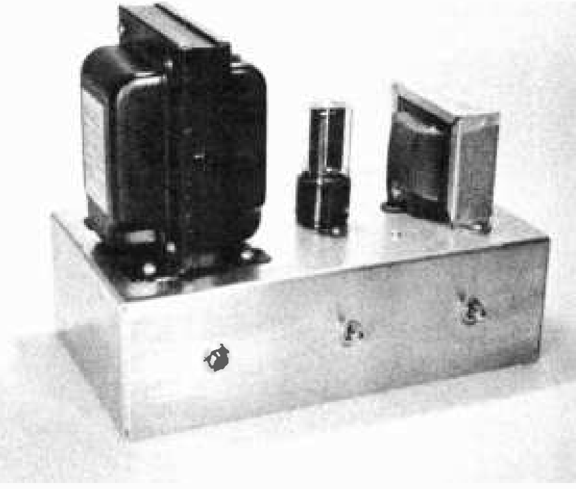
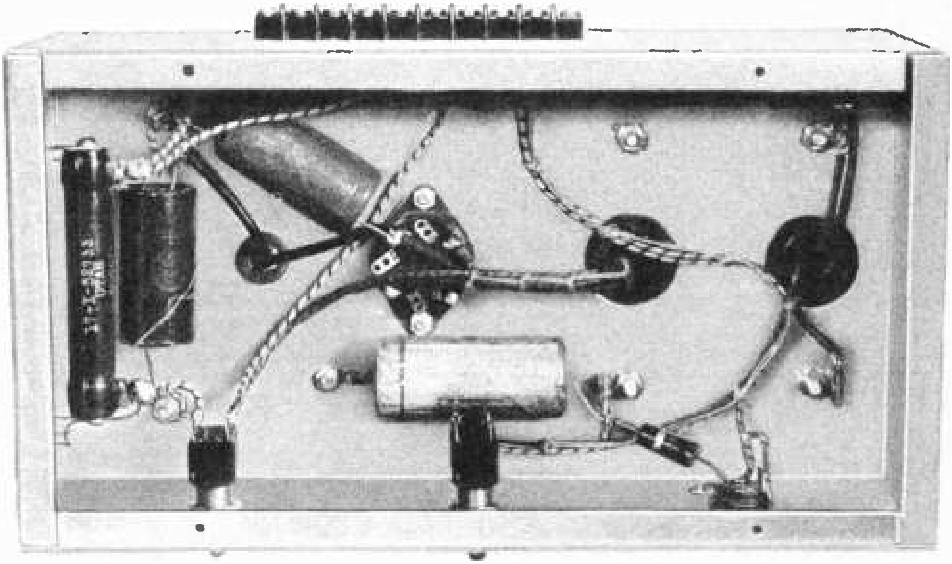


Figure 12.
TOP VIEW OF THE 350-VOLT 110-MA. POWER SUPPLY.

Figure 13.
UNDERCHASSIS OF THE 350-VOLT SUPPLY.



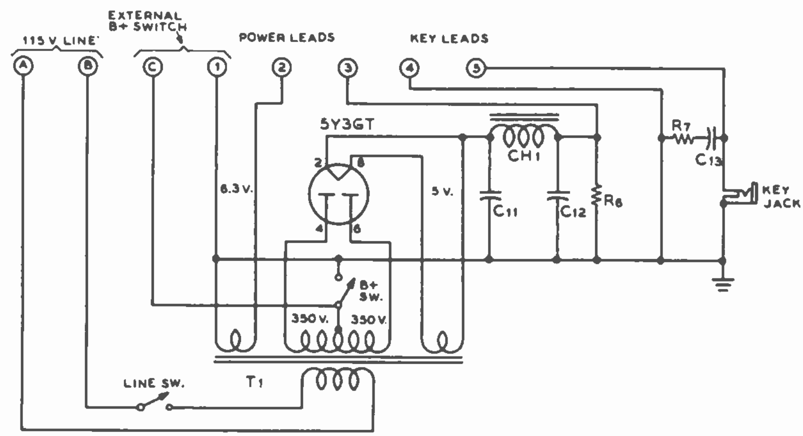


Figure 14.

SCHEMATIC OF THE 350-VOLT SUPPLY.

C_{11}, C_{12}—8-μfd. 500-volt electrolytics
C_{13}—0.5-μfd. 400-volt tubular
R_8—30,000-ohm 25-watt fixed bleeder
R_7—100-ohm 2-watt resistor

CH_1—10.5-hy. 110-ma. choke (Merit C-2993)
T_1—700 v. c.t. 110 ma., 5 v. 3 a., 6.3 v. 4.5 a. (Merit P-3153)
Switches—S.p.s.t. toggle switches

and the a-c line switch. A pair of leads, in parallel with the plate-voltage switch, are brought out for external control of the plate-voltage output of the supply. The power supply was constructed for use with the two simple two-tube transmitters at the beginning of *Chapter Three*. For this reason both the key jack and the key-click filter for these transmitters are included in the chassis of the power supply unit.

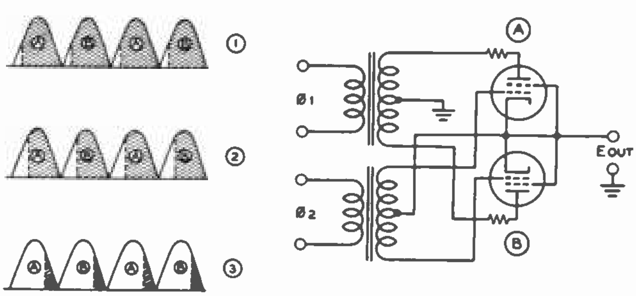


Figure 15.

SHOWING THE OPERATION OF THE THYRATRON RECTIFIER CIRCUIT.

Tubes (A) and (B) are type 2050 tetrode thyratrons. Phase 1 is the reference phase of the 115-volt line fed to the primary of the plate transformer. Phase 2 is controlled and varies the angle of the plate-supply voltage over which the thyratron tubes will conduct. The output voltage from the supply is taken from the cathodes of the tubes as in the case of any rectifier circuit. The cross-hatched area in (1), (2), and (3) represents the portion of the plate-voltage cycle during which tubes (A) and (B) are conducting. Condition (1) takes place when the grid voltage is substantially in phase with the plate voltage, so that conduction takes place over nearly the whole cycle. In (2) the phase of the grid voltage lags somewhat, while in (3) the phase of the grid voltage lags almost one-half cycle behind the plate voltage. (1) represents nearly full output voltage, (2) will give about half-voltage output, while (3) will give about the lower limit of stable output from the supply.

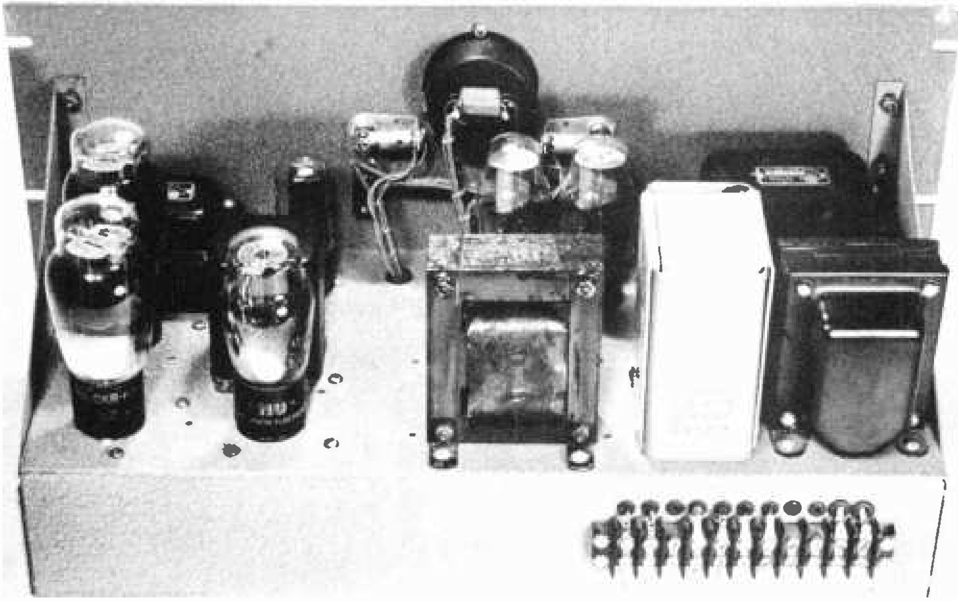


Figure 16.

REAR VIEW OF THE VARIABLE-VOLTAGE POWER SUPPLY.

Variable Voltage Power Supply

Figures 16 through 18 show a multi-purpose power supply unit designed for general testing in the amateur station or in the laboratory. The chassis of the equipment actually contains two separate units. One unit is a 200 ma. variable-voltage power supply whose output voltage can be varied from approximately 100 volts to 400 volts under full load. The other unit is a dual-output regulated grid-bias pack with provisions for modulating one or both of the bias voltages for grid-bias modulation of an r-f amplifier. Although the two power supplies are mounted contiguously they will be described separately.

Variable Voltage Power Supply A pair of 2050 grid-controlled gas thyratrons are used as rectifiers in the variable-voltage power supply. These rectifier tubes have an inverse peak rating of 1300 volts and can deliver an average output current of 100 ma. each or 200 ma. for the pair. A 1300-volt inverse-peak rating on the tubes limits the maximum secondary voltage of the power transformer to about 460 each side of center. The particular transformer used in the unit illustrated furnishes 400 volts each side of center tap and is rated to carry an output current of 200 ma. A capacitor input filter is used so that the full load voltage with the control at maximum is about 400. Due to the peak current limitation of 1 ampere on the rectifier tubes, it is necessary to insert resistors in series with the plate leads. In the unit shown it was found convenient to combine the function of peak current limiting and hash suppression by placing a resistor in series with the plate lead of each tube. In addition a buffer capacitor is placed across each half of the primary

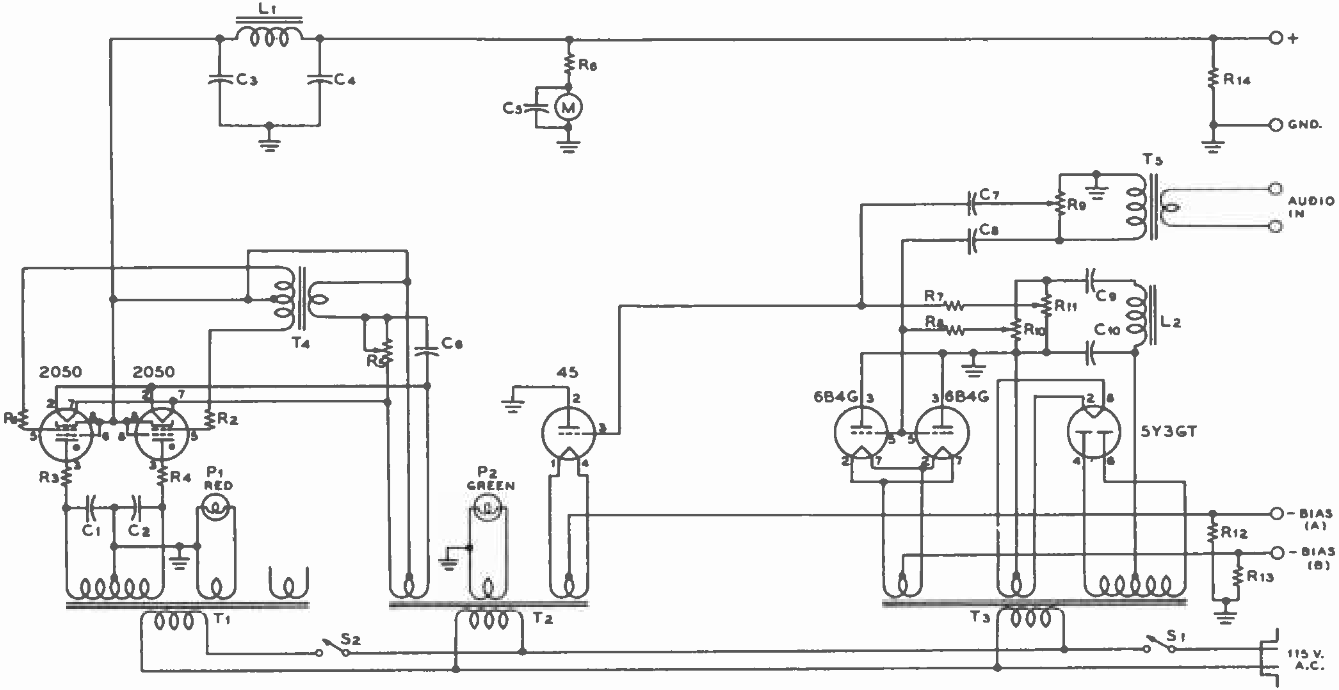


Figure 17.

SCHEMATIC OF THE VARIABLE-VOLTAGE DUAL POWER SUPPLY.

C_1, C_2—0.002-μfd. 1250-volt mica
C_3—4-μfd. 600-volt oil filled
C_4—8-μfd. 600-volt oil filled
C_5—0.003-μfd. mica
C_6—8-μfd. 150-volt elect.
C_7, C_8—0.05-μfd. 400-volt
C_9, C_{10}—8-μfd. 450-volt elect.
L_1—8.5-hy. 200-ma. choke (Stancor C-1721)
L_2—16-hy. 50-ma. choke (Stancor C-1003)
M—0-5 d-c milliammeter (Marion HM-2)

R_1, R_2—100,000 ohms ½ watt (Ohmite Little Devil)
R_3, R_4—200 ohms 10 watts (Ohmite Brown Devil)
R_5—10,000-ohm wire-wound potentiometer
R_6—Group of 2-watt resistors in series to make 100,000 ohms
R_7, R_8—100,000 ohms ½ watt (Ohmite Little Devil)
R_9—50,000-ohm potentiometer
R_{10}, R_{11}—70,000-ohm wire-wound potentiometers (Mallory 470MP)
R_{12}, R_{13}—25,000 ohms 10 watts (Ohmite Brown Devil)

R_{14}—50,000 ohms 20 watts (Ohmite Brown Devil)
S_1, S_2—S.p.s.t. toggle switches
T_1—400 volts to 460 volts each side center at 200 ma. (Stancor P-6165 used)
T_2—2.5 v. 3.5 a., 5 v. 3 a., 6.3 v. 3 a. (Stancor P-6144)
T_3—600 v. c.t. 55 ma., 5 v. 2 a., 6.3 v. 2.7 a. (Stancor P-6119)
T_4—Push-pull input, 3:1 ratio (Stancor A-4750)
T_5—Line to grid (Stancor A-4351)

of the plate transformer. Resistors R_3 and R_4 in conjunction with capacitors C_1 and C_2 serve the dual function of peak current limitation and hash suppression.

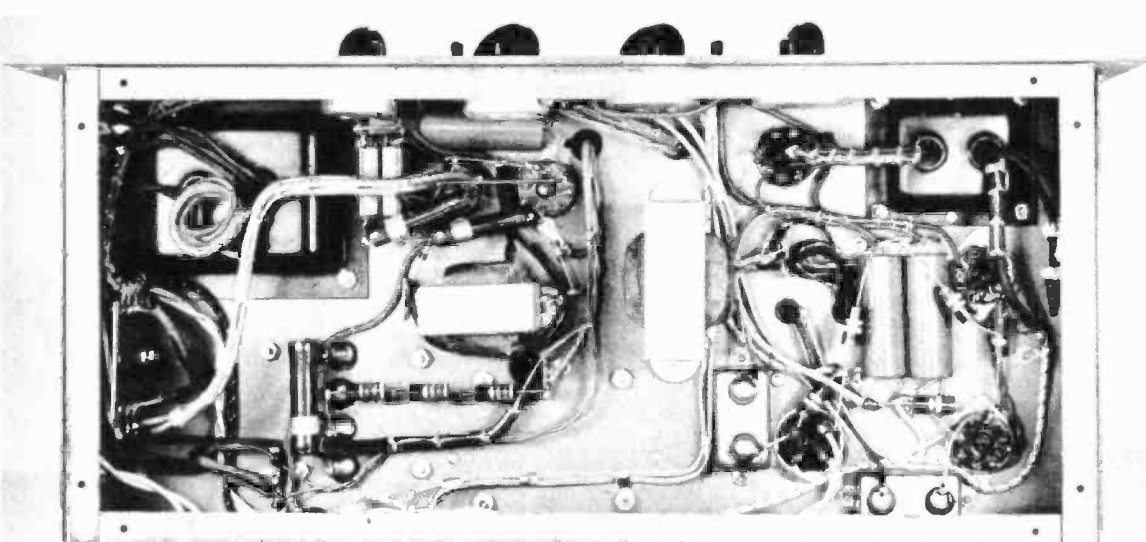
A unique feature of this power supply is the fact that the rectifier tubes are grid-controlled gas thyratrons. Hence it is possible to vary the output voltage of the power supply by varying the phase angle of the a-c voltage applied to the grids of the thyratrons. The use of thyratron tubes in this manner as controlled rectifiers is quite common in industrial practice but is seldom found in amateur equipment.

The mechanism of the action of the grids of the thyratron tubes in controlling the output voltage of the power supply is diagrammed in figure 15. The phase angle of the a-c line feeding the plates of the rectifiers, $\phi 1$, remains constant, as the reference phase, throughout this discussion. However, the phase angle of the voltage applied to the grids of the thyratrons, $\phi 2$, is varied by means of the phase-shifting network with its control R_6 in figure 18 brought out to the front panel. When the phase of the voltage applied to the grids is essentially the same as that applied to the plates, the tube conducts over substantially the entire cycle as is the case with any mercury-vapor or gas-type rectifier tube. This condition is illustrated by figure 15 (1). However, when the phase angle of the voltage applied to the grids is retarded, as in (2), the tube will not conduct until the actual negative grid voltage becomes more positive than the critical value for the applied plate voltage. When the critical value is reached, the tube ionizes and current flows through the remaining portion of the half-cycle. The portion of each half cycle during which conduction occurs is indicated by the cross-hatch lines in figure 15.

It is important to remember that a thyratron tube continues to conduct, after once being fired, so long as the plate is positive with respect to the cathode; the grid loses control completely over the flow of current once its peak potential has exceeded the critical value and ionization has taken place. Hence thyratrons must be used in a type of circuit where voltages are periodically applied, with a short resting period between operating cycles. The power supply circuit of figure 18 is an example of such an arrangement since the plate voltage on each tube becomes negative after each period of conduction.

When the phase angle of the voltage on the grid is made to lag far behind that applied to the plate, the tube conducts over only a small portion of the half cycle during which the plate is positive with respect to the cathode. (See figure 15 (3).) In a power supply such as that illustrated, this type of operation results in the lowest value of out-

Figure 18.
UNDERCHASSIS OF THE VARIABLE-VOLTAGE SUPPLY.



put voltage which may be obtained from the power supply.

The phase-shifting network in the power supply illustrated is made up of R_5 and C_5. These two components are connected across the 6.3-volt winding for the 2050 heaters in such a manner that the phase of the voltage across the primary of T_4 may be varied over a wide angle. The phase-shifted voltage then is fed to the grids of the 2050 tubes from the push-pull secondary of transformer T_4. Type 2D21 miniature thyratrons may be used in place of 2050's since their characteristics are similar. The balance of the circuit for the power supply is conventional, with a 0-5 milliammeter connected in series with the bleeder on the output of the power supply in such a manner that the milliammeter acts as a voltmeter. The output voltage is obtained by multiplying the milliammeter reading by 100.

Specifications for the 2050 tube call for a delay of at least 10 seconds after the application of heater voltage before the tube is required to conduct. This requirement is met by isolating the transformer which supplies heater power from the plate transformer. When S_1 is closed, heater power is applied to all tubes, and the bias supply becomes operative. Green pilot lamp P_2 lights whenever the heaters of the tubes are energized. Then when S_2 is closed the red pilot lamp P_1 lights, and plate voltage is applied to the 2050's. The output voltage of the power supply indicated by the milliammeter/voltmeter on the front panel, and the value of the output voltage may be varied by the front-panel control of the potentiometer R_5.

The Regulated Bias Supply The balance of the chassis of the unit is taken up by the regulated bias supply. Two separately controlled bias outputs are provided, either one of which may be varied from a few volts to about −300 volts. Bias output (A), which uses a type 45 tube as the regulator, is capable of handing a maximum grid current into the bias pack of about 50 ma. Bias output (B), using a pair of 6B4-G tubes in parallel, is capable of handling up to 200 ma. of grid current from the tubes to which it feeds bias.

The circuit of the bias supply uses a 5Y3-GT as a rectifier, with the tubes specified in the previous paragraph as reverse-connected bias regulators. Potentiometers R_{10} and R_{11}, which are brought out to the front panel, serve to control separately the output voltage from each of the bias channels. Provision has been included with the components T_5, R_7, R_8, R_9, C_7, and C_8 for modulation of the grid-bias voltage by means of an audio signal from an external speech amplifier. Since potentiometer R_9 permits controlling the ratio of the audio voltage on channel (A) with respect to that on bias channel (B), the bias pack may be used for simultaneous cascade grid-bias modulation of two successive stages in an AM transmitter. Such an arrangement

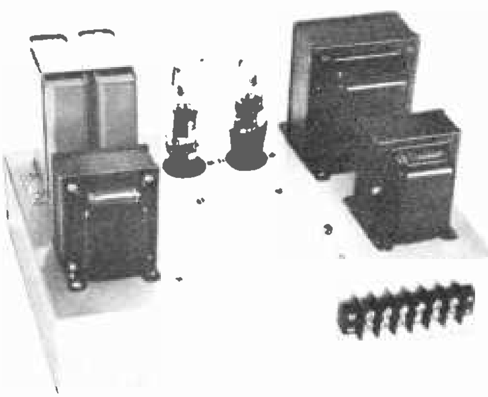


Figure 19.
VIEW OF THE 750/600 VOLT 200-MA. SUPPLY.

C_1, C_2—10-μfd. 600-volt oil filled
L_1—2-12 hy. 250-ma. swinging choke (Stancor C-1402)
L_2—4-hy. 250-ma. filter choke (Stancor C-1412)
T_1—1000 v. c.t., 300 ma. max. (Stancor P-8040)
T_2—2.5 v. 5 a., 7500 v. insulation (Stancor P-6133)
R—25,000 ohms, 25 watts fixed (Ohmite 0219)

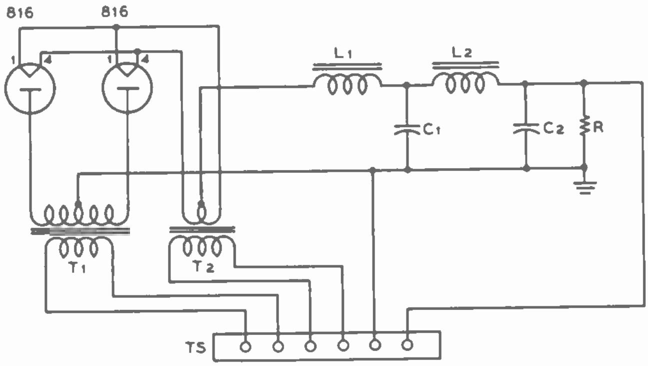


Figure 20.
SCHEMATIC OF THE 400-VOLT 250-MA. SUPPLY.

would be particularly convenient when grid-bias modulating a grounded-grid output stage (such as with one or two 304TL's) while simultaneously grid-bias modulating the stage which excites the final amplifier (which might be an 812A, 35TG, or similar type).

Obviously the bias-modulating portion of the regulated grid-bias pack may be omitted if this provision never will be needed. But if a bias supply such as the one described is to be used as a portion of a c-w transmitter, the inclusion of the few components for grid-bias modulation will allow the transmitter to be used for AM phone with little difficulty, should the occasion demand. Also, the bias supply may be separated from the variable-voltage power supply in the event that only one or the other is required simply by separating the functions of the filament transformer T_2.

400-Volt 250-Ma. Power Supply

Illustrated in figures 19 and 20 is a 400-volt power supply capable of delivering 250 ma. of current to the load. Type 816 tubes are used as rectifiers to feed a two-section choke-input filter. A high degree of filtering is obtained through the use of two 10-μfd. 600-volt oil-filled capacitors in the filter system. Ripple percentage at full output from the power supply is about 0.25 per cent. The regulation from the supply is sufficiently good so that the one power supply may be used to feed both the final amplifier and a class AB_2 or class B modulator for the r-f amplifier.

The primary of the plate transformer is brought out to a separate pair of terminals from the primary of the rectifier filament transformer. The separation of the two primary circuits allows a greater degree of flexibility in the control circuits of the transmitter of which the power supply is a unit.

750/600-Volt 200-Ma. Power Supply

A 120 to 150 watt power supply for a c-w r-f amplifier is illustrated in figures 21 and 22. The power supply will deliver either 750 volts or 600 volts at a load current of 200 ma. Selection of the output voltage is accomplished by changing the taps on the secondary of the plate transformer. The filament transformer for the 816 rectifier tubes also includes a 6.3-volt 5-ampere winding which is brought out to terminals on the rear of the unit. This filament winding may be used to operate the heaters of the tubes in the r-f portion of the transmitter fed by the power supply. Since the power supply was constructed for use with a c-w transmitter, one section of choke-input filter was used following the rectifier tubes. Ripple voltage output of the power supply at full load is approximately 3 per cent. Note that the filaments of the 816 rectifiers are operated one from each side of the center tap of the 5-volt filament winding. This simple connection allows a 5-volt center-tapped winding to be used with tubes having a 2.5-volt filament rating.

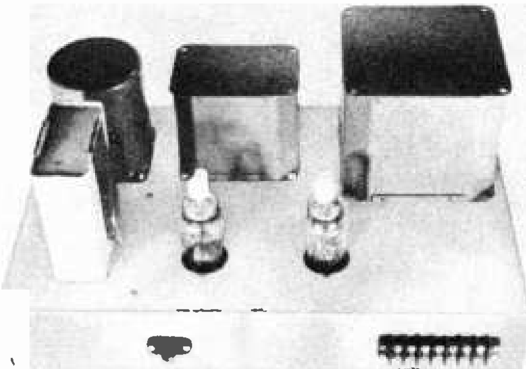


Figure 21.
VIEW OF THE 750/600 VOLT 200-MA. SUPPLY.

100-Watt Voltage Regulated Power Supply

There are occasional applications in the laboratory for a voltage regulated power supply having a sizable power output. The particular unit illustrated in figures 23 and 24 was constructed for use as the 400-volt supply for an ART-13 transmitter, but it has found many other applications in the laboratory. The power supply is capable of delivering up to 250 ma. of output current at a voltage of 325 to 450 volts. The regulation is exceptionally good for a power supply of this level of output power; the output voltage drops by less than 2 volts from no load to a current drain of 250 ma. The voltage change is so small that it is difficult to read on a conventional laboratory voltmeter with a 5-inch instrument face.

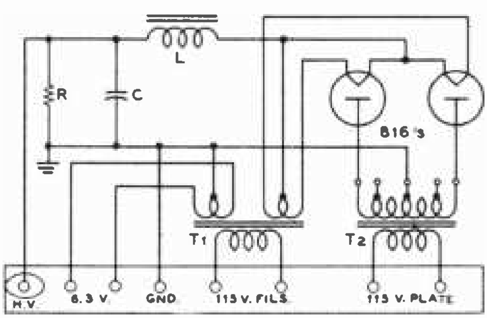


Figure 22.
SCHEMATIC OF THE 750/600 VOLT 200 MA. SUPPLY.

L—4-20 hy. 200-ma. swing choke (UTC CG-41)
T_1—5 v. c.t. 6 a., 6.3 v. c.t. 5 a. (UTC S-67)
T_2—1800 v. or 1500 v. c.t. 200 ma. (UTC S-45)
R—50,000 ohms 50 watts fixed (Ohmite 0420)
C—10-μfd. 1000-volt oil filled

Circuit of the Power Supply The circuit of the power supply is quite similar to that used for the conventional 250-volt 100-ma. regulated power supply with a 2A3 or 6B4-G series voltage-control tube. However, type 816 mercury-vapor rectifier tubes are used in the power supply, with one of the new low-drop 6AS7-G tubes as the series control element. Reference voltage in the power supply is obtained from a VR-150 gaseous regulator, and a 6SH7 pentode is used as a d-c amplifier to control the voltage on the grid of the 6AS7-G. Note that the 6.3-volt heater winding for the 6SH7 and the 6AS7-G tubes is operated at a potential of plus 150 volts by connecting the winding to the plate of the VR-150. This procedure causes the heater-cathode voltage of the 6SH7 to be zero, and permits an output voltage of up to 450 since the 300-volt heater-to-cathode rating of the 6AS7-G is not exceeded with an output voltage of 450 from the power supply.

The 6SH7 tube was used in place of the more standard 6SJ7 after it was found that the regulation of the power supply could be im-

Figure 23.
TOP VIEW OF THE VOLTAGE-REGULATED POWER SUPPLY.

Line switch and voltage-control potentiometer are on the front of the chassis while the 6-wire output connector is on the rear. Since the supply used a 5R4-GY rectifier at first, it was necessary to mount the two four-prong sockets on a plate when 816's were substituted as rectifiers.

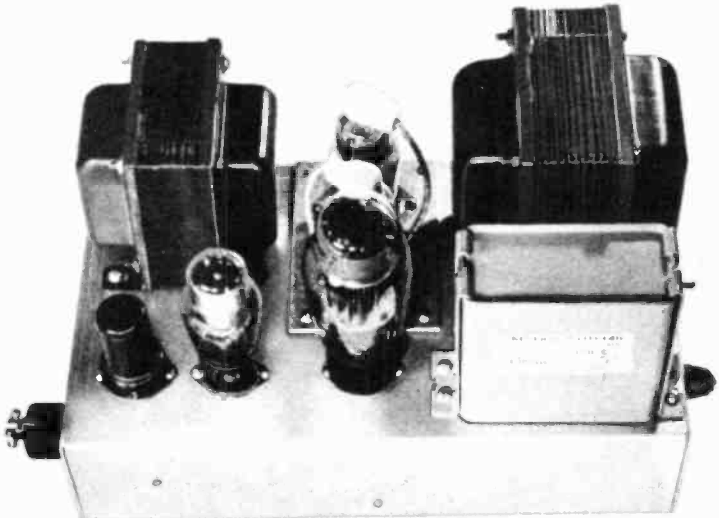
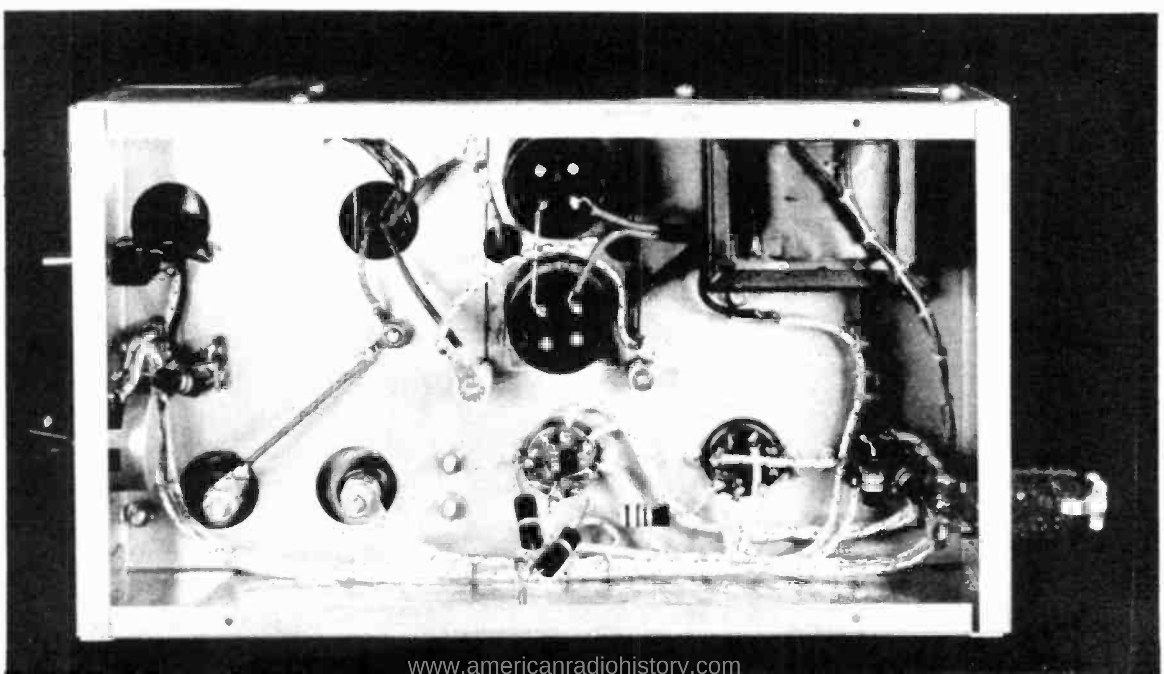


Figure 24.
UNDERCHASSIS OF THE VOLTAGE-REGULATED POWER SUPPLY.



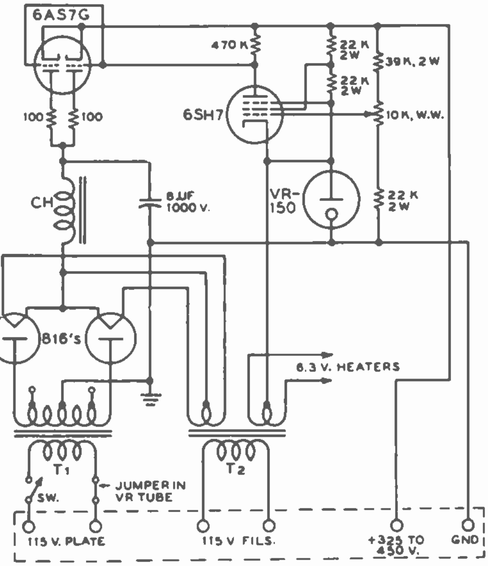


Figure 25.
SCHEMATIC OF THE VOLTAGE-REGULATED POWER SUPPLY.

CH—10-hy. 250 ma. choke (Merit C-3182)
T_1—660 or 550 v. each side, 250 ma. (Merit P-3157)
T_2—5 v. 3 a., 6.3 v. 3.6 a. (Merit P-3041)

proved by a factor of two with the 6SH7 in place of the 6SJ7. The original version of the power supply used a 5R4-GY rectifier tube in place of the 816's which now are used. The excessive drop of the 5R4-GY resulted in loss of control by the regulator portion with an output voltage of about 390 with a 225-ma. drain. Satisfactory regulation can be obtained, however, at up to 450 volts if the maximum current drain is limited to 150 ma. when using a 5R4-GY rectifier. If the power transformer is used with the taps giving 550 volts each side of center, and if the maximum drain is limited to 225 ma., a type 83 rectifier may be used as the power supply rectifier. The 660-volt taps on the power transformer deliver a voltage in excess of the maximum ratings of the 83 tube. With the 83 in the power supply, excellent regulation may be obtained with up to about 420 volts output if the output current is limited to 225 ma. But with the 816's as rectifiers the full capabilities of all the components in the power supply may be utilized.

If the power supply is to be used with an output voltage of 400 to 450 volts, the full 660 volts each side of center should be applied to the 816's. However, the maximum

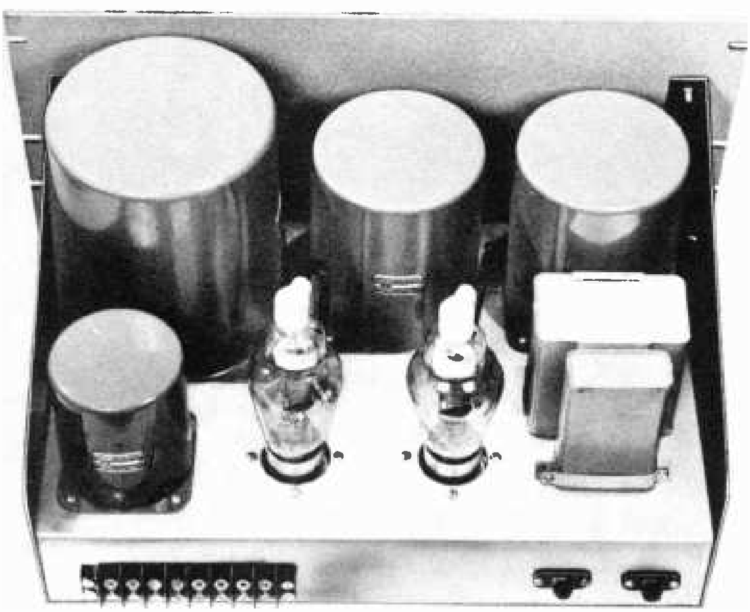


Figure 26.
REAR VIEW OF THE 1250-VOLT 250-MA. POWER SUPPLY.

The unit is constructed on an 11 by 17 by 3 inch steel chassis with a 10½ by 19 inch steel panel. The two high-voltage output terminals can be seen on the right of the rear drop of the chassis.

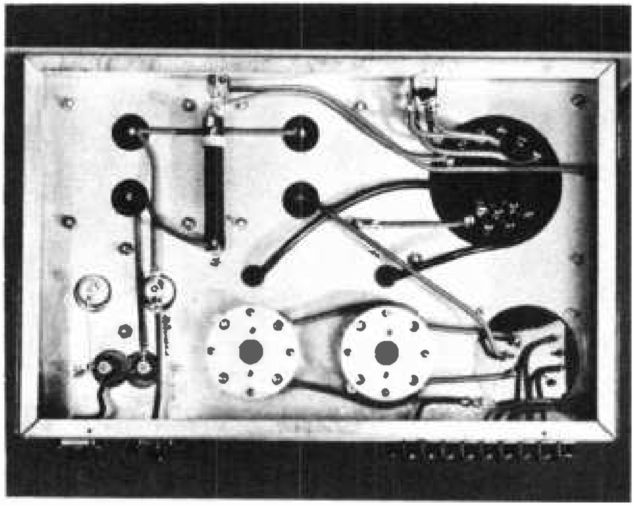


Figure 27.
UNDERCHASSIS OF THE 1250-VOLT SUPPLY.

Note the manner in which cut-outs have been made to allow for mounting the "CG" series transformers, filter capacitors, and rectifier sockets. A socket-hole punch was used for the filter capacitors and the chokes, while a "Bruno" adjustable hole cutter was used for tube sockets and transformers. Plate leads to the tubes are ignition cable, while all other leads are no. 14 "Deltabeston" gray switchboard wire (available from G. E. Supply Co.).

plate dissipation rating of the 6AS7-G will be exceeded, due to the voltage drop across the tube, if the full current rating of 250 ma. is used with an output voltage below 400 volts. If the power supply is to be used with full output current at voltages below 400 volts the 550-volt taps on the plate transformer should be connected to the 816's. Some variation in the output voltage range of the power supply may be obtained by varying the values of the resistors and the potentiometer across the output. However, be sure that the total plate dissipation rating of 26 watts on the 6AS7-G series regulator is not exceeded at maximum current output from the supply. The total dissipation in the 6AS7-G is equal to the current through it (output current plus the current passing through the two bleeder strings) multiplied by the drop through the tube (voltage across the filter capacitor minus the output voltage of the supply).

Construction The power supply is assembled on a 5½ by 10 by 3 inch aluminum alloy chassis (ICA 29004). The switch in series with the primary of the plate transformer and the voltage-control potentiometer are mounted on the front panel. Connections to the power supply are made through a Jones P-306-AB six-wire connector. If the power supply is to be used as a separate item of laboratory equipment rather than a component of a larger assembly it would be better to use a recessed plug such as the Amphenol 61-M10 for the 115-volt a-c line and a terminal strip for the high-voltage output.

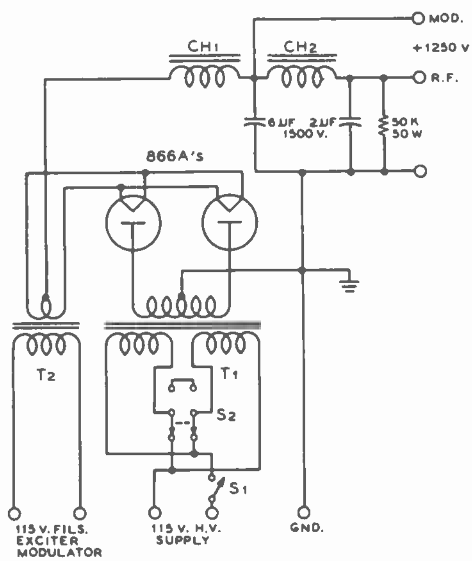


Figure 28.
SCHEMATIC OF THE 1250-VOLT SUPPLY.

CH_1—5-25 hy. 250-ma. swinging choke (UTC CG-103)
CH_2—12-hy. 250-ma. filter choke (UTC CG-102)
T_1—3000, 2470, and 800 c.t., 260 ma. (UTC CG-303)
T_2—2½ volts, 10 amps., 2500-volt working (UTC CG-34)
S_1—D.p.s.t. toggle switch (contacts in parallel)
S_2—10-amp. d.p.d.t. toggle switch

1250-Volt 250-Ma. Power Supply

One of the most popular and also one of the most convenient power ranges for amateur equipment is that which can be supplied from a 1250-volt power unit with a current capability of 200 to 300 ma. Figures 26, 27, and 28 illustrate such a power unit. The power supply has been assembled using the new "CG" series of components manufactured by UTC. Nearly all the components in this series are housed in cylindrical drawn-metal cans fitted with bottom terminals and finished in a medium grey enamel.

This power supply was constructed to supply plate voltage for the 100-watt 811 modulator described in *Chapter Seven* and for an HK-57 final amplifier which is modulated by the 811's. Plate voltage for the modulators is taken from the power supply after the first section of filter since less filtering is required for the push-pull modulators. Note that a 6-μfd. filter capacitor is used at this position so that ample storage capacity will be available to meet the peak-current requirements of the 811 tubes. Plate voltage for the final amplifier is taken off after an additional stage of filter, with a 2-μfd. filter capacitor used in this case since the peak current requirements of the final amplifier stage are less stringent.

Since the CG-303 plate transformer was provided with dual primaries for either 115-volt or 230-volt operation, it was deemed desirable to take advantage of this feature so as to make available either full voltage or half-voltage from the power supply. The two primaries are connected in series for half-voltage operation and they are connected in parallel for full-voltage output. Switch S_2 accomplishes the changeover from half to full voltage from the power unit. Switch S_1 acts as the local plate-voltage control switch. As in the case of all power supplies which use mercury-vapor rectifiers and yet do not have a time-delay relay, it is necessary to wait at least 30 seconds after application of filament voltage before the primary of the plate transformer is energized.

CHAPTER NINE

Transmitter Construction

The equipments described in this chapter are complete transmitters which either have been assembled from units described elsewhere in this book or have been constructed as complete assemblies. The complete transmitters are shown for the benefit of those who prefer to construct the transmitter as an entity rather than to work out an individual design from the exciter, power amplifier, modulator, and power supply units which have been shown elsewhere in this book, or have been described in other publications.

In any event it is important that some type of antenna coupling unit be used between the output of the transmitter and the antenna system. The increasing importance and intense public interest in television has made it imperative that a harmonic-reducing antenna coupler be included as an integral portion of a transmitter installation in a TV area. And it will not be long until all but the most remote locations must be classified as TV areas. A complete discussion of the considerations and components involved in the reduction of interference to broadcast and television reception has been included in *Chapter Twelve.*

200-Watt All-Band Transmitter

It has been the experience of many amateurs, particularly those who have started with low power and then progressed to a kilowatt, that a power level in the vicinity of 200 watts is the most practical. BCI is at a level with which the city dweller may cope, the investment in time and materials is reasonable, and the maintenance expense both in regard to the power bill and in regard to replacement costs is quite acceptable.

The transmitter described in this section has been designed to offer a high degree of flexibility and operating convenience in the 200-watt power range. The complete transmitter is made up of four assemblies: the modulator and final amplifier unit, the exciter unit, the power supply section, and the meter panel. All four units are housed in a standard Par-Metal DL-3513 cabinet which has 35 inches of available panel space.

The exciter portion of the transmitter has been described in considerable detail in *Chapter Three.* Hence this section will be devoted to a description of the other assemblies within the transmitter and to a description of the unit as a whole.

General Performance The 4-65A tube in the final amplifier operates at a plate potential of 1600 volts both for phone and c-w operation. The manufacturer's specifications for the tube limit the plate current to 120 ma. on phone and to 150 ma. on c.w. Hence the plate input to the final amplifier is limited to about 200 watts (actually 192 watts theoretically) on phone and 240 watts on c.w. At this value of power input to the final stage the transmitter operates very smoothly and with good plate circuit efficiency.

By throwing a single selector switch on the modulator and final amplifier deck the equipment is changed from phone to c-w operation. On phone a pair of 807's in class AB_2 delivers adequate power output to modulate the

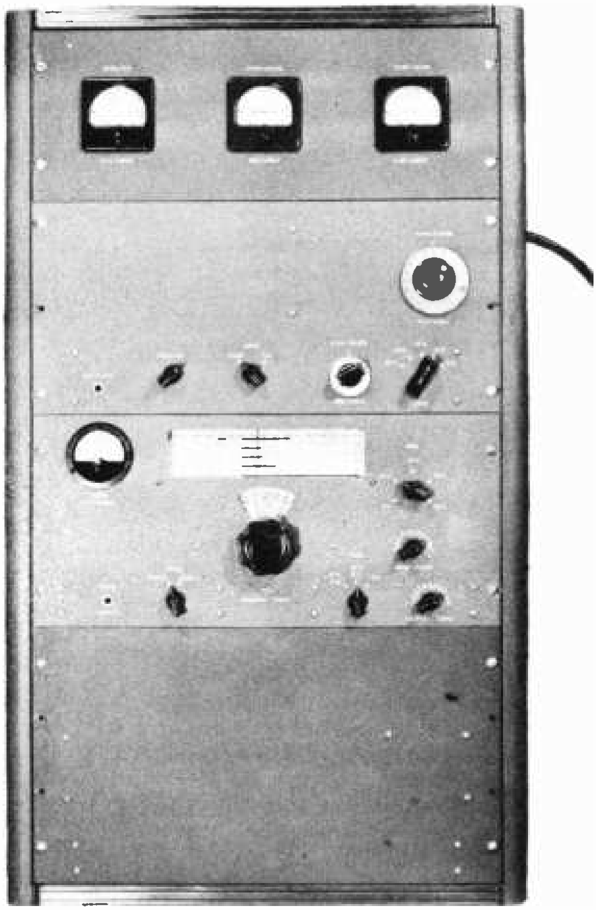


Figure 1.

FRONT OF THE ALL-BAND 200-WATT TRANSMITTER.

Decalcomania transfers (Techni-Cals) have been used to indicate the functions of the various meters, dials, and switches of the transmitter.

COIL DATA FOR 4-65A AMPLIFIER

L_1—SWITCHED GRID COIL AND LINK

3.5 Mc.—38 turns no. 22 enam. closewound on 1" dia. National XR-2 form. Link, 5 turns hookup wire wound on bottom end.

7.0 Mc.—18 turns no. 22 enam. closewound on 1" dia. National XR-2 form. Link, 5 turns hookup wire wound on bottom end.

14 Mc.—10 turns no. 18 enam. closewound on 1" dia. National XR-2 form. Link, 4 turns hookup wire wound below main coil.

21 Mc. and 28 Mc.—6 turns no. 14 bare spaced to ¾" on 1" dia. XR-2 form. Link, 3 turns hookup wire wound below main coil.

50 Mc.—4 turns no. 14 bare air wound 1" dia. and spaced to ½". Link, 2 turns hookup wire between last two turns of main coil.

L_2 and L_3 PLATE TANK COILS AND LINKS

3.5 Mc.—24 t. no. 14 enam. closewound on Millen 44001 1⅞" form. Link, 6 turns no. 14 enam. closewound at low potential end.

7.0 Mc.—14 t. no. 14 enam. spaced to 2" on Millen 44001 form. Link, 5 turns no. 14 enam. closewound at low potential end.

14 Mc.—8 t. no. 14 enam. spaced to 1¾" on Millen 44001 form. Link, 4 turns no. 14 enam. closewound at low potential end.

21 Mc. and 28 Mc.—6 turns no. 8 bare-spaced to 2" on Millen 44001 form. Link, 1 turn no. 14, heavy insulation, wound over last two turns but larger diameter to allow ¼" air space

50 Mc.—4 t. no. 8 bare, 1¼" dia. air wound, spaced to 1½". Link, 1 turn no. 14, heavy insulation, wound over last two turns but larger diameter to allow ¼" air space

final with good audio quality and low distortion On c.w., plate current to the final amplifier is biased to cutoff by means of a fixed-bias pack in the power supply unit. Then the screen circuit of the 2E26 stage in the exciter is keyed along with the frequency multiplier stages. The double-keying procedure described in *Chapter Three* gives smooth, clickless keying of the emitted carrier with no back wave in the receiver when the key is up. The transmitter is capable of operating with v-f-o control of the operating frequency on all bands 3.5 through 29.7 Mc. Additionally, the equipment may be operated with crystal control on all bands 3.5 through 54 Mc.

The 4-65A final amplifier and the speech amplifier/modulator unit both are mounted for convenience behind a single 8¾ by 19 inch dural panel. This type of mounting has proven adequate electrically and is convenient mechanically since both units are small and compact. In the event that the combination of the 4-65A final amplifier and the 807 modulator is not desirable, either unit may be built upon a single long and narrow chassis so that it will justify the use of a standard 19-inch panel.

The 4-65A Final Amplifier Simplicity is the keynote of the final amplifier unit. Only those components actually necessary to the operation of the stage have been included on the chassis. The stage itself is mounted on a 7 by 12 by 3 inch chassis. Crackle-finished steel was used in the unit illustrated simply because it was available in the proper size. The use of plated steel or aluminum as a chassis material is to be preferred electrically since low resistance grounds are easily and surely obtainable.

Mounted on the chassis are only the tube socket and the filament transformer along with the associated grid and plate tank circuits. Coils for the grid tank circuit are selected by means of a two-deck ceramic switch. The 10-meter coil serves also to tune the 15-meter band when the capacitance of the grid tuning capacitior is tuned almost to maximum. Four of the grid coils are wound on 1-inch diameter National XR-2 coil forms. The fifth grid coil, which is for operation on the 6-meter band, is made self-supporting and connects to the grid return and to the bandswitch.

Plug-in coils are used in the plate circuit of the 4-65A amplifier. The jack base which receives the coils is a Millen type 41305 and all coils except the one for 50 Mc. are mounted on Millen type 44001 coil forms. The 50-Mc. coil is self-supporting on a 40305 base. Fixed link coils are wound on each of the plug-in units. It will be noted that a double-stator capacitor is used to tune the plate circuit of the 4-65A amplifier. However, this capacitor is not used in the normal manner since it was not found necessary to include a provision for neutralizing the 4-65A.

The internal shielding of the tube is sufficiently good so that no tendency toward self-oscillation was encountered. However, when the amplifier is duplicated it is suggested that the placement of components also be duplicated in so far as it is practicable. Note particularly the fact that the five by-pass capacitors associated with the underside of the socket all return to a common ground terminal. Note also that the by-pass capacitor for the plate circuit connects above chassis to this same ground point.

Only one section of the split-stator tuning

Figure 2.

REAR OF THE 200-WATT TRANSMITTER.

Showing the mounting and cabling of the various units which go to make up the transmitter. A variable capacitor has been added to the transmitter in series with the output link. This capacitor serves to tune out the reactance of the fixed coupling link, and thus effectively to vary the coupling between the output circuit of the transmitter and the external antenna-matching network.

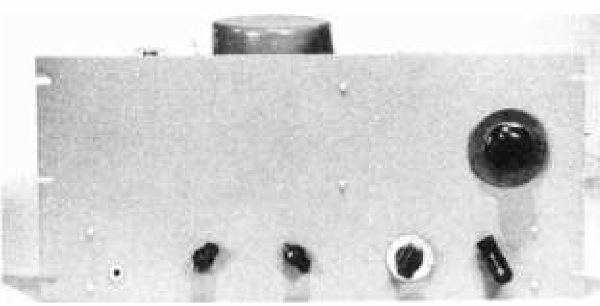


Figure 3.

THE MODULATOR AND FINAL-AMPLIFIER CHASSIS.

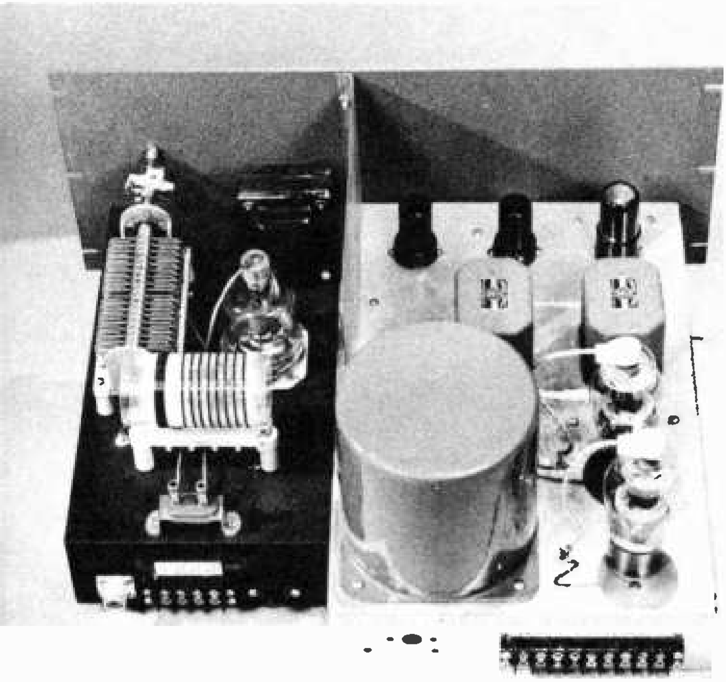


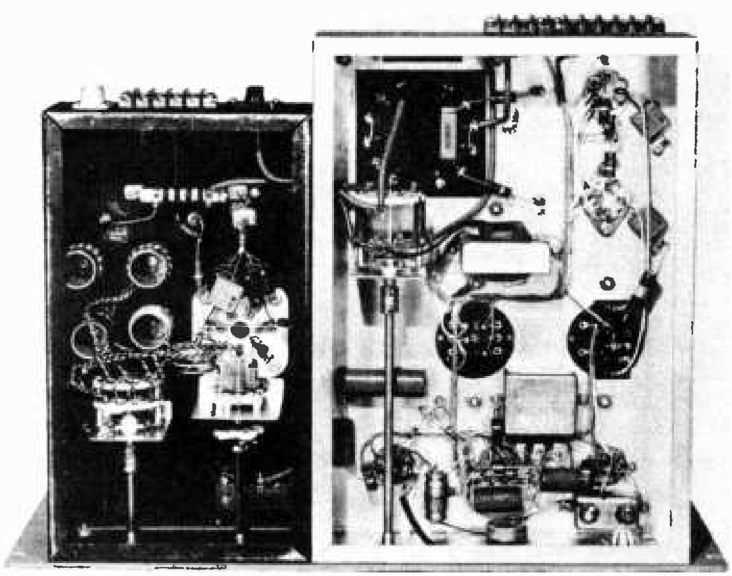
Figure 4.

LOOKING DOWN ON THE MODULATOR AND FINAL AMPLIFIER.

Figure 5.

UNDERCHASSIS OF THE MODULATOR AND FINAL AMPLIFIER.

Note the mounting of the components which go to make up the bandswitching grid circuit of the 4-65A final amplifier. The phone-c.w. switch is mounted adjacent to the base of the modulation transformer, with an extension shaft running to a knob on the front panel.



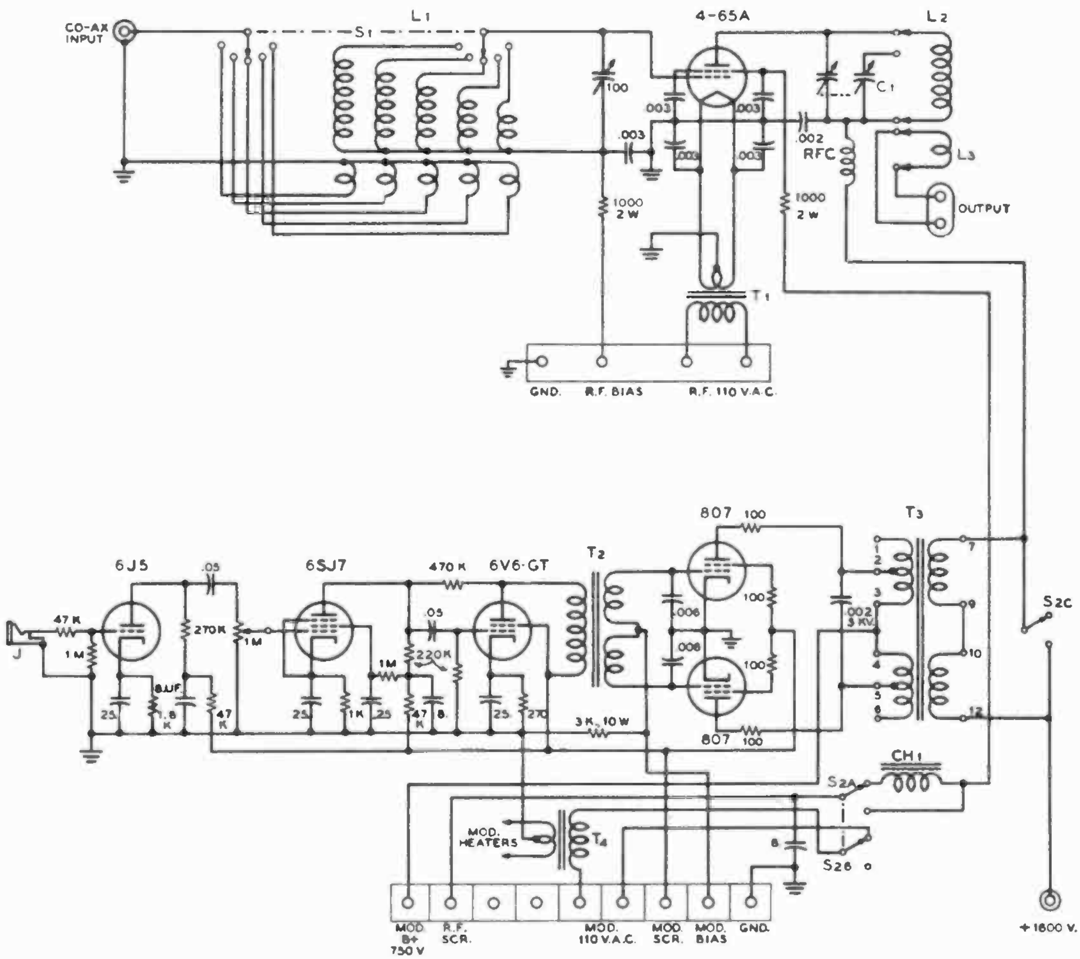


Figure 6.

SCHEMATIC OF THE MODULATOR AND FINAL AMPLIFIER.

C_1—Dual 71 µµfd., 0.077" spacing (Millen 12075)
L_1, L_2, L_3—See coil table.
T_1—6.3-volt 4-ampere filament transformer (Stancor P-4019)
T_2—Single driver plate to push-pull grids (UTC S-8)
T_3—125-watt modulation transformer (UTC CVM-3)
T_4—6.3-volt 3-ampere filament transformer (UTC S-55)
CH_1—13-hy. 65-ma. choke (Stancor C-1708)
S_1—2-pole 5-position ceramic switch (Centralab 2515 with upper portion only of each switch deck used)
S_2—Made from Centralab Switchkit. S_2A and S_2B are a 2-pole 5-position bakelite wafer while S_2C is a ceramic 90-degree wafer.
J—Closed-circuit microphone jack
RFC—Millen 34140 transmitting r-f choke

capacitor C_1 is used on all bands above 7 Mc. However, on the 3.5-Mc. band both sections of the tuning capacitor are used in parallel. A jumper is placed across two terminals on the plug bar for the 80-meter coil form to accomplish this paralleling function.

Normal grid current for the 4-65A amplifier is 9 to 12 ma. This value of grid current is easily obtainable from the exciter unit on all bands for which it is designed. Screen voltage for the 4-65A is obtained from a low-voltage power supply in the power-supply deck. For phone operation the 4-65A screen current is passed through a choke, CH_1,

Figure 7.
TOP OF THE TRANSMITTER MAIN POWER SUPPLY.

in the manner suggested by the tube manufacturer. This choke permits the screen voltage to self-modulate in accordance with the modulation applied to the plate voltage. Fixed bias of approximately 125 volts is applied to the grid circuit of the 4-65A as a safety feature and to permit keying of the excitation to the stage.

Modulator Unit The modulator deck of the transmitter includes a conventional speech amplifier which acts as a driver for a pair of 807's in Class AB_2. The speech amplifier portion of the modulator uses the 6J5-6SJ7-6V6-GT circuit with feedback from the plate of the 6V6-GT to the plate of the 6SJ7. This speech amplifier circuit has proven completely reliable and satisfactory in all respects. It has been described in different applications in many previous editions of the RADIO HANDBOOK, and its characteristic stability and low distortion when acting as a driver for a Class B or Class AB_2 modulator has been proven many times.

The 807's operate under the conditions recommended by the manufacturer for modulator service with 120 watts output. These conditions are 750 volts on the plate, 300 volts on the screen and 32 volts of fixed negative grid bias. Actually the voltage applied to the plates of the 807 is slightly in excess of 750 volts without modulation but drops slightly below this value with full plate current being taken by the tubes. Standing plate current on the 807's without modulation is approximately 40 ma. With full voice modulation plate current on the 807's will kick up to approximately 200 ma. on occasional peaks.

When the phone-c.w. switch on the modulator deck is moved to the c-w position, filament voltage is removed from all the tubes in the modulator unit, the secondary of the modulation transformer is shorted, and the series screen choke for the 4-65A final amplifier is removed from the circuit. The dimensions of the modulator chassis are 10 by 14 by 3 inches.

Power Supply All supply voltages, except those for the exciter unit, are supplied by the power-supply deck at the

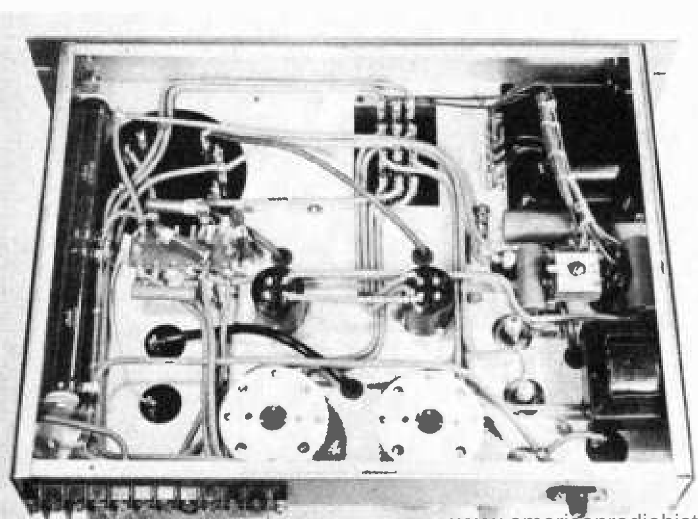


Figure 8.
MAIN POWER SUPPLY UNDERCHASSIS.

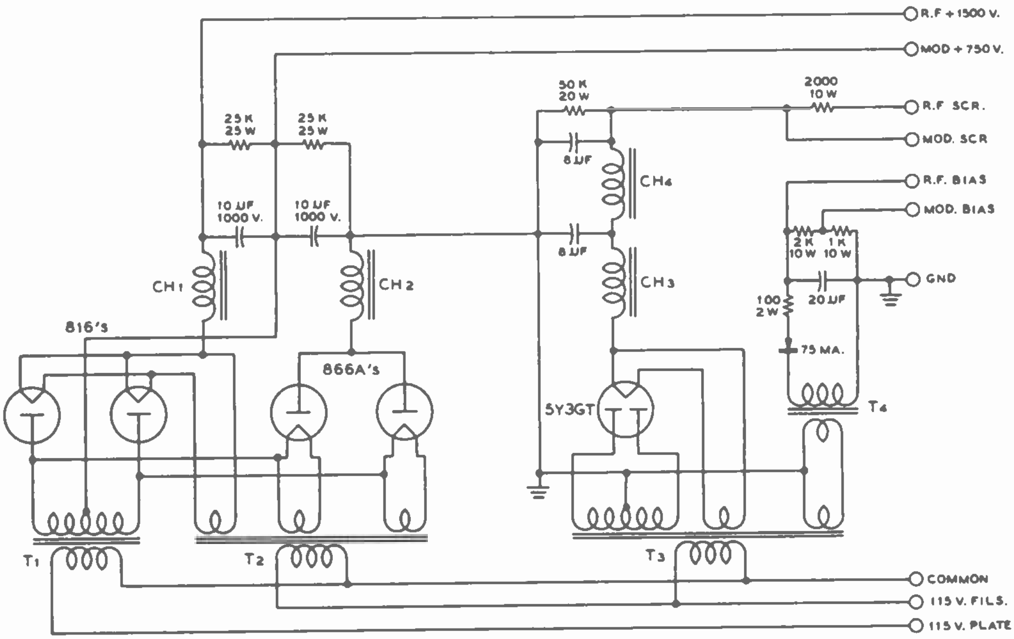


Figure 9.

SCHEMATIC OF THE MAIN TRANSMITTER POWER SUPPLY.

CH_1—5-25 hy. 175-ma. choke (UTC S-30)
CH_2—10-hy. 350-ma. swinging choke (UTC CG-104)
CH_3, CH_4—14-hy. 100-ma. filter chokes (UTC R-19)
T_1—1900 v. c.t. 360 ma. (UTC CG-302)
T_2—2.5 v. 6 a., 2.5 v. 6 a., 2.5 v. 12 a. (UTC S-71)
T_3—750 v. c.t. 120 ma., 5 v. 4 a., 6.3 v. 5 a. (UTC R-4)
T_4—6.3-volt 2.5 a. filament transformer, reversed (UTC FT-4)

bottom of the transmitter cabinet. High voltage is derived from a dual-voltage bridge rectifier. The 750 volts for the modulators is taken from the center tap of the plate transformer, while the 1600 volts for the final amplifier is taken from the 816 auxiliary rectifiers. Type 866A rectifiers are used' in the bottom half of the bridge rectifier since the total of the plate current for the final amplifier and the plate current to the modulators passes through these tubes. This total plate current passes also through the choke which is in the negative lead. Hence it is necessary to use a 350-ma. choke in the negative return of the power supply.

The 1600-volt portion of the supply has only the plate current for the final amplifier passing through it, so the smaller type 816 rectifiers may be used. Additionally, since the plate current load of the final amplifier never exceeds 150 ma., the choke in this side of the power supply is rated at only 175 ma. Two 10-µfd., 1000-volt filter capacitors connected in series across the output serve to filter the current delivered both at the 750-volt and 1600-volt taps. A single filament transformer of the bridge-rectifier type is used to light the filaments of all four rectifier tubes.

Screen voltage for the final amplifier and for the 807 modulators, plus the plate current drawn by the speech amplifier, is supplied by a small receiver-type power supply. A 5Y3-GT tube is used as rectifier in this supply. Grid bias voltage for the final amplifier and for the 807 modulators is obtained from a simple plate supply with a 75-ma. selenium rectifier. High voltage for the selenium rectifier is obtained by back connecting a 115 to 6.3 volt filament transformer in such a manner that the 6.3-volt winding of this transformer is connected to the 6.3-volt winding

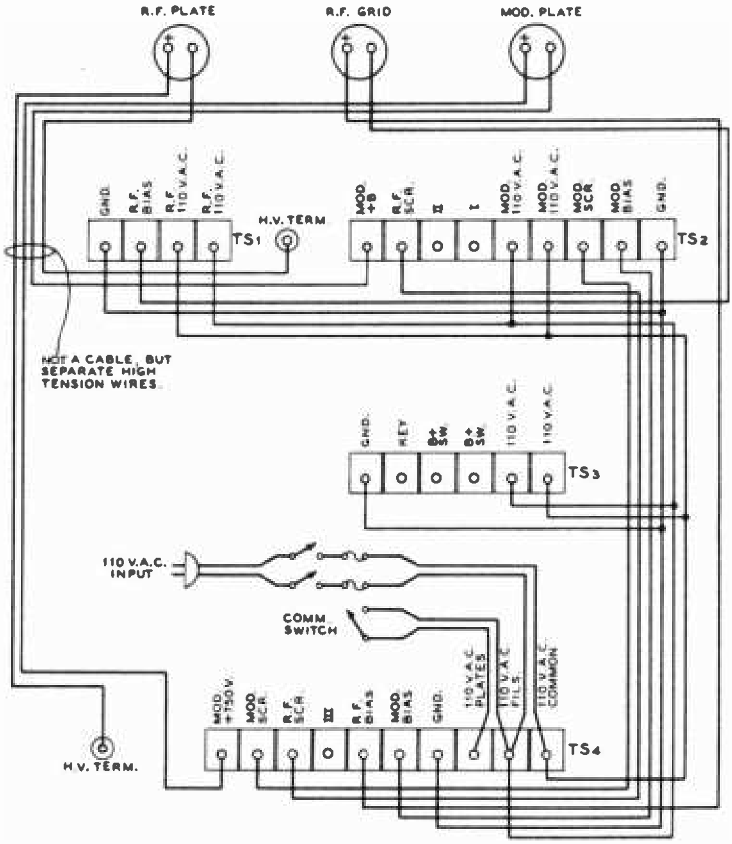


Figure 10.

CABLING DETAIL OF THE COMPLETE TRANSMITTER.

Terminal strip TS-1 is on the final amplifier, TS-2 is on the modulator chassis, TS-3 is on the exciter unit, and TS-4 is on the main power supply at the bottom of the cabinet. Refer to figure 2 for a photograph showing the cabling within the transmitter.

on the power transformer. The 115-volt winding on the transformer then is connected through the miniature selenium rectifier in the normal manner. It may be found necessary to vary the values of the resistors across the output of the grid bias supply in order to obtain the proper standing plate current on the 807 modulators.

Meter Panel and Cabling Figure 10 shows all the inter-cabling between the decks in the transmitter. The meter panel is mounted at the top of the cabinet. Separate milliammeters are used to measure plate current on the final amplifier, grid current on the final amplifier, and plate current of the 807 modulators. As is indicated on the cabling diagram, all low voltage leads are laced together, but the 750-volt and 1600-volt leads are run directly from point to point. Standard high-tension ignition cable is used for all these leads. External connections to the equipment in addition to those indicated on the cabling diagram are the ground and key leads and the leads which go to the two terminals marked B+ switch on the rear of the exciter unit. These two B+ switch terminals on the rear of the exciter should be shorted by the same switch or relay that shorts the terminals marked *Com Switch.*

A Compact Kilowatt C.W. Transmitter

Illustrated in figures 11 through 16 is the r-f portion of a compact kilowatt transmitter constructed by Alexander Toth, W3NRW. The exciter portion of the transmitter is based on the popular HK-57 exciter/transmitter described in the 11th edition of the RADIO HANDBOOK on page 302. This exciter serves to excite a pair of HK-254 triodes in the final amplifier. Exciter, final amplifier, filament supplies for the larger tubes, and the bias supply for the final amplifier all are mounted on a single 13 by 17 by 4 inch chassis. The chassis is supported from a standard 12¼-inch steel panel. Plate voltage supplies for the equipment are mounted externally. The complete schematic diagram of the transmitter is given in figure 17.

Exciter Circuit A 2E26 tube is used as a hot-cathode Colpitts crystal oscillator, with an r-f choke in the cathode circuit. This circuit makes an excellent harmonic oscillator, allowing the harmonics of the crystal frequency to be picked up in the plate tank of the tube. However, in the unit illustrated a tendency toward self-oscillation was noted with the crystal removed from the crystal socket. This tendency was eliminated by running a piece of solid hookup wire, C_1, from the grid pin of the socket through the chassis and alongside the plate structure of the 2E26. The screen voltage to the crystal oscillator tube is variable as a means of controlling the excitation applied to the following stages in the exciter.

The plate capacitor for the 2E26 and its associated coil are mounted on an inverted "L" bracket. The capacitor is mounted on a bakelite shelf inside the bracket, while the coil plugs into a socket on the rear of the same bracket. Figure 13 shows the construction of the bracket assembly which supports the plate tank for the 2E26.

The 7C5 frequency multiplier stage is capacitively coupled to the output tank of the 2E26 crystal oscillator. Also, the output from the frequency multiplier is capacitively coupled to the HK-57 buffer stage. The plate tank capacitor for this stage is mounted underneath the chassis, where it may be seen in figure 12. The plug-in socket for the plate coil is mounted directly behind the 7C5 tube. A length of low-capacitance coaxial cable running from one side of the chassis to the other serves to couple the output of the 7C5 to the grid of the HK-57 buffer.

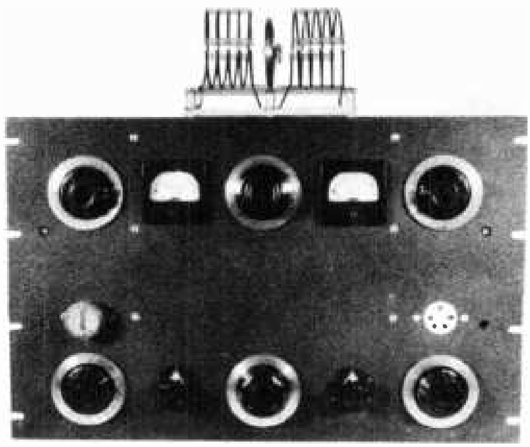


Figure 11.
FRONT VIEW OF THE KILO-WATT R-F UNIT.

Reading from left to right along the top are 2E26 plate capacitor, 0-200 d-c milliammeter switched by the selector switch directly below, final amplifier plate capacitor, 0-750 d-c milliammeter in cathode of final, variable link control for HK-57 plate. Along the bottom of the panel the controls are: 7C5 plate capacitor, 5-position switch for 0-200 milliammeter, final grid capacitor, bias control for the HK-57, plate capacitor for the HK-57.

The crystal oscillator and 7C5 multiplier occupy the left hand compartment of the transmitter chassis. This space, measuring 4 inches in width by 8 inches in height and depth, is shielded from the balance of the transmitter both above and below the chassis. The shields are bent from 1/16-inch aluminum with ⅜-inch flaps for attachment to the chassis and to the front panel. The shields also serve as brackets for supporting the chassis from the panel.

The HK-57 buffer stage occupies a compartment on the right of the main chassis which is identical to the oscillator-multiplier compartment on the left. The socket for the tube is recessed 1¼ inches below the chassis. The plate tank capacitor for the tube is mounted below the chassis, but an aluminum baffle shields this capacitor from the grid circuit of the tube. All socket leads are by-passed with short leads by postage-stamp mica capacitors.

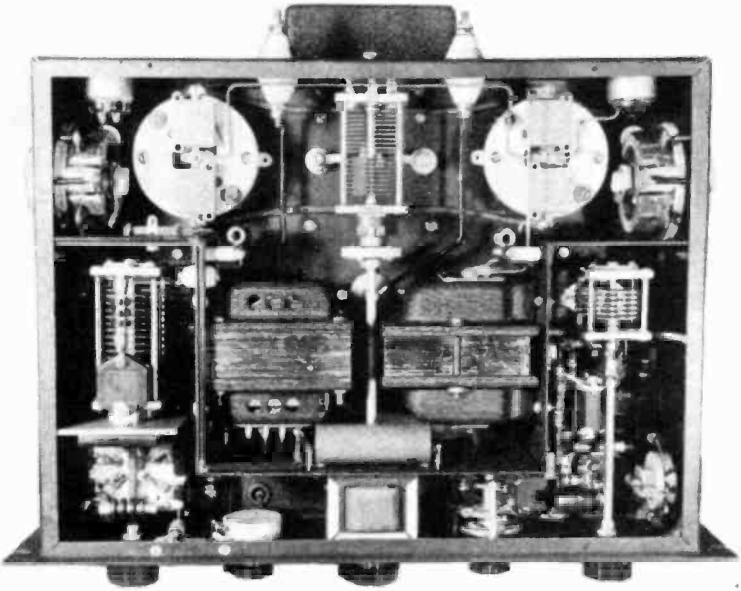


Figure 12.

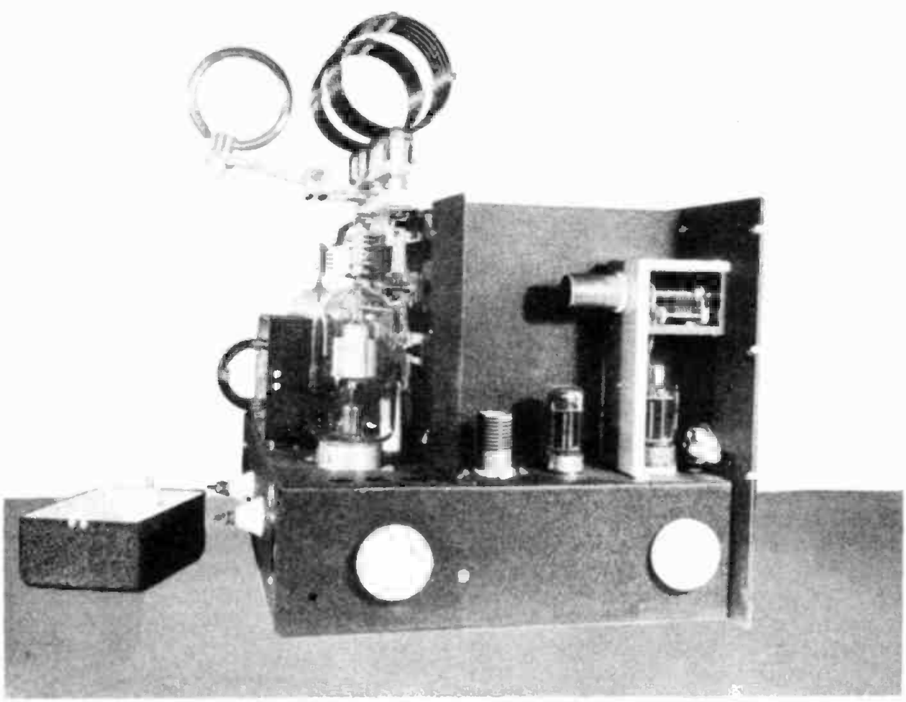
UNDERCHASSIS PHOTO OF THE R-F UNIT.

The power rheostat in the upper left corner of the chassis controls the fixed minimum bias on the final amplifier. The similar rheostat in the upper right corner acts as a variable grid leak for the final amplifier stage. The smaller rheostat in the lower right corner controls screen voltage on the 2E26 stage.

Figure 13.

LEFT SIDE VIEW OF THE R-F UNIT.

Showing the oscillator-multiplier stages and the two dural knobs which control the final amplifier grid leak and screen voltage on the 2E26 stage.



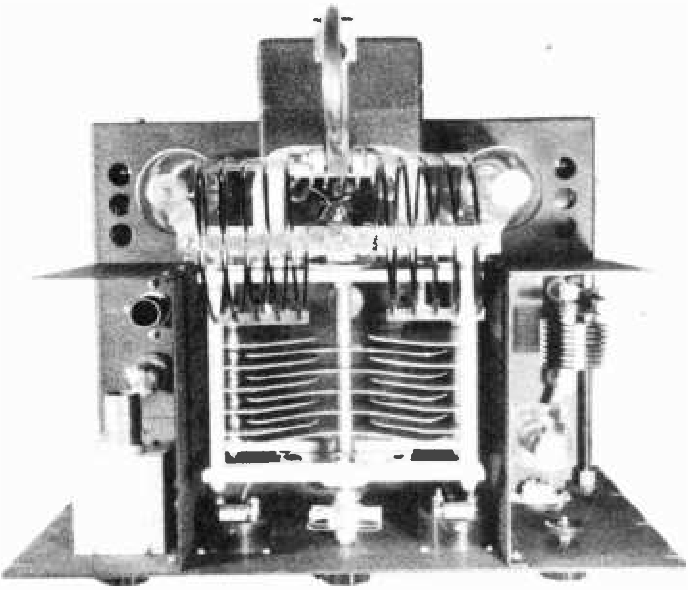


Figure 14.
TOP VIEW OF THE R-F UNIT.

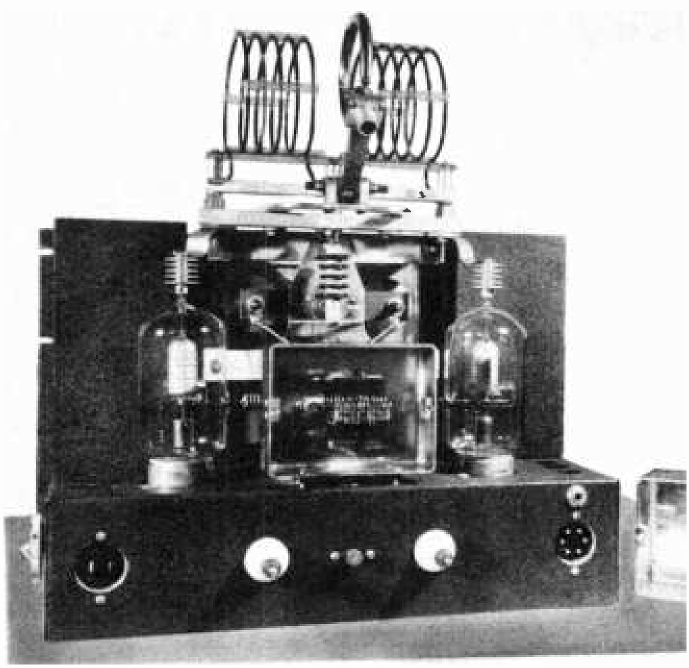


Figure 15.
REAR VIEW, SHOWING POWER CONNECTIONS.
The shield cover for the final amplifier grid coil has been removed in this photograph. On the rear of the chassis, from left to right, are: 115-volt a-c receptacle, HK-57 plate voltage feed-through insulator, ground connection for the chassis, final amplifier feed-through insulator, receptacle for filament and plate voltages for the oscillator and multiplier stages.

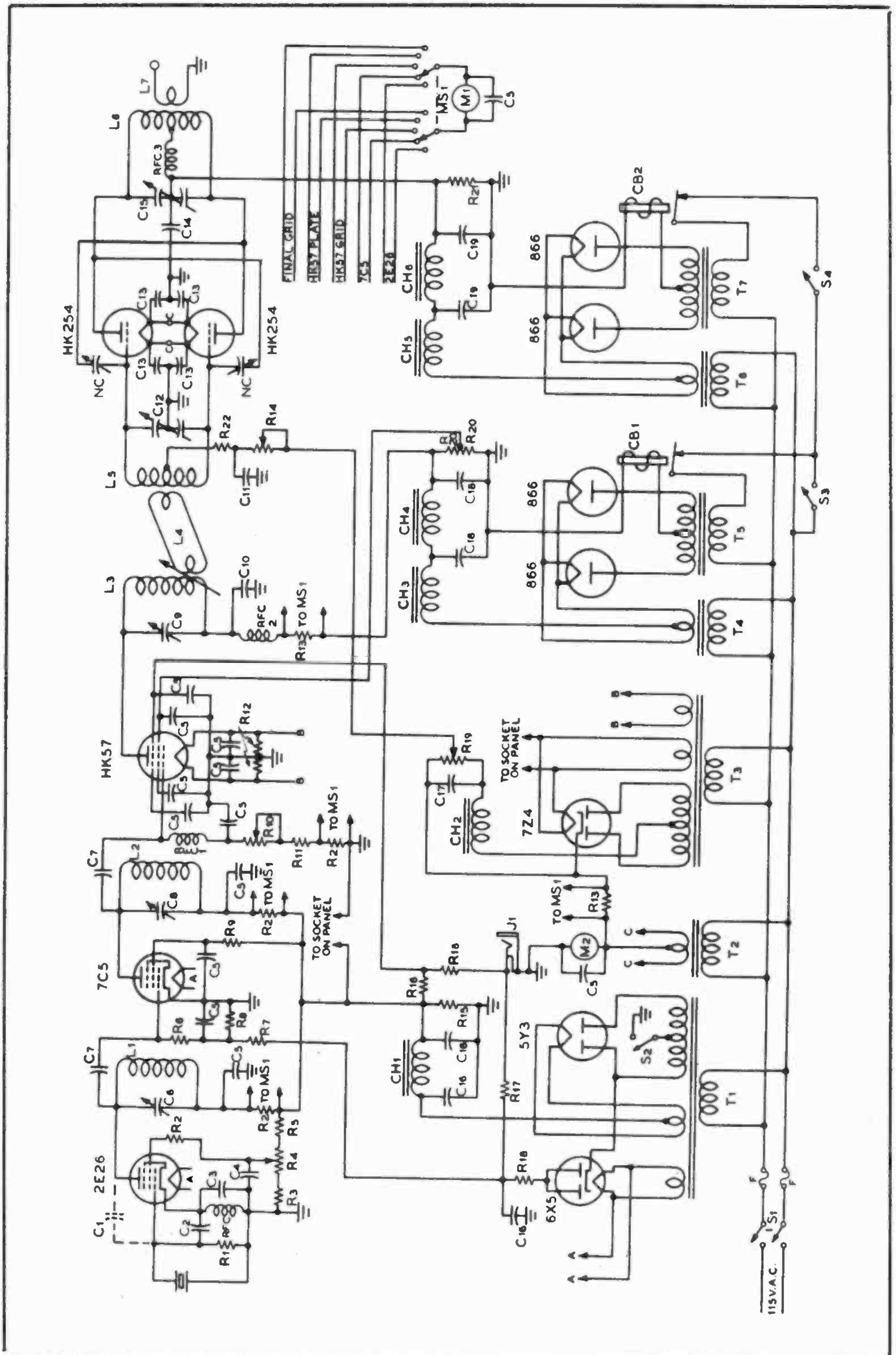

2E26
7C5
HK57
HK254
HK254
5Y3
6X5
7Z4
866
866
866
866
FINAL GRID
HK57 PLATE
HK57 GRID
7C5
2E26
TO MS1
TO SOCKET ON PANEL
115 V.A.C.
CB1
CB2
MS1
M1
M2
J1
T1
T2
T3
T4
T5
T6
T7
CH1
CH2
CH3
CH4
CH5
CH6
S1
S2
S3
S4

Figure 17.

SCHEMATIC OF THE KILOWATT R-F UNIT.

C_1—See text.
C_2—15-$\mu\mu$fd. midget ceramic
C_3—100-$\mu\mu$fd. 500-volt mica
C_4—0.01-μfd. 500-volt mica
C_5—0.003-μfd. 500-volt mica
C_6—100-$\mu\mu$fd. variable (Hammarlund MC-100-M)
C_7—50-$\mu\mu$fd. 500-volt mica
C_8—50-$\mu\mu$fd. variable (Hammarlund HFB-50C)
C_9—100-$\mu\mu$fd. variable (Hammarlund HFB-100C)
C_{10}—0.002-μfd. 2500-volt mica
C_{11}—0.002-μfd. 1250-volt mica
C_{12}—Dual 100-$\mu\mu$fd. variable, 0.050" spacing
C_{13}—0.01-μfd. 1250-volt mica
C_{14}—0.001-μfd. 7500-volt mica
C_{15}—Dual 78-$\mu\mu$fd. butterfly capacitor, 0.250" spacing, built-in NC (B&W CX78C-N2)
C_{16}—8-μfd. 450-volt elect.
C_{17}—10-μfd. 500-volt elect.
C_{18}—4-μfd. 2500-volt oil-filled capacitor
C_{19}—3-μfd. 4000-volt oil-filled capacitor
R_1—100,000 ohms 2 watts
R_2—50 ohms 2 watts
R_3—22,000 ohms 2 watts
R_4—50,000-ohm 4-watt wire-wound potentiometer (Mallory M50MP)
R_5—39,000 ohms 2 watts
R_6—100,000 ohms 2 watts
R_7—68,000 ohms 2 watts
R_8—22,000 ohms 2 watts
R_9—39,000 ohms 2 watts
R_{10}—10,000-ohm 4-watt wire-wound potentiometer (Mallory M10MP)
R_{11}—8200 ohms 2 watts
R_{12}—50 ohms 10 watts, center tapped
R_{13}—50 ohms 10 watts
R_{14}—7500-ohm 100-watt power rheostat (Ohmite 0462)
R_{15}—50,000 ohms 50 watts
R_{16}—500,000 ohms 2 watts
R_{17}—50,000 ohms 20 watts
R_{18}—5000 ohms 10 watts
R_{19}—10,000-ohm 100-watt power potentiometer (Ohmite 0463)
R_{20}—50,000 ohms 100 watts
R_{21}—50,000 ohms 200 watts
R_{22}—200 ohms 10 watts
RFC, RFC_1—2.5-mh. 125-ma. r-f chokes (National R-100U)
RFC_2—1-mh. 300-ma. r-f choke (National R-300U)
RFC_3—750-ma. r-f choke (Johnson type 754)
S_1, S_2, S_3, S_4—15-ampere heavy-duty tumbler switches (Hubbell)
J_1—Closed-circuit key jack
L_1 to L_7—See coil table
CB_1—250-ma. overload circuit breaker (Heinemann)
CB_2—500-ma. overload circuit breaker (Heinemann)
MS_1—2-gang 2-pole non-shorting 5-position ceramic selector switch
M_1—0-200 d-c milliammeter
M_2—0-750 d-c milliammeter
CH_1—10.5-hy. 110-ma. filter choke (Stancor C-1001)
CH_2—8-hy. 85-ma. filter choke (Stancor C-1709)
CH_3—5 to 18 hy. 400-ma. swinging choke (Kenyon T-513)
CH_4—10-hy. 400-ma. filter choke (Kenyon T-178)
CH_5—5 to 20 hy. 500-ma. swinging choke (Thordarson T-19C38)
CH_6—12-hy. 500-ma. filter choke (Thordarson T-19C45)
T_1—700 v. c.t. 200 ma., 5 v. 3 a., 6.3 v. 5.5 a. (Stancor P-6314)
T_2—5-volt 21-ampere filament transformer (Thordarson T-19F86)
T_3—750 v. c.t. 150 ma., 5 v. and 6.3 v. rewound (Stancor P-6014)
T_4—2.5 v. 10-ampere transformer 5000-volt insulation
T_5—3750 v. or 3120 v. c.t., 500 ma. (Thordarson T-19P64)
T_6—2.5-volt 10-ampere transformer 10,000-volt insulation
T_7—6000 v. or 4950 v. c.t., 500 ma. (Thordarson T-19P68)

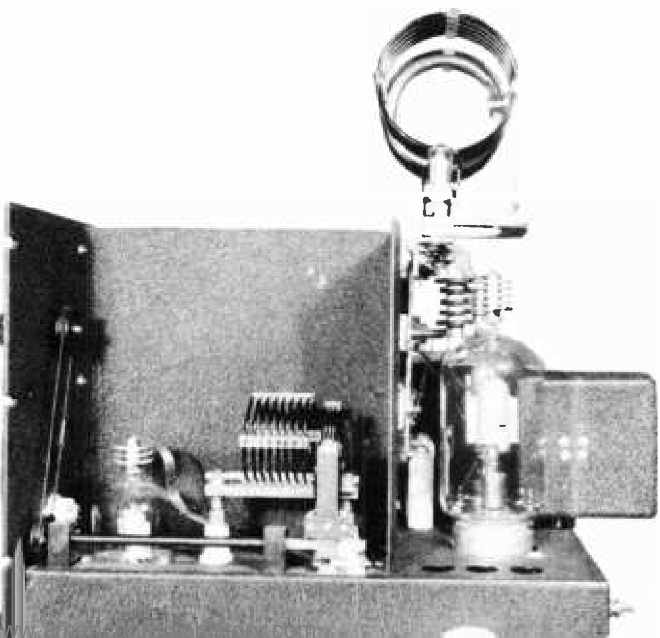


Figure 16.

RIGHT SIDE VIEW OF THE R-F UNIT.

Showing the HK-57 stage and the variable-link drive mechanism coupled to the output coil of this stage. The dural knob of the side of the chassis controls the fixed minimum bias on the final amplifier.

A parasitic suppressor consisting of 9 turns of solid hookup wire wound around a 10-ohm 2-watt resistor is included in series with the grid lead of the HK-57 tube. This parasitic suppressor may be seen in figure 12 between the grid r-f choke and the potentiometer mounted on the front panel. The potentiometer serves as a variable grid leak for the HK-57 stage.

The HK-57 tube normally operates at a plate voltage of 1500 and at a plate current of about 100 ma. Grid current will vary from 1 to 5 ma., depending upon the setting of the variable grid leak. The buffer stage is capable of supplying much more excitation to the final stage than is needed, so a variable-link system is used to control the coupling between the output link and the plate circuit of the HK-57. The setting of the variable link is controllable from the front panel of the equipment.

Push-Pull HK-254 Final Amplifier The two compartments at each end of the chassis leave a space of 9 inches in the center. This amount of space is just adequate for the installation of the B&W buterfly tank capacitor. The type of butterfly capacitor which includes intermediate size built-in neutralizing capacitors has been used in the equipment illustrated.

The tube sockets for the final amplifier tubes are submounted by 1 inch. A pair of filament by-pass capacitors is used across the socket for each of the tubes. Connection to the plates of the HK-254 tubes is made by means of pieces of 0.005" brass shim stock about 1½ inches in length. Leads of this type are sufficiently flexible that no strain of significant proportions may be placed on the plate seals of the tubes.

The compartment between the two final amplifier tubes is a shield which houses the grid coil for the output stage. The shield is made from two small aluminum chassis, with banana plugs as a means of securing the two chassis together. Through the use of this arrangement the grid coils for the output stage are completely shielded, yet it is easy to remove the shield for changing the coils. Also, through the use of this arrangement, all coils in the transmitter are accessible from the top. It is necessary only to lift the top door of the rack-cabinet which houses the transmitter for changing bands. A suitable protective interlock of course *must* be installed on the top door of the cabinet, in addition to the one on the rear door.

Plug-in coils (B&W type HDVL) are used in the plate tank circuit for the final amplifier. The inner ends of the two half-coils are brought to a single plug in the center of the plug bar, rather than to two separate plugs as the coils are manufactured. Then the two holes in the jack bar assembly which have been freed are used to support the swinging-link assembly. This arrangement is illustrated in figures 11 and 15.

The swinging link is of the Faraday-shielded coaxial type. The link is made from a short length of copper tubing into which a piece of the inner conductor and dielectric material from a section of RG-8/U has been inserted. The inner conductor is threaded into the copper tubing before the tubing is bent. Then the tubing is bent into a single turn 2½ inches in inside diameter and soldered to a brass fitting as shown in figure 13. The inner conductor and the copper tubing are soldered together at the ground end of the link. But the copper tubing is stopped at the other end of the link before the point where the inner conductor of the link is connected to the center lead of the coaxial fitting. Through the use of this coupling arrangement the one-turn coupling link is completely shielded throughout its length, as an aid to the reduction in capacitive coupling of harmonics into the antenna system.

COIL TABLE FOR KILOWATT R-F UNIT

L_1—3.5 Mc.: 30 t. no. 20 enam., 1⅜" long, 1" dia. Millen 45004 form
7.0 Mc.: 18 t. no. 20 enam. 1⅜" long, 1" dia. Millen 45004 form
14 Mc.: 10 t. no. 20 enam., 1" long, 1" dia. Millen 45004 form

L_2—7.0 Mc.: Uses L_1 coil for this band
14 Mc.: 8 t. no. 16 enam., 1" long, 1" dia. Millen 45004 form
28 Mc.: 4 t. no. 14 enam., 1" long, 1" dia. Millen 45004 form

L_3—7.0 Mc.: 14 t. no. 14 enam., 1⅞" dia. by 1⅞" long
14 Mc.: 8 t. no. 12 enam., 1⅞" dia. by 1½" long
28 Mc.: 4 t. ¼" copper tubing, 1⅞" dia. by 1½" long

L_4—2-turn variable link at low-potential end of L_3. Two turns also are wound over the center of each of the L_5 coils.

L_5—7.0 Mc.: 18 t. no. 16 enam., 1¾" dia. by 1¾" long
14 Mc.: 10 t. no. 12 enam., 1¾" dia. by 1¾" long
28 Mc.: 6 t. no. 12 enam., 1¾" dia. by 1" long

L_6—B&W kilowatt HDVL series coils for each band, modified as in text.

L_7—Single-turn coaxial shielded link; see text for description.

Final Amplifier Operation The push-pull HK-254 final amplifier normally is operated at 2500 volts with a plate current of 400 ma. Operating grid current is 80 to 90 ma. with 250 to 300 volts of grid bias. Fixed-minimum grid bias is supplied by the built-in grid-bias supply, and a variable power resistor is included for controlling the operating value of total bias. Filament voltage for the HK-254 tubes is supplied by the filament transformer on the right in the center of the underchassis view of figure 12.

Power Supplies The power transformer to the left in the center of the chassis in figure 12 supplies filament voltage to the HK-57 and in addition furnishes bias voltage to the final amplifier. This transformer has a 700-volt center-tapped winding which is used in conjunction with a 7Z4 rectifier as the bias pack. Also, the original 5-volt and 6.3-volt windings were removed from the transformer. The 5-volt winding was replaced with a much heavier winding (no. 12 enameled wire) for the HK-57 filament, and the 6.3-volt winding was replaced with a winding of slightly smaller wire for the external 6.3-volt load which may be fed from the socket on the panel.

The socket on the right in the front-panel view of figure 11 supplies high voltage from the exciter plate supply and 6.3 volts for an external v.f.o. or FM exciter unit. Then the output of the external variable frequency oscillator or FM unit may be fed into the crystal socket on the left of the front panel.

All the other power supplies for the r-f unit are mounted externally to the chassis. These power supplies may, of course, be mounted in the same rack as that which holds the r-f section, or the r-f section may be placed on the operating table with the power supplies mounted some distance away. A multiple-wire cable, with insulation on the wires appropriate for the voltages which they carry, may then be run from the power supply cabinet to the r-f unit in its cabinet.

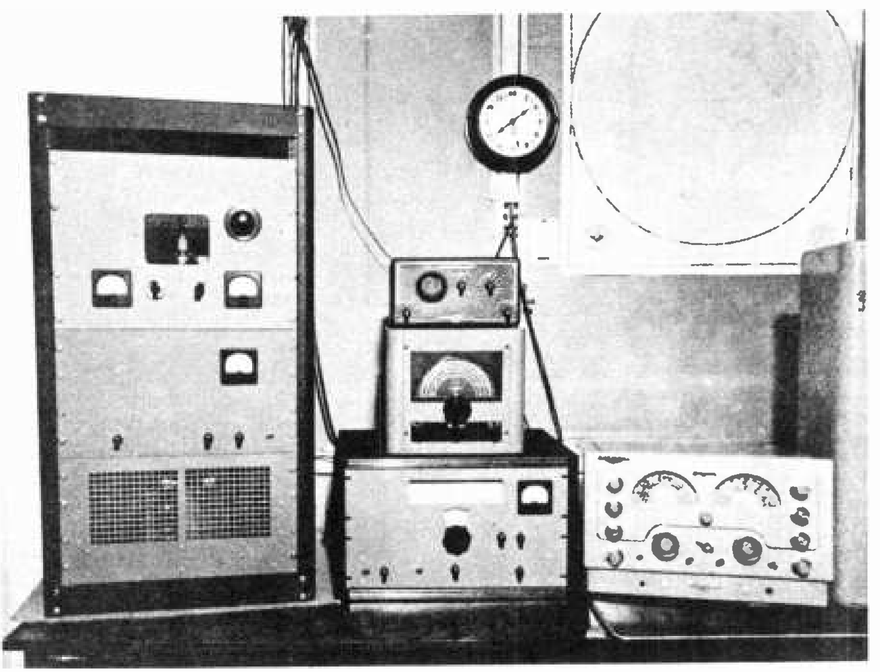


Figure 18.
SHOWING THE 400-WATT TRANSMITTER INSTALLED AT THE OPERATING POSITION OF W4JYK.

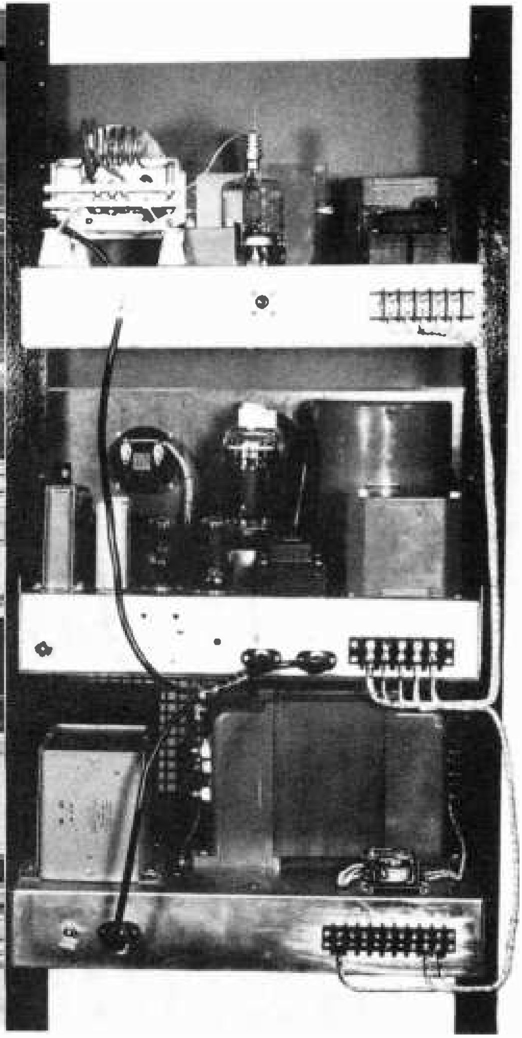


Figure 19.

REAR VIEW OF THE 400-WATT TRANSMITTER.

The components making up the transmitter were temporarily installed in a relay rack when this photograph was taken. Notice the relatively simple cabling of the wires between decks. The unconnected jack in the center of the top deck is for accepting the coaxial cable from the exciter unit on the operating desk. The jack to the far left of the modulator panel is for the patching of signals into the modulator other than that from the microphone.

400-Watt AM-FM-CW Transmitter

The type 4-125A beam-tetrode tube is convenient from a number of standpoints for use as the final amplifier in a transmitter in the 350 to 400 watt power range. The tube is compact, easy to drive, and operates smoothly and without need for neutralization on the 28-Mc. band. The transmitter illustrated in figures 18 and 19 was assembled from the De-Luxe Band-Pass Exciter described in *Chapter Three*, the 4-125A Final Amplifier from *Chapter Five*, the 200-Watt 813 Modulator from *Chapter Seven* and operates with high voltage supplied from a 2000/1750-volt 300-ma. power supply.

The units in the transmitter rack require a total panel space of 35 inches; this is the sum of the 14 inches for the 4-125A stage, and the 10½ inches for the modulator and power supply panels. Hence the equipment will completely fill the panel space of a standard 35-inch welded-type enclosed cabinet. The cabinet illustrated in figure 18 is of the "assembled" type and has a total panel space of 36¾ inches.

The exciter unit may be mounted in a separate cabinet with 10½ inches of panel space, or it may be mounted in the same housing as the transmitter portion. Since all the operating controls of the transmitter are brought out at the exciter unit, it will be most convenient in a majority of cases to operate the exciter unit on the operating desk with the transmitter in a separate cabinet.

Switching from phone to c.w. is accomplished by the switch in the lower left position on the modulator panel. With this switch in the c-w position, the secondary of the modulation transformer is shorted and plate voltage is removed from the 813 modulators. The exciter unit may then be keyed in the normal manner to effect keying of the transmitter.

High-Voltage Power Supply All the components which go to make up the transmitter, with the exception of the high-voltage power supply, have been described in some detail in earlier chapters of this book. Hence this section will be devoted to a description of the 2000-volt power supply.

The 1750/2000-volt power supply may be seen as the bottom unit in the rack in the photographs of figures 18 and 19. Figure 20 gives the schematic of the high-voltage supply.

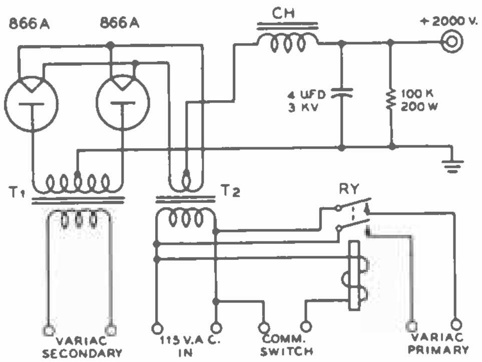


Figure 20.

SCHEMATIC OF THE HIGH-VOLTAGE POWER SUPPLY.

CH—5-25 hy. 500-ma. heavy-duty swing choke (UTC CG-109)
T_1—4800 and 3500 v. c.t. at 300 ma. (UTC CG-305)
T_2—2.5 v. 10 a., 5000-volt working (UTC CG-120)
RY—D.p.d.t. relay, 115-volt coil, 12.5-a. contacts (Leach 1157)

The plate supply is capable of delivering either 1750 or 2000 volts at 300 ma. continuous load to the power amplifier or to the combination of the power amplifier and the modulator. Type 866 tubes are used as rectifiers, followed by a single section of choke-input filter. In most cases it is desirable to use a two-section filter on a power supply of this type. But with the use of a good-quality input choke and a 4-μfd. filter capacitor the ripple voltage is reduced to a value just below 5 per cent. This value of ripple is adequate for c-w operation of the output stage; and the ripple voltage is reduced to a much lower value for AM phone as a result of the filtering action of the secondary of the modulation transformer.

The power supply uses a relay to control the application of a-c line power to the primary of the plate transformer—or to the primary of the variable auto-transformer which may be used to control the primary voltage. Hence the switching current for controlling the power supply is small enough so that the wafer-type communication switch in the exciter unit is adequate for controlling the entire transmitter.

Provision is included for the use of a Variac, a Powerstat, or other type of variable-ratio auto-transformer for varying the plate voltage applied to the 4-125A output tube and to the modulators. An 860-v.a. Variac such as the General Radio type V-5 will be satisfactory for controlling the output voltage of the power supply in most cases, but it will be best to use the next larger size of variable autotransformer to allow a safety factor if the power supply is to be used continuously at full output. If a variable auto-transformer is not to be used for controlling the output voltage, terminals "Variac primary" and "Variac secondary" may be connected together by two wires.

A time-delay relay has not been included in the power supply as illustrated. Hence it is necessary to wait for at least 30 seconds after application of filament voltage to the transmitter before plate voltage is applied. If it should be desired that this period always will be allowed, even by an operator unfamiliar with the transmitter, it is a relatively simple matter to include a time-delay relay in the control circuit of the power supply. Either the thermal type or the motor-driven type of time-delay relay has proven to be completely satisfactory in an application of this type.

Test and Measurement Equipment

All amateur stations are required by law to have certain items of test equipment available within the station. A c-w station is required to have a frequency meter or other means in addition to the transmitter frequency control for insuring that the transmitted signal is on a frequency within one of the frequency bands assigned for such use. A radiophone station is required in addition to have a means of determining that the transmitter is not being modulated in excess of its modulation capability, and in any event not more than 100 per cent. Further, any station operating with a power input greater than 900 watts is required to have a means of determining the exact input to the final stage of the transmitter, so as to insure that the power input to the plate circuit of the output stage does not exceed 1000 watts.

The additional test and measurement equipment required by a station will be determined by the type of operation contemplated. It is desirable that all stations have an accurately calibrated volt-ohmeter for routine transmitter and receiver checking and as an assistance in getting new pieces of equipment into operation. An oscilloscope and an audio oscillator make a very desirable adjunct to a phone station using AM or FM transmission, and are a necessity if single-sideband operation is contemplated. A calibrated signal generator is almost a necessity if much receiver work is contemplated, although a frequency meter of the LM or BC-221 type, particularly if it includes internal modulation, will serve in place of the signal generator. Extensive antenna work invariably requires the use of some type of field-strength meter, and a standing-wave meter of some type is very helpful. Lastly, if much v-h-f work is to be done, a simple grid-dip meter will be found to be one of the most used items of test equipment in the station.

Unitized Miniature Test Equipment

Many of the items of test equipment used on occasion in the amateur station require a small power supply for plate and heater volt-

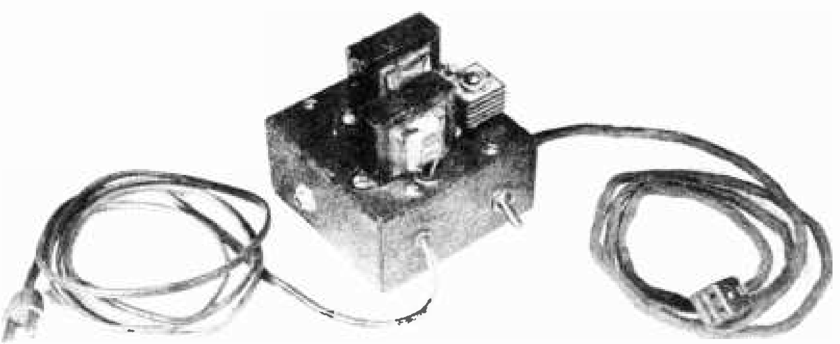


Figure 1.
THE MINIATURE TEST-EQUIPMENT POWER SUPPLY.

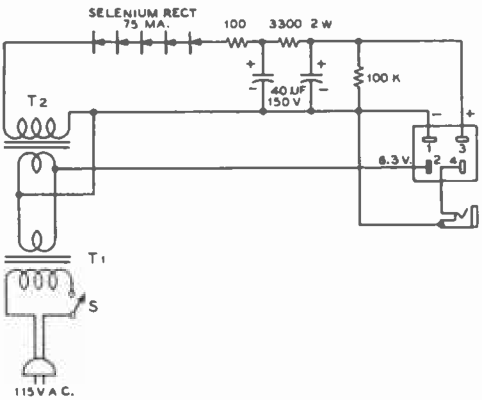


Figure 2.
SCHEMATIC OF THE MINIATURE POWER SUPPLY.
Transformers T_1 and T_2 are 6.3-volt filament transformers with a current rating of 1.2 to 2 amperes. Transformer T_2 is reversed with respect to T_1 so that the transformers are operating back-to-back.

age. The power unit often is a major, though still small, item of expense in the test equipment unit. The small test equipment units shown in the following pages have been designed so that either of them may be fed from a small universal power unit. The power unit terminates in a four-wire cable with a standard Jones plug which may be plugged into either of the units of test equipment. Other items of test equipment with similar power requirements may be constructed in such a manner that the power cable from the miniature power supply may be plugged into them.

The Power Unit

The power supply for the test equipment series is shown in figure 1 with its schematic given in figure 2. The unit is built into and on a tiny 2 by 4 by 4 inch metal box (Par-Metal MC-442). Two 6.3-volt 1.2-ampere filament transformers connected back-to-back supply the high voltage to the 75-ma. selenium rectifier. The output of the selenium rectifier is filtered by an RC network with a bleeder across the output of the filter. No-load voltage from the "high" voltage supply is 135 volts. The output voltage at various values of load is: 5 ma., 115 v.; 8 ma., 90 v.; 12.5 ma., 62.5 v.; and 14 ma., 55 volts. Hence the power supply is capable of delivering about 0.75 watts maximum to an external load.

Since the drain of the plate supply from the 6.3-volt line does not exceed 0.7 ampere, and since this current is in quadrature with respect to the resistive filament load, the filament transformer, T, can supply up to 0.9 ampere at 6.3 volts to the heaters of a unit of test equipment. This amount of heater current is adequate for any of the test equipment units shown, or for a BC-221 frequency meter with which the power supply also may be used. When used with a BC-221 the power supply delivers about 75 volts, a voltage which has been found to be quite adequate for operation of the frequency meter.

The power supply unit includes a toggle switch in series with the 115-volt line for power control. Also a closed-circuit jack, with

Figure 3.
THE MINIATURE AUDIO OSCILLATOR
A standard pair of hea phones is shown alongsi for size comparison.

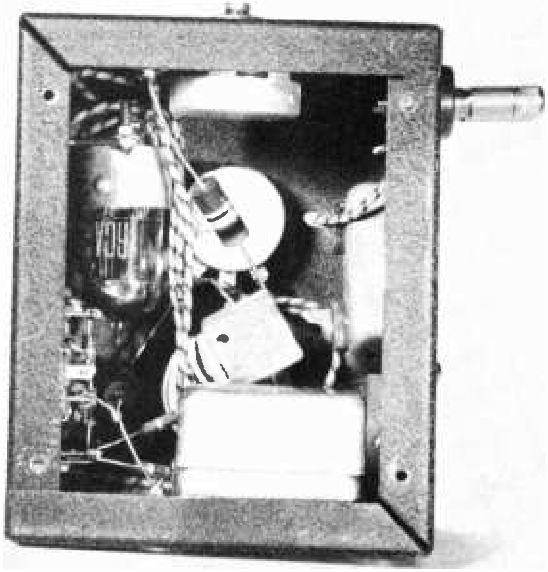


Figure 4.
INSIDE THE MINIATURE AUDIO OSCILLATOR.
The 12AU7 tube and its socket are mounted in an inverted position inside the housing.

one side grounded, is included in the power supply unit with the active terminal of the jack fed through the power cable. This circuit was planned for use in series with the grid return of the grid-dip oscillator, with a 0-1 d-c milliammeter plugged into the jack. Other uses for the circuit may suggest themselves when planning a new item of test equipment for use with the miniature power supply.

One-Tube Sine-Wave Audio Oscillator

Many amateurs and servicemen would like to include a sine-wave audio oscillator in their test equipment complement. But the relative infrequency of use of such a test unit makes the purchase of a Hewlett Packard or similar manufactured unit financially impracticable. Even the simplified oscillators described in previous editions of the RADIO HANDBOOK would involve too great an expenditure to be justified by the relative infrequency of use. For those persons the miniature oscillator shown in figures 3, 4, and 5 is an ideal solution to the audio-oscillator problem.

The miniature audio oscillator delivers several volts of sine-wave audio over the frequency range from 150 to 3500 cycles per

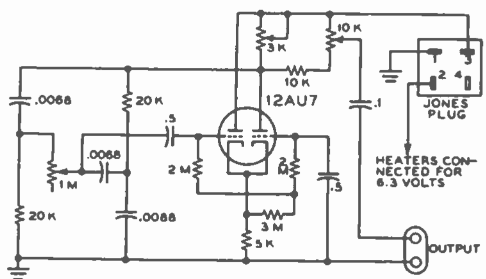


Figure 5.
SCHEMATIC OF THE MINIATURE AUDIO OSCILLATOR.
The one-megohm potentiometer acts as the frequency control, the 10,000-ohm potentiometer serves as output level control, and the 3000-ohm potentiometer controls the amplitude of oscillation and hence the output waveform of the unit.

second. The wave form is acceptable at 150 cycles and is a quite good sine wave above about 300 cycles. The circuit uses a 12AU7 as a cathode-coupled amplifier with the grid of the first section acting additionally as a diode to furnish automatic-level-control voltage to the second section.

An RC phase-shifting network, connected between the plate of the second section and the grid of the first, determines the frequency of oscillation. A one-megohm potentiometer is the variable element in the phase-shift network which controls the frequency of operation. The 3000-ohm potentiometer serving as plate load for the output section of the 12AU7 acts as a regeneration control. Its setting is not critical except to obtain the very best waveform at the low-frequency end of the audio range.

The output voltage from the oscillator varies somewhat with frequency. But for routine modulation testing where some waveform distortion on the lower frequencies may be tolerated, a single setting of the regeneration control will suffice. The 10,000-ohm potentiometer serves as an output attenuator.

This simple oscillator is adequate for the tuning of AM, FM, and single-sideband transmitters over the voice frequency range. The frequency range of the oscillator may be shifted by making a proportionate change in all three of the 0.0068-μfd. capacitors. An increase in capacitance will move both the upper frequency and lower frequency limits downward, though the ratio between the two extremes will remain the same as in the unit illustrated —approximately 20 to 1.

Grid-Dip Meter

As one proceeds in his experimental work to higher and higher frequencies the availability of specialized test equipment becomes of increasing importance. For work in the 20-Mc. to 250-Mc. range a grid-dip meter is one of those items of test equipment which will be found invaluable in circuit alignment work.

Basically, a grid-dip meter is simply a low-power oscillator with a meter for indicating rectified grid current. Some provision is always included in the design for coupling the tank circuit of the oscillator to the circuit under test. The main application of the grid-dip meter is as a means of indicating the resonant frequency of a circuit to which it is coupled. For making a measurement of this type the tank circuit is coupled to the circuit under test, either directly or by means of a link, and the frequency of oscillation of the grid-dip meter is then varied over the frequency range where the external tank circuit is expected to resonate. When the frequency of oscillation of the grid-dip meter coincides with the resonant frequency of the external tank, power is extracted from the tank circuit of the grid-dip meter and the grid current of the oscillator tube takes a sudden dip.

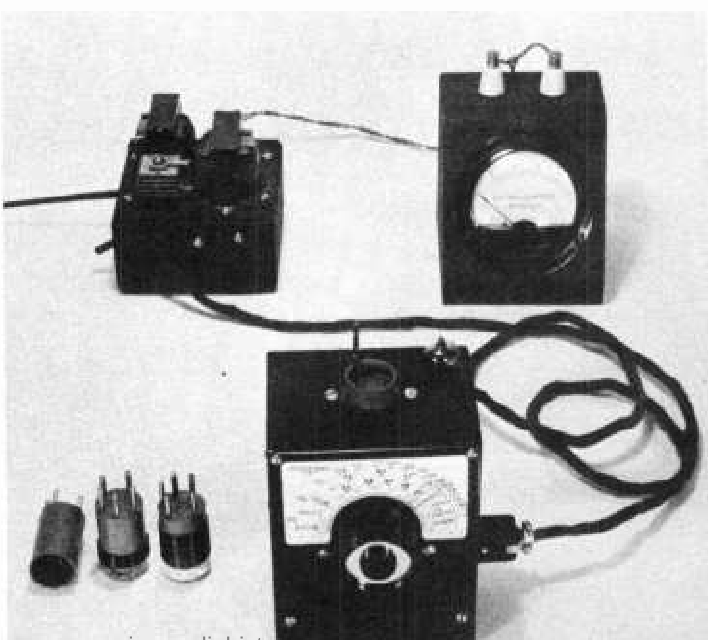


Figure 6.
THE COMPLETE GRID-DIP METER.

The miniature power supply is in the left rear with the 0-1 d-c milliammeter alongside. The dip-meter oscillator unit is in the foreground with the 90 to 175 Mc. coil in place. The coils for the other ranges are alongside the oscillator unit.

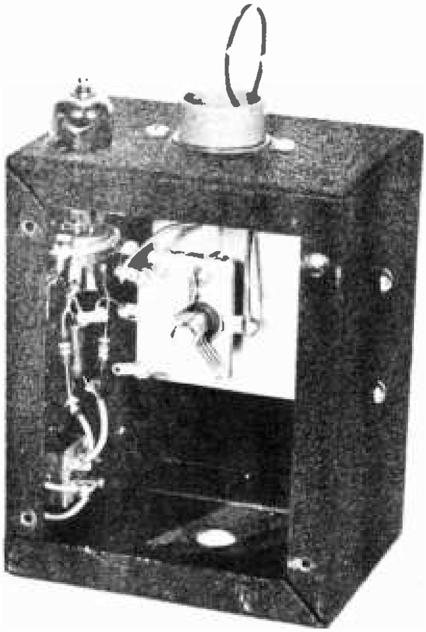


Figure 7.
INTERNAL VIEW OF THE GRID-DIP METER.

Hence the explanatory name for the instrument.

Since the basic application of the grid-dip meter is as a means of determining the resonant frequency of a tank circuit, it is fairly obvious that the meter will be more convenient to operate if it is capable of covering a relatively large frequency range. A frequency range on each coil of two to one is generally considered to be adequate.

Another use of the grid-dip meter is as an unshielded signal generator for the preliminary alignment of receivers in the v-h-f range. For this type of a job the dip meter is coupled relatively tightly to the receiver until the signal can be tuned in by the detector stage. Then the coupling is backed off for the rough alignment of the r-f stages. After the r-f stages have been aligned roughly the dip meter may be turned off and the final alignment made on noise from the first tuned circuit, from an antenna, or on a signal from a shielded generator if one should be available.

Circuit of the Unit The oscillator uses one-half of a 6J6 tube in an ultra-audion circuit. The ultra-audion oscillator circuit is used since it permits the use of a simple two-terminal coil without a tap or a tickler. The number of components associated with the oscillator itself is very small, as can be seen from the schematic, figure 8, and the inside photo of the oscillator box, figure 7. The unit is housed in a standard crackle-finished metal box with outside dimensions of 3 by 4 by 5 inches. A somewhat smaller box could have been used for the oscillator, subject to the 3⅞-inch limitation in width of the National MCN dial.

Four coils are used with the oscillator to obtain a frequency range from 14 to 180 Mc. Additional coils may be wound for operation on frequencies lower than 14 Mc., if this should be desired. However, the upper frequency limit of the unit illustrated is about 190 Mc. due to lead length and the type of construction employed. This upper frequency is adequate as long as use is not contemplated on frequencies higher than the amateur 144-Mc. band or on the police and taxicab frequencies in the vicinity of 160 Mc.

If operation of the grid-dip oscillator should be desired on the high-band TV channels and the amateur 220-Mc. band it will be necessary to give special attention to the characteristics of the tuned circuit between the plate and the grid of the 6J6. One satisfactory arrangement would be to use a small butterfly capacitor such as the Cardwell ER-8-BF/S with one pair of stator lugs connected directly to the grid and plate coupling capacitors at the tube socket. The coils for different frequency ranges then may be bolted to the pair of bolts on the opposite ends of the stators.

Power supply for the dip meter is the miniature selenium-rectifier unit described previously. This power supply unit furnishes 6.3 volts at 0.45 amperes for the heater of the 6J6 and about 100 volts at 6 ma. as plate supply. A four-wire cable five feet in length runs from the power unit to the dip meter. In addition to carrying power to the dip meter this cable carries the grid return back to the power unit. The 0-1 d-c milliammeter then is plugged into the jack on the side of the power unit.

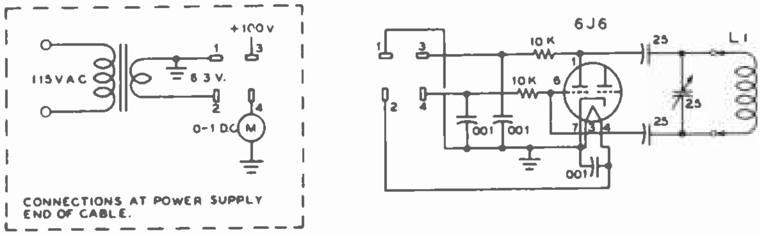


Figure 8.

SCHEMATIC OF THE GRID-DIP METER.

The coil for the 90 to 175 Mc. range consists of 1 turn of no. 14 enamelled with a diameter of 1 inch. The base for the coil is a standard coil form with all but 3/8" of the cylindrical portion sawed off. The coil for the 47 to 91 Mc. range consists of 6 turns of no. 14 enamelled with an inside diameter of 5/8"; this coil is mounted inside the standard Millen 45005 coil form. For 26 to 47 Mc. the coil consists of 6 turns no. 14 enamelled closewound on a 1-inch diameter form (Millen 45005). For the 14 to 26 Mc. range the coil consists of 16 turns of no. 22 enamelled spaced to 7/8" on a 1-inch diameter Millen 45005 coil form.

Normal grid current to the oscillator runs from 0.2 to 0.6 ma. The higher readings are obtained on the lower frequency bands and the lowest reading at the upper frequency limit of the unit in the vicinity of 180 Mc. A sharp dip in grid current is obtained when the coil of the oscillator is coupled to an external circuit resonant at the frequency of operation of the oscillator. By making the power supply and indicating instrument separate from the oscillator, it is possible to hold the oscillator unit conveniently in the hand so that its tank coil may be coupled to the external circuit whose resonant frequency it is desired to determine.

Measurement of Capacitance Since the grid-dip meter indicates resonance of an external circuit to its frequency of oscillation, the dip meter may be used in conjunction with a calibrated capacitor for the measurement of an unknown capacitance. This capability is convenient when it becomes necessary to determine the capacitance of a small ceramic or mica capacitor when its markings have been obscured—or were obscure in the first place. Many of the fixed capacitors available from surplus stocks do not conform to RMA or ASA color-code markings, hence their capacitance must be measured before they are used in a circuit.

Since a high degree of accuracy will not be required for a rough capacitance check of this type, the calibrated capacitor may consist of a small straight-line-capacitance variable such as a National UM-100 or Johnson 100H15 with a simple 0-100 dial. A small coil of 5 or 6 turns with one-inch diameter is then soldered to the capacitor, the capacitor is set full in with its dial at 100, and the resonant frequency of the circuit checked with the grid-dip meter. The grid-dip meter is left set at this frequency and the unknown capacitor (whose capacitance is assumed to be less than the maximum capacitance of the variable capacitor) is soldered across the variable capacitor. Then, with the dip meter operating at the same frequency, the capacitance of the "calibrated" capacitor is decreased until the circuit again resonates at the frequency of operation of the dip meter. The amount by which the capacitance of the "calibrated" capacitor has been decreased is equal to the capacitance of the unknown capacitor which has been added. For the purpose of a simple check such as this, with a 0-100 dial and a variable capacitor with 100 $\mu\mu$fd. maximum, the reading of the 0-100 dial may be taken as the capacitance of the variable.

Standing-Wave Indicators

Most amateurs operating on the frequency bands above 14 Mc. are interested in ascertaining and then in minimizing the voltage-standing-wave ratio on the transmission lines which feed their antenna systems. The first problem,

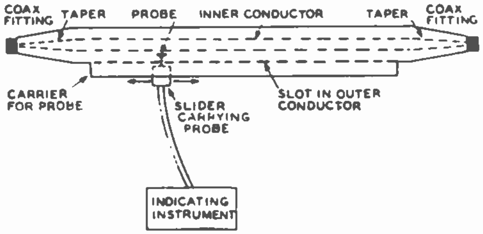


Figure 9.

DIAGRAMMATIC REPRESENTATION OF A SLOTTED LINE.

The conductor ratios in the slotted line, including the tapered end sections should be such that the characteristic impedance of the equipment is the same as that of the transmission line with which the equipment is to be used. The indicating instrument may be operated by the d-c output of the rectifier coupled to the probe, or it may be operated by the a-c components of the rectified signal if the signal generator or transmitter is amplitude modulated by a constant percentage.

after a new antenna has first been installed, is of course to obtain a satisfactory directional pattern. After the directive pattern is satisfactory, and the front-to-back ratio is all that is required if the system is a nominally unidirectional affair, the next problem becomes that of matching the antenna transmission line to the driven element or elements of the antenna array. Some instrument for measuring the standing-wave ratio on the antenna transmission line must be available if the antenna-to-feed-line impedance match is to be made with any degree of accuracy.

Types of Transmission Lines There are four general types of transmission lines in common use at amateur stations for feeding the antenna system from the transmitter. These lines are: (1) solid-dielectric coaxial lines (RG-8/U, etc.), (2) molded parallel-wire lines of the ribbon or tubular type, (3) two-wire open lines, and (4) two-wire solid-dielectric shielded lines. The type (4) line is used only infrequently due to the relatively high costs of such lines and due to the fact that such lines frequently are characterized by somewhat higher losses than the other types of lines which have been enumerated.

Coaxial Lines It is obviously impracticable to measure the voltage-standing-wave ratio in a length of coaxial line since the voltages and currents inside the line are completely shielded by the outer conductor of the cable. Hence it is necessary to insert some type of instrument into a section of the line in order to be able to ascertain the conditions which are taking place inside the shielded line. Where measurements of a high degree of accuracy are required, the *slotted line* is the instrument which is most frequently used. Such an instrument, diagrammed in figure 9, is an item of test equipment which could be constructed by an amateur with a home workshop including a lathe and other metal working tools. Commercially built slotted lines are very expensive since they are constructed with a high degree of accuracy for precise laboratory work.

The slotted line consists essentially of a section of air-dielectric line having the same characteristic impedance as the transmission line into which it is inserted. Tapered fittings for the transmission line connectors at each end of the slotted line usually are required due to differences in the diameters of the slotted line and the line into which it is inserted. A narrow slot from ⅛-inch to ¼-inch in width is cut into the outer conductor of the line. A probe then is inserted into the slot so that it is coupled to the field inside the line. Some sort of accurately machined track or lead screw must be provided to insure that the probe maintains a constant spacing from the inner conductor as it is moved from one end of the slotted line to the other. The probe usually includes some type of rectifying element whose output is fed to an indicating instrument alongside the slotted line.

The unfortunate part of the slotted-line system of measurement is that the line must be somewhat over one-half wavelength long at the test frequency, and for best results should be a full wavelength long. This requirement is easily met at frequencies of 420 Mc. and above where a full wavelength is 28 inches or less. But for the lower frequencies such an instrument is completely impracticable.

Bridge-Type Standing-Wave Indicators The bridge type of standing-wave indicator is used quite generally for making measurements on commercial coaxial transmission lines. A simplified version suitable for amateur use is available from M. C. Jones Electronics Co., Bristol, Conn. ("Micro-Match").

One type of bridge standing-wave indicator

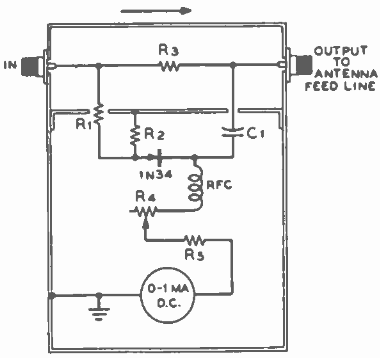


Figure 10.
BRIDGE-TYPE STANDING-WAVE INDICATOR.

This type of test equipment is suitable for use with coaxial feed lines.

C_1—0.001-μfd. midget ceramic capacitor
R_1, R_2—22-ohm 2-watt carbon resistors
R_3—Resistor equal in resistance to the characteristic impedance of the coaxial transmission line to be used
R_4—50,000-ohm wire-wound potentiometer
R_5—4700-ohm 1-watt resistor
RFC—R-f choke suitable for operation at the measurement frequency.

is diagrammed in figure 10. This type of instrument compares the electrical impedance of the transmission line with that of the resistor R_3 which is included within the unit. Experience with such units has shown that the resistor R_3 should be a good grade of non-inductive carbon type. The Ohmite "Little Devil" type of resistor in the 2-watt rating has given good performance. The resistance at R_3 should be equal to the characteristic impedance of the antenna transmission line. In other words, this resistor should have a value of 51 ohms for lines having this characteristic impedance such as RG-8/U and RG-58/U. For use with lines having a nominal characteristic impedance of 70 ohms, a selected "68 ohm" resistor having an actual resistance of 70 ohms may be used.

Balance within the equipment is checked by mounting a resistor, equal in value to the nominal characteristic impedance of the line to be used, on a coaxial plug of the type used on the end of the antenna fed line. Then this plug is inserted into the *input* receptacle of the instrument and a power of 2 to 4 watts applied to the *output* receptacle on the desired frequency of operation. Note that the signal is passed through the bridge in the direction opposite to normal for this test. The resistor R_4 is adjusted for full-scale deflection on the 0-1 milliammeter. Then the plugs are reversed so that the test signal passes through the instrument in the direction indicated by the arrow on figure 10, and the power level is maintained the same as before. If the test resistor is matched to R_3, and stray capacitances have been held to low values, the indication on the milliammeter will be very small. The test plug with its resistor is removed and the plug for the antenna transmission line is inserted. The meter indication now will read the reflection coefficient which exists on the antenna transmission line at the point where the indicator has been inserted. From this reading of reflection coefficient the actual standing-wave ratio on the transmission line may be determined by reference to the chart of figure 16.

Measurements of this type are quite helpful in determining whether or not the antenna is presenting a good impedance match to the transmission line being used to feed it. However, a test instrument of the type shown in figure 10 must be inserted into the line for a measurement, and then removed from the line when the equipment is to be operated. Also, the power input to the line feeding the input terminal of the standing-wave indicator must not exceed 4 watts. The power level which the unit can accept is determined by the dissipation limitation of resistors R_1 plus R_2.

It is also important, for satisfactory operation of the test unit, that resistors R_1 and R_2 be exactly equal in value. The acual resistance of these two is not critically important, and deviations up to 10 per cent from the value given in figure 10 will be satisfactory. But the two resistors must have the same value, whether they are both 21 ohms or 24 ohms, or some value in between.

Measurements on Molded Parallel-Wire Lines One of the most satisfactory and least expensive devices for obtaining a rough idea of the standing-wave ratio on a transmission line of the molded parallel-wire type is the "twin-lamp" which was first described by Wright in the October, 1947, issue of the magazine *QST*. This ingenious instrument may be constructed of new components for a total cost of about 25 cents; this fact alone places the twin-lamp in a class by itself as far as test instruments are concerned.

Figure 11 shows a sketch of a twin-lamp while figure 12 is a photograph showing the simplicity of the device. The indicating portion of the system consists merely of a length of

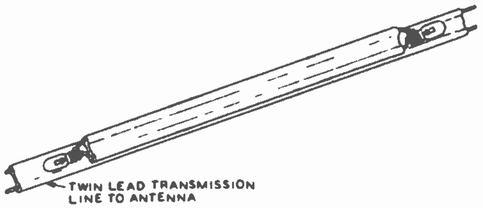


Figure 11.
SKETCH OF THE "TWIN LAMP" TYPE OF S-W-R INDICATOR.

Figure 12.
PHOTO SHOWING THE SIMPLICITY OF THE "TWIN LAMP" INDICATOR.

300-ohm Twin-Lead about 10 inches long with a dial lamp at each end. In the unit illustrated the dial lamps are standard 6.3-volt 150-ma. bayonet-base lamps. The lamps are soldered to the two leads at each end of the short section of Twin-Lead.

To make a measurement the short section of line with the lamps at each end is merely taped to the section of Twin-Lead (or other similar transmission line) running from the transmitter or from the antenna changeover relay to the antenna system. When there are no standing waves on the antenna transmission line the lamp toward the transmitter will light while the one toward the antenna will not light. With 300-ohm Twin-Lead running from the antenna changeover relay to the antenna, and with about 200 watts input on the 28-Mc. band, the dial lamp toward the transmitter will light nearly to full brilliancy. With a standing-wave ratio of about 1.5 to 1 on the transmission line to the antenna the lamp toward the antenna will just begin to light. With a high standing-wave ratio on the antenna feed line both lamps will light nearly to full brilliancy. Hence the instrument gives an indication of relatively low standing waves, but when the standing-wave ratio is high the twin-lamp merely indicates that they are high without giving any idea of the actual magnitude.

Operation of the Twin-Lamp The twin lamp operates by virtue of the fact that the capacitive and inductive coupling of the wire making up one side of the twin-lamp is much greater to the transmission-line lead immediately adjacent to it than to the transmission-line lead on the other side. The same is of course true of the wire on the other side of the twin-lamp and the transmission-line lead adjacent to it. A further condition which must be met for the twin-lamp to operate is that the section of line making up the twin-lamp must be short with respect to a quarter wavelength. Then the current due to capacitive coupling passes through both lamps in the same direction, while the current due to inductive coupling between the leads of the twin-lamp and the leads of the antenna transmission line passes through the two lamps in opposite directions. Hence, in a line without reflections, the two currents will cancel in one lamp while the other lamp is lighted due to the sum of the currents.

The basic fact which makes the twin-lamp a "directional coupler" is a result of the condition whereby the capacitive coupling is a *scalar* action not dependent upon the direction of the waves passing down the line, yet the inductive coupling is a *vector* action which *is* dependent upon the direction of wave propagation down the line. Thus the capacitive current is the same and is in the same phase for energy travelling in either direction down the line. But the inductive current travels in one direction for energy travelling in one direction and in the other direction for energy going the other direction. Hence the two currents add at

Figure 13.
SHOWING INDUCTIVE AND CAPACITIVE CURRENT FLOW IN A "TWIN LAMP" ATTACHED TO A LINE HAVING A LOW VALUE OF REFLECTED SIGNAL.

one end of the line for a wave passing toward the antenna, while the currents add at the other end of the twin-lamp for the waves reflected from the antenna. When the waves are strongly reflected upon reaching the antenna, the reflected wave is nearly the same as the direct wave, and both lamps will light. This condition of strong reflection from the antenna system is that which results in a high standing-wave ratio on the antenna feed line.

Use of the Twin Lamp with Various Feed Lines The twin-lamp is best suited for use with antenna transmission lines of the flat ribbon type. Lines with a high power rating are available in impedances of 75 ohms, 205 ohms, and 300 ohms in the flat ribbon type. In addition, one manufacturer makes a 300-ohm line in two power-level ratings with a tubular cross section. A twin-lamp made from flat 300-ohm line may be used with this tubular line by taping the twin-lamp tightly to the tubular line so that the conductors of the twin-lamp are as close as possible on each side to the conductors of the antenna line.

Use of the Twin-Lamp with Open-Wire Lines The twin-lamp principle may also be used in conjunction with conventional open-wire lines of the 460-ohm to 600-ohm variety. For this application the indicator, consisting of a loop of number 16 or 18 wire, can best be mounted on a frame made up of thin (¼ inch) material such as plexiglass or lucite or even wood which has been thoroughly dried and impregnated with varnish or shellac. In any event the frame should be as light as possible and as much out of the field of the transmission line as is practicable. If the frame should have a very large amount of mass in the strong field of the antenna transmission line it, in itself, could introduce a moderate amount of reflection on the line and thus cause standing waves. The two wires, with the lamps at each end, should be spaced about ⅜-inch from the wires of the main feed line and should be placed above the feeder wires rather than alongside. Notches should be cut in the support frame so that the spacing between the pickup line and the antenna transmission line will be maintained accurately.

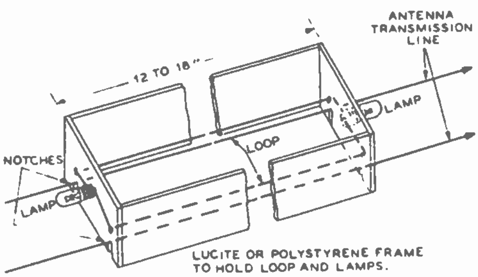


Figure 14.
SKETCH OF A "TWIN LAMP" TYPE OF INDICATOR FOR OPEN-WIRE LINES.

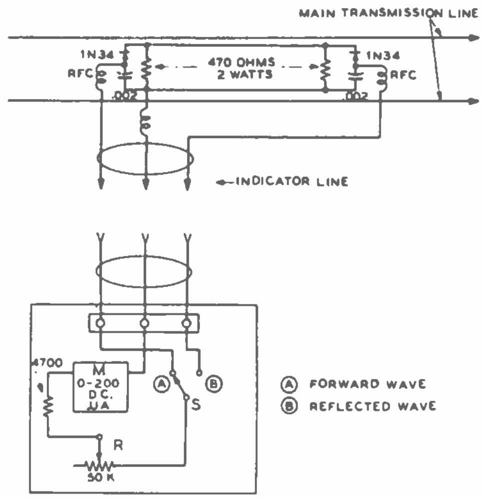


Figure 15.
SHOWING THE USE OF A "TWIN LAMP" TYPE OF INDICATOR WITH A D-C INSTRUMENT.

This arrangement gives a much more accurate indication of the standing-wave ratio on a transmission line than does the similar arrangement with dial lamps for indicators.

Use of the Twin-Lamp with Rectifiers and a Meter The twin-lamp principle may be used in conjunction with two rectifiers and a d-c instrument for obtaining a much higher degree of accuracy in the measurement of the standing-wave ratio existing on a transmission line. A schematic diagram showing the connections for such an instrument is given in figure 15. True, such a device is somewhat more complex than the simple version with a pair of dial lamps, but the "indicating twin-lamp" is capable of giving an actual figure for the standing-wave ratio on a transmission line rather than the very approximate and relative indication obtained with the use of dial lamps.

The principle of the device is the same as that of the simple twin-lamp. But the net voltage drop across each end of the measuring line is rectified with a 1N34 rectifier and the indication of this voltage may be read on a d-c instrument. From the ratio of the meter indications at each end of the measuring line it is possible to estimate the standing-wave ratio existing on the transmission line with a fair degree of accuracy.

The procedure for making a measurement is as follows: (1) Tape the measuring section to the main transmission line if the ribbon type of line is being used, or place the structure of figure 14 on the open-wire line at a convenient spot if the latter type of line is being used. In either event the dial lamps at each end are replaced by a 470-ohm load resistor, a 1N34 crystal diode, a 0.002-μfd. postage stamp mica, and an r-f choke which presents a high impedance at the operating frequency being used at the transmitter. An additional r-f choke is connected to the loop itself at one end or the other to furnish a d-c return for the rectified signal. A three-wire cable is then run from the measuring line down to the box which houses the d-c meter, the selector switch, and the resistors. The three-wire cable may be made up of three strands of hookup wire, or it may consist of one strand of hookup wire as a common wrapped around a length of ribbon line or standard "pull apart" lamp cord.

(2) The 50,000-ohm resistor R is adjusted for maximum resistance and the switch S is placed in position (A) for measurement of the forward wave. *Reduced* power is then applied to the transmitter, if it is of a power rating more than 25 to 50 watts. The indication on the meter M is then noted. If the indication is too low, it may be increased by decreasing the amount of resistance at R. If the indication is too high, it may be decreased by reducing transmitter power still further, by replacing the 470-ohm resistors at each end of the measuring line with a lower value, or by adding more resistance at R. With a power of 200 watts in the antenna transmission line and the values shown, a full-scale deflection could be obtained on a test installation with resistor R set at somewhat less than full resistance. These tests were made with the ribbon type of measuring line.

(3) After transmitter power and the setting of R have been adjusted for full-scale deflection on the meter M, switch S is thrown to position (B) and the indication noted. With a perfectly matched line the indication will be zero. But "flat" lines are seldom realized in practice, so the ratio of the reflected-wave reading to the forward-wave reading is obtained by simple division. If the 0-1 d-c milliammeter is used as the indicating instrument the sensitivity of the measuring line will be reduced, but the dial readings of the 0-1 instrument on the reflected wave will give the reflection coefficient directly. The reflection coefficient thus obtained may then be compared with the chart of figure 16 to obtain the standing-wave ratio on the transmission line.

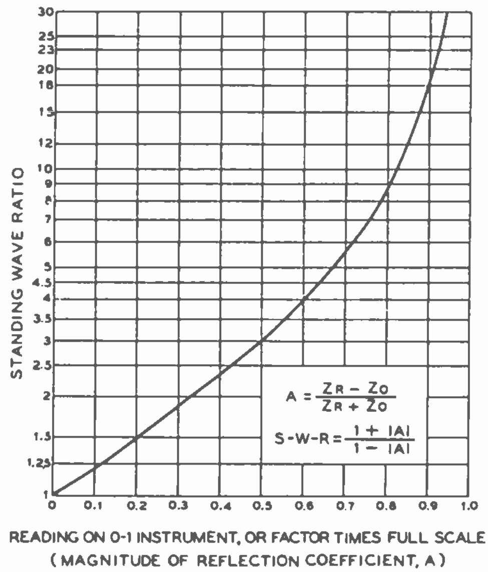


Figure 16.

RELATION BETWEEN STANDING-WAVE RATIO AND REFLECTION COEFFICIENT.

This chart may be used to convert reflection-coefficient indications such as are obtained with a bridge-type standing-wave indicator or an indicating twin lamp into values of standing-wave ratio.

Calibration of the Measuring Line The chart of figure 16 has been calculated on the basis of the formulas also shown on the chart. The accuracy with which the actual instrument will give results which correspond with the calculated values depends upon the linearity of the rectifiers, upon the assumption that the r-f chokes isolate the indicator line completely from the measuring line and its rectifiers, and that the two 470-ohm resistors are matched in resistance and impedance. In practice some deviations may be expected. But upon the test sample used on the 28-Mc. band the deviations were small enough to be ignored.

If it is desired to perform an actual calibration upon the instrument as a means of determining the accuracy with which the particular instrument corresponds with the calculated chart of figure 16, the procedure is as follows: (1) Place a load resistor equal to the characteristic impedance of the antenna transmission line at the antenna end of the line in place of the antenna. This resistor must be capable of dissipating substantially the full output of the transmitter, so the output of the transmitter will have to be cut down and the sensitivity of the indicating instrument increased until full scale on M may be obtained in the (A) position of switch S when the load resistance is dissipating its full rating of power output from the transmitter.

(2) Place switch S in position (B). The indication on the meter should fall to zero. If the meter does not fall substantially to zero, the discrepancy may be due to reflections from bends or other discontinuities in the antenna transmission line, or it may be due to imperfect choking action in the r-f chokes.

(3) After the indication has been made to fall to zero in position (B) while still reading full scale at (A), replace the load resistor at the antenna end of the feed line with a resistor of one-half the characteristic impedance of the antenna line. Adjust the meter reading to full scale in the (A) position and check the reading in the (B) position. The reading should be aproximately 0.33, indicating a standing-wave ratio of 2 to 1.

(4) Substitute other values of resistance as termination for the antenna transmission line and calculate the reflection coefficient and standing-wave ratio from the formulas given on the chart of figure 16. If the deviation from the theoretical chart is appreciable, it may be wise to draw a new chart of standing-wave ratio against meter indication. But if the deviation from the theoretical chart is considerable, it probably will be found that some external factor is influencing the readings, and hence that the readings may not repeat. If spurious couplings to the measuring line are eliminated, the calibration of the instrument should check quite closely with figure 16.

CHAPTER ELEVEN

Antennas and Transmission Lines

The material within this chapter is confined to descriptions of practical types of antennas and antenna arrays for operation on the amateur bands. For theoretical discussions of antenna radiation and signal propagation, the reader is referred to the RADIO HANDBOOK, eleventh edition, and to the ANTENNA MANUAL, first edition.

Half-Wave Antennas All antennas commonly used by amateurs, excepting the terminated rhombic, are based on the fundamental Hertz type, which is a wire in space a half wavelength long electrically. A linear, resonant dipole, which is a half wavelength long *electrically,* is actually slightly less than a half wave long *physically,* due to the capacitance to ground, "end effects," and the fact that the velocity of a high-frequency radio wave traveling along the conductor is not quite as high as it is in free space.

Physical Length of a Half-Wave Antenna If the cross section of the conductor which makes up the antenna is kept very small with respect to the antenna length, the effects mentioned in the previous paragraph are relatively constant so that an electrical half wave is a fixed percentage shorter than a physical half-wavelength. This percentage is approximately 5 per cent. Therefore, most linear half-wave antennas are close to 95 per cent of a half wave long physically. Thus, a half-wave antenna resonant at exactly 80 meters would be one-half of 0.95 times 80 meters in length. Another way of saying the same thing is that a wire resonates at a wavelength of about 2.1 times its length in meters. If the diameter of the conductor begins to be an appreciable fraction of a wavelength, as when tubing is used as a v-h-f radiator, the factor becomes slightly less than 0.95. For the use of wire and not tubing on frequencies below 30 Mc., however, the figure of 0.95 may be taken as accurate. This assumes a radiator removed from surrounding objects, and with *no bends.*

Frequency describes the number of wave cycles or peaks passing a point per second. Wavelength describes the distance the wave travels through space during one cycle or oscillation of the antenna current; it is the distance in meters between adjacent peaks or adjacent troughs of a wave train.

As a radio wave travels 300,000,000 meters a second (speed of light), a frequency of 1 cycle per second corresponds to a wavelength of 300,000,000 meters. So, if the frequency is multiplied by a million, the wavelength must be divided by a million, in order to maintain their correct ratio.

A frequency of 1,000,000 cycles per second (1,000 kc.) equals a wavelength of 300 meters. Multiplying frequency by 10 and dividing wavelength by 10, we find: a frequency of 10,000 kc. equals a wavelength of 30 meters. Multiplying and dividing by

10 again, we get: a frequency of 100,000 kc. equals 3 meters wavelength. Therefore, to change wavelength to frequency (in kilocycles), simply divide 300,000 by the wavelength in meters (λ).

$$F_{kc} = \frac{300{,}000}{\lambda}$$

$$\lambda = \frac{300{,}000}{F_{kc}}$$

Now that we have a simple conversion formula for converting wavelength to frequency and vice versa, we can combine it with the wavelength versus antenna length formula, and we have the following:

Length of a half-wave radiator made from wire (no. 14 to no. 10):

3.5-Mc. to 30-Mc. bands

$$\text{Length in feet} = \frac{468}{\text{Freq. in Mc.}}$$

50-Mc. band

$$\text{Length in inches} = \frac{5600}{\text{Freq. in Mc.}}$$

144-Mc. band

$$\text{Length in inches} = \frac{5500}{\text{Freq. in Mc.}}$$

The length of a wave in free space is somewhat longer than the length of an antenna for the same frequency. The actual free-space length of a half wave is given by the following expressions:

$$1/2 \text{ wave} = \frac{492}{\text{Freq. in Mc.}} \text{ in feet}$$

$$1/2 \text{ wave} = \frac{5905}{\text{Freq. in Mc.}} \text{ in inches}$$

The half-wave horizontal dipole is the most common and most practicable antenna for use by the average amateur on the 3.5-Mc. and 7.0-Mc. bands. The actual form of the dipole and the manner in which it is fed are capable of a large number of variations. And in fact, the form and manner of feed make negligible difference in the radiation characteristics of the antenna system. The radiation pattern and field intensity of a dipole are determined by the total current flow at the center of the radiator, and by external conditions such as height above ground and proximity to surrounding objects. So the form of the half-wave radiator and the feed system to be used are entirely a matter of convenience to be chosen by the operator.

Usually a high-frequency dipole is mounted as high and as much in the clear as possible, for obvious reasons. However, it is sometimes justifiable to bring part of the radiating system directly to the transmitter, feeding the antenna without benefit of a transmission line. This is permissible when (1) there is insufficient room to erect a 160- or 80-meter horizontal dipole and feed line, (2) when a long wire is operated on one of the higher frequency bands on a harmonic. In either case, it is usually possible to get the main portion of the antenna in the clear because of its length. This means that the power lost by bringing the antenna directly to the transmitter is relatively small.

Even so, it is not best practice to bring the high-voltage end of an antenna into the operating room, especially for 'phone operation, because of the possibility of r-f feedback from the strong antenna field. For this reason we dispense with a feed line in conjunction with a Hertz antenna only as a last resort.

The Zepp Antenna System The zeppelin or "zepp" antenna system, illustrated in figure 1, is very commonly used when it is desired to operate a single radiating wire on a number of harmonically related frequencies.

The zepp antenna system is easy to tune up, and can be used on several bands by merely retuning the feeders. The overall efficiency of the zepp antenna system is probably not quite as high for long feeder lengths as for some of the antenna systems which employ nonresonant transmission lines, but where space is limited and where operation on more than one band is desired, the zepp has some decided advantages.

Addition of the coupling coil naturally will electrically lengthen the antenna; thus, in order to bring this portion of the antenna back to resonance, we must electrically shorten it by means of the series tuning capacitor, C_1. The two wires in the folded portion of the antenna system do not have to be exactly a quarter wave long physically, although the total *electrical* length of the folded portion must be equal to one-half wavelength electrically.

When the total electrical length of the two feeder wires, plus the coupling coil, is slightly greater than any odd multiple of one-quartr wave, then series tuning capacitors must be used to shorten the electrical length of the feeders sufficiently to establish resonance. If, on the other hand, the electrical length of the feeders and the coupling coil is slightly less than any odd multiple of one-quarter wave (or approaches an even number of quarter waves), then parallel tuning (wherein a variable capacitor is shunted across the coupling coil) must be used in order to increase the electrical length of the whole feeder system to a multiple of one-quarter wavelength.

Stub-Fed Zepp-Type Radiator Figure 2C shows a modification of the zepp-type antenna system to allow the use of a non-resonant transmission line between the radiating portion of the antenna and the transmitter. The "zepp" portion of the antenna is resonated as a quarter-wave stub and the non-resonant feeders are connected to the stub at a point where standing waves on the feeder are minimized.

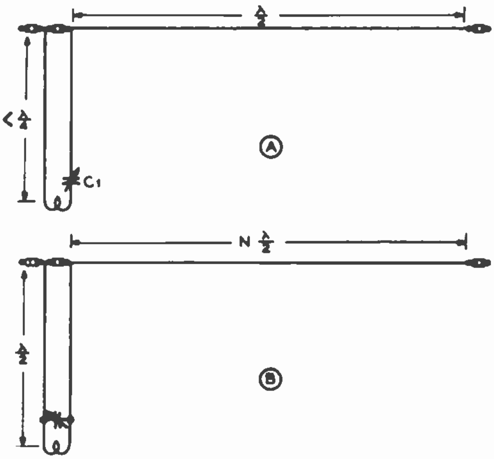


Figure 1.

THE ZEPP ANTENNA SYSTEM.

The radiating portion of the antenna system should be made approximately a free-space half wave long, rather than the usual 95 per cent of an electrical half wave as used for a center-fed antenna. Figure 1A shows the use of series tuning of the feeders when the total feeder length is somewhat less than an odd number of quarter waves. A length of about 45 feet has proven quite satisfactory for the 3.5-Mc. band and above. With this feeder length, series tuning may be used on all bands through 14 Mc., with parallel tuning on the 21-Mc. and 28-Mc. bands. Shown at (B) is the parallel-tuned feeder system for use when the feeder length is approximately an even number of quarter waves.

Center-Fed Half-Wave Horizontal Antennas

The center feeding of a half-wave antenna system is usually to be desired over an end-fed system since the center-fed system is inherently balanced to ground and is therefore less likely to be troubled by feeder radiation. A number of center-fed systems are illustrated in figure 2.

The Tuned Doublet The current-fed doublet with spaced feeders, sometimes erroneously called a center-fed zepp, is an inherently balanced system if the two legs of the radiator are electrically equal. This fact holds true regardless of the frequency, or of the harmonic, on which the system is operated. The system can successfully be operated over a wide range of frequencies if the system as a whole (both tuned feeders and the center-fed flat top) can be resonated to the operating frequency. It is usually possible to tune such an antenna system to resonance with the aid of a tapped coil and a tuning capacitor that can optionally be placed either in series with the antenna coil or in parallel with it. A series tuning capacitor can be placed in series with one feeder leg without unbalancing the system if the capacitor is placed in the immediate vicinity of the antenna coil.

This type of antenna system is shown in figure 2D. The antenna is a current-fed system when the radiating wire is a half wave long electrically, or when the system is operated on its odd harmonics, but becomes a voltage-fed radiator when operated on its even harmonics.

The antenna has a different radiation pattern when operated on its harmonics, as would be expected. The arrangement used on the second harmonic is better known as the Franklin colinear array. The pattern is similar to a half-wave dipole except that it is sharper in the broadside direction. On higher har-

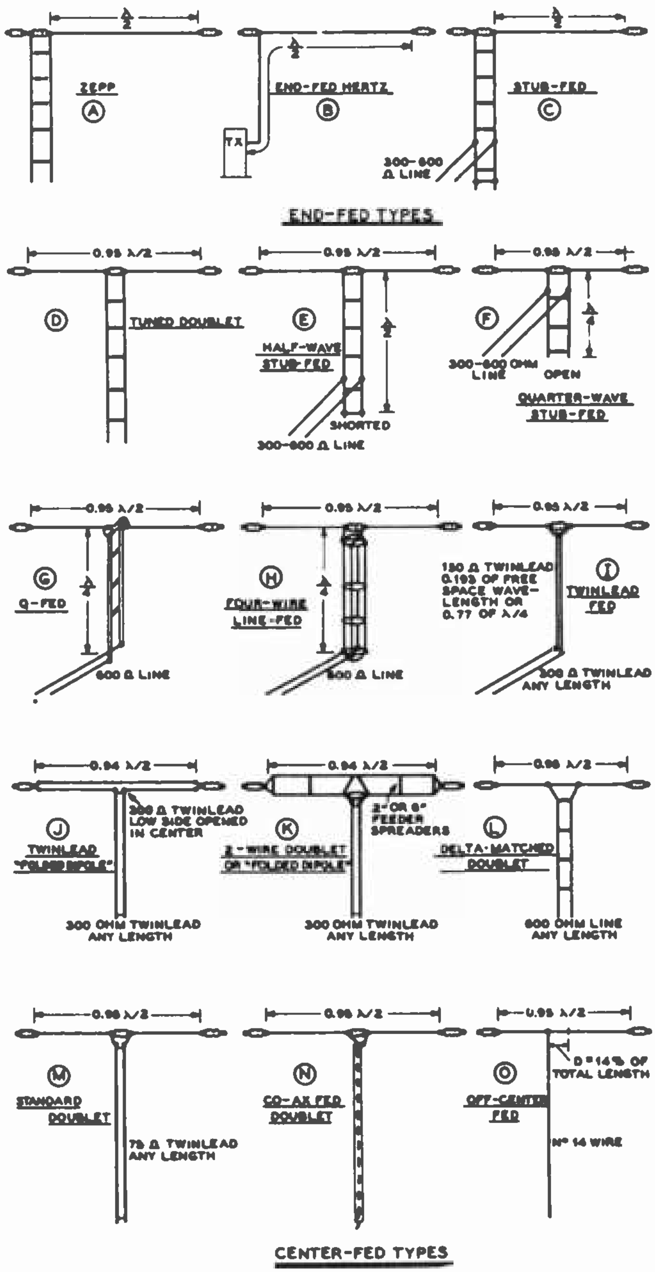


Figure 2.

METHODS OF FEEDING A HALF-WAVE DIPOLE.

The feed systems shown at (A), (B), and (C) are of greatest advantage when it is required to locate the transmitter adjacent to one end of the radiating wire. The other illustrations show a variety of methods for center feeding a half-wave dipole.

monics of operation there will be multiple lobes of radiation from the system.

Figures 2E and 2F show alternative arrangements for using an untuned transmission line between the transmitter and the tuned-doublet radiator. In figure 2E a half-wave shorted line is used to resonate the radiating system, while in figure 2F a quarter-wave open line is utilized.

Doublets with Quarter-Wave Transformers The average value of feed impedance for a center-fed half wave doublet is 75 ohms. Alternative methods of matching this rather low value of impedance to a medium-impedance transmission line are shown in (G), (H), and (I) of figure 2. Each of these three systems uses a quarter-wave transformer to accomplish the impedance transformation. The only difference between the three systems lies in the type of transmission line used in the quarter-wave transformer. (G) shows the "Johnson Q" system whereby a line made up of ½-inch dural tubing is used for the low-impedance linear transformer. A line made up in this manner is frequently called a set of "Q bars." Illustration (H) shows the use of a four-wire line as the linear transformer, and (I) shows the use of a piece of 150-ohm twinlead electrically ¼-wave in length as the transformer between the center of the dipole and a piece of 300-ohm twinlead. In any case the impedance of the quarter-wave transformer will be of the order of 150 to 200 ohms.

Multi-Wire Doublets An alternative method for increasing the feed-point impedance of a dipole so that a medium-impedance transmission line may be used is shown in figure 2J and 2K. This system utilizes more than one wire in parallel for the radiating element, but only one of the wires is broken for attachment of the feeder. The most common arrangement uses two wires in the flat top of the antenna so that an impedance multiplication of four is obtained.

The antenna shown in figure 2J is the so-called twinlead "folded dipole" which is so popular an antenna system on the medium-frequency amateur bands. In this arrangement both the antenna and the transmission line to the transmitter are constructed of 300-ohm twinlead. The flat top of the antenna is made slightly less than the conventional length (462 Freq. in Mc. instead of 468 Freq. in Mc. for a single-wire flat top) and the two ends of the twinlead are joined together at each end. The center of one of the conductors of the twinlead flat top is broken and the two ends of the twinlead feeder are spliced into the flat top leads. As a protection against moisture pieces of flat polyethylene taken from another piece of 300-ohm twinlead may be molded over the joint between conductors with the aid of an electric iron or soldering iron.

Figure 2K shows the basic type of 2-wire doublet or "folded dipole" wherein the radiating section of the system is made up of standard antenna wire spaced by means of feeder spreaders. The feeder again is made of 300-ohm twinlead since the feed-point impedance is approximately 300 ohms, the same as that of the twinlead folded dipole.

The folded-dipole type of antenna has the broadest response characteristic (greatest bandwidth) of any of the conventional half-wave antenna systems constructed of small wires or conductors. Hence such an antenna may be operated over the greatest frequency range without producing detuning at the transmitter of any common half-wave antenna type.

The Marconi Antenna The quarter-wave antenna operating against ground, commonly called the "Marconi" antenna, is probably the simplest type of effective radiating system for the 160-meter band. The Marconi type antenna allows the use of half the length of wire which would be required for a half-wave Hertz radiator. The ground acts as a mirror in effect, and takes the place of the additional quarter wave of wire which would be required if the end of the wire were not returned to ground.

The Marconi antenna is generally not as satisfactory for long-distance communication as the Hertz type, the reduced radiation efficiency being due to the rather high effective angle of radiation plus losses due to the ground connection. However, the Marconi may be made almost as good a radiator on frequencies below about 3 Mc. if sufficient care is taken with regard to the ground system.

The fundamental practical form of the Marconi antenna system is shown in figure 3A. Other Marconi antennas differ from this type primarily in regard to the method of feeding the energy to the radiator. The feed method shown in figure 3B can often be used to advantage, particularly in mobile work, when it is desired to ground the bottom of the Marconi antenna.

Variations on the basic Marconi antenna shown in figure 4A are shown in the other illustrations of figure 4. Figures 4B and 4C show the "L"-type and "T"-type Marconi antennas. These arrangements have been more or less superseded by the top-loaded forms of the Marconi antenna shown in figures 4D, 4E, and 4F. In each of these latter three figures an antenna somewhat less than one quarter wave in length has been *loaded* to increase its effective length by the insertion of a *loading coil* at or near the top of the radiator. The arrangement shown at figure 4D gives the least loading but is the most practical mechanically. The system shown at figure 4E gives an intermediate amount of loading,

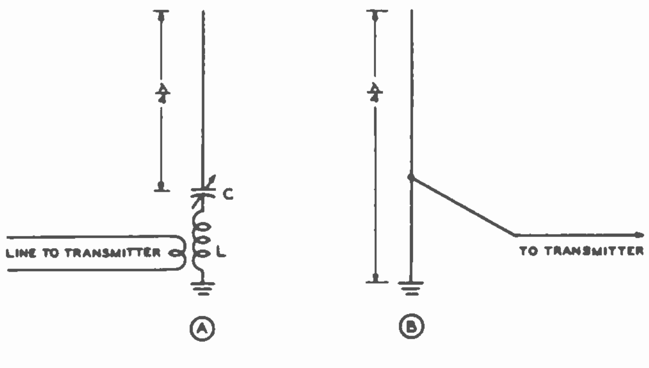


Figure 3.
FEEDING A QUARTER-WAVE MARCONI ANTENNA.

The (A) arrangement is preferable when the lower end of the antenna is not grounded. The shunt feed system at (B) will be found quite effective when the lower end of the radiator must be grounded for mechanical reasons.

while that shown at figure 4F, utilizing a "hat" just above the loading coil, gives the greatest amount of loading. The object of all the top-loading methods shown is to produce an increase in the effective length of the radiator, and thus to raise the point of maximum current in the radiator as far as possible above ground. Raising the maximum-current point in the radiator above ground has two desirable results: The percentage of low-angle radiation is increased and the amount of ground current at the base of the radiator is reduced, thus reducing the ground losses.

Loading Coils To resonate inductively an inductive-loaded Marconi, the inductance would have to be in the form of a variometer in order to permit continuous variation of the inductance. The more common practice is to use a tapped loading coil. The loading coil should preferably be placed a short distance from the *top or far end* of the radiator; this reduces the current flowing in the ground connection by raising the radiation resistance, resulting in better radiation efficiency. More than the required amount of inductance for resonance is clipped in series with the antenna, and the system is then resonated by means of the series variable capacitor at the base of the radiator, the same as though the radiator were actually too long physically.

To estimate whether a loading coil will probably be required, it is necessary only to note if the length of the antenna wire and ground lead is over a quarter wavelength; if so, no loading coil is needed, provided the series tuning capacitor has a high maximum capacitance.

Amateurs primarily interested in the higher frequency bands, but who like to work 160 or 80 meters occasionally, can usually manage to resonate one of their antennas as a Marconi by working the whole system, feeders and all, against a water pipe ground, and resorting to a loading coil if necessary. A high-frequency-rotary, zepp, doublet, or a single-fed antenna will make quite a good 160 or 80 meter Marconi if high and in the clear, with a rather long feed line to act as a radiator on the relatively low frequency. Where two-wire feeders are used, the feeders should be tied together for Marconi operation.

Importance of Ground Connections With a quarter-wave antenna and a ground, the antenna current generally is measured with a meter placed in the antenna circuit close to the ground connection. Now, if this current flows through a resistor, or if the ground itself presents some resistance, there definitely will be a power loss in the form of heat. Improving the ground connection, therefore, provides a definite means of reducing this power loss, and thus increasing the radiated power.

The best possible ground consists of as many wires as possible, each at least a quarter wave long, buried just below the surface of the earth, and extending out from a common point in the form of radials. Copper wire of any size larger than no. 16 is satisfactory, though the larger sizes will take longer to disintegrate. In fact, the radials need not even be buried; they may be supported just above the earth, and insulated from it. This arrangement is called a *counterpoise,* and operates by virtue of its high capacitance to ground.

Unless a large number of radials is used, fairly close to the ground, the counterpoise will act more like the bottom half of a half-wave Hertz than like a ground system. How-

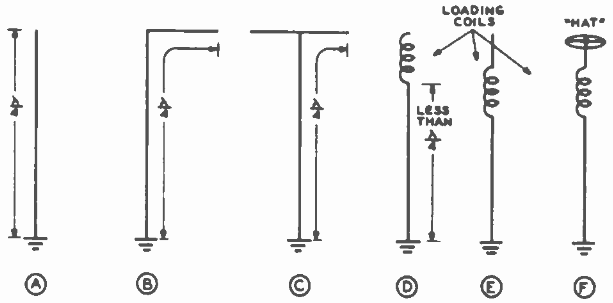


Figure 4.
LOADED MARCONI ANTENNAS.
The alternative loading systems are discussed in the text.

ever, the efficiency with a counterpoise will be quite good, regardless. It is when the radials are buried, or laid on the ground, that a large number should be used for best efficiency. Brodacast stations use as many as 120 radials of from 0.3 to 0.5 wavelength long.

A large number of radials not only provides a low resistance earth connection, but also, if long enough, produces the effect of locating the radiator over highly conducting earth.

When it is impossible to extend buried radials in all directions from the ground connection for an inverted-L type Marconi, it is of importance that a few wires be buried directly below the flat top, and spaced at least 10 feet from one another.

If the antenna is physically shorter than a quarter wavelength, the antenna current is higher, due to lower radiation resistance. Consequently, the power lost in resistive soil is greater. The importance of a good ground with short, inductive-loaded Marconi radiators is, therefore, quite obvious. With a good ground system, even very short (one-eighth wavelength) antennas can be expected to give a high percentage of the efficiency of a quarter-wave antenna used with the same ground system. This is especially true when the short radiator is *top loaded* with a high Q (low loss) coil.

Water-Pipe Grounds Water pipe, because of its comparatively large surface and cross section, has a relatively low r-f resistance. If it is possible to attach to a junction of several water pipes (where they branch in several directions and run for some distance under ground), a satisfactory ground connection will be obtained. If one of the pipes attaches to a lawn or garden sprinkler system in the immediate vicinity of the antenna the effectiveness of the system will approach that of buried copper radials.

The main objection to water-pipe grounds is the possibility of high resistance joints in the pipe, due to the "dope" put on the coupling threads. By attaching the groundwire to a junction with three or more legs, the possibility of requiring the main portion of the r-f current to flow through a high resistance connection is greatly reduced.

The presence of water in the pipe adds nothing to the conductivity; therefore it does not relieve the problem of high resistance joints. Bonding the joints is the best insurance, but this is, of course, impracticable where the pipe is buried. Bonding together with copper wire the various water faucets above the surface of the ground will improve the effectiveness of a water pipe ground system hampered by high-resistance pipe couplings.

Marconi Dimensions A Marconi antenna is an odd number of electrical quarter waves long (usually only one quarter wave in length) and is always resonated to the operating frequency. The correct loading of the final amplifier is accomplished by varying the coupling, *rather than by detuning the antenna from resonance.*

Physically, a quarter-wave Marconi may be made anything from one-eighth to three-eighths wavelength overall, meaning the total length of the antenna wire and ground lead from the end of the antenna to the point where the ground lead attaches to the junction of the radials or counterpoise wires, or the water pipe enters the ground. The longer the antenna is made physically, the lower will be the current flowing in the ground connection, and the greater will be the overall radiation efficiency. However, when the antenna length exceeds three-eighths wavelength, the antenna becomes difficult to resonate by means of a series capacitor, and it begins to take shape as an end-fed Hertz, requiring parallel tuned tank at the base of the antenna.

Directive Antenna Arrays

It is becoming of increasing importance in amateur communication to be capable of concentrating the radiated signal from the transmitter in a certain desired direction and to be able to discriminate against reception from directions other than the desired one. Such capabilities involve the use of directive antenna arrays.

The various forms of the half-wave horizontal antenna produce maximum radiation at right angles to the wire, but the directional effect is not great, excepting for very low vertical angles of radiation (such as would be effective on 10 meters) Nearby objects also minimize the directivity of a dipole radiator, so that it hardly seems worth while to go to the trouble to rotate a simple half-wave dipole in an attempt to improve transmission and reception in any direction.

When a multiplicity of radiating elements is located and phased so as to reinforce the radiation in certain desired directions and to neutralize radiation in other directions, a directive antenna array is formed.

The function of a directive antenna when used for *transmitting* is to give an increase in signal strength in some direction at the expense of radiation in other directions. For *reception,* one might find useful an antenna giving little or no gain in the direction from which it is desired to receive signals if the antenna is able to *discriminate against interfering* signals and static arriving from other directions. A good directive transmitting antenna, however, also can be used to good advantage for reception.

If radiation can be confined to a narrow beam, the signal intensity can be increased a great many times in the desired direction of transmission. This is equivalent to increasing the power output of the transmitter. On the very high frequencies, it is more economical to use a directive antenna than to increase transmitter power, if more than a few watts of power is being used.

Horizontal Pattern vs. Vertical Angle There is a certain optimum vertical angle of radiation for sky wave communication, this angle being dependent upon distance, frequency, time of day, etc. Energy radiated at an angle much lower than this optimum angle is largely lost, while radiation at angles much higher than this optimum angle oftentimes is not nearly so effective.

For operation at frequencies in the vicinity of 14 Mc., the most effective angle of radiation is usually about 15° above the horizon, from *any* kind of antenna. The most effective angles for 10-meter operation are those in the vicinity of 10°.

The fact that many simple arrays give considerably more gain at 10 and 20 meters than one would expect from consideration of the horizontal directivity, can be explained by the fact that, besides providing some horizontal directivity, they concentrate the radiation at a lower *vertical* angle. The latter actually may account for the greater portion of the gain obtained by some simple 10-meter arrays. The gain that can be credited to the increased horizontal directivity is never more than 4 or 5 db at most, with the simpler arrays. At 40 and 80 meters, this effect is not so pronounced, most of the gain from an array at these frequencies resulting from the increased horizontal directivity.

Long Wire Radiators

Harmonically operated antennas radiate better in certain directions than others, but cannot be considered as having appreciable directivity unless several half wavelengths long. The current in adjoining half-wave elements flows in opposite directions at any instant, and thus, the radiation from the various elements adds in certain directions and neutralizes in others.

A half-wave doublet in free space has a "doughnut" of radiation surrounding it. A full wave has 2; 3 half waves 3; and so on. When the radiator is made more than 4 half wavelengths long, the *end* lobes (cones of radiation) begin to show noticeable power gain over a half-wave doublet, while the broadside lobes get smaller and smaller in amplitude, even though numerous.

The horizontal radiation pattern of such antennas depends upon the vertical angle of radiation being considered. If the wire is more than 4 wavelengths long, the maximum radiation at vertical angles of 15° to 20° (useful for dx) is in line with the wire, being slightly greater a few degrees either side of the wire than directly off the ends. The directivity of the main lobes of radiation is not particularly sharp, and the minor lobes fill in between the main lobes to permit work-

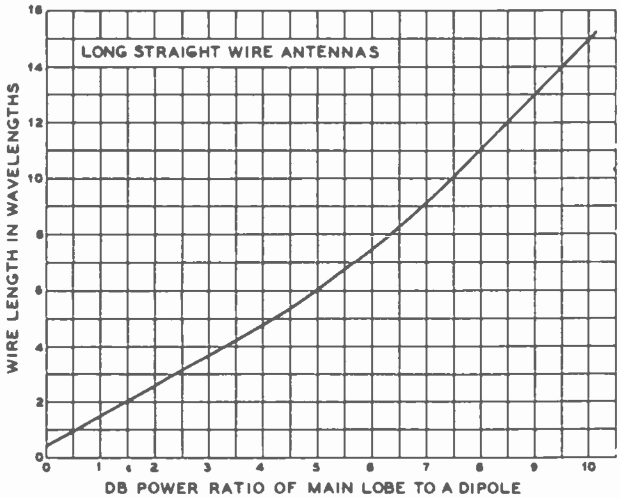


Figure 5.
DIRECTIVE GAIN OF LONG-WIRE ANTENNAS.

ing stations in nearly all directions, though the power radiated broadside to the radiator will not be great if the radiator is more than a few half wavelengths long. The directive gain of long-wire antennas, in terms of the wire length in wavelengths is given in figure 5.

To maintain the out-of-phase condition in adjoining half-wave elements throughout the length of the radiator, it is necessary that a harmonic antenna be fed either at *one end* or at a *current loop*. If fed at a voltage loop, the adjacent sections will be fed *in* phase, and a different radiation pattern will result.

The V Antenna

If two long-wire antennas are built in the form of a V, it is possible to make two of the maximum lobes of one leg shoot in the same direction as two of the maximum lobes of the other leg of the V. The resulting antenna is bidirectional (two opposite directions) for the main lobes of radiation. Each side of the V can be made any odd or even multiple of quarter wavelengths, depending on the method of feeding the apex of the V. The complete system must be a multiple of half waves. If each leg is an even number of quarter waves long, the antenna must be voltage-fed at the apex; if an odd number of quarter waves long, current feed must be used.

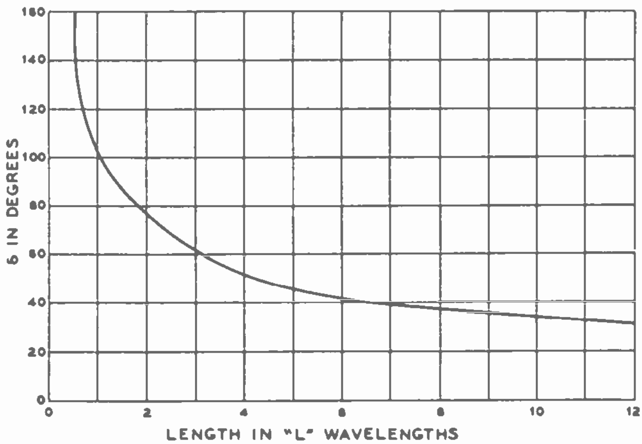
By choosing the proper apex angle, figure 6, the lobes of radiation from the two long-wire antennas aid each other to form a bidirectional beam. Each wire by itself would have a radiation pattern similar to that for antennas operated on harmonics. The reaction of one upon the other removes two of the four main lobes, and increases the other two in such a way as to form two lobes of still greater magnitude. The average directive gain of a "V" beam is given in terms of side lengths by figure 7.

The Rhombic Antenna

The terminated *rhombic* or *diamond* is probably the most effective directional antenna that is practical for amateur communication. This antenna is non-resonant, with the result that it can be used on three amateur bands, such as 10, 20 and 40 meters. When the antenna is non-resonant, i.e., properly terminated, the system is unidirectional, and the wire dimensions are not critical. The rhombic antenna can be suspended over irregular terrain without greatly affecting its practical operation.

When the feed end is terminated with a resistance of a value between 700 and 800 ohms the backwave is eliminated, the forward gain is increased, and the antenna can be used on several bands without changes. The terminating resistance should be capable of dissipating one-third the power output of the transmitter, and should have very little reactance. A bank of lamps can be connected in series-parallel for this purpose, or heavy duty carbon rod resistances can be used. For

Figure 6.
INCLUDED ANGLE FOR A "V" BEAM.
Given is the angle between the two legs of a "V" beam antenna in terms of the length of each leg. The included angle may be made somewhat less than given above when the leg length is less than 2 wavelengths.



medium or low power transmitters, the non-inductive *plaque* resistors will serve as a satisfactory termination. Several manufacturers offer special resistors suitable for terminating a rhombic antenna. The terminating device should, for technical reasons, present a small amount of inductive reactance at the point of termination. However, this should not be too great.

A compromise terminating device commonly used consists of a terminated 250-foot or longer length of line, made of resistance wire which *does not have too much resistance per unit length*. If the latter qualification is not met, the reactance of the line will be excessive. A 250-foot line consisting of no. 25 nichrome wire, spaced 6 inches and terminated with 800 ohms, will serve satisfactorily. Because of the attenuation of the line, the lumped resistance at the end of the line need dissipate but a few watts even when high power is used. A half-dozen 5000-ohm 2-watt carbon resistors in parallel will serve for all except very high power. The attenuating line may be folded back on itself to take up less room.

The determination of the best value of terminating resistors must be made while *transmitting*, as the input impedance of the average receiver is considerably lower than 800 ohms. This mismatch will *not* impair the *effectiveness* of the array on *reception*, but as a result, the value of resistor which gives the best directivity on reception will not give the most gain when transmitting. It is preferable to adjust the resistor for maximum gain when transmitting, even though there will be but little difference between the two conditions.

The input resistance of the rhombic which is reflected into the transmission line that feeds it is always somewhat less than the terminating resistance, and is around 700 to 750 ohms when the terminating resistor is 800 ohms.

The antenna should be fed with a non-resonant line having a characteristic impedance of 650 to 700 ohms. The four corners of the rhombic should be at least one-half wavelength above ground for the lowest frequency of operation. For three-band operation the proper tilt angle ϕ for the center band should be observed.

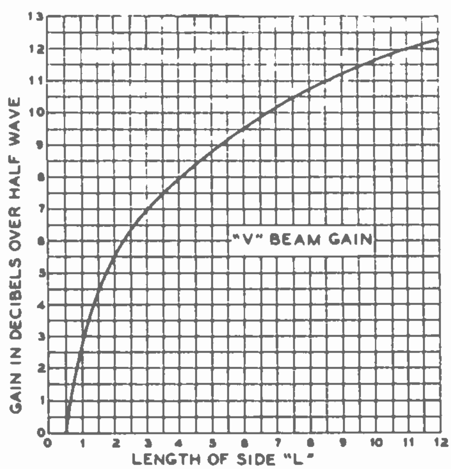


Figure 7.
DIRECTIVE GAIN OF "V" BEAM.

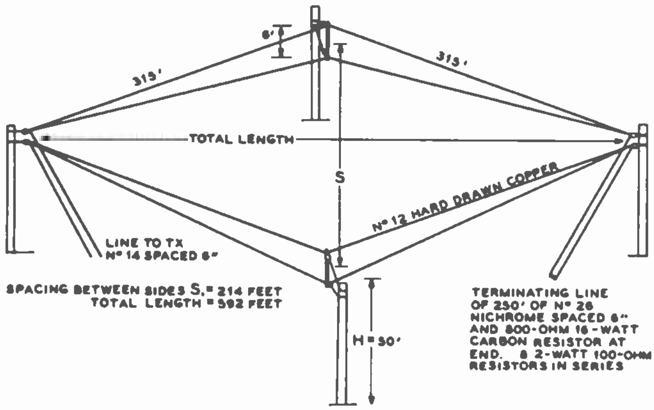


Figure 8.
RECOMMENDED AMATEUR-BAND RHOMBIC ANTENNA.
The system illustrated above may be used without change on the 7.0, 14, 21, and 28 Mc. amateur bands.

The rhombic antenna transmits a horizontally-polarized wave at a relatively low angle above the horizon. The angle of radiation (wave angle) decreases as the height above ground is increased in the same manner as with a dipole antenna. The rhombic should not be tilted in any plane whenever possible. In other words, the poles should all be of the same height and the plane of the antenna should be parallel with the ground.

A considerable amount of directivity is lost when the terminating resistor is left off the end and the system is operated as a resonant antenna. If it is desired to reverse the direction of the antenna it is much better practice to run transmission lines to both ends of the antenna, and then run the terminating line to the operating position. Then with the aid of two d-p-d-t switches it will be possible to connect either feeder to the antenna changeover switch and the other feeder to the terminating line, thus reversing the direction of the array and maintaining the same termination for either direction of operation.

Stacked-Dipole Arrays

The characteristics of a half-wave dipole already have been described. When another dipole is placed in the vicinity and excited either directly or parasitically, the resultant radiation pattern will depend upon the spacing and phase differential, as well as the relative magnitude of the currents. With spacings less than 0.65 wavelength, the radiation is mainly broadside to the 2 wires (bi-directional) when there is no phase difference, and *through* the wires (end fire) when the wires are 180° out of phase. With phase difference between 0° and 180° (45°, 90°, and 135° for instance), the pattern is unsymmetrical, the radiation being *greater in one direction* than in the opposite direction.

With spacings of more than 0.8 wavelength, more than two main lobes appear for all phasing combinations; hence, such spacings are seldom used.

With the dipoles driven so as to be in phase, the most effective spacing is between 0.5 and 0.7 wavelength. The latter provides greater gain, but minor lobes are present which do not appear at 0.5-wavelength spacing. The radiation is broadside to the plane of the wires, and the gain is slightly greater than can be obtained from two dipoles out of phase. The gain falls off rapidly for spacings less than 0.375 wavelength, and there is little point in using spacing of 0.25 wavelength or less with in-phase dipoles, except where it is desirable to increase the radiation resistance.

When the dipoles are fed 180° *out of phase*, the directivity is through the plane of the wires, and is greatest with *close spacing*, though there is but little difference in the pattern after the spacing is made less than 0.125 wavelength. The radiation resistance becomes so low for spacings of less than 0.1 wavelength that such spacings are not practicable.

In the three foregoing examples, most of the directivity provided is in a plane at a right angle to the two wires, though when out of phase, the directivity is in a line *through* the wires, and when in phase, the directivity is *broadside* to them. Thus, if the wires are oriented vertically, mostly horizontal directivity will be provided. If the wires are oriented horizontally, most of the directivity obtained will be *vertical* directivity.

To increase the sharpness of the directivity in all planes that include one of the wires, additional identical elements are added *in the line of the wires,* and fed so as to be in *phase.* The familiar H array (figure 10) is one array utilizing both types of directivity in the manner prescribed. The 2-section Kraus flat-top beam is another.

These two antennas in their various forms are directional in a horizontal plane, in addition to being low-angle radiators, and are perhaps the most practicable of the *bidirectional* stacked-dipole arrays for amateur use. More phased elements can be used to provide greater directivity in planes including one of the radiating elements. The H then becomes a Sterba curtain array.

For undirectional work the most practicable stacked-dipole arrays for amateur-band use are parasitically-excited systems using relatively close spacing between the reflectors and the directors. The next most practicable unidirectional array is an H or a Sterba curtain with a similar system placed approximately one-quarter wave behind. The added array may be directly fed by means of a section of line one-quarter wave in length, or it may be parasitically excited. The use of a reflector in conjunction with any type of stacked-dipole broadside array will increase the gain by approximately 3 db.

Colinear Arrays The simple colinear antenna array (figure 9) is a very effective radiating system for the 3.5-Mc. and 7.0-Mc. bands, but its use is not recommended on higher frequencies since such arrays do not possess any vertical directivity. The elevation radiation pattern for such an array is essentially the same as for a half-wave dipole. This consideration applies whether the elements are of normal length or are extended.

The colinear antenna consists of two or more radiating sections from 0.5 to 0.65 wavelength long, with the current in phase in each section. The necessary phase reversal between sections is obtained through the use of resonant tuning stubs as illustrated in figure 9. The gain of a colinear array using half-wave elements in decibels is approximately equal to the number of elements in the array. The exact figures are as follows:

Number of Elements	2	3	4	5	6
Gain in decibels	1.8	3.3	4.5	5.3	6.2

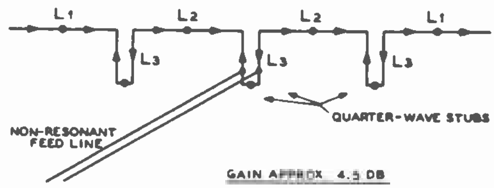


Figure 9.
FOUR-ELEMENT COLINEAR ANTENNA ARRAY.

As additional in-phase colinear elements are added to a doublet, the radiation resistance goes up much faster than when additional half waves are added out of phase (harmonic operated antenna).

For a colinear array of from 2 to 6 elements, the terminal radiation resistance in ohms at any current loop is approximately 100 times the number of elements.

It should be borne in mind that the *gain* from a colinear antenna depends upon the *sharpness* of the horizontal directivity since no vertical directivity is provided. An array with several colinear elements will give considerable gain, but will cover only a very limited arc.

Double Extended Zepp The gain of a conventional 2-element Franklin colinear antenna can be increased to a value approaching that obtained from a 3-element Franklin, simply by making the 2 radiating elements 230° long instead of 180° long. The phasing stub is shortened correspondingly to maintain the whole array in resonance. Thus, instead of having 0.5-wavelength elements and 0.25-wavelength stub, the elements are made 0.64 wavelength long and the stub approximately 0.18 wavelength long.

COLINEAR ANTENNA DESIGN CHART

FREQUENCY IN MC.	L_1	L_2	L_3
14.4	33'4"	34'3"	17'1"
14.2	33'8"	34'7"	17'3"
14.0	34'1"	35'	17'6"
7.3	65'10"	67'6"	33'9"
7.15	67'	68'8"	34'4"
7.0	68'5"	70'2"	35'1"
4.0	120'	123'	61'6"
3.9	123'	126'	63'
3.6	133'	136'5"	68'2"

The correct radiator dimensions for a 230° double zepp can be obtained from the *Colinear Antenna Design Chart* simply by multiplying the L_1 values by 1.29. The length for L_3 must be determined experimentally for best results. It will be between 0.15 and 0.2 wavelength.

The *vertical* directivity of a colinear antenna having 230° elements is the same as for one having 180° elements. There is little advantage in using extended sections when the total length of the array is to be greater than about 1.5 wavelength overall since the gain of a colinear antenna is proportional to the overall length, whether the individual radiating elements are ¼ wave, ½ wave or ¾ wave in length.

Broadside Arrays

Colinear elements may be stacked above or below another string of colinear elements to produce what is commonly called a *broadside* array. Such an array, when horizontal elements are used, possesses vertical directivity in proportion to the number of broadsided sections which have been used. Since broadside arrays do have good vertical directivity their use is recommended on the 14-Mc. band and on those higher in frequency. One of the most popular of simple broadside arrays is the "Lazy H" array of figure 10. Horizontal colinear elements stacked two above two make up this antenna system which is highly recommended for amateur work on 10 and 20 meters when substantial gain without too much directivity is desired. It has high radiation resistance and a gain of approximately 5.5 db. The low radiation resistance results in low voltages and a broad resonance curve, which permits use of inexpensive insulators and enables the array to be used over a fairly wide range in frequency. For dimensions, see the stacked dipole design table.

The Sterba Curtain Vertical stacking may be applied to strings of colinear elements longer than 2 half waves. In such arrays, the end quarter wave of each string of radiators usually is bent in to meet a similar bent quarter wave from the opposite end radiator. This provides better balance and better coupling between the upper and lower elements when the array is current-fed. Arrays of this type are shown in figure 11, and are commonly known as Sterba curtains.

Correct length for the elements and stubs can be determined for any stacked dipole array from the *Stacked-Dipole Design Table.*

In sketches of 9, 10, and 11 the arrowheads represent the direction of current flow at any given instant. The dots on the radiators represent points of maximum current. All arrows should point in the same direction in each portion of the radiating sections of an antenna in order to provide a field in phase for broadside radiation. This condition is satisfied for the arrays illustrated in figure 11.

In the case of each of the arrays of figure 11, and also the "Lazy H" of figure 10, the array may be made unidirectional and the gain increased by 3 db if an exactly similar array is constructed and placed approximately ¼ wave behind the driven array. A screen or mesh of wires slightly greater in area than the antenna array may be used instead of an additional array as a reflector to obtain a unidirectional system. The spacing between the reflecting wires may vary from 0.05 to 0.1 wavelength with the spacing between the reflecting wires made smallest directly behind the driven elements. The wires in the untuned reflecting system should be parallel to the radiating elements of the array, and the spac-

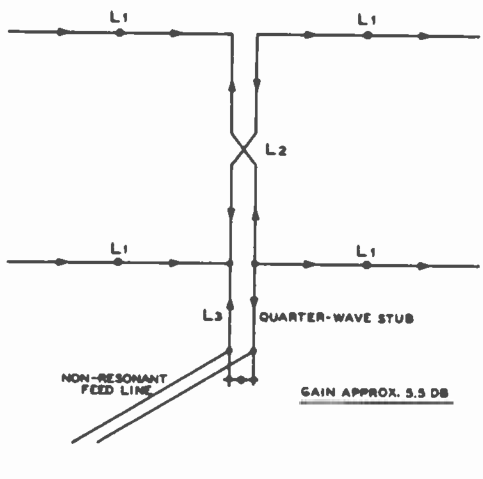


Figure 10.

THE "LAZY H" ANTENNA ARRAY.

Both horizontal and vertical directivity is obtained by stacking the colinear elements. The array as shown will be bi-directional and will exhibit a gain of about 5.5 db. By adding a reflector constructed the same as the antenna the gain may be increased to about 9 db.

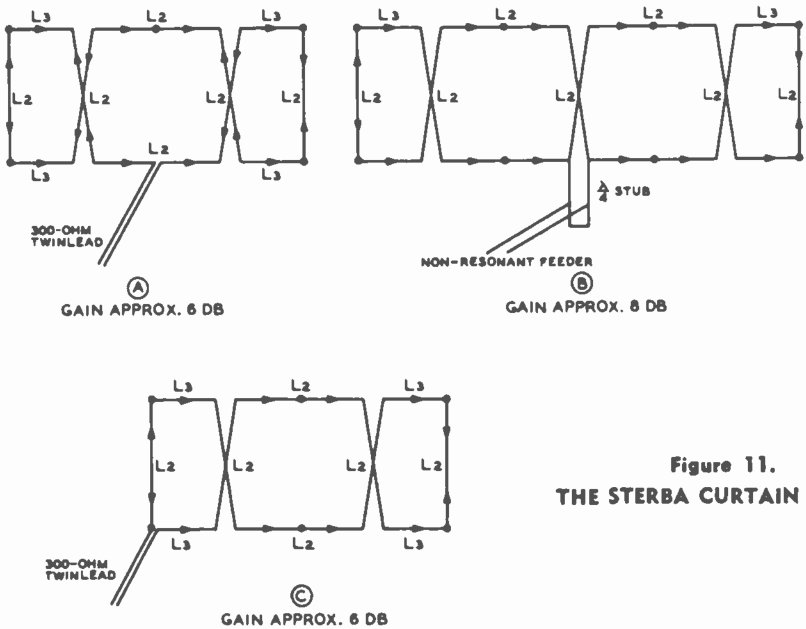


Figure 11.
THE STERBA CURTAIN ARRAY.

ing of the complete reflector system should be approximately 0.2 to 0.25 wavelength behind the driven elements.

End-Fire Directivity

By spacing 2 half-wave dipoles, or colinear arrays, at a distance of from 0.1 to 0.25 wavelength and driving the two 180° out of phase, directivity is obtained *through the* 2 *wires* at right angles to them. Hence, this type of bidirectional array is called *end fire.*

Remember that *end-fire* refers to the radiation with *respect to the* 2 *wires* in the array rather than with respect to the array as a whole.

The vertical directivity of an end-fire bidirectional array which is oriented horizontally can be increased by placing a similar end-fire array a half wave below it, and excited in the same phase. Such an array is a combination broadside and end-fire affair. However, most arrays are made either broadside *or* end-fire, rather than a combination of both, though the latter are satisfactory if designed properly.

Unidirectional End-Fire Arrays A simple undirectional end-fire array is illustrated in figure 12. If such an array is made 2 wavelengths long its gain will be approximately 8.5 db; if it is made 3 wavelengths long its gain will be about 10 db. Such arrays are convenient when it is desired to construct a high-gain array to radiate in a line between two poles. A shorter version may also be installed on a rotating structure.

Kraus Flat-Top Beam A very effective bidirectional end-fire array is the Kraus *Flat-Top Beam.* Essentially, this antenna consists of two close-spaced dipoles or colinear arrays. Because of the close spacing, it is possible to obtain the proper phase relationships in multi-section flat tops by crossing the wires at the voltage loops, rather than by resorting to phasing stubs. This greatly simplifies the array. (See figure 13.) Any number of sections may be used, though the 1- and 2-section arrangements are the most popular. Little extra gain is obtained by using more than 4 sections, and trouble from phase shift may appear.

A center-fed single-section flat-top beam cut according to the table, can be used quite successfully on its second harmonic, the pattern being similar except that it is a little sharper. The single-section array can also be used on its fourth harmonic with some success, though there then will be four cloverleaf lobes, much the same as with a full-wave antenna.

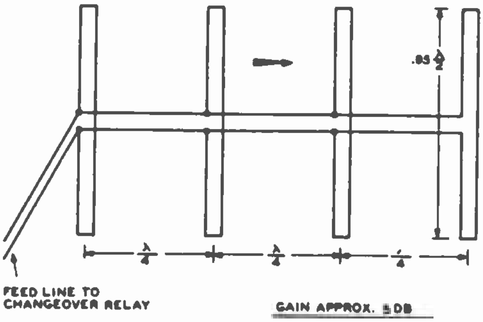


Figure 12.
SIMPLE END-FIRE ANTENNA ARRAY.

If a flat-top beam is to be used on more than one band, tuned feeders are necessary.

The radiation resistance of a flat-top beam is rather low, especially when only one section is used. This means that the voltage will be high at the voltage loops. For this reason, especially good insulators should be used for best results in wet weather.

The exact lengths for the radiating elements are not especially critical, because slight deviations from the correct lengths can be compensated for in the stub or tuned feeders. Suitable radiator lengths and approximate stub dimensions are given in the accompanying design table.

Figure 13 shows *top views* of 8 types of flat-top beam antennas. The dimensions for using these antennas on different bands are given in the design table. The 7- and 28-Mc. bands are divided into two parts, but the dimensions for either the low- or high-frequency ends of these bands will be satisfactory for use over the entire band.

In any case, the antennas are tuned to the frequency used, by adjusting the shorting wire on the stub, or tuning the feeders, if no stub is used. The data in the table may be extended to other bands or frequencies by applying the proper factor. Thus, for 50 to 52 Mc. operation, the values for 28 to 29 Mc. are divided by 1.8.

All of the antennas have a bi-directional horizontal pattern on their fundamental frequency. The maximum signal is broadside to the flat top. The single-section type has this pattern on both its fundamental frequency and second harmonic. The other types have 4 main lobes of radiation on the second and higher harmonics. The nominal gains of the different types over a half-wave comparison antenna are as follows: single-section, 4 db; 2-section, 6 db; 3-section, 7 db; 4-section, 8 db.

The maximum spacings given make the beams less critical in their adjustments. Up to one-quarter wave spacing may be used on the fundamental for the 1-section types and also the 2-section center-fed, but it is not desirable to use more than 0.15 wavelength spacing for the other types.

Although the center-fed type of flat-top generally is to be preferred because of its symmetry, the end-fed type often is convenient or desirable. For example, when a flat-top beam is used vertically, feeding from the lower end is in most cases more convenient.

If a multisection flat-top array is end-fed instead of center-fed, and tuned feeders are used, stations off the ends of the array can be worked by tying the feeders together and working the whole affair, feeders and all, as a long-wire harmonic antenna. A single-pole double-throw switch can be used for changing the feeders and directivity.

The Corner-Reflector Antenna The corner-reflector antenna is a particularly good directional radiator for the v-h-f and u-h-f region. The antenna may be used with the radiating element vertical, in which case the directivity is in the horizontal or azimuth plane, or the system may be used with the driven element horizontal in which case the radiation is hori-

STACKED DIPOLE DESIGN TABLE

FREQUENCY IN MC.	L_1	L_2	L_3
7.0	68'2"	70'	35'
7.3	65'10"	67'6"	33'9"
14.0	34'1"	35'.	17'6"
14.2	33'8"	34'7"	17'3"
14.4	34'4"	34'2"	17'
21.0	22'9"	23'3"	11'8"
21.5	22'3"	22'9"	11'5"
27.3	17'7"	17'10"	8'11"
28.0	17'	17'7"	8'9"
29.0	16'6"	17'	8'6"
50.0	9'7"	9'10"	4'11"
52.0	9'3"	9'5"	4'8"
54.0	8'10"	9'1"	4'6"
144.0	39.8"	40.5"	20.3"
146.0	39"	40"	20"
148.0	38.4"	39.5"	19.8"

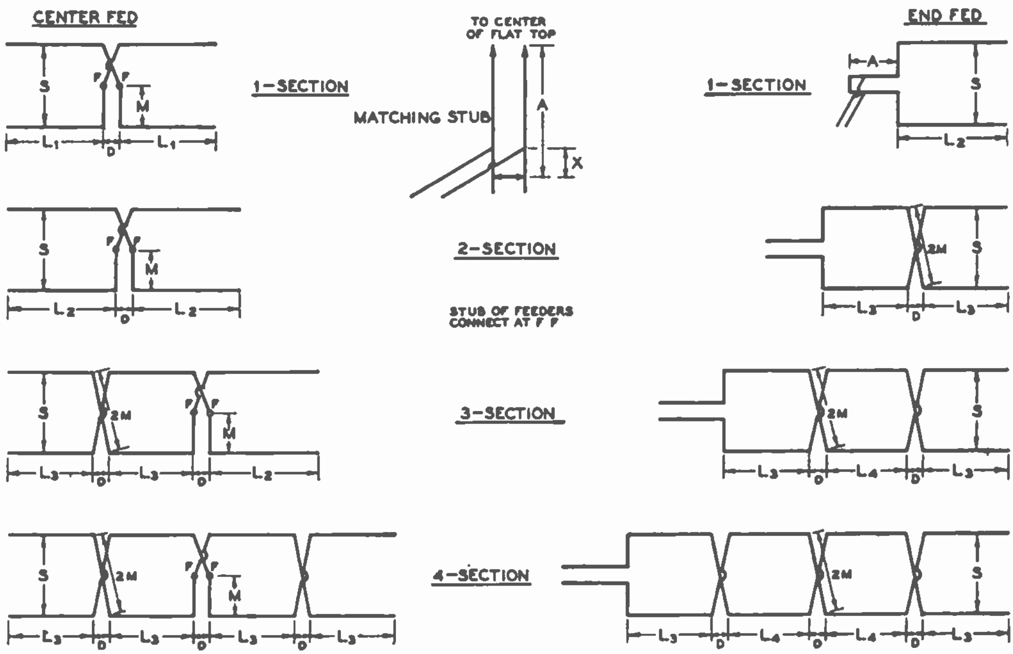


Figure 13

FLAT-TOP BEAM DESIGN DATA.

FREQUENCY	Spac-ing	S	L_1	L_2	L_3	L_4	M	D	A(¼) approx.	A(½) approx.	A(¾) approx.	X approx.
7.0-7.2 Mc.	λ/8	17′4″	34′	60′	52′8″	44′	8′10″	4′	26′	60′	96′	4′
7.2-7.3	λ/8	17′0″	33′6″	59′	51′8″	43′1″	8′8″	4′	26′	59′	94′	4′
14.0-14.4	λ/8	8′8″	17′	30′	26′4″	22′	4′5″	2′	13′	30′	48′	2′
14.0-14.4	.15λ	10′5″	17′	30′	25′3″	20′	5′4″	2′	12′	29′	47′	2′
14.0-14.4	.20λ	13′11″	17′	30′	22′10″	....	7′2″	2′	10′	27′	45′	3′
14.0-14.4	λ/4	17′4″	17′	30′	20′8″	....	8′10″	2′	8′	25′	43′	4′
28.0-29.0	.15λ	5′2″	8′6″	15′	12′7″	10′	2′8″	1′6″	7′	15′	24′	1′
28.0-29.0	λ/4	8′8″	8′6″	15′	10′4″	....	4′5″	1′6″	5′	13′	22′	2′
29.0-30.0	.15λ	5′0″	8′3″	14′6″	12′2″	9′8″	2′7″	1′6″	7′	15′	23′	1′
29.0-30.0	λ/4	8′4″	8′3″	14′6″	10′0″	....	4′4″	1′6″	5′	13′	21′	2′

Dimension chart for flat-top beam antennas. The meanings of the symbols are as follows:

L_1, L_2, L_3 and L_4, the lengths of the sides of the flat-top sections as shown in Figure 13. L_1 is length of the sides of single-section center-fed, L_2 single-section end-fed and 2-section center-fed, L_3 4-section center-fed and end-sections of 4-section end-fed, and L_4 middle sections of 4-section end-fed.

S, the spacing between the flat-top wires.

M, the wire length from the outside to the center of each cross-over.

D, the spacing lengthwise between sections.

A (¼), the approximate length for a quarter-wave stub.

A (½), the approximate length for a half-wave stub.

A (¾), the approximate length for a three-quarter wave stub.

X, the approximate distance above the shorting wire of the stub for the connection of a 600-ohm line. This distance, as given in the table, is approximately correct only for 2-section flat-tops. For single-section types it will be smaller and for 3- and 4-section types it will be larger.

The lengths given for a half-wave stub are applicable only to single-section center-fed flat-tops. To be certain of sufficient stub length, it is advisable to make the stub a foot or so longer than shown in the table, especially with the end-fed types. The lengths, A, are measured from the point where the stub connects to the flat-top.

Both the center and end-fed types may be used horizontally. However, where a vertical antenna is desired, the flat-tops can be turned on end. In this case, the end-fed types may be more convenient, feeding from the lower end.

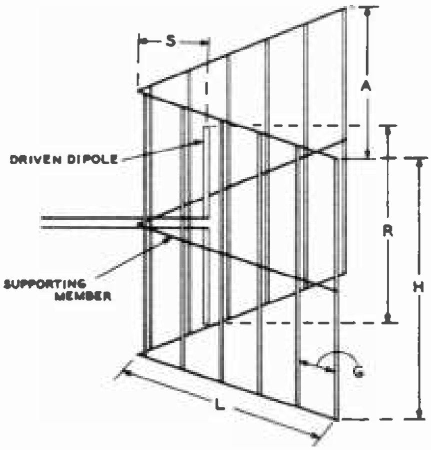


Figure 14.
CORNER-REFLECTOR ANTENNA CONSTRUCTION.

zontally polarized and most of the directivity is in the vertical plane. With the antenna used as a horizontally polarized radiating system the array is a very good low-angle beam array although the nose of the horizontal pattern is still quite broad. When the radiator is oriented vertically the corner reflector operates very satisfactorily as a direction-finding antenna.

Design data for the corner-reflector antenna is given in the chart *Corner-Reflector Design Data.* The planes which make up the reflecting corner may be made up of solid sheets of copper or aluminum for the u-h-f bands, although spaced wires with the ends soldered together at top and bottom may be used as the reflector on the lower frequencies. Copper screen may also be used for the reflecting planes.

The values of spacing given in the corner-reflector chart have been chosen such that the center impedance of the driven element would be approximately 70 ohms. This means that a quarter-wave matching transformer such as a "Q" section may be used to provide an impedance match between the center-impedance of the element and a 460-ohm line constructed of no. 12 wire spaced 2 inches.

It is possible to increase the directive gain of a corner-reflector antenna system by installing a colinear array at the focus of the corner in place of the driven dipole. The dimension H must of course be increased proportionately due to the greater radiator length.

Undirectional Parasitic End-Fire Arrays

"THREE-ELEMENT ROTARY" TYPE

If a single parasitic element is placed adjacent to a driven dipole at a distance of from 0.1 to 0.25 wavelength the parasitic element can be tuned to make the array unidirectional.

Two-Element Array The optimum spacing for a reflector in a two-element array is approximately 0.15 wavelength and with optimum adjustment of the length of the reflector a gain of approximately 5 db will be obtained. With this adjustment for maximum forward gain (the reflector length will be approximately equal to 492/(Freq. in Mc.) feet) the radiation resistance of the driven dipole will be approximately 25 ohms.

If the parasitic element is to be used as a director the optimum spacing between it and the driven element is 0.1 wavelength. The director will be found to be approximately 0.90 x 492/(Freq. in Mc.) (somewhat shorter than the driven element) and the gain will theoretically be slightly greater than with the optimum adjustment for a reflector but the radiation resistance will be in the vicinity of 15 ohms.

In both the case of the director and the reflector in a two-element array the point of adjustment for maximum forward gain will be found to be somewhat different from that for maximum front-to-back ratio. The two adjustments are quite close together and either one may be chosen, depending upon the operating conditions desired. A sacrifice of approximately 1.0 db in forward gain is involved when the two-element array is adjusted for maximum front-to-back ratio.

Three Elements and More The use of two parasitic elements instead of one adds little to the mechanical difficulties of rotation, and the gain and discrimination (especially the latter) are considerably improved over that obtained with a single director or a single reflector instead of a combination of both. The three-element array using a close-spaced director, driven element, and close-spaced reflector will exhibit as much as 30 db front-to-back ratio and 20 db front-to-side ratio for *low angle radiation.* The theoretical gain is approximately 7 db over a dipole in free space. In actual practice,

CORNER-REFLECTOR DESIGN DATA

Corner Angle	Freq. Band, Mc.	R	S	H	A	L	G	Feed Imped.	Approx. Gain, db
90	50	110"	82"	140"	200"	230"	18"	72	10
60	50	110"	115"	140"	230"	230"	18"	70	12
60	144	38"	40"	48"	100"	100"	5"	70	12
60	220	24.5"	25"	30"	72"	72"	3"	70	12
60	420	13"	14"	18"	36"	36"	screen	70	12

NOTE: Refer to figure 14 for construction of corner-reflector antenna.

the array will often show 10 db or more gain over a horizontal dipole placed the same height above ground (at 28 and 14 Mc.).

The use of more than three elements is desirable when the length of supporting structure is such that spacings of approximately 0.2 wavelength between elements becomes possible. Four-element arrays are quite common on the 28-Mc. and 50-Mc. bands, and five elements are sometimes used for increased gain and discrimination. As the number of elements is increased the gain and front-to-back ratio increases but the radiation resistance decreases and the bandwidth or frequency range over which the antenna will operate without reduction in effectiveness is decreased.

The gain of a properly adjusted four-element array is approximately 9 db over a dipole at the same height and the five-element system will show about 1 db additional gain over the four-element. The apparent gain, however, will be somewhat greater due to increased low-angle radiation.

Supporting Boom Construction The supporting boom may be of wood or metal, and if of metal it may be bolted directly to the parasitic elements without altering the electrical characteristics of the array. It is necessary that the boom be sufficiently rigid to hold the elements in the same plane and that it be strong enough to withstand the wind loading likely to be encountered in the area.

The simplest type of boom for those persons in the vicinity of a large metals supply house is a length of large diameter 24ST aluminum tubing, or a length of rectangular aluminum extrusion. The corners of these rectangular sections of tubing are rounded, but the sides are flat, making it a relatively simple matter to align and drill the holes for insertion of the elements.

For those who prefer wood construction, a standard straight-side ladder may be used as the supporting boom. Or a fabricated structure such as is shown in figures 20, 22, and 26 of this chapter may be employed for the supporting boom.

Material for Elements While the elements may consist of wire supported on a wood framework, self-supporting elements of tubing are much to be preferred. The latter type array is easier to construct, looks better, is no more expensive, and avoids the problem of getting sufficiently good insulation at the ends of the elements. The voltages reach such high values towards the ends of the elements that losses will be excessive, unless the insulation is excellent.

The elements may be fabricated in thin-walled steel conduit, or hard drawn thin-walled copper tubing, but dural tubing is much better. Or, if you prefer, you may purchase tapered copper-plated steel tubing elements designed especially for the purpose. Kits are available complete with rotating mechanism and direction indicator, for those who desire to purchase the whole assembly in a ready-to-install condition.

Element Spacing and Length The optimum spacing for a two-element array is, as has been mentioned before, approximately 0.1 wavelength for a director and 0.15 wavelength for a reflector. However, when both a director and a reflector are combined with the driven element to make up a three-element array the optimum spacing is approximately 0.2 wavelength between the driven element and either of the two parasitic elements. This same spacing is also satisfactory for arrays using more than three elements. Less spacing may be used but the bandwidth, gain, and radiation resistance will decrease.

The optimum length for the parasitic elements in a multi-element array becomes more critical as the spacing between the elements

UNIDIRECTIONAL PARASITIC END-FIRE ARRAYS								
ANTENNA TYPE	DRIVEN ELEMENT LENGTH	REFLECTOR LENGTH	FIRST DIRECTOR LENGTH	SECOND DIRECTOR LENGTH	THIRD DIRECTOR LENGTH	SPACING BETWEEN ELEMENTS	APPROX GAIN DB	APPROX. RAD. RES. OHMS
2-ELEMENT USING REFLECTOR	$\frac{462}{F_{MC.}}$	$\frac{480}{F_{MC.}}$	MAXIMUM GAIN			0.15	5.3	24
2-ELEMENT USING REFLECTOR	$\frac{462}{F_{MC.}}$	$\frac{495}{F_{MC.}}$	MAXIMUM FRONT-TO-BACK RATIO			0.15	4.3	30
2-ELEMENT USING DIRECTOR	$\frac{462}{F_{MC.}}$	—	$\frac{462}{F_{MC.}}$	MAXIMUM GAIN		0.1	5.5	14
2-ELEMENT USING DIRECTOR	$\frac{462}{F_{MC.}}$	—	$\frac{445}{F_{MC.}}$	MAXIMUM-FRONT-TO-BACK RATIO		0.1	4.8	20
3-ELEMENT 0.1 λ SPACING	$\frac{462}{F_{MC.}}$	$\frac{495}{F_{MC.}}$	$\frac{444}{F_{MC.}}$	—	—	0.1	7.0	5
3-ELEMENT 0.2 λ SPACING	$\frac{462}{F_{MC.}}$	$\frac{498}{F_{MC.}}$	$\frac{450}{F_{MC.}}$	—	—	0.2	9.0	18
3-ELEMENT 0.25 λ SPACING	$\frac{462}{F_{MC.}}$	$\frac{495}{F_{MC.}}$	$\frac{450}{F_{MC}}$	—	—	0.25	9.0	30
4-ELEMENT 0.2 λ SPACING	$\frac{462}{F_{MC.}}$	$\frac{490}{F_{MC.}}$	$\frac{442}{F_{MC.}}$	$\frac{438}{F_{MC.}}$	—	0.2	10.0	13
5-ELEMENT 0.2 λ SPACING	$\frac{462}{F_{MC.}}$	$\frac{490}{F_{MC.}}$	$\frac{442}{F_{MC.}}$	$\frac{438}{F_{MC.}}$	$\frac{434}{F_{MC.}}$	0.2	11.0	10

Figure 15.

DESIGN DATA FOR PARASITIC ANTENNA ARRAYS.

The values given for gain and effective radiation resistance are subject to considerable variation as a result of element tuning, but the values given are average. Dimensions are in feet.

is decreased. For 0.1 or 0.15 wavelength spacing the elements can best be adjusted to the optimum length, using 492/(Freq. in Mc.) for the reflector, 0.94 x 492/(Freq. in Mc.) for the driven element, and 0.90 x 492/(Freq. in Mc.) for the director as starting dimensions.

When the spacing between elements is made 0.2 wavelength, however, it is quite practicable merely to adjust the elements to length and install the antenna system. Further adjustment will add little to performance. A table of recommended dimensions for multi-element parasitic arrays is given in figure 15.

Feed Systems For Parasitic End-Fire Arrays The table of figure 15 gives, in addition to other information, the approximate radiation resistance referred to the center of the driven element of multi-element parasitic arrays. It is obvious, from these low values of radiation resistance, that especial care must be taken in materials used and in the construction of the elements of the array to insure that ohmic losses in the conductors will not be an appreciable percentage of the radiation resistance. It is also obvious that some method of impedance transformation must be used to match the low radiation resistance of these antenna arrays to the normal range of characteristic impedance used for antenna transmission lines.

A group of possible methods of impedance matching is shown in figures 16, 17, and 18. All these methods have been used but certain of them offer advantages over some of the other methods. Generally speaking it is not desirable to break the center of the driven element of an array for feeding the system. Breaking the driven element rules out the practicability of building an all-metal or "plumber's delight" type of array, and imposes mechanical limitations with any type of construction. However, when continuous rotation is desired, an arrangement such as shown in figure 18D, utilizing a broken driven element with a rotatable transformer for coupling from the antenna transmission line to the driven element has proven to be quite satisfactory. In fact the method shown in figure 18D is probably the most practicable method of feeding the driven element when continuous rotation of the antenna array is required.

The feed systems shown in figures 16 will, under normal conditions, show the lowest losses of any type of feed system since the currents flowing in the matching network are the lowest of all the systems commonly used. The "Folded Element" match shown in figure 16A and the "Yoke" match shown in figure 16B are the most satisfactory electrically of all standard feed methods. However, both methods require the extension of an additional conductor out to the end of the driven element as a portion of the matching system. The folded-element match is best on the 50-Mc. band and higher where the additional section of tubing may be supported below the main radiator element without undue difficulty. The yoke-match is more satisfactory mechanically on the 28-Mc. and 14-Mc. bands since it is only necessary to suspend a wire below the driven element proper. The wire may be spaced below or above the self-supporting element by means of several small strips of polystyrene which have been drilled for both the main element and the small wire and threaded on the main element. If the yoke is placed above the driven element it may be stressed to reduce sag in the element.

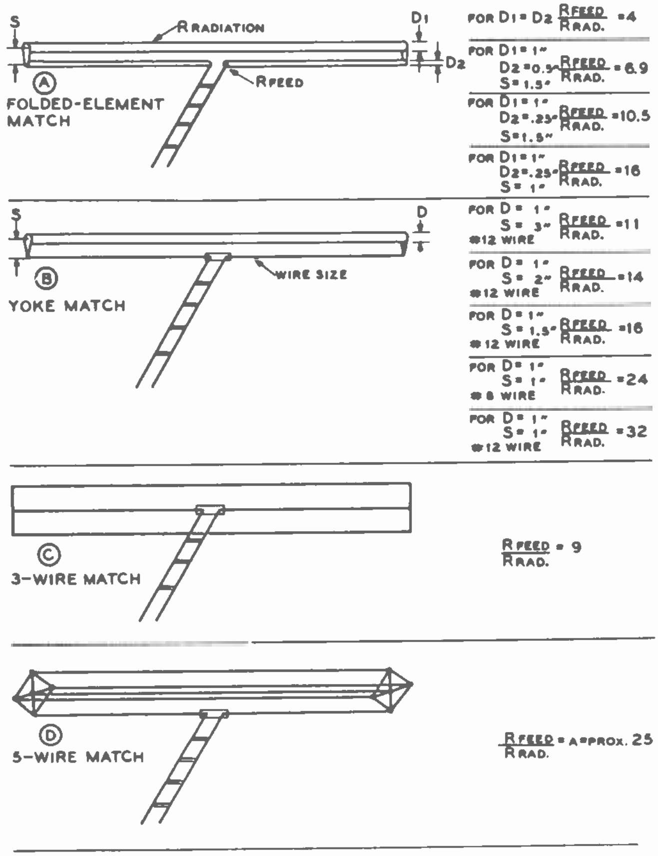


Figure 16.

DATA FOR FOLDED-ELEMENT MATCHING SYSTEMS.

In all normal applications of the data given the main element as shown is the driven element of a multi-element parasitic array. Directors and reflectors have not been shown for the sake of clarity.

The Folded-Element Match Calculations The calculation of the operating conditions of the folded-element matching system and the yoke match, as shown in figures 16A and 16B is relatively simple. A selected group of operating conditions have been shown on the drawing of figure 16. In applying the system it is only necessary to multiply the ratio of feed to radiation resistance (given in the figures to the right of the suggested operating dimensions in figure 16) by the radiation resistance of the antenna system to obtain the impedance of the cable to be used in feeding the array. Approximate values of radiation resistance for a number of commonly used parasitic-element arrays are given in figure 15.

As an example, suppose a 3-element array with 0.2 wavelength spacing between elements is to be fed by means of a 465-ohm line constructed of no. 12 wire spaced 2 inches. Figure 15 shows that the approximate radiation resistance of the antenna array will be 18 ohms. Hence we need a ratio of impedance step up of 26 to obtain a match between the characteristic impedance of the transmission line and the radiation resistance of the driven element of the antenna array. Inspection of the ratios given in figure 16 shows that the fourth set of dimensions given under figure 16B will give a 24-to-1 step up, which is sufficiently close. So it is merely necessary to use a 1-inch diameter driven element with a no. 8 wire spaced 1 inch centers (½ inch below the outside wall of the 1-inch tubing) below the 1-inch element. The no. 8 wire is broken and a 2-inch insulator placed in the center. The feed line then carries from this insulator down to the transmitter. The center insulator should be supported rigidly from the 1-inch tube so that the spacing between the piece of tubing and the no. 8 wire will be accurately maintained.

In many cases it will be desired to use the

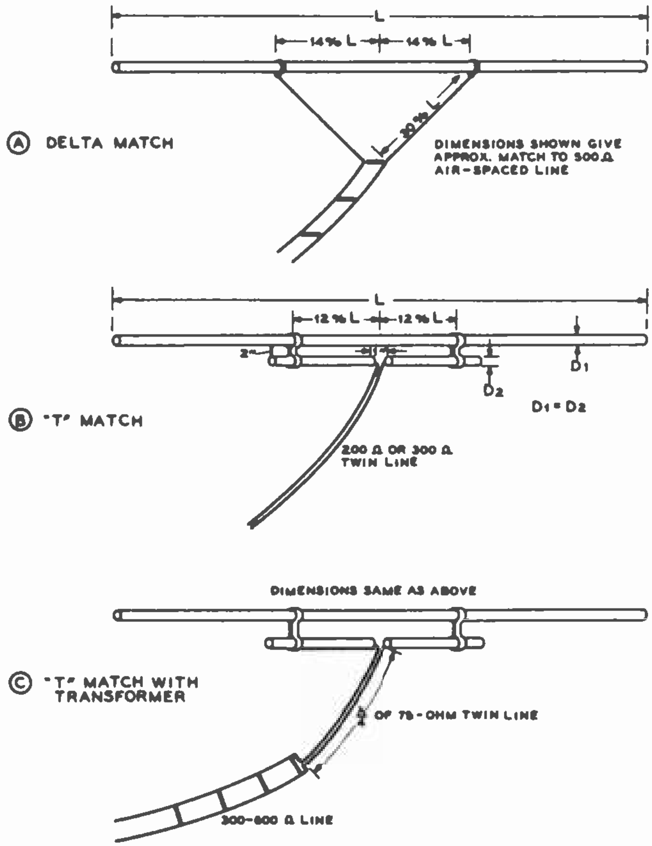


Figure 17.
AVERAGE DIMENSIONS FOR DELTA AND "T" MATCH.

folded-element or yoke matching system with different sizes of conductors or different spacings than those shown on figure 16. Note, then, that the impedance transformation ratio of these types of matching systems is dependent *both upon the ratio of conductor diameters* and *upon their spacing.* The following equation has been given by Roberts (*RCA Review,* June, 1947) for the determination of the impedance transformation when using different diameters in the two sections of a folded element:

$$\text{Transformation ratio} = \left(1 + \frac{Z_1}{Z_2}\right)^2$$

In this equation Z_1 is the characteristic impedance of a line made up of the smaller of the two conductor diameters spaced the center-to-center distance of the two conductors in the antenna, and Z_2 is the characteristic impedance of a line made up of two conductors the size of the larger of the two. This assumes that the feed line will be connected in series with the *smaller* of the two conductors so that an impedance step up of greater than four will be obtained. If an impedance step up of less than four is desired, the feed line is connected in series with the *larger* of the two conductors and Z_1 in the above equation becomes the impedance of a hypothetical line made up of the larger of the two conductors and Z_2 is made up of the smaller.

The conventional 3-wire match to give an impedance multiplication of 9 and the 5-wire match to give a ratio of approximately 25 are shown in figures 16C and 16D. The 4-wire match, not shown, will give an impedance transformation ratio of approximately 16. Both of these matching systems are commonly used.

Delta Match and "T" Match The delta match and the "T" match are shown in figure 17. Both these systems are widely used and can

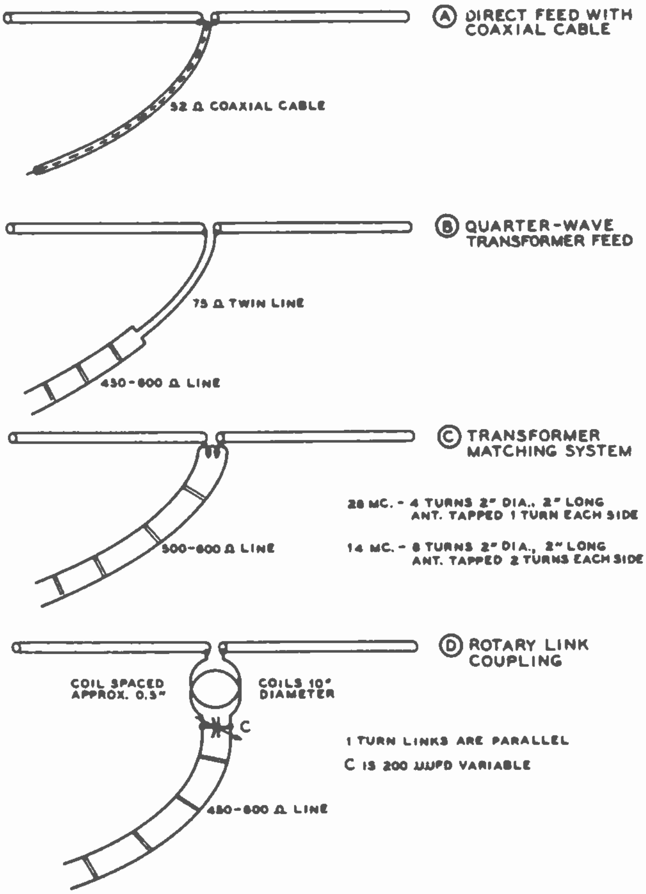


Figure 18.
FEED METHODS WHERE THE DRIVEN ELEMENT MAY BE BROKEN.

be adjusted to give a reasonable standing-wave ratio on 300 to 600 ohm feed line. In the case of all three of the systems shown it will be necessary to make adjustments in the tapping distance along the driven radiator until minimum standing waves on the antenna transmission line are obtained. Since it is sometimes impracticable to eliminate completely the standing waves from the antenna transmission line, it is common practice to cut the feed line, after standing waves have been reduced to a minimum, to a length which will give satisfactory loading of the transmitter over the desired frequency range of operation. If a low s-w-r can be obtained on the feed line, this line may be of any length.

In cases where it does not prove practicable to obtain a satisfactorily low standing wave ratio when using the "T" match to the driven element the arrangement shown at figure 17C has proven very helpful. In those cases where the standing-wave ratio cannot be reduced to a sufficiently low value it has been found that the impedance at the feed point in the "T" section is *lower* than that of the antenna transmission line. Hence the inclusion of a quarter-wave transformer between this feed point and the feed line will present a higher impedance to the antenna transmission line. In all cases when using polyethylene-filled line for a matching transformer, the length of the transformer should be *shorter* than ¼ wave. The physical length will be ¼ wave times the velocity factor of the cable or line being used.

Feed Systems Using a Driven Element with Center Feed Four methods of exciting the driven element of a parasitic array are shown in figure 18. The system shown at (A) has proven to be quite satisfactory in the case of an antenna-reflector two-element array or in the case of a three-element array with 0.2 to 0.25 wavelength spacing between the elements of the antenna system. The feed point impedance of the center of the driven element is close enough to the characteristic impedance of the 52-ohm coaxial cable so that the standing-wave ratio on the 52-ohm coaxial cable is of the order of 2-to-1. (B) shows an arrangement for feeding an array with a broken driven element from an open-wire line with the aid of a quarter-wave matching transformer. With 465-ohm line from the transmitter to the antenna this system will give a close match to a 12-ohm impedance at the center of the driven element. (C) shows an arrangement which uses an untuned transformer with lumped inductance for matching the transmission line to the center impedance of the driven element.

Rotary Link Coupling In many cases it is desirable to be able to allow the antenna array to rotate continuously without regard to snarling of the feed line. If this is to be done some sort of slip rings or rotary joint must be made in the feed line. One relatively simple method of allowing unrestrained rotation of the antenna is to use the method of rotary link coupling shown in figure 18D. The two coupling rings are 10 inches in diameter and are usually constructed of ¼-inch copper tubing supported one from the rotating structure and one from the fixed structure by means of standoff insulators. The capacitor C in figure 18D is adjusted, after the antenna has been tuned, for minimum standing-wave ratio on the antenna transmission line. The dimensions shown will allow operation with either a 14-Mc. or 28-Mc. array, with appropriate adjustment of the capacitor C. The rings must of course be parallel and must lie in a plane normal to the axis of rotation of the rotating structure.

Two-Wire Open Lines A two-wire open transmission line is easy to construct, and it is capable of the lowest loss per unit length of any of the types of transmission lines commonly used by amateurs. The two-wire open line is not recommended for use at frequencies above the amateur 220-Mc. band, since radiation from the feed line would be excessive above this frequency.

The characteristic impedance of any two-wire parallel-line system is approximately equal to:

$$Z_0 = 276 \log_{10} \frac{2S}{d}$$

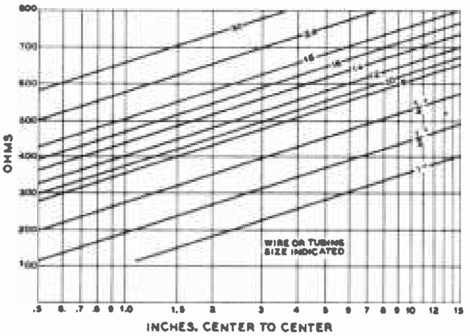


Figure 19.
CHARACTERISTIC IMPEDANCE OF TWO-WIRE OPEN LINES.

Where S is the exact distance between the centers of the conductors and d is the diameter of the wire measured in the same units as S. The equation is quite accurate so long as the wire spacing is relatively large compared to the wire diameter. Figure 19 gives in graphical form the characteristic impedance of most practicable two-wire open lines.

Stacked Array for 28 and 50 Mc.

Figure 20 shows the stacked 11-10 meter and 6-meter antenna array in use at W6FFF. The antenna system is an excellent example of the neat and lightweight structure which can result from careful overall planning of the entire structure. The system represents a very moderate cash outlay, yet gives excellent results over both frequency ranges.

The antenna structure is of the rotating-mast type, with coaxial. feed lines for both antennas being fed from the base of the structure to the driven elements of the arrays through the rotating mast. Constructional details on the rotating-mast structure are given in figure 18 on page 413 of the RADIO HANDBOOK, eleventh edition.

Construction details of the antenna system are given in figure 21. It may be seen that the 28-Mc. array is mounted to a short length of 1-inch galvanized iron pipe. Two angle-iron brackets are welded to this short length of pipe, and the boom for the antenna then is welded to the lengths of angle iron. This

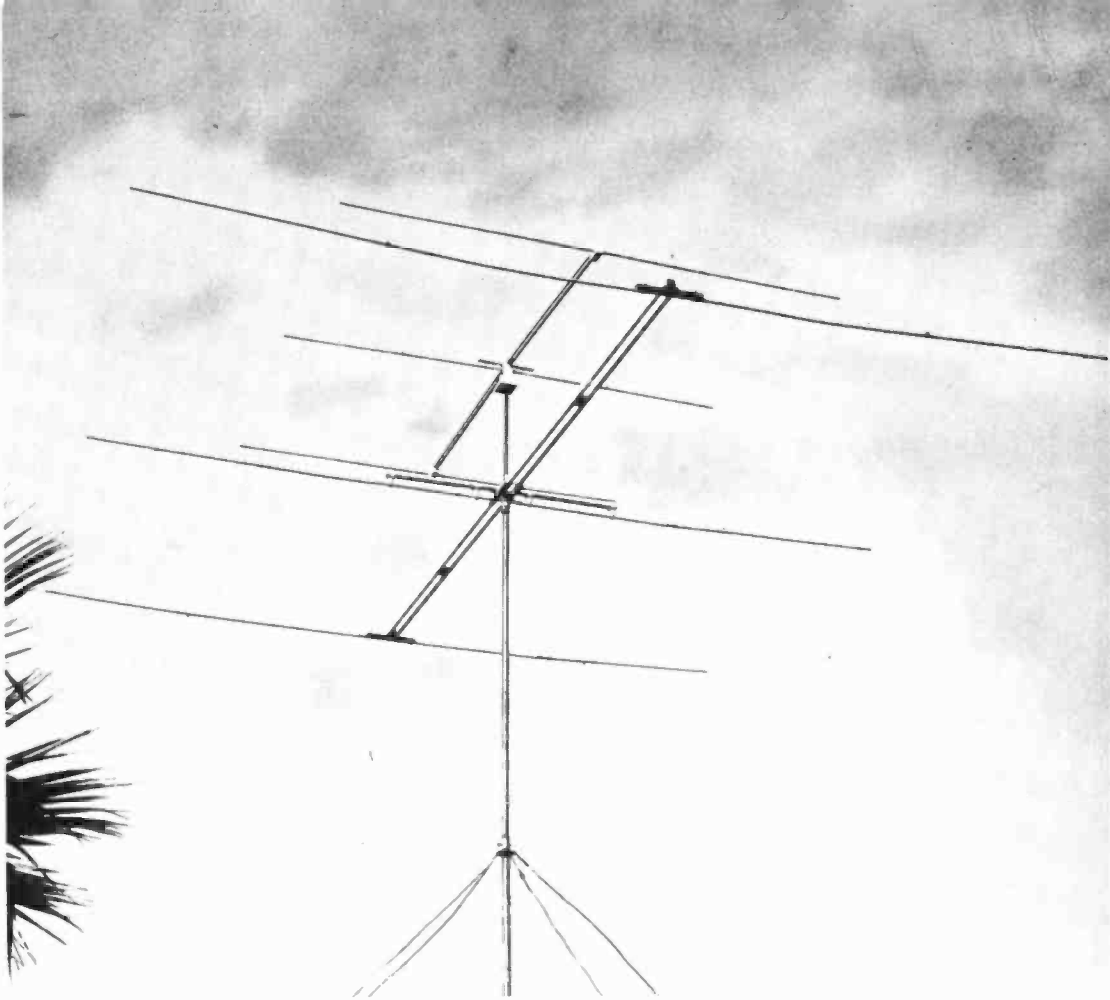


Figure 20.

LIGHTWEIGHT STACKED 28-MC. AND 50-MC. ANTENNA ARRAY.

Both antennas are supported by a lightweight rotating mast structure. The two coaxial feed lines for the antennas pass down the rotating support pipe to the operating position.

length of pipe then is joined to the main 1-inch support pipe, with lock nuts thoroughly tightened to keep the assembly from unscrewing with use or in a heavy wind. It was found most convenient to drill the angle irons to pass quarter-inch carriage bolts before the irons are welded to the short length of pipe.

All materials used in the antenna system are widely available, since standard plumbing supplies are used throughout. No machine work is required, and the welding may be done anywhere. If it is desired to install a 50-Mc. array atop the one for 28-Mc., the smaller array may be supported about 4 feet above the larger antenna by means of a length of ½-inch pipe. The ½-inch pipe is screwed to the stub of the 1-inch pipe projecting above the larger array by means of a standard 1-inch to ½-inch pipe reducer. If the smaller array is not to be used, a 1-inch pipe cap may be placed over the end of the 1-inch stub of pipe. All pipe joints should be treated with pipe compound to prevent rusting of the threads, and all lock nuts must be thoroughly tightened.

Construction of the Antennas The boom longerons were made from a single length of 1" by 4" selected stock in each case. After the length is selected for each boom at the lumber yard, have each

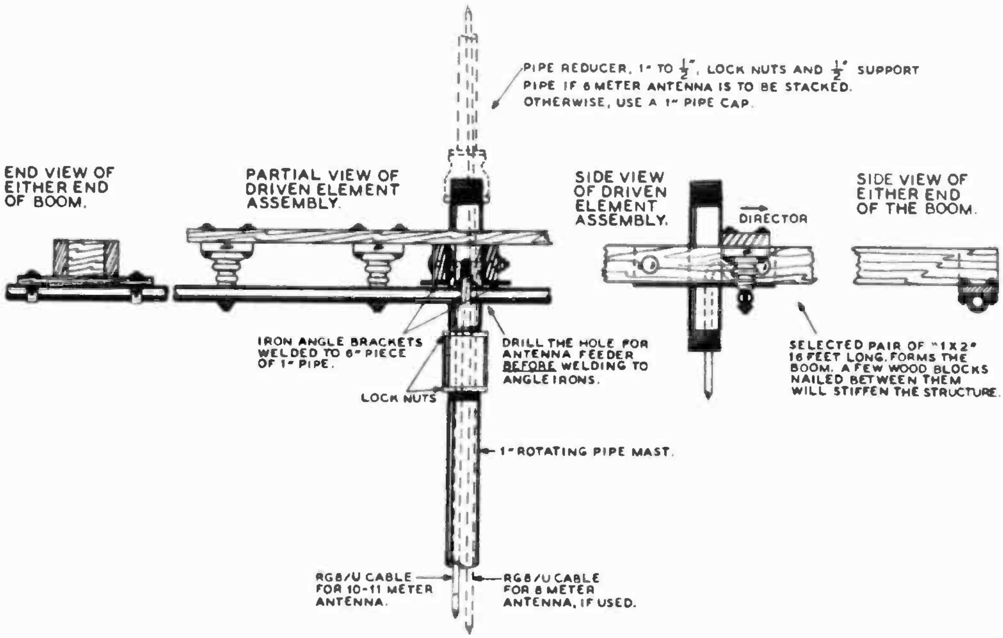


Figure 21.
CONSTRUCTIONAL DETAILS OF THE LIGHTWEIGHT ARRAY.

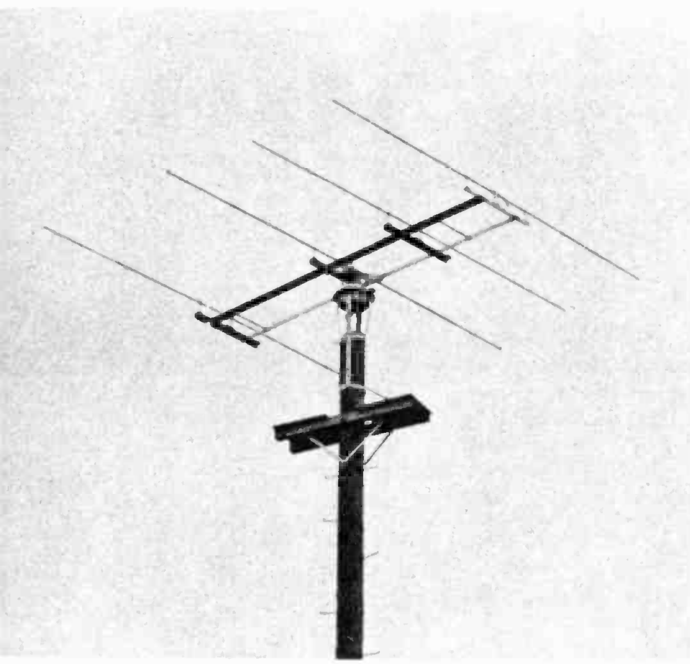


Figure 22.
FOUR-ELEMENT 28-MC. ROTATABLE ARRAY.

This antenna system (in use at W9EZN) uses a commercial rotator installed atop a standard power pole.

length ripped to make two matched 1" by 2" pieces. When the two pieces thus obtained are placed on edge it will probably be found that they have a slight curve, but the curve should be matched for both pieces. Place the two pieces so that the curve is in an upward direction at the ends. Then the weight of the parasitic elements will just about compensate for the initial droop in the boom. Strips of ½-inch oak flooring material will make good mountings at the ends of the boom for the parasitic elements.

The boom length in each case is equal to one-half wavelength. Stiffening blocks halfway out on each side are used on the 28-Mc. boom, while no stiffening blocks are required for the 50-Mc. array. With quarter-wave spacing of the parasitic elements as used in these antennas, the frequency response is quite broad. The lengths are cut to standard dimensions (RADIO HANDBOOK, eleventh edition, page 402, figure 2) at 50.5 Mc. for the 50-Mc. band and 28.2 Mc. for the 27-Mc. and 28-Mc. bands. (Driven element, 462/F; reflector, 495/F; and director, 450/F, with frequencies in megacycles and lengths in feet.) Satisfactory operation over the active portion of the 50-Mc. band, and over the entire 26.96 to 29.7 Mc. range is thus obtained, thanks to the relatively wide spacing of the parasitic elements.

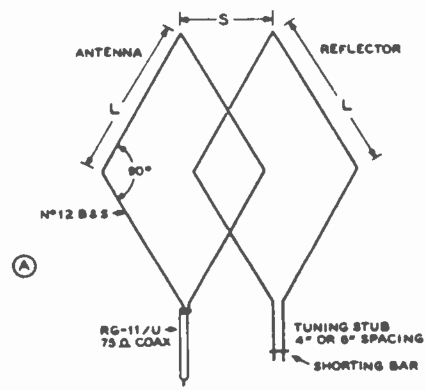
Experience has shown that the elements may be constructed of the relatively soft but easily available electrical conduit. The ten-foot lengths may be used as the center portions of the 28-Mc. elements, with the adjustable ends made of aluminum tubing of the next smaller size. Both antennas are quite light in weight. It is not difficult to install the 28-Mc. array atop the rotating pipe, after the pipe has been lowered as far as it will travel. Then the 50-Mc. array may be installed, and all the appropriate lock nuts tightened. The installation is essentially a one-man job, but some help may be needed to pull the coaxial feed lines down the pipe as the antennas are being lifted into place.

The driven element of both arrays is split in the center, with each half being supported by a pair of standoff insulators. The driven element then is fed directly by the 52-ohm RG-8/U coaxial line; the inner conductor is connected directly to one side of the radiator while the outer conductor of the coaxial line is connected to the other side. The feed-point impedance of such a three-element array is approximately 30 ohms, which gives a standing-wave ratio of less than 2 to 1 on the coaxial line.

THE CUBICAL QUAD

A highly popular array for the 10 and 20 meter amateur bands is the "cubical quad" antenna. Essentially the antenna is a "stretched out" folded dipole backed up by a reflector of the same configuration.

The theoretical gain, based upon conventional methods of gain calculation for directional arrays, is approximately 7 db over a matched, resonant half-wave dipole. However, various experimenters have reported measured gains on the order of 10 db, which compares favorably with a multi-element parasitic array of the 3- or 4-element beam type using dipole elements.



	L	S
14150 KC.	18' 9"	12'
21200 KC.	11' 3"	8' 8"
29000 KC.	8' 3"	6'
50000 KC.	4' 9"	3' 6"

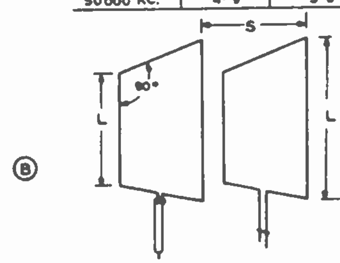


Figure 23.
THE CUBICAL QUAD ANTENNA.

This type of antenna offers a compromise between gain, bandwidth, and simplicity of construction for a rotary array on the amateur bands between 14 and 54 Mc. The array may be fed at low impedance either at an apex or in the center of a side.

One very satisfactory version of the cubical quad is shown schematically in figure 23. The supporting frame, of light wood, can take any of numerous suitable configurations, and the design will be left to the reader.

Optionally, the array can be rotated 90 degrees so that the "cube" is lying down instead of on edge. The feed line and tuning stub then are connected to the mid point of the two bottom elements. Little difference in operation will be noted.

Because the driven element is resonant and the feed point impedance is low, it is permissible to connect directly to the coaxial line without interposing a "line balance converter" such as a bazooka or a phase inverting section. Actual tests have shown that little if any improvement can be expected from the addition of such a device under these circumstances.

Some versions of the cubical quad use two or more turns for the driven element and two or more for the reflector. This is not required for the driven element when low impedance line is employed, and the use of more than one turn for the reflector actually is detrimental to the bandwidth characteristics of the antenna. The standing-wave ratio of the antenna shown in figure 23 will depend somewhat upon the tuning of the reflector and upon the height above ground, but will be low in any case.

The tuning stub is made from no. 12 bare copper wire, of a length approximately equal to one half the distance S. The position of the shorting bar is adjusted experimentally either for maximum gain, maximum front-to-back ratio, or a compromise between the two, as desired. After the adjustment is made, the extra length of tuning stub can be cut off if desired.

The useful band width of the array is determined primarily by the parasitic element. The antenna can be used over a frequency range of about plus or minus 150 kc. on the 14 Mc. band, and a correspondingly greater amount on the higher frequency bands, with little variation in performance.

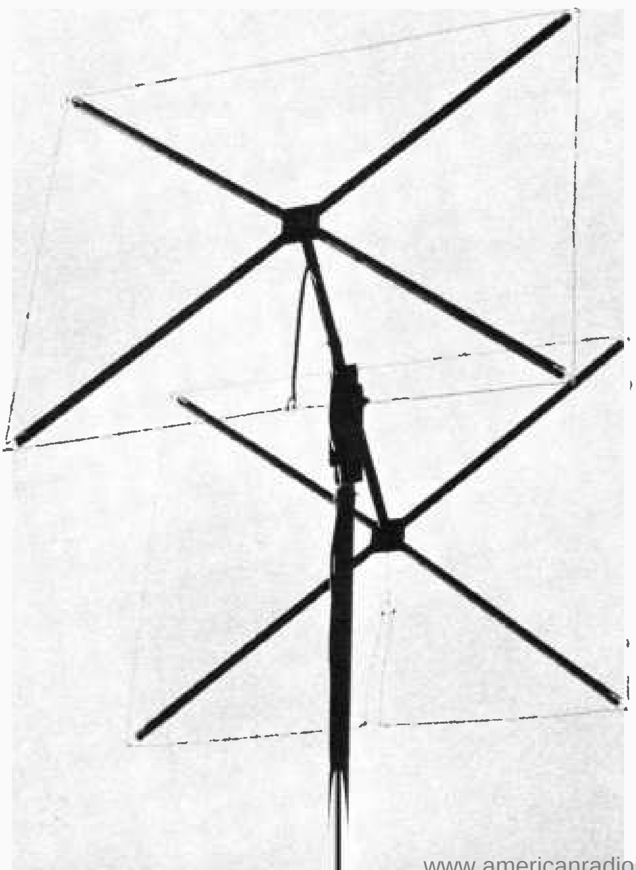


Figure 24.

A CUBICAL QUAD FOR THE 50-MC. BAND.

Dimensions as given in figure 23 were used in the construction of this antenna. Note the use of small plastic strips as insulators at the ends of each of the arms for supporting the loop of wire.

HELICAL BEAM ANTENNAS

Most v-h-f and u-h-f antennas are either vertically polarized or horizontally polarized (plane polarization). However, *circularly* polarized antennas have interesting characteristics which may be useful for certain applications. The installation of such an antenna can effectively solve the problem of horizontal vs. vertical polarization.

A circularly polarized wave has its energy divided equally between a vertically polarized component and a horizontally polarized component, the two being 90 degrees out of phase. The circularly polarized wave may be either "left handed" or "right handed," depending upon whether the vertically polarized component leads or lags the horizontal component.

A circularly polarized antenna will respond to any plane polarized wave whether horizontally polarized, vertically polarized, or diagonally polarized. Also, a circularly polarized wave can be received on a plane polarized antenna, regardless of the polarization of the latter. When using circularly polarized antennas at both ends of the circuit, however, both must be left handed or both must be right handed. This offers some interesting possibilities with regard to reduction of QRM. At the time of writing, there has been no standardization of the "twist" for general amateur work.

Perhaps the simplest antenna configuration for a directional beam antenna having circular polarization is the helical beam popularized by Dr. John Kraus, W8JK. The antenna consists simply of a helix working against a ground plane and fed with coaxial line. In the u-h-f and the upper v-h-f range the physical dimensions are sufficiently small to permit construction of a rotatable structure without much difficulty.

When the dimensions are optimized, the characteristics of the helical beam antenna are such as to qualify it as a "broad band" antenna. An optimized helical beam shows little variation in the pattern of the main lobe and a fairly uniform feed point impedance averaging approximately 125 ohms over a frequency range of as much as 1.7 to 1. The direction of "electrical twist" (right or left handed) depends upon the direction in which the helix is wound.

A six-turn helical beam is shown schematically in figure 25. The dimensions shown will give good performance over a frequency range of plus or minus 20 per cent of the design frequency. This means that the dimensions are not especially critical when the array is to be used at a single frequency or over a narrow band of frequencies, such as an amateur band. At the design frequency the beam width is about 50 degrees and the power gain about 12 db referred to a non-directional circularly polarized antenna.

The Ground Screen For the frequency range 100 to 500 Mc. a suitable ground screen can be made from "chicken wire" poultry netting of 1-inch mesh, fastened to a round or square frame of either metal or wood. The netting should be of the type that is galvanized *after* weaving. A small, sheet metal ground plate of diameter equal to approximately D/2 should be centered on the screen and soldered to it. Tin, galvanized iron, or sheet copper is suitable. The outer conductor of the RG-63/U (125 ohm) coax is connected to this plate, and the inner conductor contacts the helix through a hole in the center of the plate. The end of the coax should be taped with "Scotch" electrical tape to keep water out.

The Helix It should be noted that the beam proper consists of six full turns. The start of the helix is spaced a distance of S/2 from the ground screen,

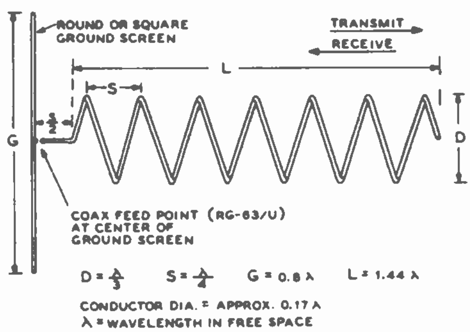


Figure 25.

THE "HELICAL BEAM" ANTENNA.

This type of directional antenna system gives excellent performance over a frequency range of 1.7 to 1.8 to 1. Its dimensions are such that it ordinarily is not practicable, however, for use as a rotatable array on frequencies below about 100 Mc. The center conductor of the feed line should pass through the ground screen for connection to the feed point. The outer conductor of the coaxial line should be grounded to the ground screen.

and the conductor goes directly from the center of the ground screen to the start of the helix.

Aluminum tubing in the "SO" (soft) grade is suitable for the helix. Alternatively, lengths of the relatively soft aluminum electrical conduit may be used. In the v-h-f range it will be necessary to support the helix on either two or four wooden longerons in order to achieve a sufficiently strong structure. The longerons should be of as small cross section as will provide sufficient rigidity, and should be given several coats of varnish. The ground plane butts against the longerons and the whole assembly is supported from the balance point if it is to be rotated.

Aluminum tubing in the larger diameters ordinarily is not readily available in lengths greater than 12 feet. In this case several lengths can be spliced by means of short telescoping sections and sheet metal screws.

The tubing is close wound on a drum and then spaced to give the specified pitch. Note that the length of one complete turn when spaced is somewhat greater than the circumference of a circle having the diameter D. However, it is useless anyhow to attempt to calculate how much to allow for the decrease in diameter when the turns are spaced because the tubing will spring to an unpredictably larger diameter when it is removed from the drum used as a winding form. The increase in diameter will depend upon the hardness, diameter, and wall thickness of the particular tubing used. It probably will be necessary to experiment with a single turn on drums of various diameters to find the diameter of winding form which will give the desired helix diameter when the turns are spaced to the proper pitch.

Broad-Band 144 to 225 Mc. Helical Beam A highly useful v-h-f helical beam which will receive signals with good gain over the complete frequency range from 144 through 225 Mc. may be constructed by using the following dimensions (180 Mc. design center):

D....................................22 in.
S................................16½ in.
G....................................53 in.
Tubing o.d. ....1 in.

The D and S dimensions are to the center of the tubing. These dimensions must be held rather closely, since the range from 144 through 225 Mc. represents just about the practical limit of coverage of this type of antenna system.

Figure 26.
A 3-ELEMENT ROTARY FOR 14 MC.
This antenna system (in use at W9EZN) uses a T-match for coupling from the open-wire feed line to the driven element. Note the use of strain guys and turnbuckles for strengthening and stabilizing the main boom.

High-Band TV Coverage Note that an array constructed with the above dimensions will give unusually good high-band TV reception in addition to covering the 144-Mc. and 220-Mc. amateur bands and the taxi and police services.

On the 144-Mc. band the beam width is approximately 60 degrees to the half-power points, while the power gain is approximately 11 db over a non-directional circularly polarized antenna. For high-band TV coverage the gain will be 12 to 14 db, with a beam width of about 50 degrees. And on the 220-Mc. amateur band the beam width will be about 40 degrees with a power gain of approximately 15 db.

The antenna system will receive vertically polarized or horizontally polarized signals with equal gain over its entire frequency range. Conversely, it will transmit signals over the same range, which then can be received with equal strength on either horizontally polarized or vertically polarized receiving antennas. The standing-wave ratio will be very low over the complete frequency range if RG-63/U coaxial feed line is used. If the beam is arranged for rotation, care should be taken not to flex this type of transmission line on too small a diameter.

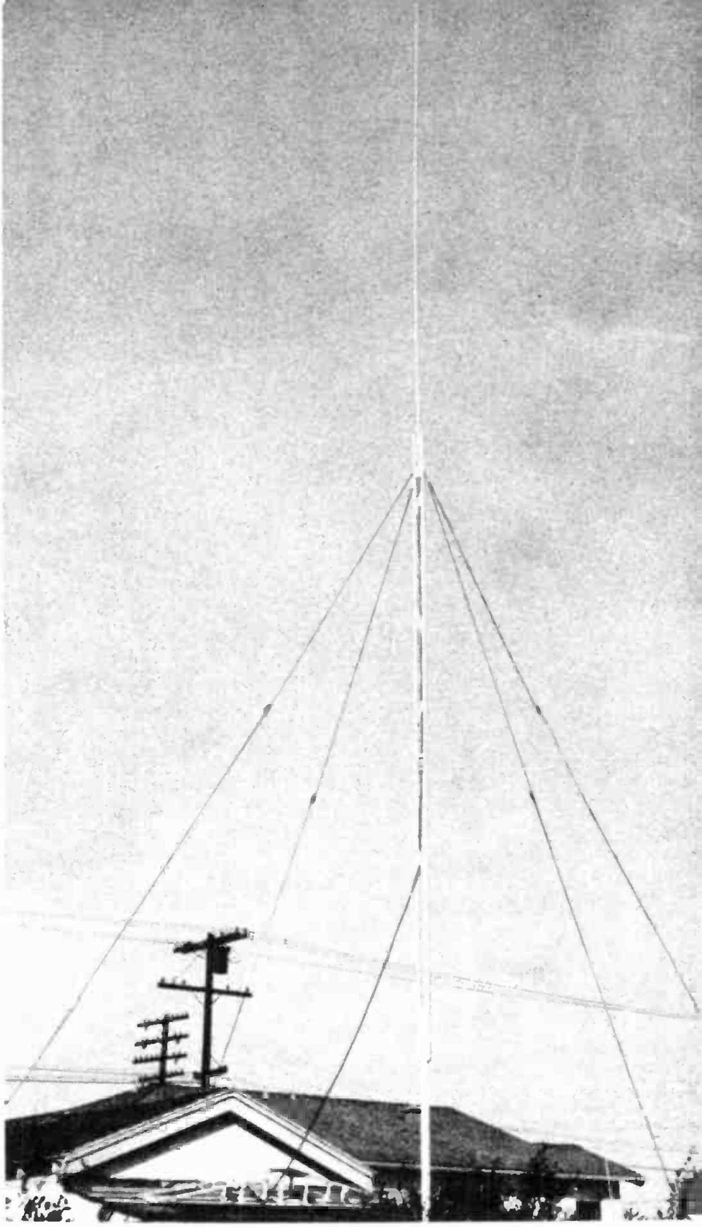


Figure 27.

THE "DROOPING GROUND PLANE" VERTICAL ANTENNA.

This vertically polarized antenna uses the four guy wires as a "drooping ground plane" for the vertical radiator. Note the use of two sets of insulators in the guy wires. One set is spaced 8½ feet from the metal collar about the mast; the guys between these insulators and the mast are used on the 28-Mc. band. The second set is spaced 8½ feet from the first set; when jumpers are placed across the first set of insulators the total length of the ground plane then becomes about 17 feet for operation on the 14-Mc. band. Additional sets of insulators may be placed at appropriate points in the guy wires for operation in conjunction with various vertical radiator rods on other amateur bands.

DUAL-BAND "DROOPING GROUND PLANE" ANTENNA.

Although the ground-plane vertical is not the ideal antenna by any standards, it still is a type of antenna system which can give excellent performance in terms of the amount of space required. It radiates a moderate amount of power at the extremely low angles of radiation which characterize dx propagation to certain portions of the world. Further, it is easy to install, particularly so when constructed as shown in figures 27 and 28, and is easily altered for operation on another frequency band.

The capability of easy alteration may be of advantage in the event that the 21-Mc. band is opened with little prior notice. The array shown in figure 27 may be lowered in just a few moments by loosening one of the guy wires, the vertical rod may be lengthened or shortened by adding or removing a section, and the placement of the insulators in the guy wires may be altered. However, if it is desired to make a quick change from a lower frequency to a higher frequency band, experience has shown that the guy-wire "ground plane" may be left at the full length for the lower frequency band. Thus when making a quick change from 20 to 10 the guy-wire ground plane may be left at its full 17-foot length. The standing-wave ratio on the coaxial feed line probably is increased somewhat, but the antenna system still operates satisfactorily.

Several other advantages of the ground-plane vertical as a standby antenna may be cited: Such an antenna will give a much improved range of reliable ground-wave communication with 10 and 11 meter mobile stations, as compared with the usual horizontally polarized rotary array. The vertical is a useful accessory to the rotary beam on the same band for obtaining a quick check on the direction from which the most satisfactory signals are arriving. A further application of the ground plane is as an additional antenna system for operation in diversity with the existing horizontally polarized antenna system; the fading characteristics of a signal received on a vertical antenna almost invariably will be sufficiently different from the fading of the same signal on a horizontal antenna so that diversity reception will allow the signal to be read solid a greater percentage of the time than on either of the antennas alone.

Construction of the Antenna System Select a straight 16-foot length of 1" by 4" which is free of knots and other imperfections. Have the piece ripped down the center to make a matched pair of nominal 1 by 2's. If there is a slight curvature the pieces may be assembled with the curves opposing so that the net result is a straight pole. If more height is desired, a 2 by 2 will fit nicely between the two legs at the bottom. The sections should be overlapped about one foot and bolts run through the three pieces. This has been done in the case of the antenna illustrated in figure 27.

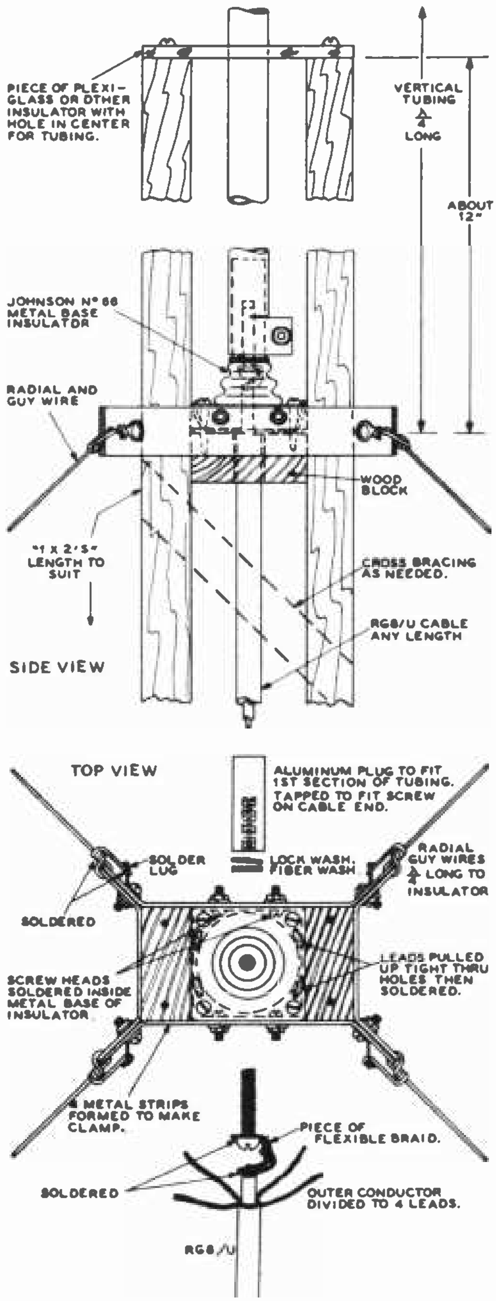


Figure 28.

CONSTRUCTIONAL DETAILS OF THE "DROOPING GROUND PLANE" VERTICAL.

Because the block under the insulator is small (about the same size as the insulator base) and has a hole through the center, it will have a tendency to split unless some close-grained wood such as oak is used. Undersize holes should be drilled before inserting the wood screws which hold the insulator base to the block. Two countersunk wood screws on each side are used to hold the block between the 1 by 2 uprights. The metal-strip clamp shown in figure 28 serves to make the whole assembly quite strong at this point.

A quarter wave of tubing at 14 Mc. has considerable wind resistance, which may cause small tubing to bend at the top of the pole. Hence it will be wise to run the piece of tubing inserted into the first section clear to the bottom. This procedure will in effect double the wall thickness at the bottom and serve to strengthen the structure. Of course a standard whip antenna, either of the sectional or drawn tapered type may be used for the self-supporting radiator portion of the antenna system in place of the sections of aluminum tubing.

When the antenna is to be used on several bands, install "egg" insulators at the appropriate positions in the guy-wire "radials." These then may be jumpered for the lower frequency bands, and only the first section used on the highest frequency band. Similarly, the first section of aluminum tubing above the supporting insulator should be the correct length for the highest frequency band. Then the added sections for the lower frequency bands should be pre-cut to length so that when they are inserted fully to the base of the bottom section the total length will be correct for the desired band.

THE DISCONE ANTENNA

The Discone antenna is a vertically polarized omnidirectional radiator which has very broad band characteristics and permits a simple, rugged structure. This antenna presents a substantially uniform feed point impedance, suitable for direct connection of a coaxial line, over a range of several octaves. Also, the vertical pattern is suitable for ground-wave work over several octaves, the gain varying only slightly over a very wide frequency range.

Commercial versions of the Discone antenna for various applications are manufactured by the Federal Telephone and Radio Corporation. A Discone type antenna for amateur

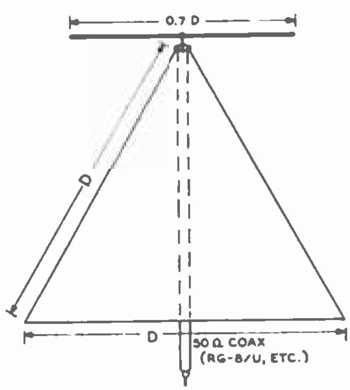


Figure 29.

THE "DISCONE" BROAD-BAND RADIATOR.

This antenna system radiates a vertically polarized wave over a very wide frequency range. The "disc" may be made of solid metal sheet, a group of radials, or wire screen; the "cone" may best be constructed by forming a sheet of thin aluminum. A single antenna may be used for operation on the 50, 144, and 220 Mc. amateur bands. The dimension D is determined by the lowest frequency to be employed, and is given in the chart of figure 30.

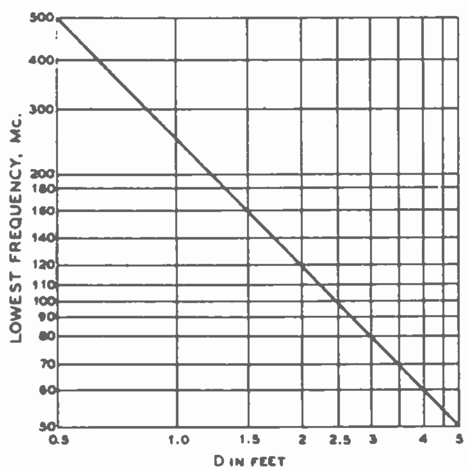


Figure 30.

DESIGN CHART FOR THE "DISCONE" ANTENNA.

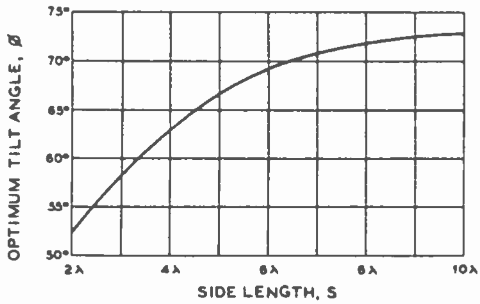


Figure 31.
V-H-F RHOMBIC ANTENNA DESIGN CHART.
The optimum tilt angle (see figure 32) for "zero angle" radiation depends upon the side length.

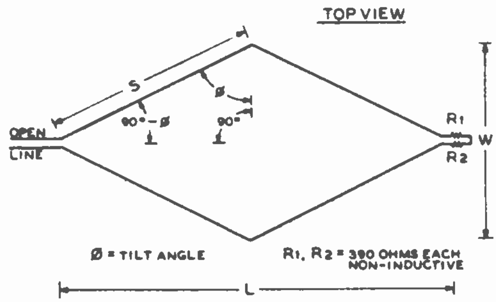


Figure 32.
RHOMBIC ANTENNA.

work can be fabricated from inexpensive materials with ordinary hand tools.

A Discone antenna suitable for multi-band amateur work in the v-h-f/u-h-f range is shown schematically in figure 29. The distance D should be made approximately equal to a free-space quarter wavelength at the lowest operating frequency. The antenna then will perform well over a frequency range at least of 8 to 1. At certain frequencies within this range the vertical pattern will tend to "lift" slightly, causing a slight reduction in gain at zero angular elevation, but the reduction is very slight.

Below the frequency at which the slant height of the conical skirt is equal to a free-space quarter wavelength the standing-wave ratio starts to climb, and below a frequency approximately 20 per cent lower than this the standing-wave ratio climbs very rapidly. This is termed the "cut off" frequency of the antenna. By making the slant height approximately equal to a free-space quarter wavelength at the lowest frequency employed (refer to chart), a VSWR of less than 1.5 will be obtained throughout the operating range of the antenna.

The Discone antenna may be considered as a cross between an electromagnetic horn and an inverted ground plane "unipole" antenna. It looks to the feed line like a properly terminated high-pass filter.

Construction Details The top disk and the conical skirt may be fabricated either from sheet metal, screen (such as "hardware cloth"), or 12 or more "spine" radials. If screen is used a supporting framework of rod or tubing will be necessary for mechanical strength except at the higher frequencies. If spines are used, they should be terminated on a stiff ring for mechanical strength except at the higher frequencies.

The top disk is supported by means of three insulating pillars fastened to the skirt. Either polystyrene or low-loss ceramic is suitable for the purpose. The apex of the conical skirt is grounded to the supporting mast and to the outer conductor of the coaxial line. The line is run down through the supporting mast. An alternative arrangement, one suitable for certain mobile applications, is to fasten the base of the skirt directly to an effective ground plane such as the top of an automobile.

VHF Horizontal Rhombics

For v-h-f transmission and reception in a fixed direction, a horizontal rhombic permits 10 to 16 db gain with a simpler construction than does a phased dipole array, and has the further advantage of being useful over a wide frequency range.

Except at the upper end of the v-h-f range a rhombic array having a worthwhile gain is too large to be rotated. However, in locations 75 to 150 miles from a large metropolitan area a rhombic array is ideally suited for working into the city on extended (horizontally polarized) ground-wave while at the same time making an ideal antenna for TV reception.

The useful frequency range of a v-h-f rhombic array is about 2 to 1, or about plus 40% and minus 30% from the *design frequency.*

This coverage is somewhat less than that of a high frequency rhombic used for sky-wave communication. For ground wave transmission or reception the only effective vertical angle is that of the horizon, and a frequency range greater than 2 to 1 cannot be covered with a rhombic array without an excessive change in the vertical angle of maximum radiation or response.

The dimensions of a v-h-f rhombic array are determined from the design frequency and figure 31, which shows the proper *tilt angle* (see figure 32) for a given leg length. The gain of a rhombic array increases with leg length. There is not much point in constructing a v-h-f rhombic array with legs shorter than about 4 wavelengths, and the beam width begins to become excessively sharp for leg lengths greater than about 8 wavelengths. A leg length of 6 wavelengths is a good compromise between beam width and gain.

The tilt angle given in figure 31 is based upon a "wave angle" of zero degrees. For leg lengths of 4 wavelengths or longer, it will be necessary to elongate the array a few per cent (pulling in the sides slightly) if the horizon elevation exceeds about 3 degrees.

Table II gives dimensions for two "dual purpose" rhombic arrays. One covers the 6-meter amateur band and the "low" television band. The other covers the 2-meter amateur band, the "high" television band, and the 1¼-meter amateur band. The gain is approximately 12 db over a matched half wave dipole and the beam width about 6 degrees.

The Feed Line The recommended feed line is an open-wire line hav-

TABLE I

CHARACTERISTICS OF COMMON TRANSMISSION LINES

	ATTENUATION db/100 FEET VSWR = 1.0			VELOCITY FACTOR V	μμFD PER FT.	REMARKS
	30 MC	100 MC	300 MC			
OPEN WIRE LINE, Nº 12 COPPER.	0.15	0.3	0.6	0.98-0.99	—	BASED UPON 4" SPACING BELOW 50 MC.; 2" SPACING ABOVE 50 MC. RADIATION LOSSES INCLUDED. CLEAN, LOW LOSS CERAMIC INSULATION ASSUMED. RADIATION HIGH ABOVE 150 MC.
RIBBON LINE, REC. TYPE, 300 OHMS. (7/28 CONDUCTORS)	0.86	2.2	5.3	0.82 ✔	6 ✔	FOR CLEAN, DRY LINE. WET WEATHER PERFORMANCE RATHER POOR. BEST LINE IS SLIGHTLY CONVEX. AVOID LINE THAT HAS CONCAVE DIELECTRIC. SUITABLE FOR LOW POWER TRANSMITTING APPLICATIONS. LOSSES INCREASE AS LINE WEATHERS. HANDLES 400 WATTS AT 30 MC. IF VSWR IS LOW.
TUBULAR "TWIN-LEAD" REC. TYPE, 300 OHMS, 5/16" O.D., (AMPHENOL TYPE 14-271)	—	—	—	—	—	CHARACTERISTICS SIMILAR TO RECEIVING TYPE RIBBON LINE EXCEPT FOR MUCH BETTER WET WEATHER PERFORMANCE.
RIBBON LINE, TRANS. TYPE, 300 OHMS.	—	—	—	—	—	CHARACTERISTICS VARY SOMEWHAT WITH MANUFACTURER, BUT APPROXIMATE THOSE OF RECEIVING TYPE RIBBON EXCEPT FOR GREATER POWER HANDLING CAPABILITY AND SLIGHTLY BETTER WET WEATHER PERFORMANCE.
TUBULAR "TWIN-LEAD" TRANS. TYPE, 7/16 O.D. (AMPHENOL 14-076)	0.85	2.3	5.4	0.79	6.1	FOR USE WHERE RECEIVING TYPE TUBULAR "TWIN-LEAD" DOES NOT HAVE SUFFICIENT POWER HANDLING CAPABILITY. WILL HANDLE 1 KW AT 30 MC. IF VSWR IS LOW.
RIBBON LINE, RECEIVE. TYPE, 150 OHMS.	1.1	2.7	6.0	0.77 ✔	10 ✔	USEFUL FOR QUARTER WAVE MATCHING SECTIONS. NO LONGER WIDELY USED AS A LINE.
RIBBON LINE, RECEIVE. TYPE, 75 OHMS.	2.0	5.0	11.0	0.68 ✔	19 ✔	USEFUL MAINLY IN THE H-F RANGE BECAUSE OF EXCESSIVE LOSSES AT V-H-F AND U-H-F. LESS AFFECTED BY WEATHER THAN 300 OHM RIBBON.
RIBBON LINE, TRANS. TYPE, 75 OHMS.	1.5	3.9	8.0	0.71 ✔	18 ✔	VERY SATISFACTORY FOR TRANSMITTING APPLICATIONS BELOW 30 MC. AT POWERS UP TO 1 KW. NOT SIGNIFICANTLY AFFECTED BY WET WEATHER.
RG-8/U COAX (52 OHMS)	1.0	2.1	4.2	0.66	29.5	WILL HANDLE 2 KW AT 30 MC. IF VSWR IS LOW. 0.4" O.D. 7/21 CONDUCTOR.
RG-11/U COAX (75 OHMS)	0.94	1.9	3.8	0.66	20.5	WILL HANDLE 1.4 KW AT 30 MC. IF VSWR IS LOW. 0.4" O.D. 7/26 CONDUCTOR.
RG-17/U COAX (52 OHMS)	0.38	0.85	1.8	0.66	29.5	WILL HANDLE 7.8 KW. AT 30 MC. IF VSWR IS LOW. 0.87" O.D. 0.19" DIA. CONDUCTOR
RG-58/U COAX (53 OHMS)	1.95	4.1	8.0	0.66	28.5	WILL HANDLE 430 WATTS AT 30 MC. IF VSWR IS LOW. 0.2" O.D. Nº 20 CONDUCTOR.
RG-59/U COAX (73 OHMS)	1.9	3.8	7.0	0.66	21	WILL HANDLE 680 WATTS AT 30 MC. IF VSWR IS LOW. 0.24" O.D. Nº 22 CONDUCTOR.
TV-59 COAX (72 OHMS)	2.0	4.0	7.0	0.66	22	"COMMERCIAL" VERSION OF RG-59/U FOR LESS EXACTING APPLICATIONS. LESS EXPENSIVE.
RG-22/U SHIELDED PAIR (95 OHMS)	1.7	3.0	5.5	0.66	16	FOR SHIELDED, BALANCED-TO-GROUND APPLICATIONS. VERY LOW NOISE PICK UP. 0.4" O.D.
K-111 SHIELDED PAIR (300 OHMS)	2.0	3.5	6.1	—	4	DESIGNED FOR TV LEAD-IN IN NOISY LOCATIONS. LOSSES HIGHER THAN REGULAR 300 OHM RIBBON, BUT DO NOT INCREASE AS MUCH FROM WEATHERING.

✔ APPROXIMATE. EXACT FIGURE VARIES SLIGHTLY WITH MANUFACTURER.

	6 METERS AND LOW BAND TV	2 METERS, HIGH BAND TV, AND 1¼ METERS
S (side)	90′	32′
L (length)	166′ 10″	59′ 4″
W (Width)	67′ 4″	23′ 11″

S = 6 wavelenths at design frequency
Tilt angle = 68°

TABLE II

ing a surge impedance between 450 and 600 ohms. With such a line the VSWR will be less than 2 to 1. A line with two-inch spacing is suitable for frequencies below 100 Mc., but closer spacing is recommended for higher frequencies.

Such a line can be fed directly into a television receiver with 300-ohm input, because the match at the antenna end will be sufficiently good to suppress ghosts due to "line echoes" even though there is a moderate mismatch at the receiver. If the array is to be used only for receiving, 300-ohm Twin-Lead may be used if the feed line is not unusually long. For long line lengths an open-wire line is recommended for reception because of lower losses.

The small rhombic of Table II can be strung inside the larger rhombic without bad effects. Separate feed lines are recommended with this arrangement.

The Termination If the array is to be used only for reception, a suitable termination consists of two 390-ohm metalized resistors in series. If 2-watt resistors are employed, this termination also is suitable for transmitter outputs of 10 watts or less. For higher powers, however, resistors having negligible reactance in the upper v-h-f range are not readily available.

For powers up to several hundred watts a suitable termination consists of a "lossy" line consisting of stainless steel wire (corresponding to no. 24 or 26 B&S gauge) spaced 2 inches, which in turn is terminated by two 390-ohm 2-watt metalized resistors. The dissipative line should be at least 6 wavelengths long.

Space Tapered Legs A slight improvement in the characteristics of a rhombic array can be realized by using two wires for each leg, spaced vertically at the side apices by means of spreaders. The spacing at the side apices may be made about 0.1 wavelength.

Rotary-Beam Control System

The following description gives the circuit details and some of the mechanical considerations of a more or less standard rotary-beam

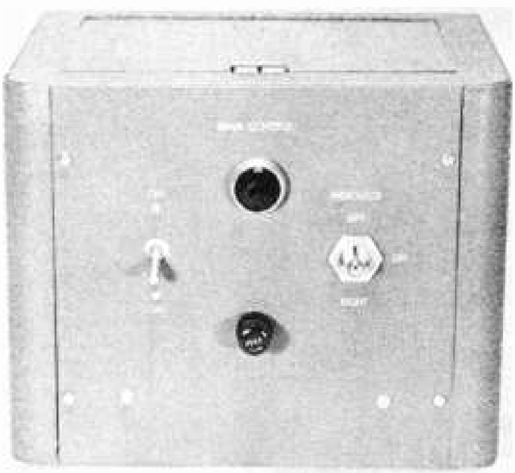


Figure 33. CONTROL BOX FOR THE ROTARY ANTENNA SYSTEM.

antenna control system. The installation uses the common propeller pitch-change motor as the driving motor and reduction gear. A pair of 115-volt synchros (Selsyns) repeat back antenna position information to the operating position.

The installation consists of three units: the motor and synchro generator at the base of the antenna, the control box, and the rotating-globe direction indicator. An 8-wire cable runs a distance of about 50 feet from the control box to the base of the antenna, and a 5-wire cable runs from the control box to the direction indicator. Power for the installation is obtained through a standard line cord from the control box which plugs into an outlet.

The components which go to make up the installation are illustrated in figures 33, 34, and 35. The three-element 28-Mc. antenna illustrated in figure 36 is supported by a rotating mast of 1½-inch diameter steel tubing with a radial load bearing about 10 feet above the ground. The thrust of the antenna system is taken by the pitch-change mechanism at the base of the mast.

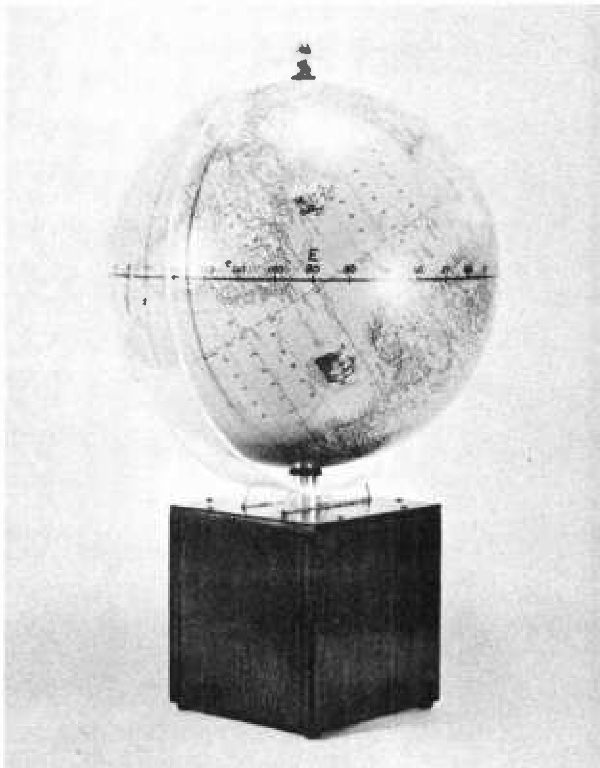
The rotating support mast for the array is constructed of sections from a surplus steel-tubing mast. The mast comes in 5-foot sections with the end 6 inches of each section reduced in diameter so that successive sections may be telescoped together. Quarter-inch holes are drilled through each junction between sections so that a bolt may be run through the junction. The bolt serves to tighten the junction and to pin the sections together so that torque from the rotator at the base will be transmitted to the antenna at the top.

The 1½-inch diameter of the base of the mast fits neatly over a projection in the center of the rotating portion of the pitch-change motor. Also, a hole is conveniently provided in this projection of the pitch-change motor for pinning of the projection to the base of the mast, by drilling matching holes in the bottom section of tubing.

The Control Box A photograph of the control box is given in figure 33, while the schematic diagram of the control box is given at the left in figure 35. The control box includes a main switch, fuse, pilot light, and the direction control for antenna rotation. When the main switch is turned on the pilot lamp lights and primary voltage is applied to the two synchro units in the indicator system. The two synchros tend to pull into step as soon as voltage is applied to their primary windings. The rotor of the synchro at the base of the antenna is fixed, since it is geared to the rotating mast of the antenna, so the synchro which is connected to the rotating globe indicator will rotate until its rotor is in the same relative position as the rotor of the synchro at the base of the antenna.

The direction control is a three-way toggle switch. It is spring loaded so that as soon as the force is released the switch returns to the off position. Note that the switch contacts are not required to carry the rather heavy current in the 24-volt a-c line. One section of the switch applies voltage to the primary of the 24-volt transformer in either of the LEFT (counter-clockwise) or the RIGHT (clockwise) positions. The second section of the switch actuates a s.p.d.t. relay with the

Figure 34.
THE "ROTATING GLOBE" DIRECTION INDICATOR.



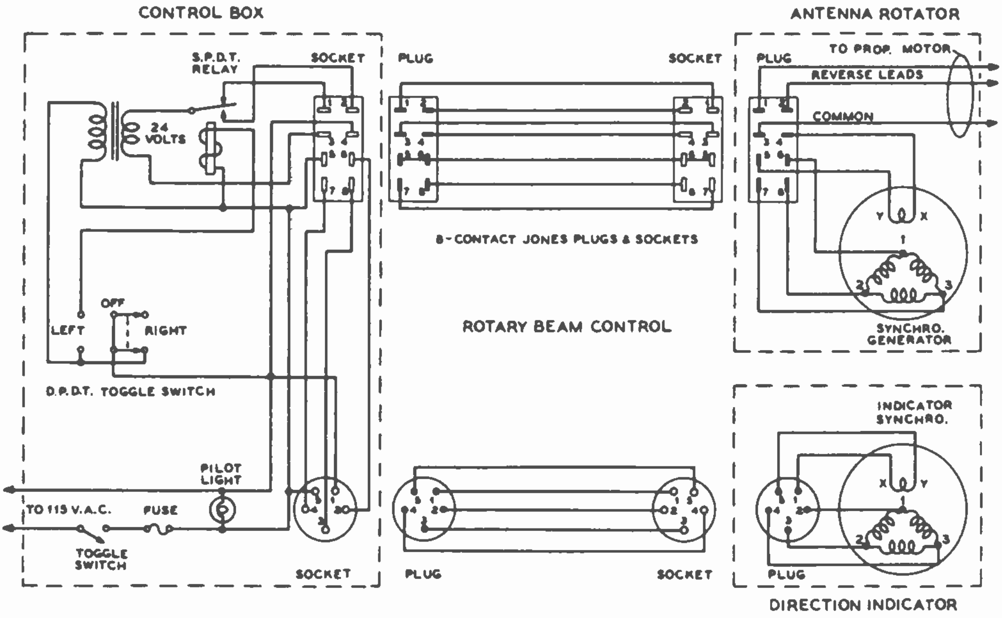


Figure 35.
SCHEMATIC OF THE COMPLETE ANTENNA CONTROL SYSTEM.

115-volt line in the LEFT position, but leaves the relay unactuated in the RIGHT position. In the unactuated position the relay feeds current to the RIGHT (clockwise) lead of the motor; the common lead of the motor being connected at all times. When the relay is actuated by placing the control switch in the LEFT position, current is fed to the LEFT lead of the motor.

Cables Cables are run between the major units of the control and indicator system. The use of cables and plugs allows rapid and convenient interconnection or separation of the units. An 8-wire cable with 8-contact plugs at each end, runs from the control box to the antenna rotator. The plugs and receptacles are Jones P-408 series. Similarly, a 5-wire cable is run from the control box to the rotating-globe direction indicator. Amphenol type 86 series plugs and connectors are used on the indicator cable.

Note that the "hot" receptacles or ends of cables always are terminated in female plugs or receptacles, while the "cold" ends always are terminated in the appropriate male fittings. Through this procedure in the use of cable connectors it is always safe to handle a cable or a connector without the danger of electrical shock.

The Rotating-Globe Indicator The use of a rotating-globe type of direction indicator is convenient in that it immediately gives an idea of the optimum direction and of the coverage of the directional antenna. Also, the indication is given in terms of the familiar globe rather than in terms of a great-circle projection with its attendant distortion in the relative areas of the land and ocean masses.

The unit illustrated in figure 34 was constructed from a 12-inch globe obtained from a book store. The globe was dismounted from its carrier and a small hole drilled at the home city of the station. Then another small hole was drilled at exactly the opposite point on the globe, and both holes enlarged to clear a ¼-inch screw. An adapter 1-inch in diameter and about 1½ inches long was machined of dural rod by a machine shop. One end of the adapter was machined to take the shaft of the synchro motor and the other end was bored to take a ¼-inch rod. Provision for set screws at each end of the adapter was made by the machine shop.

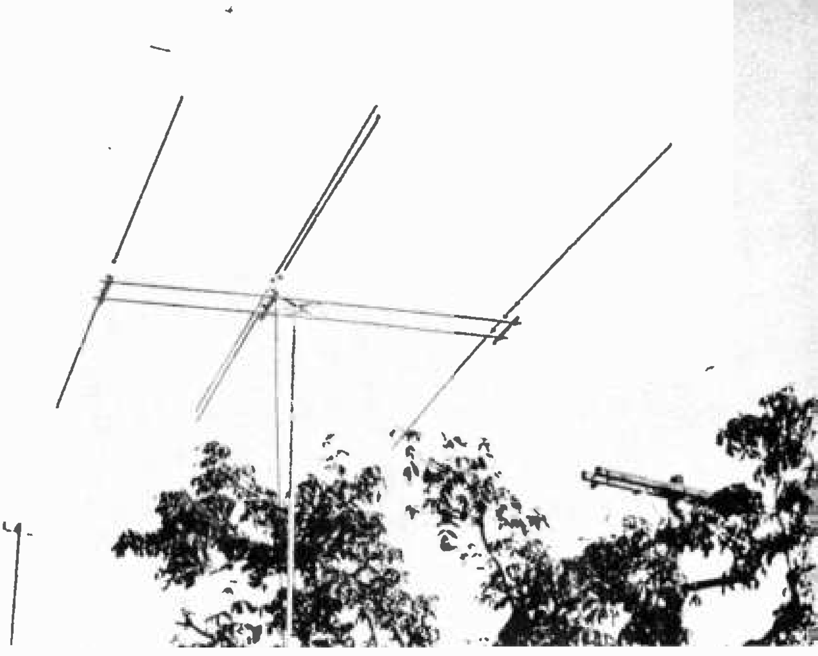


Figure 36.
MANUFACTURED 3-ELEMENT 28-MC. ROTARY.
This antenna is used in conjunction with the control and indicator systems of figures 33, 34, and 35 at W6DGN.

The shaft for the rotating globe is a 14-inch length of ¼-inch welding rod, with one end of the rod threaded about 1½ inches. The shaft then was assembled to the globe with rubber washers at each end, using shellac to cement the rubber washers to the globe.

The mounting box for the globe, which has the synchro motor mounted inside and the cable fitting on the rear, was constructed of ¾-inch plywood. A false bottom inside the mounting box holds the flange for mounting the synchro motor. The marker and top bearing is made of ¼-inch Plexiglas. The Plexiglas first was cut and filed to shape, and the hairline marker drawn. Then the material was heated in the oven and bent to shape around a drum which worked out to give the correct clearance of about one-half inch between the marker and the globe. Holes were drilled in the completed marker and the base was cemented to the marker with Plexiglas cement.

Alignment The alignment of the indicator system was accomplished by pointing the antenna at the north star, with the voltage applied to both synchros. Then the set screw in the adapter which holds the motor shaft was loosened and the globe rotated by hand until the marker aligned with north. Then the set screw was tightened.

CHAPTER TWELVE

Television and Broadcast Interference

The problem of interference to television reception is one of the most difficult and most serious ever to confront the radio amateur. But the problem can be solved if tackled in an orderly manner, as is attested by the fact that thousands of amateurs have eliminated the TV interference originally caused by their transmitters.

In an area of high TV-signal field intensity the TVI problem is capable of complete solution with the taking of routine measures both at the amateur transmitter and at the affected receivers. But in fringe areas of low TV-signal field strength the complete elimination of TVI is a difficult and challenging problem. But, as is attested by the work of W1DBM and many others, it still is a problem capable of solution. An extensive bibliography of material pertaining to TVI is included at the end of this chapter.

Types of TVI There are three main types of TVI which may be caused singly or in combination by the emissions from an amateur transmitter. These types of interference are:

(1) Overloading of the TV set by the transmitter fundamental

(2) Impairment of the picture by spurious emissions

(3) Impairment of the picture by the radiation of harmonics

All three conditions may take place as a result of a transmitter in the 14-Mc. band or higher in frequency, but only the first two are most likely to occur as a result of operation of the normal transmitter in the frequency bands below 7.3 Mc.

TV Set Overloading Even if the amateur transmitter were perfect and had no harmonic radiation or spurious emissions whatever, it still would be likely to cause overloading of TV sets whose antennas were within a few hundred feet of the transmitting antenna. This type of overloading is essentially the same as the common type of BCI encountered when operating a medium-power or high-power amateur transmitter within a few hundred feet of the normal type of BCL receiver. The field intensity in the immediate vicinity of the transmitting antenna is sufficiently high that the amateur signal will get into the BC or TV set either through overloading of the front end, or through the i-f and audio system. A characteristic of this type of interference is that it always will be eliminated when the transmitter temporarily is operated into a dummy antenna. Another characteristic of this type of overloading is that its effects will be substantially continuous over the entire frequency coverage of the BC or TV receiver. Channels 2 through 13 will affected in approximately the same manner.

With the overloading type of interference the problem is simply to keep the *fundamental* of the transmitter out of the affected receiver. Other types of interference may or may not show up when the fundamental is

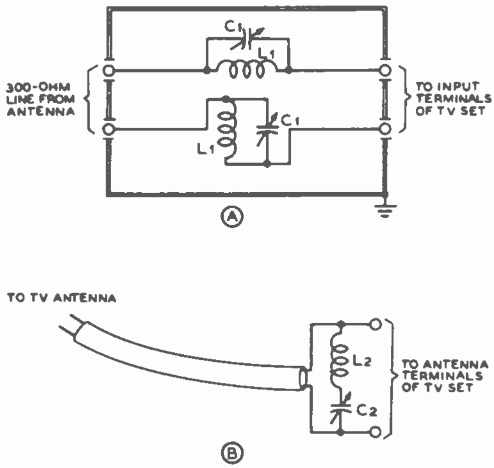


Figure 1.

TUNED TRAPS FOR THE TRANSMITTER FUNDAMENTAL.

The arrangement at (A) has proven to be effective in eliminating the condition of general blocking as caused by a 28-Mc. transmitter in the vicinity of a TV receiver. The tuned circuits L_1-C_1 are resonated separately to the frequency of transmission. The adjustment may be done at the station, or it may be accomplished at the TV receiver by tuning for minimum interference on the TV screen.

Shown at (B) is an alternative arrangement with a series-tuned circuit across the antenna terminals of the TV set. The tuned circuit should be resonated to the operating frequency of the transmitter. This arrangement gives less attenuation of the interfering signal than that at (A); the circuit has proven effective with interference from transmitters on the 50-Mc. band, and with low-power 28-Mc. transmitters.

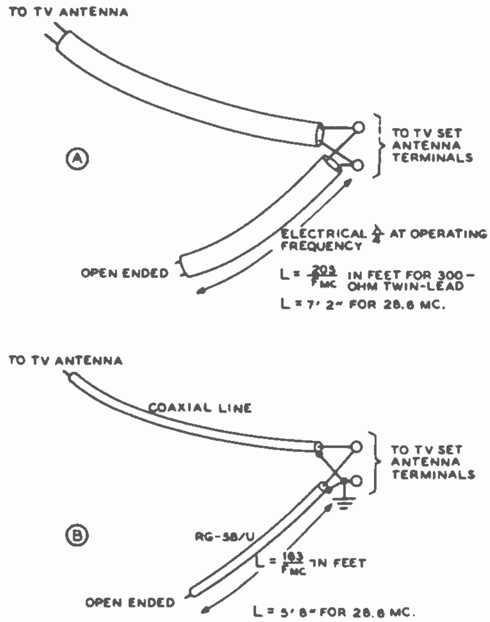


Figure 2.

RESONANT-LINE TRAPS FOR THE TRANSMITTER FUNDAMENTAL.

The section of transmission line should be cut slightly long for the initial test, and then should be trimmed a small amount at a time until ample attenuation of the transmitter fundamental is obtained. The "knife-and-anvil" type of pruning shears are convenient for cutting the line, particularly the coaxial type.

taken out of the TV set (they probably will appear), but at least the fundamental *must* be eliminated first.

The elimination of the transmitter fundamental from the TV set is normally the only operation performed on or in the vicinity of the TV receiver. After the fundamental has been eliminated as a source of interference to reception, work may then be begun on or in the vicinity of the transmitter toward eliminating the other two types of interference.

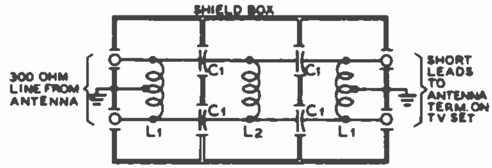
Taking Out the Fundamental More or less standard BCI-type practice is most commonly used in taking out fundamental interference. Wavetraps and filters are installed, and the antenna system may or may not be modified so as to offer less response to the signal from the amateur transmitter. In regard to a comparison between wavetraps and filters, the same considerations apply as have been effective in regard to BCI for many years; wavetraps are quite effective when properly installed and adjusted, but they must be readjusted whenever the band of operation is changed, or even when moving from one extreme end of a band to the other. Hence, wavetraps, and their v-h-f counterparts in open-ended and shorted trap lines are not recommended except when operation will be confined to a relatively constant portion of one amateur band. However, figures 1 and 2 show some of the most common signal trapping arrangements, including the use of sections of transmission lines as traps.

High-pass filters in the antenna lead of the TV set have proven to be quite satisfactory as a means of eliminating TVI of the overloading type. In many cases when the interfering transmitter is operated only on the bands below 7.3 Mc., the use of a high-pass filter in the antenna lead has completely eliminated all TVI. In some cases the installation of a high-pass filter in the antenna transmission line and an a-c line filter of a standard variety has proven to be completely effective in eliminating the interference from a transmitter in one of the lower frequency amateur bands.

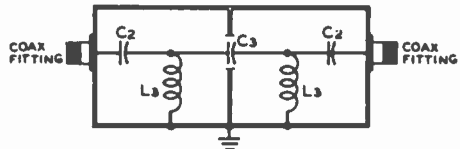
Several types of high-pass filters for insertion into the antenna transmission line are illustrated in figure 3. Types for use both with coaxial and with balanced transmission lines have been shown. In most cases the filters may be constructed in one of the small shield boxes which are now on the market. Input and output terminals may be standard connectors, or the inexpensive type of terminal strips usually used on BC and TV sets may be employed. Coaxial terminals should of course be employed when a coaxial feed line is used to the antenna. In any event the leads from the filter box to the TV set should be very short, including both the antenna lead and the ground lead to the box itself. If the leads from the box to the set have much length, they may pick up enough signal to nullify the effects of the high-pass filter.

Experience has shown that shielded transmission lines from the antenna to the TV set are much less likely to pick up a strong signal from a local amateur transmitter. The shielded transmission line may be either of the coaxial type, or it may be of the new shielded 300-ohm variety. In either case the shield should be carefully and effectively grounded to the frame of the TV set. The presence of the grounded sheath about the antenna transmission line eliminates pickup of the "parallel" type on the antenna feed line. Hence, only the actual TV antenna will be of significance in picking up the amateur signal.

Assuming that pickup from the antenna transmission line has been eliminated as a factor, a type of TV antenna which in itself will have small pickup should be employed—whenever there is a choice in the matter. Essentially this means that an antenna of the closed-circuit type, such as those using a folded dipole as the main element or elements should be used. Such an antenna will have less signal pickup at the relatively low frequencies below 7.3 Mc. than will an antenna of the split radiator type.



(A) FOR 300-OHM LINE, SHIELDED OR UNSHIELDED



(B) FOR 50-75 OHM COAXIAL LINE

Figure 3.

HIGH-PASS TRANSMISSION LINE FILTERS.

The arrangement at (A) will stop the passing of all signals below about 45 Mc. from the antenna transmission line into the TV set. Coils L_1 are each 1.2 microhenrys (21 turns no. 24 enam. closewound on 1/4-inch dia. polystyrene rod) with the center tap grounded. It will be found best to scrape, twist, and solder the center tap before winding the coil. The number of turns each side of the tap may then be varied until the tap is in the exact center of the winding. Coil L_2 is 0.6 microhenry (15 turns no. 24 enam. closewound on 1/4-inch dia. polystyrene rod). The capacitors should be about 16.5 μμfd., but either 15 or 20 μμfd. ceramic capacitors will give satisfactory results. A similar filter for coaxial antenna transmission line is shown at (B). Both coils should be 0.12 microhenry (7 turns no. 18 enam. spaced to 1/2 inch on 1/4-inch dia. polystyrene rod). Capacitors C_2 should be 75 μμfd. midget ceramics, while C_3 should be a 40-μμfd. ceramic.

Blocking from 50-Mc. Signals Operation on the 50-Mc. amateur band in an area where channel 2 is in use for TV imposes a special problem in the matter of blocking. The input circuits of most TV sets are sufficiently broad so that an amateur signal on the 50-Mc. band will ride through with little attenuation. Also, the normal TV antenna will have a quite large response to a signal in the 50-Mc. band since the lower limit of channel 2 is 54 Mc.

High-pass filters of the normal type simply are not capable of giving sufficient attenuation to a signal whose frequency is so close to the necessary pass band of the filter.

Hence one of the methods illustrated in figures 1 and 2 must be used to trap out the amateur signal at the input of the TV set. The trap must be tuned, or the section of transmission line cut, for a particular frequency in the 50-Mc. band—and this frequency will have to be near the lower frequency limit of the 50-Mc. band to obtain adequate rejection of the amateur signal while still not materially affecting the response of the receiver to channel 2.

Elimination of Spurious Emissions All spurious emissions from amateur transmitters (ignoring harmonic signals for the time being) must be eliminated to comply with FCC regulations. But in the past many amateur transmitters have emitted spurious signals as a result of key clicks, parasitics, and overmodulation transients. In most cases the operators of the transmitters were not aware of these emissions since they were radiated only for a short distance and hence were not brought to his attention. But with one or more TV sets in the neighborhood it is probable that such spurious signals will be brought quickly to his attention.

A discussion of key clicks, along with a method for eliminating them has been discussed in *Chapter One*. The elimination of parasitic oscillations and overmodulation transients has been discussed in detail in the RADIO HANDBOOK, eleventh edition, with further information given in chapters five and seven of this edition.

Two new wrinkles recently suggested for the elimination of self-oscillation and parasitic oscillation from beam tetrode amplifier stages are illustrated in figure 4. The use of a short section of coaxial transmission line as an additional means of holding the screen at ground potential is shown in figures 4A and 4B. This measure has proven effective, with a 6 to 15 inch length of coaxial cable at Z, in the taming of a single-ended 807 stage operating in the v-h-f range. A means of raising the resonant frequency of the grid circuit for eliminating parasitics is shown at figure 4C.

Suppression of Harmonic Radiation After any condition of blocking at the TV receiver has been eliminated, and when the transmitter is completely free of transients and parasitic oscillations, it is probable that TVI will be eliminated in certain cases. Certainly general interference should be eliminated, particularly if the transmitter is a medium-power affair operated on one of the lower frequency bands, and the station is in a high-signal TV area. But when the transmitter is to be operated on one of the higher frequency bands, and particularly in a marginal TV area, the job

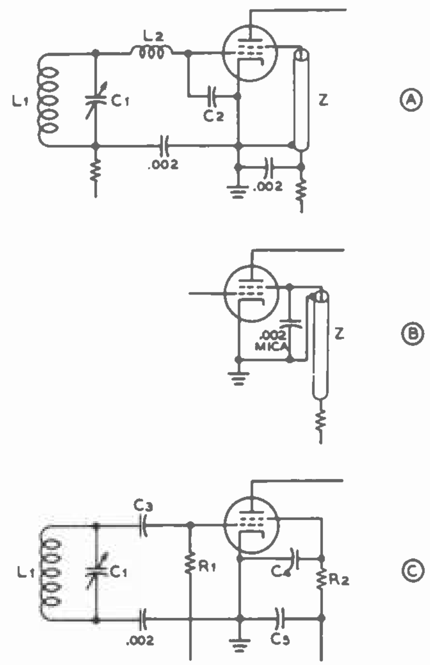


Figure 4.
ANTI-PARASITIC CIRCUIT SUGGESTIONS.

Shown at (A) is the combination of a low-pass filter in the grid circuit plus a detuning trap in the screen return. C_2 should be a small ceramic capacitor of about 15 μμfd. connected directly from grid to cathode on the tube socket. A starting value for L_2 is 6 turns of no. 18 enam. wound on a ¼-inch diameter insulating rod. The largest inductance which will still permit full excitation on the highest frequency band should be employed. Suggestions for the short section of coaxial line at Z as a means of detuning the screen circuit are included in the text. At (C) is shown the use of a 15-μμfd. series ceramic capacitor as C_3 for raising the resonant frequency of the grid circuit as a means of stopping parasitic oscillations. Also shown at (C) is the use of a double screen bypass system. Capacitor C_4 may be a small ceramic trimmer capacitor of about 50 μμfd. maximum, R may be a 10-ohm 2-watt carbon, while R_1 is the conventional grid leak for the stage. Capacitor C_5 is the conventional 0.002-μfd. to 0.01-μfd. mica.

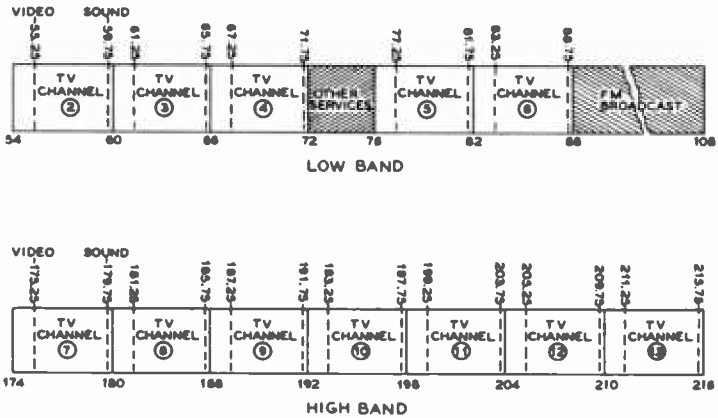


Figure 5.

FREQUENCIES OF THE TV CHANNELS.

Indicated are the frequencies of TV channels 2 through 13, with both the video and sound carrier frequencies shown.

of TV-proofing will just have begun. The elimination of harmonic radiation from the transmitter is a difficult and tedious job which must be done in an orderly manner if completely satisfactory results are to be obtained.

First it is well to become familiar with the TV channels presently assigned, with the TV intermediate frequencies commonly used, and with the channels which will receive interference from harmonics of the various amateur bands. Figures 5 and 6 give this information.

Even a short inspection of figures 5 and 6 will make obvious the seriousness of the interference which can be caused by harmonics of amateur signals in the higher frequency bands. With any sort of reasonable precautions in the design and shielding of the transmitter it is not likely that harmonics higher than the 6th will be encountered. Hence the main offenders in the way of harmonic interference will be those bands above 14 Mc.

Nature of Harmonic Interference Investigations into the nature of the interference caused by amateur signals on the TV screen, assuming that blocking has been eliminated as described earlier in this chapter, have revealed the following facts:

1. An unmodulated carrier, such as a c-w signal with the key down or an AM signal without modulation, will give a cross-hatch or herringbone signal on the TV screen. This same general type of picture also will occur in the case of a narrow-band FM signal either with or without modulation.
2. A relatively strong AM signal will give in addition to the herringbone a very serious succession of light and dark bands across the TV picture.
3. A c-w signal without transients, and in the absence of overloading of the TV set, will result merely in the turning on and off of the herringbone on the picture.

To discuss condition (1) above, the herringbone is a result of the beat note between the TV video carrier and the amateur harmonic. Hence the higher the beat note the less obvious will be the resulting cross-hatch. Further, it has been shown that a much stronger signal is required to produce a discernible herringbone when the interfering harmonic is as far away as possible from the video carrier, without running into the sound carrier. Thus, as a last resort, or to eliminate the last vestige of interference after all corrective measures have been taken, operate the transmitter on a frequency such that the interfering harmonic will fall about 50 or 100 kc. lower in frequency than the sound carrier. The worst possible interference from a continuous

TRANSMITTER FUNDAMENTAL	2ND	3RD	4TH	5TH	6TH	7TH	8TH	9TH	10TH
7.0 - 7.3		21-21.9 TV I.F					56-58.4 CHANNEL (2)	63-65.7 CHANNEL (3)	70-73 CHANNEL (4)
14.0 - 14.4			56-57.6 CHANNEL (2)	70-72 CHANNEL (4)	84-86.4 CHANNEL (6)	98-100.8 FM BROAD-CAST			
21.0 - 21.45 (TV I.F)		63-64.35 CHANNEL (3)	84-85.8 CHANNEL (6)	105-107.25 FM BROAD-CAST				189-193 CHANNELS (9) (10)	210-214.5 CHANNEL (13)
26.96 - 27.23	53.92-54.46 CHANNEL (2) ABOVE 27 MC. ONLY	80.88-81.69 CHANNEL (5)	107.84-108.92 FM BROAD-CAST			189 CHANNEL (9)	218 CHANNEL (13)		
28.0 - 29.7	56-59.4 CHANNEL (2)	84-89.1 CHANNEL (6)			168-178.2 CHANNEL (7)	196-207.9 CHANNELS (10) (11) (12)			
50.0 - 54.0	100-108 FM BROAD-CAST		200-216 CHANNELS (11) (12) (13)				POSSIBLE INTERFERENCE TO U-H-F CHANNELS	450-486	500-540

Figure 6.

HARMONICS OF THE AMATEUR BANDS.

Shown are the harmonic frequency ranges of the amateur bands between 7 and 54 Mc., with the TV channels which are most likely to receive interference from these harmonics.

carrier will be obtained when the interfering signal is very close in frequency to the video carrier.

Isolating the Source of the Interference Throughout the testing procedure it will be necessary to have some sort of indicating device as a means of determining harmonic field intensities. The best indicator for field intensities some distance from the transmitting antenna will probably be the TV receiver of some neighbor with whom friendly relations are still maintained. This person then will be able to give a check, occasionally, on the relative nature of the interference. But it will probably be necessary to go and check yourself periodically the results obtained, since the neighbor probably will not be able to give any sort of a quantitative analysis of the progress which has been made.

An additional device for checking relatively high field intensities in the vicinity of the transmitter will be almost a necessity. The simple indicating wavemeter (made from a Silver 903 wavemeter, a 1N34, and a microammeter) described in the eleventh edition of the RADIO HANDBOOK on page 423 will accomplish this function. Also, it will be very helpful to have a receiver with an S meter capable of covering at least the 50 to 100 Mc. range and preferably the range to 216 Mc. This device may consist merely of the station receiver and a simple converter using the two halves of a 6J6 as oscillator and mixer.

The first check can best be made with the neighbor who is receiving the most serious or the most general interference. Turn on the transmitter and check all channels to determine the extent of the interference and the number of channels affected. Then disconnect the antenna and substitute a group of 100-watt lamps as a dummy load for the transmitter. Experience has shown that 8 100-watt lamps connected in two seriesed groups of four in parallel will take the output of a kilowatt transmitter on 28 Mc. if connections are made symmetrically to the group of lamps. Then note the interference. Now remove plate voltage from the final amplifier and determine the extent of interference caused by the exciter stages.

In the average case, when the final amplifier is a beam tetrode stage and the exciter is relatively low powered and adequately shielded, it will be found that the interference drops materially when the antenna is removed and a dummy load substituted. It will also be found in such an average case that the interference will stop when the exciter only is operating.

General Considerations for Reduced Harmonic Radiation It might be well at this point to discuss the general conditions which will result in reduced harmonic generation in the amateur transmitter. In the first place, it is best to have only one high-level r-f stage in the transmitter. This consideration has been discussed in some detail in *Chapter Five,* but it should be obvious that if there is only one high-level stage in the transmitter and all low-level stages are shielded, there will be only one stage from which harmonic signals of any sizeable amplitude will be obtained.

Second, it is best that the high-level stage in the transmitter be operated in the class B region rather than class C. Contrary to popular opinion, the output stage in any amateur transmitter may be operated class B for all modes of transmission other than amplitude modulation of the output stage. A reduction in the conversion efficiency of the output stage of about 10 per cent will result from dropping the grid bias and excitation to obtain class B operation. But the small reduction in output power certainly will not be noticeable on the air, while the driving power requirements for the stage and the harmonic signal output of the stage will have been sharply reduced.

If the output stage must be operated class C, for high-level amplitude modulation, and if a fairly sizable driver stage must be used to obtain adequate excitation to the final amplifier, it is quite important that the driver be operated as a straight-through class B amplifier. Under no conditions should a high-level driver be operated as a frequency multiplier; the operation of a high-level driver as a frequency multiplier is the surest way of having a high level of harmonic signal on hand in the transmitter. Consequently, all frequency multiplication should be done in the low-level stages of the transmitter—preferably with relatively small receiving tubes operating well within their transmitting ratings.

Suppression of Harmonics It will be assumed in the following paragraphs that the transmitter is operating in such a manner that no harmonic interference is being caused by the exciter stages. Hence all the measures to be discussed will be given in terms of the output stage. Of course, if it is found that the exciter is causing interference, the same general course of remedies may be applied to the stages in the exciter until they are cleaned up; then the final stage may be tackled.

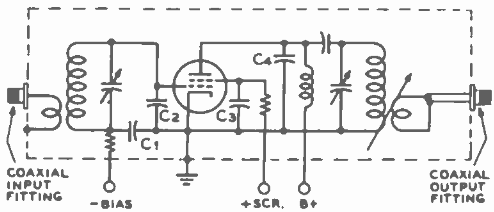


Figure 7.

SHIELDED AMPLIFIER WITH COMMON RETURN POINT.

All leads shown as being grounded should return to the cathode terminal, which then is grounded to the shielding compartment. Lead filters in the bias, screen, and plate voltage leads may be found necessary, as described in the text.

The suppression of harmonic radiation may usually be accomplished in an orderly manner of five steps. All the steps may not be required in the case of a low power transmitter, but in the case of a transmitter of relatively high power level it is best to start with the first step and proceed through each one until the interference is eliminated. The five steps are:

(1) Reduce the generation of harmonics in the transmitter.

(2) Shield the exciter and the transmitter.

(3) Filter the supply leads within and leaving the transmitter.

(4) Use a coaxial output line from the transmitter to an antenna coupler.

(5) Install harmonic traps and filters on the antenna feed line.

It can be seen from the above that the program proceeds in an orderly manner, first reducing the harmonic amplitude in the transmitter, then eliminating the radiation of harmonics by spurious paths, then stopping the transmission of harmonics along the one necessary path from the transmitter to the antenna.

It is difficult to give a detailed procedure for the reduction of the harmonic level within the transmitter. The methods discussed under the previous paragraph "General Considerations for Reduced Harmonic Radiation" are important, whenever applicable. When practicable, the use of a single-ended stage with short copper-strap conductors from the return to a common ground point is desirable. A push-pull final amplifier is somewhat more likely to generate a high-level of even harmonics than a single-ended stage. But the odd harmonic output from both types of stages will be about the same.

The use of harmonic traps in the plate lead or leads of the final amplifier has been recommended by several writers, but others who have used such traps feel that their use is not necessarily desirable. Certainly it is possible to increase the harmonic output of a transmitter by the use of a trap just the same as the harmonic output may be reduced. This is another instance of a fact previously mentioned: the use of sharply tuned traps as a means of harmonic reduction is not a recommended procedure. Even if we assume that all such sharply tuned traps are properly aligned in the first place, they must be changed each time the frequency of operation of the transmitter is moved an appreciable amount. By-passing, shielding and filtering are recommended as relatively broad systems in preference to the use of sharply tuned circuits.

The use of low-inductance by-pass capacitors from the elements of the output tube to ground has proven to be an effective procedure. Small ceramic fixed or variable capacitors are desirable for use in parallel with the normal grid, screen, and cathode by-pass or tuning capacitor. For the plate circuit, high-voltage vacuum capacitors have proven to be quite effective; and National makes a "TuBy" tubular by-pass capacitor with a capacitance of 15 $\mu\mu$fd. and voltage ratings of either 1500 or 3000 volts. These small tubular by-pass capacitors are much less expensive than the vacuum type, and are satisfactory for plate-to-ground applications where the peak voltage will be less than 3000 volts.

Shielding The matter of shielding is one about which little information has been available to the amateur in the past. Certainly it is impossible to enclose the transmitter and exciter completely in a soldered copper box. The question then becomes, how much deviation from the ideal case may be tolerated before the shielding loses its effectiveness. The answer must, of course, be given in relative terms. But it is safe to say that slots and louvers in the shielding are most likely to be found the offenders as far as harmonic leakage is concerned.

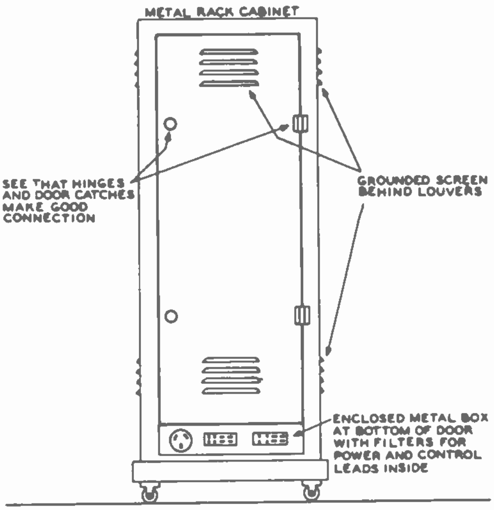


Figure 8.
ISOLATING MEASURES FOR THE RACK-ENCLOSED TRANSMITTER.

It is important to remember that a slot in a piece of metal is exactly as good a radiator as a piece of wire having the dimensions of the slot. This may be a new concept to some, but the slot between the rear door and the housing of a 6-foot enclosed relay rack can radiate *horizontally* polarized waves in the vicinity of 80 Mc. (channel 5) as effectively as a horizontal half-wave dipole. Several hinges or door catches will serve to break up the slot, thus raising its resonant frequency out of the low TV band at least. Louvers in the side of the cabinet can be effective radiators in the vicinity of the high-band TV range. The soldering or bolting of copper screen in place behind the louvers will be found effective in completing the shielding.

Meter faces and glass-front meter panels can be effective v-h-f radiators. Meters should not be installed in such a position that they can destroy the shielding of a compartment. The leads which connect to the meters should be carefully filtered, a by-pass capacitor should be placed across the meter terminals, and if necessary the meters should be covered by copper screen. The use of copper screen in place of, or behind, the glass of a glass-front meter panel will complete the shielding.

Viewing windows in the front panel of a power amplifier stage should have copper screen installed in place of or behind the glass. Where the esthetic effect of copper window screen would not be desirable, 1/8-inch or 1/4-inch mesh brass or bronze screen may be substituted with a considerable improvement in the appearance of the opening.

In general it may be stated that small holes, or groups of small holes as would be the case when screen is used, will not seriously destroy the shielding of a compartment. But large holes or slots will have an appreciable radiation resistance in the v-h-f range. When screen is used to cover a slot or a hole it is important that the metal of the screen be firmly bonded to the metal of the housing at intervals of not more than a few inches. The paint should be scraped from the region in the cabinet where the screen is to be bolted to insure good electrical contact.

Filtering of Leads The shielding of a compartment can be completely destroyed if wires and leads leaving the compartment can carry energy out of the shielded enclosure. A lead 2½ or 3 feet long can act as a very effective radiator of harmonic signals in the low TV band. Hence it is quite important that r-f signals be stopped from travelling along the leads which leave the transmitter or exciter enclosure.

The filtering of leads within a transmitter may be accomplished either on a deck-by-deck basis, or in terms of the whole transmitter. Where the transmitter is completely enclosed in a metal housing which includes the shielding provisions mentioned in the previous section, it will be more satisfactory to shield only those leads which leave the transmitter enclosure. All the leads from the transmitter may be brought out in the conventional manner at the bottom rear, with an isolating and filtering compartment at this spot. The filtering compartment may then act as the termination of all the external leads to the transmitter.

The wavemeter-microammeter "gimmick" will be found to be quite helpful in locating the offending leads and in determining the frequencies being radiated. In many cases, especially when the transmitter is running relatively high power, it will be found that the indicator will show a reading regardless of the setting of the wavemeter dial. This condition usually is the result of the rather intense fundamental-frequency field inside the transmitter. This trouble may be eliminated by placing the measuring device outside the transmitter, with a probe loop link coupled to the indicator. A line of small-size Twin-Lead

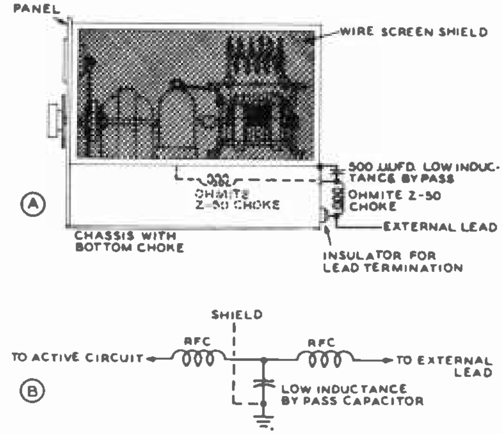


Figure 9.

LEAD-FILTER CIRCUIT.

Showing the physical and electrical details of an effective method for stopping the passage of r-f signals down power and control leads.

about 4 feet long, or a similar length of twisted hookup wire, with a loop around the wavemeter coil at one end and a loop about 1 inch in diameter at the other end usually will give adequate isolation of the fundamental from the resonant circuit of the indicator.

In any event be *exceedingly careful* when probing to determine the location and amplitude of harmonic fields. Mount the pickup loop for the "gimmick" on the end of about a 2-foot length of dowel rod. Then the loop may be moved about without danger of contact with dangerous potentials while watching the indicating meter.

There are two types of leads entering the high-field intensity portion of the transmitter which may require filters. These are control leads, bias and plate voltage leads, and all other types of leads which carry a relatively low current, all taken as one group, and a-c line power leads which carry a relatively heavy current. Filters for the two types of leads are somewhat different, due to the difference in current carrying capability.

Figure 9 shows in semi-schematic form one method which has proven effective in stopping r-f energy from travelling down supply wires and thus being radiated. Note that a "T" section filter has been used rather than

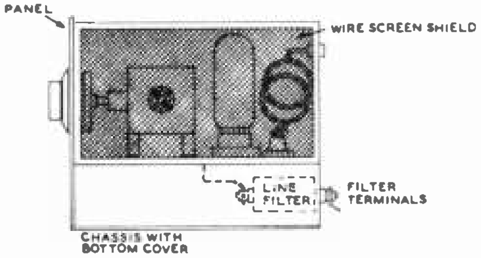


Figure 10.
INSTALLATION OF A LINE FILTER.
Showing an effective method for installing a conventional metal-case line filter so that its output leads project through the chassis.

the more common "pi" section type. The logic behind this selection is as follows: The harmonic voltage appearing on the active leads is relatively low, but the current through the by-pass capacitor may be moderately high in value. If the external lead were attached directly to the by-pass capacitor, the lead still could radiate effectively as an odd-quarter-wave wire being fed from a low-impedance source. But by connecting an additional r-f choke in series from the lead to the by-pass capacitor, the current passing through the by-pass capacitor is effectively stopped from passing on to the lead wire.

The r-f chokes used in the filter may be manufactured units such as suggested in figure 9, or they may be wound on such small coil forms as available. The inductance of the chokes should be from 10 to 25 microhenries, they should be wound as single-layer solenoids with as large a ratio of length to diameter as is practicable, and the turns should be spaced to reduce capacitive coupling from one end of the choke to the other.

Button-type mica by-pass capacitors and post-type ceramic by-pass units are characterized by the lowest value of inductance of all types which might be suitable. The wire-lead type of by-pass capacitors, either ceramic or mica, often will be suitable and certainly are more easily available in a range of capacitances and voltage ratings. But the wire leads in themselves add a considerable amount of inductance to the by-pass circuit. For use in high-voltage circuits, the 500-$\mu\mu$fd. 10,000-volt ceramic filter capacitors designed for application in high-voltage TV power supplies have proven to be satisfactory as by-pass capacitors.

High-Current Lead Filters In some cases it will be necessary to install line filters in series with the a-c line leads which feed the transmitter. Commercially manufactured line filters may do an adequate job if installed as shown in figure 10, or as has been done in the case of the "Shielded 4-400A Kilowatt Amplifier" described in *Chapter Five*. Alternatively, the filter may be assembled in the same general manner as shown in figure 9, using high-current solenoid-type chokes in series with the line. Suitable chokes are the Ohmite Z-20, Z-21, and Z-22 with current ratings of 5, 10, and 20 amperes respectively. Two of these dual-winding chokes will be required; one can be installed in series with both sides of the line inside the shielded compartment, and one installed outside for connection of the external leads.

Antenna Couplers Many amateur stations and substantially all commercial stations have long used antenna coupling arrangements as a means of insuring an optimum impedance match between the plate circuit of the final amplifier and the antenna transmission line. Such coupling devices do not, as often stated, introduce a significant power loss but rather they permit optimum loading of the final amplifier stage for best plate-circuit efficiency at rated power input or power output. And, of greatest interest in connection with the TVI problem, such circuits can offer a very large attenuation to harmonic signals while transmitting the fundamental with negligible attenuation.

A wide variety of circuit arrangements may be used in harmonic-attenuating antenna coupling units. However, the most satisfactory circuits for use in amateur transmitters are the link coupled tank circuit, as shown in figure 11, and the pi network as shown in figures 14 and 15.

In the case of the link-coupled-tank type of antenna-coupling circuit, as shown in figure 11, it will be found best to install the unit externally to an existing transmitter, with a coaxial transmission line from the final-amplifier tank to the external circuit. Both the final amplifier and the coupler should be shielded to reduce direct radiation from the circuit elements.

Coupling between the two tank circuits, and between the antenna tank and the antenna transmission line should be as loose as is practicable while still giving adequate loading of the final amplifier. Coupling between the two tank circuits may be varied through

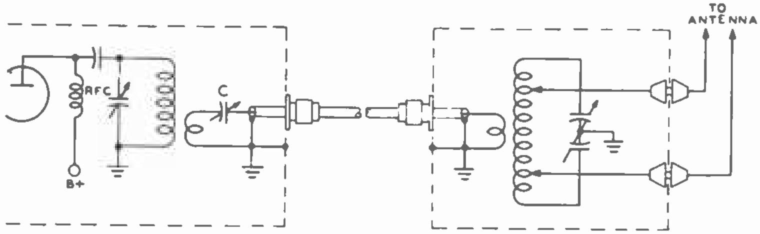


Figure 11.

BASIC CIRCUIT OF SHIELDED ANTENNA COUPLER.

Note the use of a coaxial transmission line from the shielded transmitter to the antenna-coupler enclosure. Variable-link arrangements may be included at both ends of the link line, but if only one variable link is to be used it should be at the final amplifier tank. The capacitor C is convenient for tuning out the reactance of the link coil, and may be used as a coupling variation if a variable link is not included at the final amplifier tank.

the use of a variable link at either end, though it is preferable to have the variable link at the final-amplifier end. The capacitor C in figure 11 may be used in place of or in addition to variable-link coupling at the final amplifier. If a variable link is used, this capacitor may be used to tune out the reactance of the link coil so that a minimum amount of physical coupling between the link and the final amplifier coil will be required. If the link coil is fixed with respect to the final amplifier plate coil, the capacitor C may be used to vary the coupling of the external circuits to the plate circuit of the final amplifier.

Figures 12 and 13 show alternative circuits for a complete antenna coupling unit. Notice that each unit includes a switch to select any one of three transmitting antennas, and an antenna changeover relay in addition to the link-coupled tank circuit. Figure 12 shows also how a capacitor may be installed in series with the link as an additional means of varying the coupling between the output circuit and the final amplifier.

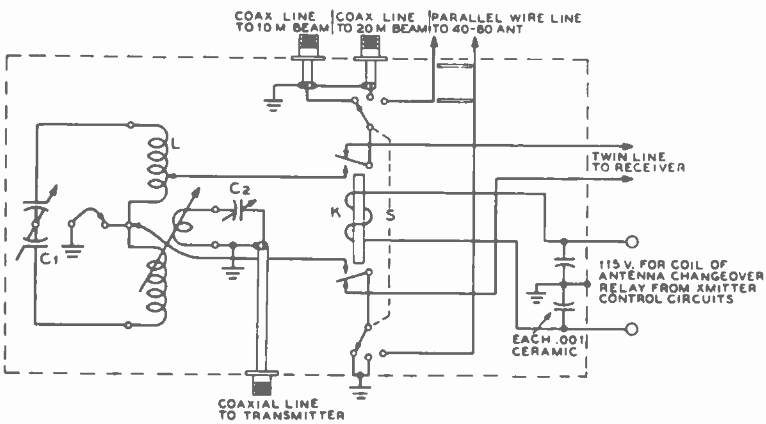


Figure 12.

CIRCUIT OF A PRACTICAL ANTENNA COUPLER.

This arrangement includes the antenna changeover relay, an antenna selector switch, and a universal-type antenna coupler. The tuned circuit of the antenna coupler is not in the circuit in the receive position of the changeover relay. Capacitor C_2 serves to tune out the reactance of the coupling link and may or may not be included as desired.

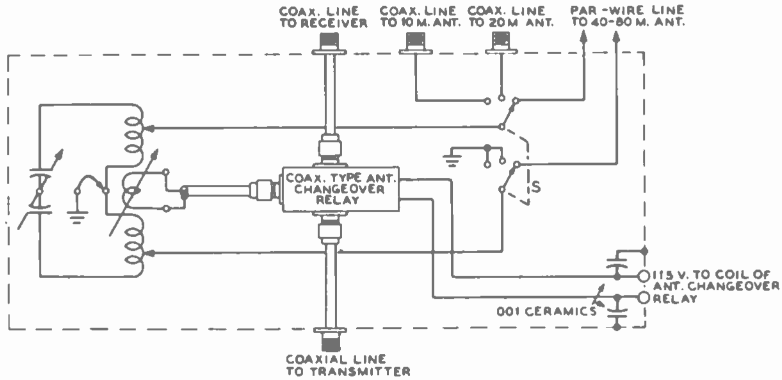


Figure 13.

COAXIAL-TYPE ANTENNA COUPLER.

This arrangement differs from that of figure 12 in that a coaxial changeover relay is used, coaxial line is used from the coupler to the receiver, and the tuned circuit of the coupler is in the circuit for receiving as well as for transmitting.

There are several significant differences between the circuits of figures 12 and 13. In the circuit of figure 12 the receiver is connected directly to the antenna transmission line for receiving. Also, two-wire twin-line is used as a transmission line from the antenna coupler and the receiver. Note that the antenna coupling arrangement is not in use when receiving.

In the circuit of figure 13 the antenna coupling arrangement is connected into the circuit both for transmitting and receiving. There are advantages and disadvantages to this arrangement. Certainly this arrangement will deliver the best signal voltage to the receiver at the tuned frequency of the coupling network. But the coupling of the receiver to the antenna will fall off when the receiver is tuned to a frequency somewhat different from that to which the antenna network is resonant. Hence, the arrangement of figure 13 is best when reception will be mainly at a frequency within 50 or 100 kc. of the frequency being used for transmission. Signals still will be audible over the complete 11-meter and 10-meter bands, but reception will be markedly better at the frequency being used for transmission. Note also that a coaxial transmission line is used from the antenna tuner to the receiver, and that a coaxial antenna changeover relay is shown. A conventional double-circuit changeover relay could be used if twin-line is to be used to the receiver input from the tuning network.

Impedance Matching With the PI Network

The pi network, as diagrammed in figure 14, is an effective means of obtaining an impedance match between a source of r-f energy and a load impedance. Such networks are frequently used in military equipment where it is desired to match an r-f amplifier stage into an antenna of unspecified impedance characteristics. Hence these networks also are of interest to the radio amateur who is faced either with the problem of utilizing an existing military transmitter, or is faced with the more general problem of feeding a random length of wire from the output stage of an all-band transmitter.

Determining Load Impedance for the R-F Amplifier The first problem in designing a pi network to couple the energy from an r-f amplifier into a load is to determine the impedance which should be presented to the r-f amplifier stage. This value may be determined to a fair approximation through the following procedure:

Assumed:

1. R-f amplifier plate voltage, E_{bb}.
2. R-f amplifier plate power input, W_i.
3. R-f amplifier plate efficiency, N_p.

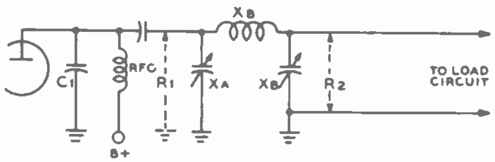


Figure 14.
PI-NETWORK IMPEDANCE MATCHING CIRCUIT.

Then:

4. Fundamental component of amplifier plate swing (peak), $E_{pm} = \frac{N_p}{0.9} E_{bb}$
5. Watts output, $W_o = W_i N_p$
6. Load impedance for r-f amplifier, $R_L = \frac{E^2_{pm}}{2\,W_o}$

As an example take the case of an 813 tube operating at 1500 plate volts, at 167 ma. plate current to give an input of 250 watts, and operating with a plate circuit efficiency of 75 per cent.

Then:

4. $E_{pm} = \frac{.75}{0.9} 1500 = 0.833 \times 1500 =$ 1250 volts
5. $W_o = 250 \times 0.75 = 187.5$ watts
6. $R_L = \frac{1250^2}{375} = \frac{1,560,000}{375} = 4160$ ohms

Basic Equations for PI Network Design Referring again to figure 14, the basic equations for the design of a pi network to effect a match between two impedances are as follows:

R_1 = Impedance at input of network (same as R_L above).

R_2 = Impedance at output of network (antenna or transmission line load).

X_A = Capacitive reactance of input capacitor.

X_B = Inductive reactance of series inductor.

X_C = Capacitive reactance of output capacitor.

1. The absolute value of X_B must be equal to or less than the geometric mean of R_1 and R_2.
   Another way of stating this is to say that $\sqrt{R_1 R_2 - X_B^2}$ must be a positive real number.
2. $X_A = \frac{-R_1 X_B}{R_1 + \sqrt{R_1 R_2 - X_B^2}}$
3. $X_C = \frac{-R_2 X_B}{R_2 + \sqrt{R_1 R_2 - X_B^2}}$

When the value of X_B is made equal to the geometric mean between the input and output impedances (when the maximum possible value of inductance is used in the filter network), the capacitive reactances of X_A and X_C will be equal in magnitude to the value of X_B. This is the maximum possible value of inductance that may be used in a pi network and still afford an impedance match. If a larger value of inductance than this value is used for X_B it will be impossible to transfer a sufficient amount of energy from the input to the output end of the network regardless of the values of capacitance used for X_A and X_C. Further, when this maximum value of inductance is used the network acts as an electrical quarter-wave transmission line and exhibits all the characteristics which would be expected of such a line. In addition to using the largest possible inductance, the quarter-wave-line type of pi matching network also uses the smallest possible values of capacitance which will provide an impedance match between two resistances.

It is more common, however, to use a somewhat smaller value of inductance than the maximum possible value in the design of a pi network which is intended to provide a match to a range of load impedances. One way of accomplishing this result is to select a value of inductance which will afford a match to the lowest value of load resistance which is expected to be encountered, and then vary the values of the input and output capacitance to afford a match to higher values of load resistance.

As an example of the design procedure let us assume that the 813 stage previously mentioned is to be used to feed load resistances from 75 to 600 ohms, but that the lowest value of impedance which will ever be used as a load is 50 ohms. The load resistance to be presented to the 813 tube is 4160 ohms (from the previous example) in all cases.

1. $R_1 = 4160$ ohms
2. Minimum R_2 ever to be matched is 50 ohms. Then:

$$X_B = \sqrt{R_1 R_2} = \sqrt{4160 \times 50} =$$
$$\sqrt{208{,}000} = 456 \text{ ohms}$$

3. Under these conditions X_A and X_C would have reactances of -456 ohms.

This same value of inductance (456 ohms) will then be used as a basis for making the calculations for other values of load impedance.

1. For $R_2 = 75$ ohms:
2. $\sqrt{R_1 R_2 - X_B^2} =$

$$\sqrt{4160 \times 75 - 456^2} =$$
$$\sqrt{312{,}000 - 208{,}000} =$$
$$\sqrt{104{,}000} = 330$$

3. $X_A = \dfrac{-R_1 X_B}{R_1 + \sqrt{R_1 R_2 - X_B^2}} =$

$$\frac{-4160 \times 456}{4160 + 330} = \frac{-1{,}900{,}000}{4490} = -424 \text{ ohms}$$

4. $X_C = \dfrac{-R_2 X_B}{R_2 + \sqrt{R_1 R_2 - X_B^2}} =$

$$\frac{-75 \times 456}{75 + 330} = \frac{-3410}{405} = -84.5 \text{ ohms}$$

1. For $R_2 = 300$ ohms:
2. $\sqrt{R_1 R_2 - X_B^2} =$

$$\sqrt{4160 \times 300 - 456^2} =$$
$$\sqrt{1{,}250{,}000 - 208{,}000} =$$
$$\sqrt{1{,}042{,}000} = 1021$$

3. $X_A = \dfrac{-4160 \times 456}{4160 + 1021} = \dfrac{-1{,}900{,}000}{5181}$

$$= -378 \text{ ohms}$$

4. $X_C = \dfrac{-300 \times 456}{300 + 1021} = \dfrac{-13{,}700}{1321}$

$$= -103 \text{ ohms}$$

1. For $R_2 = 600$ ohms:
2. $\sqrt{R_1 R_2 - X_B^2} =$

$$\sqrt{4160 \times 600 - 456^2} =$$
$$\sqrt{2{,}500{,}000 - 208{,}000} =$$
$$\sqrt{2{,}292{,}000} = 1510$$

3. $X_A = \dfrac{-4160 \times 456}{4160 + 1510} = \dfrac{-1{,}900{,}000}{5670}$

$$= -336 \text{ ohms}$$

4. $X_C = \dfrac{-600 \times 456}{600 + 1510} = \dfrac{-27{,}400}{2110}$

$$= -129 \text{ ohms}$$

The actual values of capacitance and inductance required to obtain the reactances specified by the above calculations can be determined for any particular frequency of operation through the use of the standard formulas for determining the reactance of coils and capacitors:

$$L = \frac{X_L}{2\pi f}, \quad C = \frac{1}{2\pi f X_C}.$$

Where frequency is expressed in megacycles, capacitance is in microfarads, inductance is in microhenries, and π is 3.14.

It will be seen from inspection of the values of capacitive reactance obtained from the above calculations that the square of the ratio of the capacitances in a pi network (operating with a coil of somewhat less inductance than the maximum permissible value) is approximately equal to the impedance transformation ratio of the pi network. A pi network operating under these conditions with an impedance transformation of the order of 1 to 10 will introduce approximately 30 db more attenuation to the second-harmonic output of the r-f stage than to the desired signal output. Since the second harmonic energy at the plate circuit of the tube already may be down of the order of 20 db, the second-harmonic radiation should be something like 50 db down from the fundamental output level of the transmitter. Attenuation to the third harmonic of the r-f stage will be greater. These attenuation figures assume, of course, that the pi network has been tuned properly, that there are no stray resonances which tend to favor a harmonic, and that the feed-point im-

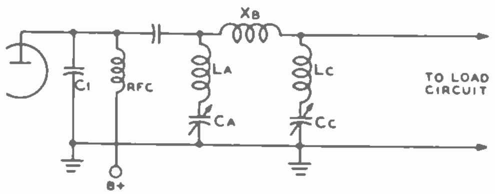


Figure 15.
PI NETWORK WITH HARMONIC SUPPRESSION.

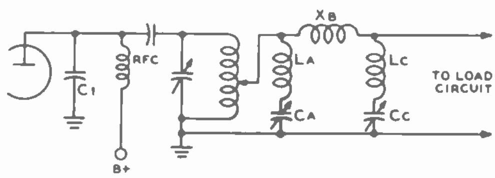


Figure 16.
PI NETWORK WITH TUNED AMPLIFIER TANK CIRCUIT.

pedance of the antenna to the second harmonic is the same as it is to the fundamental.

In many cases, however, particularly when TVI is a factor, the attenuation to harmonic radiation afforded by the conventional pi network is not great enough by many decibels. The configuration of the pi network lends itself particularly well to the introduction of additional suppression circuits to afford an additional reduction to the intensity of harmonic radiation. Any or all of the three impedances which go to make up the pi network may be resonated to cause extremely high attenuation to a particular harmonic of the fundamental output of the transmitter. As an example, X_A may be series resonated to the second harmonic, X_B may be parallel resonated to the fourth or fifth harmonic, and X_C may be series resonated to the third harmonic. In any event the net reactance of each of the legs of the pi network to the fundamental operating frequency should be unaltered by the fact that the impedance of the particular leg has been resonated at some harmonic of the operating frequency.

Figure 15 shows a pi network impedance matching circuit with two of the three branches resonated to afford rejection of a harmonic of the transmitted frequency. It is most practicable to resonate the two shunt branches of the network since one side of these two impedances is grounded. As has been mentioned before the net reactance of the combination of L_A and C_A at the fundamental operating frequency must still be the value X_A which was determined from the previous calculation. With n representing the harmonic it is desired to suppress ($n = 2$ for second harmonic, etc.) the values for L_A and C_A (or for L_C and C_C) may be determined from the following expressions:

$$L_A = \frac{X_A}{(1 - n^2)\ 2\pi f} \qquad C_A = \frac{(1 - n^2)}{n^2\ 2\pi f\ X_A}$$

In both these expressions f is equal to the fundamental frequency of operation of the pi network. In many cases it will be desirable to wind L_A so that it has slightly less inductance than specified above. Then a small trimmer capacitor may be placed across it to trim its net reactance to such a value that it will resonate at the proper harmonic of the operating frequency with the adjustment of C_A which gives proper operation of the impedance-matching action of the pi network.

Notes in Regard to the Pi Network The peak voltages to be expected across the input capacitor of the pi network are the same as would be encountered across the capacitor of a single-ended tank circuit in the plate of the amplifier tube. For the case cited above the peak voltage across the capacitor X_A would be 1250 volts for c-w or FM operation and twice this value for phone operation. The normal safety factors will apply to the selection of the plate spacing for this capacitor. Also, as can be determined from inspection of the values obtained for X_A in the previous calculations, the tuning capacitor which forms X_A need not have a particularly large capacitance range. If the 813 tube were to be operated on the 3.5-Mc. band the maximum capacitance required would be approximately 150 $\mu\mu$fd., so that a 200-$\mu\mu$fd. capacitor would be more than adequate. The peak voltage to be expected across the output capacitor of the network will be less than the voltage across the input capacitor by the square root of the ratio of impedance transformation of the network. Thus if the network is transforming from 5000 ohms to 200 ohms load, the ratio of impedance transformation is 25, the square root of this ratio is 5, so that the voltage across the output capacitor in the network would be 1/5 that across the input capacitor. If the value of E_{pm} on the output tube were 1250 volts as it was for the 813 case mentioned before, the

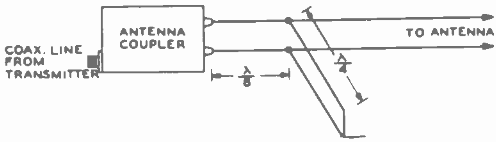


Figure 17.

LINEAR TRAP FOR THE SECOND HARMONIC.

The quarter-wave stub may be constructed of the same line as used for the antenna transmission line. It will have no effect at the operating frequency of the transmitter, but will act as a short across the line at the second harmonic. The eighth-wave section of line between the antenna coupler and the trap will act as a quarter-wave section at the second harmonic and thus will present a high impedance at the second harmonic to the terminals of the antenna coupler.

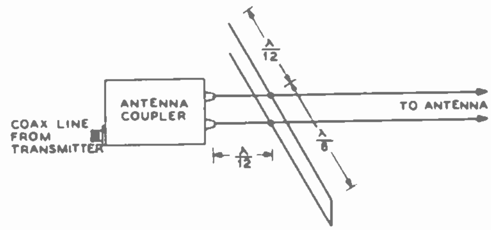


Figure 18.

LINEAR TRAP FOR THE THIRD HARMONIC.

The one-sixth-wave section of line acts as a shorted half-wave line at the third harmonic, while the one-twelfth-wave section acts as an open-ended quarter-wave line. The two sections act together to make up a shorted quarter-wave line at the fundamental so as not to impair the transmission of the fundamental frequency energy.

peak voltage across the output capacitor would be 250 volts.

A considerably greater maximum capacitance is required of the output capacitor of a pi network of the type just described which is to provide a transformation to a low value of load impedance. If the 813 stage just cited were to operate on the 3.5-Mc band a maximum capacitance of approximately 500 $\mu\mu$fd. would be required in the output capacitor.

An alternative circuit which will afford improved harmonic attenuation over the circuits of figures 14 and 15 is shown in figure 16. In this circuit the pi network is coupled to a tank circuit in the plate of the final amplifier. Thus the tank circuit will give a moderate amount of harmonic attenuation before the signal is fed to the input of the pi network.

The impedance to be reflected by the pi network to the tap-on point on the plate tank circuit will be approximately the normal load impedance of the tube divided by the square of the turns ratio of the whole coil to the tap on the coil. Thus if the normal working load impedance of the final amplifier tube should be 5000 ohms, and a 9-turn plate tank coil is used with a tap on the third turn, the value of R_1 at the input of the network should be 5000 divided by 3^2 or about 550 ohms.

Transmission Line Traps Transmission line traps may, under favorable conditions, offer a reduction in harmonic radiation after all other harmonic eliminating steps have been taken and other sources of harmonic radiation have been eliminated. Such traps are made of sections of transmission line, and are of a usable length only in the case of the 28-Mc. and 50-Mc. bands. The spacing of the conductors should be made as small as possible to reduce direct radiation from the trap section.

A trap arrangement suitable for attenuation of the second harmonic is illustrated in figure 17, while an arrangement for suppressing the third harmonic is illustrated in figure 18. In either case the traps have a relatively high Q and thus are effective over only a relatively narrow frequency range.

BROADCAST INTERFERENCE

Interference to the reception of signals in the broadcast band (540 to 1600 kc.) or in the FM broadcast band (88 to 108 Mc.) by amateur transmissions is a serious matter to those amateurs living in densely populated areas. Although broadcast interference has recently been overshadowed by the seriousness of television interference, the condition of BCI is still with us.

In general, signals from a transmitter operating properly are not picked up by receivers tuned to other frequencies unless the receiver is of inferior design, or is in poor condition. Therefore, if the receiver is of good design and is in good repair, the burden of rectifying the trouble rests with the owner of the interfering station.

Phone and c-w stations both are capable of causing broadcast interference, key-click annoyance from the code transmitters being particularly objectionable. The elimination of key clicks has been discussed in detail in *Chapter One.*

A knowledge of each of the several types of broadcast interference, their cause, and methods of eliminating them is necessary to the successful disposition of this trouble. An effective method of combatting one variety of interference is often of no value whatever in the correction of another type. Broadcast interference seldom can be cured by "rule of thumb" procedure.

Broadcast interference, as covered in this section refers primarily to standard (amplitude modulated, 550-1600 kc.) broadcast. Interference with FM broadcast reception is much less common, due to the wide separation in frequency between the FM broadcast band and the more popular amateur bands, and due also to the limiting action which exists in all types of FM receivers. Occasional interference with FM broadcast by a harmonic of an amateur transmitter has been reported; if this condition is encountered, it may be eliminated by the procedures discussed in the first portion of this chapter under Television Interference.

The use of frequency-modulation transmission by an amateur station is likely to result in much less interference to broadcast reception than either amplitude-modulated telephony or straight keyed c.w. This is true because, insofar as the broadcast receiver is concerned, the amateur FM transmission will consist of a plain unmodulated carrier. There will be no key clicks or voice reception picked up by the b-c-l set (unless it happens to be an FM receiver which might pick up a harmonic of the signal), although there might be a slight click when the transmitter is put on or taken off the air. This is one reason why narrow-band FM has become so popular with phone enthusiasts who reside in densely populated areas.

Interference Classifications

Depending upon whether it is traceable directly to causes within the *station* or within the *receiver*, broadcast interference may be divided into two main classes. For example, that type of interference due to transmitter over-modulation is at once listed as being caused by improper operation, while an interfering signal that tunes in and out with a broadcast station is probably an indication of cross-talk in the receiver, and the poorly-designed input stage of the receiver is held liable. The various types of interference and

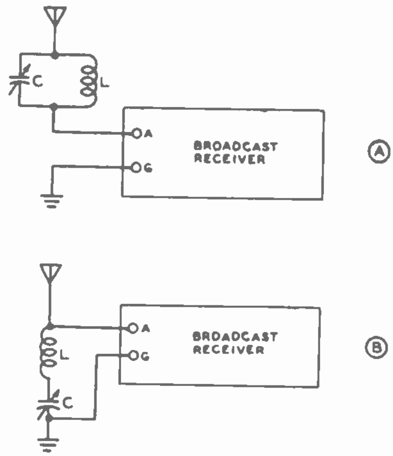


Figure 19.

CONVENTIONAL WAVE TRAP CIRCUITS.

The circuit at (A) is the most common arrangement but under certain conditions the (B) circuit may give improved results. Manufactured wave traps for the desired band of operation may be purchased or the traps may be assembled from the data in figure 21.

recommended cures will be discussed in the following paragraphs.

Blanketing This is not a tunable effect, but a total blocking of the receiver. A more or less complete "washout" covers the entire receiver range when the carrier is switched on. This produces either a complete blotting out of all broadcast stations, or else knocks down their volume several decibels—depending upon the severity of the interference. Voice modulation of the carrier causing the blanketing will be highly distorted or even unintelligible. Keying of the carrier which produces the blanketing will cause an annoying fluctuation in the volume of the broadcast signals.

Blanketing generally occurs in the immediate neighborhood (inductive field) of a powerful transmitter, the affected area being directly proportional to the power of the transmitter. This type of interference occurs most frequently where the receiver uses an outside antenna which happens to resonate at a frequency close to that of the offending transmitter. Also it is more prevalent with transmitters which operate in the 160-meter and 80-meter bands, as compared to those on the higher frequencies.

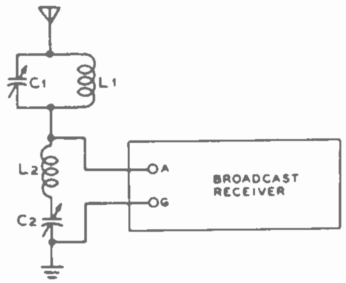


Figure 20.

HIGH ATTENUATION WAVE TRAP CIRCUIT.

The two circuits may be tuned to the same frequency for highest attenuation of a strong signal, or the two traps may be separately tuned to different bands of operation.

The remedies are to (1) shorten the receiving antenna and thereby shift its resonant frequency, or (2) remove it to the interior of the building, (3) change the direction of either the receiving or transmitting antenna to minimize their mutual coupling, or (4) keep the interfering signal from entering the receiver input circuit by installing a wave-trap tuned to the signal frequency. (See figure 19.)

A suitable wave-trap is quite simple in construction, consisting only of a coil and midget variable capacitor. When the trap circuit is tuned to the frequency of the interfering signal, little of the interfering voltage reaches the grid of the first tube. Commercially manufactured wave-traps are available from several concerns, including the J. W. Miller Co. in Los Angeles. However, the majority of amateurs prefer to construct the traps from spare components selected from the "junk box."

The circuit shown in figure 20 is particularly effective because it consists of two traps. The shunt trap blocks or rejects the frequency to which it is tuned, while the series trap across the antenna and ground terminals of the receiver provides a very low impedance path to ground at the frequency to which it is tuned and by-passes the signal to ground. In moderate interference cases, either the shunt or series trap may be used alone, while similarly, one trap may be tuned to one of the frequencies of the interfering transmitter and the other trap to a different interfering frequency. In either case, each trap is effective over but a small frequency range and must be readjusted for other frequencies.

The wave-trap must be installed as close to the receiver antenna terminal as practicable, hence it should be as small in size as possible. The variable capacitor may be a midget air-tuned trimmer type, and the coil may be wound on a 1-inch dia. form. The table of figure 21 gives winding data for wave-traps built around standard variable capacitors. For best results, both a shunt and a series trap should be employed as shown.

Figure 22 shows a two-circuit coupled wave-trap that is somewhat sharper in tuning and more efficacious. The specifications for the secondary coil L_1 may be obtained from the table of figure 21. The primary coil of the shunt trap consists of 3 to 5 closewound turns of the same size wire wound in the same direction on the same form as L_1 and separated from the latter by 1/8 of an inch.

Overmodulation A carrier modulated in excess of 100 per cent acquires sharp cutoff periods which give rise to transients. These transients create a broad signal and often generate spurious responses at odd places on the dial. Transients caused by overmodulation of a radio-telephone signal may at the same time bring about impact or shock excitation of nearby receiving antennas and power lines, generating interfering signals in that manner.

Broadcast interference due to overmodulation is frequently encountered. The remedy is to reduce the modulation percentage or to use a clipper-filter system or a high-level splatter suppressor in the speech circuit of the transmitter.

BAND	COIL, L	CAPACITOR, C
1.8 Mc.	1 inch no. 30 enam. closewound on 1" form	75-μμfd. var.
3.5 Mc.	42 turns no. 30 enam. closewound on 1" form	50-μμfd. var.
7.0 Mc.	23 turns no. 24 enam. closewound on 1" form	50-μμfd. var.
14 Mc.	10 turns no. 24 enam. closewound on 1" form	50-μμfd. var.
21 Mc.	7 turns no. 24 enam. closewound on 1" form	50-μμfd. var.
28 Mc.	4 turns no. 24 enam. closewound on 1" form	25-μμfd. var.
50 Mc.	3 turns no. 24 enam. spaced 1/2" on 1" form	25-μμfd. var.

Figure 21.

COIL AND CAPACITOR TABLE FOR AMATEUR-BAND WAVETRAPS.

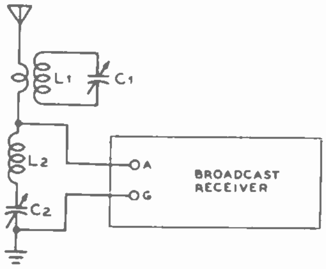


Figure 22.
MODIFICATION OF THE FIGURE 20 CIRCUIT.
In this circuit arrangement the parallel-tuned tank is inductively coupled to the antenna with a 3 to 6 turn link instead of being placed in series with the antenna lead.

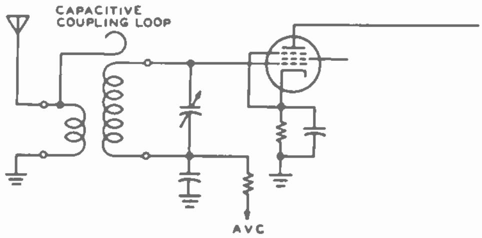


Figure 23.
CAPACITIVE BOOST COUPLING CIRCUIT.
Such circuits, included within the broadcast receiver to bring up the stage gain at the high-frequency end of the tuning range, have a tendency to increase the susceptibility of the receiver to interference from amateur-band transmissions.

Cross Modulation Cross modulation or "cross talk" is characterized by the amateur signal "riding in" on top of a strong broadcast signal. There is usually no heterodyne note, the amateur signal being tuned in and out with the program carriers.

This effect is due frequently to a faulty input stage in the affected receiver. Modulation of the interfering carrier will swing the operating point of the input tube. This type of trouble is seldom experienced when a variable-μ tube is used in the input stage.

Where the receiver is too ancient to incorporate such a tube, and is probably poorly shielded at the same time, it will be better to attach a wave trap of the type shown in figure 19 rather than to attempt rebuilding of the receiver. The addition of a good ground and a shield can over the input tube often adds to the effectiveness of the wave trap.

Transmission via Capacitive Coupling A small amount of capacitive coupling is now widely used in receiver r.f. and antenna transformers as a gain booster at the high-frequency end of the tuning range. The coupling capacitance is obtained by means of a small loop of wire cemented close to the grid end of the secondary winding, with one end directly connected to the plate or antenna end of the primary winding. (See figure 23.)

It is easily seen that a small capacitor at this position will favor the coupling of the higher frequencies. This type of capacitive coupling in the receiver coils will tend to pass amateur high-frequency signals into a receiver tuned to broadcast frequencies.

The amount of capacitive coupling may be reduced to eliminate interference by moving the coupling turn further away from the secondary coil. However, a simple wave trap of the type shown in figure 19, inserted at the antenna input terminal, will generally accomplish the same result and is more to be recommended than reducing the amount of capacitive coupling (which lowers the receiver gain at the high-frequency end of the broadcast band). Should the wave trap alone not suffice, it will be necessary to resort to a reduction in the coupling capacitance.

In some simple broadcast receivers, capacitive coupling is obtained by closely coupled primary and secondary coils, or as a result of running a long primary or antenna lead close to the secondary coil of an unshielded antenna coupler.

Phantoms When two strong local carriers are separated by a certain number of kilocycles, the beat note resulting from cross-modulation between them may fall on some frequency within the broadcast band and will be audible at that point. If such a "phantom" signal falls on a local broadcast frequency, there will be heterodyne interference as well. This is a common occurrence with broadcast receivers in the neighborhood of two amateur stations, or an amateur and a police station. It also sometimes occurs when only one of the stations is located in the immediate vicinity.

As an example: an amateur signal on 3514 kc. might beat with a local 2414-kc. police carrier to produce a 1100-kc. phantom. If the two carriers are strong enough in the vicinity of a circuit which can cause rectification, the 1100-kc. phantom will be heard in the broadcast band. A poor contact between two oxidized wires can produce rectification.

Two stations must be transmitting simultaneously to produce a phantom signal; when either station goes off the air the phantom disappears. Hence, this type of interference is apt to be reported as highly intermittent and might be difficult to duplicate unless a test oscillator is used "on location" to simulate the missing station. Such interference cannot be remedied at the transmitter, and often the rectification takes place some distance from the receivers. In such occurrences it is most difficult to locate the source of the trouble.

It will also be apparent that a phantom might fall on the intermediate frequency of a simple superhet receiver and cause interference of the untunable variety if the manufacturer has not provided an i-f wave-trap in the antenna circuit.

This particular type of phantom may, in addition to causing i-f interference, generate harmonics which may be tuned in and out with heterodyne whistles from one end of the receiver dial to the other. It is in this manner that "birdies" often result from the operation of nearby amateur stations.

When one component of a phantom is a steady, unmodulated carrier, only the intelligence present on the other carrier is conveyed to the broadcast receiver.

Phantom signals almost always may be identified by the suddenness with which they are interrupted, signalizing withdrawal of one party to the union. This is especially baffling to the inexperienced interference-locater, who observes that the interference suddenly disappears, even though his own transmitter remains in operation.

If the mixing or rectification is taking place in the receiver itself, a phantom signal may be eliminated by removing either one of the contributing signals from the receiver input circuit. A wave-trap of the type shown in figure 19, tuned to either signal, will do the trick. If the rectification is taking place outside the receiver, the wave-trap should be tuned to the frequency of the phantom, instead of to one of its components. I-f wave-traps may be built around a 2.5-millihenry r-f choke as the inductor, and a compression-type mica padding capacitor. The capacitor should have a capacitance range of 250—525 $\mu\mu$fd. for the 175- and 206-kc. intermediate frequencies; 65—175 $\mu\mu$fd. for 260 kc. and other intermediates lying between 250 and 400 kc.; and 17—80 $\mu\mu$fd. for 456, 465, 495, and 500 kc. Slightly more capacitance will be required for resonance with a 2.1 millihenry choke.

Spurious Emissions This sort of interference arises from the transmitter itself. The radiation of any signal (other than the intended carrier frequency) by an amateur station is prohibited by FCC regulations. Spurious radiation may be traced to imperfect neutralization, parasitic oscillations in the r-f or modulator stages, or to "broadcast-band" variable-frequency oscillators or e.c.o.'s.

Low-frequency parasitics may actually occur on broadcast frequencies or their near subharmonics, causing direct interference to programs. An all-wave monitor operated in the vicinity of the transmitter will detect these spurious signals.

The remedy will be obvious in individual cases. Elsewhere in this book are discussed methods of complete neutralization and the suppression of parasitic oscillations in r-f and audio stages.

A-c/d-c Receivers Inexpensive table-model a-c/d-c receivers are particularly susceptible to interference from amateur transmissions. In fact, it may be said with a fair degree of assurance that the majority of BCI encountered by amateurs operating in the 1.8-Mc. to 29-Mc. range is a result of these inexpensive receivers. In most cases the receivers are at fault; but this does absolve the amateur of his responsibility in attempting to eliminate the interference.

Stray Receiver Rectification In most cases of interference to inexpensive receivers, particularly those of the a-c/d-c type, it will be found that stray receiver rectification is causing the trouble. The offending stage usually will be found to be a high-mu triode as the first audio stage following the second detector. Tubes of this type are quite non-linear in their grid characteristic, and hence will readily rectify any r-f signal appearing between grid and cathode. The r-f signal may get to the tube as a result of direct signal pickup due to the lack of shielding, but more commonly will be fed to the tube from the power line as a result of the series heater string.

The remedy for this condition is simply

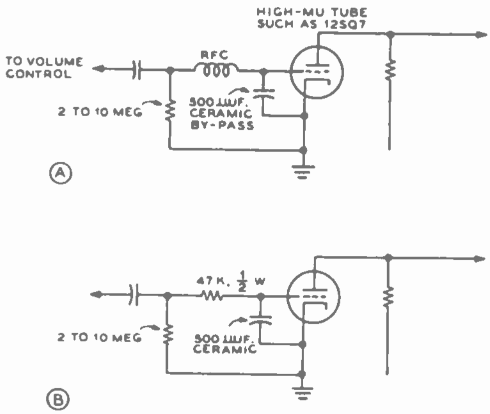


Figure 24.

CIRCUITS FOR ELIMINATING AUDIO-STAGE RECTIFICATION.

to insure that the cathode and grid of the high-mu audio tube (usually a 12SQ7 or equivalent) are at the same r-f potential. This is accomplished by placing an r-f by-pass capacitor with the shortest possible leads directly from grid to cathode, and then adding an impedance in the lead from the volume control to the grid of the audio tube. The impedance may be an amateur band r-f choke (such as a National R-100U) for best results, but for a majority of cases it will be found that a 47,000-ohm ½-watt resistor in series with this lead will give satisfactory operation. Suitable circuits for such an operation on the receiver are given in figure 24.

"Floating" Volume Control Shafts Several sets have been encountered where there was only a slightly interfering signal; but, upon placing one's hand up to the volume control, the signal would greatly increase. Investigation revealed that the volume control was installed with its shaft insulated from ground. The control itself was connected to a critical part of a circuit, in many instances to the grid of a high-gain audio stage. The cure is to install a volume control with *all* the terminals insulated from the shaft, and then to ground the shaft.

Spray-Shield Tubes Although they are no longer made, there are yet quite a few sets in use which employ spray-shield tubes. These are used in both r-f and in audio circuits. In some audio applications of this type of tube, the cathode and the spray-shield (to which the cathode is connected) are not at ground potential, but are bypassed to ground with an electrolytic capacitor of large capacitance. This type of capacitor is a very poor r-f filter, and in a strong r-f field, some detection will take place, producing interference. The best cure is to install a standard glass tube with a glove shield, which is then actually grounded, and also to shield the grid leads to these tubes. As an alternative, bypassing the electrolytic cathode capacitor with a .05-μfd. tubular paper capacitor may be tried.

Power-Line Pickup When radio-frequency energy from a radio transmitter enters a broadcast receiver through the a-c power lines, it has either been fed back into the lighting system by the offending transmitter, or picked up from the air by overhead power lines. Underground lines are seldom responsible for spreading this interference.

To check the path whereby the interfering signals reach the lines, it is only necessary to replace the transmitting antenna with a dummy antenna and adjust the transmitter for maximum output. If the interference then ceases, overhead lines have been picking up the energy. The trouble can be cleared up by installing a wave trap or a commercial line filter in the power lines at the receiver. If

BAND	COIL, L	CAPACITOR, C
3.5 Mc.	17 turns no. 14 enameled 3-inch diameter 2¼-inch length	100-μμfd. variable
7.0 Mc.	11 turns no. 14 enameled 2½-inch diameter 1½-inch length	100-μμfd. variable
14 and 21 Mc.	4 turns no. 10 enameled 3-inch diameter 1⅛-inch length	100-μμfd. variable
27 and 28 Mc.	3 turns ¼-inch o.d. copper tubing 2-inch diameter 1-inch length	100-μμfd. variable

Figure 25.

COIL AND CAPACITOR TABLE FOR A-C LINE TRAPS.

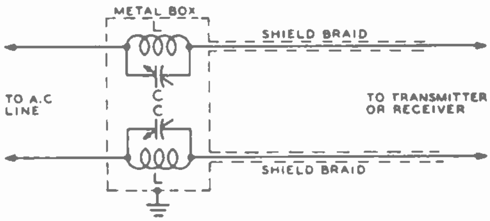


Figure 26.

RESONANT POWER-LINE WAVE TRAP CIRCUIT.

The resonant type of power-line filter is more effective than the more conventional "brute force" type of line filter, but requires tuning to the operating frequency of the transmitter.

the receiver is reasonably close to the transmitter, it is very doubtful that changing the direction of the transmitting antenna to right angles with the overhead lines will eliminate the trouble.

If, on the contrary, the interference continues when the transmitter is connected to the dummy antenna, radio-frequency energy is being fed directly into the power line by the transmitter, and the station must be inspected to determine the cause.

One of the following reasons for the trouble will usually be found: (1) the r-f stages are not sufficiently bypassed and/or choked, (2) the antenna coupling system is not performing efficiently, (3) the power transformers have no electrostatic shields; or, if shields are present, they are ungrounded, (4) power lines are running too close to an antenna or r-f circuits carrying high currents. If none of these causes apply, wave-traps must be installed in the power lines at the transmitter to remove r-f energy passing back into the lighting system.

The wave-traps used in the power lines at transmitter or receiver must be capable of passing relatively high current. The coils are accordingly wound with heavy wire. Figure 25 lists the specifications for power line wave-trap coils, while figure 26 illustrates the method of connecting these wave-traps. Observe that these traps are enclosed in a shield box of heavy iron or steel, well grounded.

All-Wave Receivers Each complete-coverage home receiver is a potential source of annoyance to the transmitting amateur. The novice short-wave broadcast-listener who tunes in an amateur station often considers it an interfering signal, and complains accordingly.

Neither selectivity nor image rejection in most of these sets is comparable to those properties in a communication receiver. The result is that an amateur signal will occupy too much dial space and appear at more than one point, giving rise to interference on adjacent channels and distant channels as well.

If carrier-frequency harmonics are present in the amateur transmission, serious interference will result at the all-wave receiver. The harmonics may, if the carrier frequency has been so unfortunately chosen, fall directly upon a favorite short-wave broadcast station and arouse warranted objection.

The amateur is apt to be blamed, too, for transmissions for which he is not responsible, so great is the public ignorance of short-wave allocations and signals. Owners of all-wave receivers have been quick to ascribe to amateur stations all signals they hear from tape machines and V-wheels, as well as stray tones and heterodyne flutters.

The amateur cannot be held responsible when his carrier is deliberately tuned in on an all-wave receiver. Neither is he accountable for the width of his signal on the receiver dial, or for the strength of image repeat points, if it can be proven that the receiver design does not afford good selectivity and image rejection.

If he so desires, the amateur (or the owner of the receiver) might sharpen up the received signal somewhat by shortening the receiving antenna. Set retailers often supply quite a sizable antenna with all-wave receivers, but most of the time these sets perform almost as well with a few feet of inside antenna.

The amateur *is* accountable for harmonics of his carrier frequency. Such emissions are unlawful in the first place, and he must take all steps necessary to their suppression. Practical suggestions for the elimination of harmonics have been given earlier in this chapter.

Image Interference In addition to those types of interference already discussed, there are two more which are common to superhet receivers. The prevalence of these types is of great concern to the amateur, although the responsibility for their existence more properly rests with the broadcast receiver.

The mechanism whereby image production takes place may be explained in the following manner: when the first detector is set to the frequency of an incoming signal, the high-frequency oscillator is operating on another frequency which differs from the signal by the number of kilocycles in the intermediate frequency. Now, with the setting of these two stages undisturbed, there is another signal which will beat with the high-frequency oscillator to produce an i-f voltage. This other signal is the so-called image, which is separated from the desired signal by twice the intermediate frequency.

Thus, in a receiver with 175-kc. i.f., tuned to 1000 kc.: the h-f oscillator is operating on 1175 kc., and a signal on 1350 kc. (1000 kc. plus 2 x 175 kc.) will beat with this 1175 kc. oscillator frequency to produce the 175-kc. i.f. signal. Similarly, when the same receiver is tuned to 1400 kc., an amateur signal on 1750 kc. can come through. The dial point where any 160-meter signal will produce an image can be determined from the equation:

$$F_b = (F_{am} - 2\ i.f.)$$

Where F_b = receiver dial frequency

F_{am} = amateur transmitter frequency, and

i.f. = receiver intermediate frequency.

If the image appears only a few cycles or kilocycles from a broadcast carrier, heterodyne interference will be present as well. Otherwise, it will be tuned in and out in the manner of a station operating in the broadcast band. Sharpness of tuning will be comparable to that of broadcast stations producing the same a-v-c voltage at the receiver.

The second variety of superhet interference is the result of harmonics of the receiver h-f oscillator beating with amateur carriers to produce the intermediate frequency of the receiver. The amateur transmitter will always be found to be on a frequency equal to some harmonic of the receiver h-f oscillator, *plus or minus the intermediate frequency.*

As an example: when a broadcast superhet with 465-kc. i.f. is tuned to 1000 kc., its high-frequency oscillator operates on 1465 kc. The third harmonic of this oscillator frequency is 4395 kc., which will beat with an amateur signal on 3930 kc. to send a signal through the i.f. amplifier. The 3930 kc. signal would be tuned in at the 1000-kc. point on the dial.

Some oscillator harmonics are so related to amateur frequencies that more than one point of interference will occur on the receiver dial. Thus, a 3500-kc. signal may be tuned in at six points on the dial of a nearby broadcast superhet having 175 kc. i.f. and no r-f stage.

Insofar as remedies for image and harmonic superhet interference are concerned,

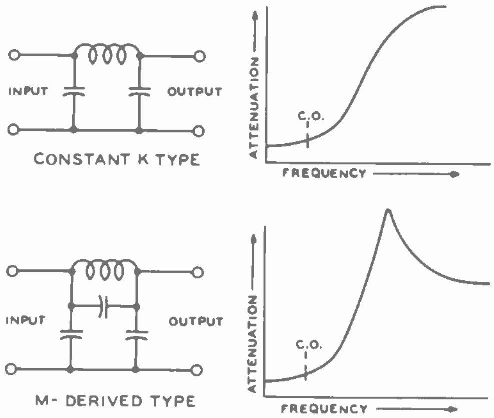


Figure 27.

TYPES OF LOW-PASS FILTERS.

Filters such as these may be used in the circuit between the antenna and the input of the receiver.

it is well to remember that *if* the amateur signal did not in the first place reach the input stage of the receiver, the annoyance would not have been created. It is therefore good policy to try to eliminate it by means of a wave-trap or low-pass filter. Broadcast superhets are not always the acme of good shielding, however, and the amateur signal is apt to enter the circuit through channels other than the input circuit. If a wave-trap or filter will not cure the trouble, the only alternative will be to attempt to select a transmitter frequency such that neither image nor harmonic interference will be set up on favorite stations in the susceptible receivers. The equation given earlier may be used to determine the proper frequencies.

Low Pass Filters The greatest drawback of the wave-trap is the fact that it is a single-frequency device; i.e.—it may be set to reject at one time only one frequency (or, at best, an extremely narrow band of frequencies). Each time the frequency of the interfering transmitter is changed, every wave-trap tuned to it must be retuned. A much more satisfactory device is the *wave filter* which requires no tending. One type, the low-pass filter, passes all frequencies below one critical frequency, and eliminates all higher frequencies. It is this property that makes the device ideal for the task of removing amateur frequencies from broadcast receivers.

A good low pass filter designed for maximum attenuation around 1700 kc. will pass all broadcast carriers, but will reject signals originating in any amateur band. Naturally such a device should be installed only in standard broadcast receivers, never in all-wave sets.

Two types of low-pass filter sections are shown in figure 27. A composite arrangement comprising a section of each type is more effective than either type operating alone. A composite filter composed of one K-section and one shunt-derived M-section is shown in figure 28, and is highly recommended. The M-section is designed to have maximum attenuation at 1700 kc., and for that reason C_3 should be of the "close tolerance" variety. Likewise, C_3 should not be stuffed down inside L_2 in the interest of compactness, as this will alter the inductance of the coil appreciably, and likewise the resonant frequency.

If a fixed 150 μμfd. mica capacitor of 5 per cent tolerance is not available for C_3, a compression trimmer covering the range of 125—175 μμfd. may be substituted and adjusted to give maximum attenuation at about 1700 kc.

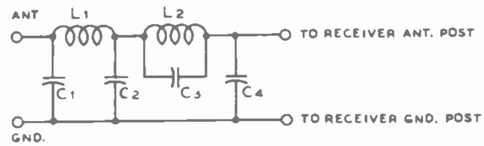


Figure 28.
COMPOSITE LOW-PASS FILTER CIRCUIT.

This filter is highly effective in reducing broadcast interference from all high frequency stations, and requires no tuning. Constants for 400 ohm terminal impedance and 1600 kc. cutoff are as follows: L_1, 65 turns no. 22 d.c.c. closewound on 1½ in. dia. form. L_2, 41 turns ditto, not coupled to L_1. C_1, 250 μμfd. fixed mica capacitor. C_2, 400 μμfd. fixed mica capacitor. C_3 and C_4, 150 μμfd. fixed mica capacitors, former of 5% tolerance. With some receivers, better results will be obtained with a 200 ohm carbon resistor inserted between the filter and antenna post on the receiver. With other receivers the effectiveness will be improved with a 600 ohm carbon resistor placed from the antenna post to the ground post on the receiver. The filter should be placed as close to the receiver terminals as possible.

REFERENCES ON TELEVISION INTERFERENCE

QST

Seybold, "Curing Interference to Television Reception," Aug. 1947, p. 19. Harmonic suppression in a 14-Mc. transmitter.

Grammer, "Interference with Television Broadcasting,"' Sept. 1947, p. 24. A survey of the TVI situation, with general recommendations.

Rand, "TVI Can Be Reduced," May 1948, p. 31. Discussing the use of many methods of harmonic suppression with a 28-Mc. transmitter.

Hills, "Traps for TVI Elimination," Oct. 1948, p. 132. Installation of tuned traps at the input of the TV receiver.

Grammer, "TVI from 21 Mc.," Dec. 1948, p. 20. Discussion of ARRL tests of i-f interference from 21-Mc. signals.

Rand, "More on TVI Elimination," Dec. 1948, p. 29. Improvements in methods of harmonic reduction, use of orderly procedure.

Rand, "The Little Slugger," Feb. 1949, p. 11. Description of a completely filtered low-power exciter/transmitter for TV areas.

Tesco, "Another TVI Kink," Feb. 1949, p. 60. Use of a tinfoil sleeve on the receiver TV line as a trap for interference.

Gemmill, "Harmonic Suppression in Class C Amplifiers." Feb. 1949, p. 28. Effect of operating conditions and circuit components on the harmonic output from Class C amplifiers.

Grammer, "Pointers in Harmonic Reduction," Apr. 1949, p. 14. Well presented discussion of methods for isolating, measuring, and reducing the generation and radiation of harmonics.

Gemmill, "Re 'Harmonic Suppression in Class C Amplifiers'," Apr. 1949, p. 34. Further information on adjustment of traps in plate circuit.

Rand, "TVI Patterns," May 1949, p. 43. Group of 24 TVI patterns showing interference from 250-watt 28-Mc. transmitter without suppression measures and as measures were successfully included in the installation.

Grammer, "High-Pass Filters for TVI Reduction," May 1949, p. 46. Description of high-pass filters for elimination of TV-set blocking.

Grammer, "TVI Tips," June 1949, p. 44. Excellent discussion of the degree of TV interference in terms of the frequency of the interfering carrier within the channel.

—TV Tips, July 1949, p. 64. "Some Suggestions for 50 Mc.," showing use of series resonant circuit tuned to 50 Mc. across receiver input terminals. "Class B and Degeneration," Burnett. Reduction of harmonics by operating r-f stages in the Class B region. "TV Antennas," Grammer. Selection of TV antennas with an eye to those types which will afford minimum pickup of amateur fundamental signals.

CQ

Owens, "Down with Harmonics," Feb. 1948, p. 29. Discussing the generation of even-order harmonics in a push-pull Class C amplifier.

Bach, "You Can Live with TV!" June 1948, p. 33. Reducing the generation of harmonic frequencies within the transmitter.

Bach, "You Can Live with TV!" July, 1948, p. 36. Reducing the radiation of harmonic signals.

Brown, "The TV Receiver: Its Operation and Common Forms of Interference," July 1948, p. 31. General information on the receiver end of TVI.

Scherer, "TVI Corrective Measures," Aug. 1948, p. 34. In-the-field experiences resulting in the elimination of TVI.

Scherer, "The Trap Box," Mar. 1949, p. 43. Description of a box containing six variable traps for determining the frequency of a signal causing TVI.

Scherer, "The Harmonic Chaser," Apr. 1949, p. 22. Description of a simple two-tube v-h-f converter for use as a field strength meter.

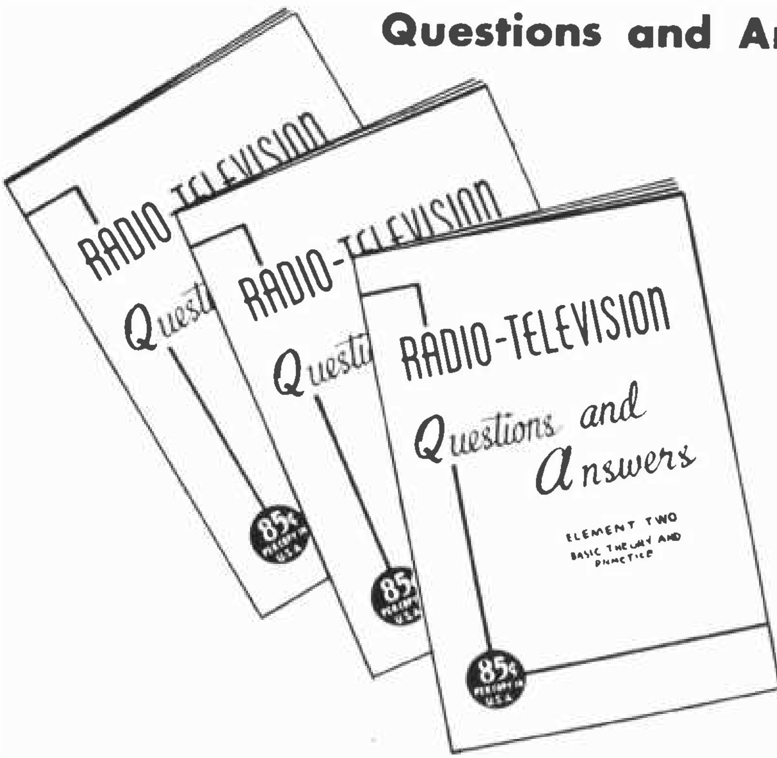
Rand, "Cure Your TVI—Three Easy Lessons," May 1949, p. 20. Excellent article suggesting the attack on TVI in an orderly manner.

Seybold, "Shielding Experiments and TVI," June 1949, p. 31. Discussion of experiments with shielding and filtering of leads.

Get Your Commercial License!

WITH THESE BRAND-NEW BOOKS

"RADIO-TELEVISION Questions and Answers"



A **separate book** for each element of the study-guide questions pertaining to the various classes of commercial U. S. A. radio operator licenses.

You need buy only those elements required for the license you want.

The F.C.C. is expected henceforth to revise questions **element by element.** Now, to keep up to date, you need buy only a new element, not a complete new book!

NOW READY!

Element 2: Basic Theory and Practice
Element 3: Radiotelephony
Element 4: Advanced Radiotelephony

85c EACH AT YOUR DEALER — On mail orders from us, $1 postpaid for one, or 90c each for two or more. Add tax in California.

Editors and Engineers LIMITED 1300 KENWOOD ROAD Santa Barbara CALIFORNIA

—Just the book to recommend to your beginner friends

A New, Better Fourth Edition of

THE RADIO AMATEUR NEWCOMER

The Only Comprehensive Book for the Beginner!

Ideal for those just getting started (or interested) in radio. You need no other book to get your license and get on the air. WRITTEN BY THE EDITORS OF "RADIO HANDBOOK."

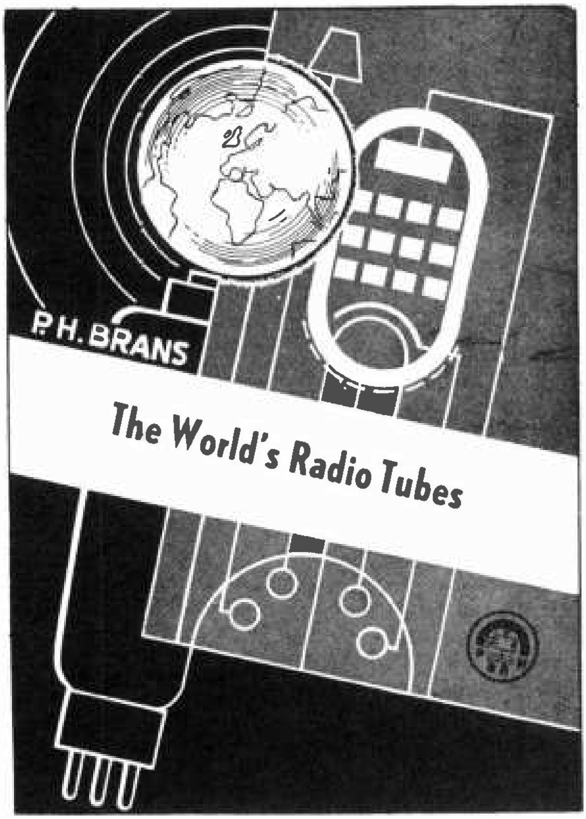
MORE MATERIAL THAN EVER BEFORE!

- How-to-build simple equipment for a complete station on all newcomer bands.
- Operating instructions.
- Simple theory.
- Complete section of study questions, including those needed to pass the license exam.
- U.S.A. Amateur radio regulations.

$1.00 AT YOUR DEALER — On mail orders from us, $1.10 postpaid. Add sales tax in California.

Editors and Engineers LIMITED 1300 KENWOOD ROAD Santa Barbara CALIFORNIA

SURPLUS RADIO CONVERSION MANUAL
SURPLUS RADIO CONVERSION MANUAL



THE

WORLD'S RADIO TUBES

(Radio Tube Vade Mecum)

The Only Book of Its Kind in the World—and one of the world's largest-selling radio books.

COMPLETE—AVAILABLE IN TWELVE LANGUAGES!

CHARACTERISTIC TUBE DATA OF

- U. S.
- BRITISH
- FRENCH
- CZECH
- SWISS
- GERMAN
- AUSTRALIAN
- ITALIAN
- RUSSIAN
- JAPANESE
- SCANDINAVIAN

and all other available types

More listings than ever before. • New, larger page size; 427 pages
Better paper and appearance

Of the previous, smaller edition, ELECTRONICS said, "Here at last is the radio tube handbook radio engineers have dreamed of . . . in many carefully prepared tables and charts." "Probably the most complete and authoritative set of tube-data in existence," said RADIO CRAFT.

$3.00 AT YOUR DEALER — On mail orders from us, $3.10 postpaid. Add tax in California. Foreign orders, $3.25 postpaid.

Editors and Engineers 1300 KENWOOD ROAD Santa Barbara CALIFORNIA

INDEX

A

Absorption-Type Wavemeter, Use of........291
Adjustment of Crystal Oscillators....46, 71, 85
Adjustment of Receivers........................27, 32
Alignment, Receiver:
  I.F. 32
  Superheterodyne Converter....33, 36, 42, 150
All-Wave Receivers, Interference in..........307
AM Equipment..166
Amplifier:
  Class B, Grounded Grid..........................116
  Class C, Types..103
  Degenerative Feedback....................169, 188
  Inverse Feedback............................169, 188
  Load Impedance.......................................298
  Single-Ended R-F......................85, 103, 107
  Standard Push-Pull Circuit.....................111
Amplitude Modulation Equipment............166
Antennas:
  Broadside Arrays...........................258, 260
  Characteristics and Considerations....248, 255
  Colinear 259
  Coupler 295
  Coupling to Transmitter.........103, 127, 295
  Delta-Matched 251
  Diamond 256, 280
  Dipole 251
  Directional Arrays...................................255
    Close-Spaced Parasitic Element..........264
    Double Extended Zepp.........................259
    Kraus Flat-Top Beam..........................261
    Multiple-Stacked Broadside................260
    Sterba Curtain......................................260
  Directivity 255
  Double Extended Zepp............................259
  Doublet 251
  Doublet Multi-Wire.......................252, 267
  Effect of Ground......................................253
  Electrical Length.....................................249
  End Fed...249
  End-Fire Directivity........................261, 264
  Flat-Top Beam..261
  Franklin Colinear......................................259
  Ground Connection.........................253, 254
  Half Wave..248
  Hertz 249
  Horizontal Pattern vs Vertical Angle......255
  Johnson Q..252
  Kraus Flat-Top Beam...............................261
  Lazy H...260
  Loading Coils..253
  Long Wire Directive Antennas.................255
  Marconi (Grounded) Antennas...............252
  Mechanisms, Antenna Rotating...............282
  Multi-Wire Doublet..........................252, 267
  Non-Resonant (Rhombic)............256, 280
  Parasitic Arrays...264
  Phased Arrays..260
  Q-Matching Section...................................252
  Radiation, End-Fire..........................261, 264
  Radiation Resistance.......................251, 266
  Resonance 249
  Rhombic 256, 280
  Rotary (Rotatable)................264, 270, 275
  Rotating Mechanisms.................................282
  Stacked Dipole...258
  Standing Wave Indicator............................243
  Sterba Curtain...260
  Three Element Rotary.................................264
  Transmission Lines.............................270, 281
  Tuned Doublet...250
  Tuned Feeder Considerations.....................249
  Two-Wire Doublet...............................252, 267
  Undirectional, Parasitic.......................260, 264
  V Type..256
  Vertical 253
  Voltage-Fed 249
  Zepp 249
Audio Bandwidth, FM..................................... 97
Audio-Frequency Amplifiers............................166
Audio-Frequency Impedance Matching,
  Modulators.......................174, 181, 187, 194
Audio Oscillator, One Tube.............................238
Audio System, Transmitter..............................166
Auto Transformer.. 10

B

Balanced Lines..270,281
Bandpass Circuits......................................33, 63
Bandset Capacitor......................................25, 28
Bandswitching Transmitter............ 55, 58, 63
Bandswitching Exciter, 15-20 Watt...... 58, 63
Barrage Array, Sterba...................................260
BC-348, 175-Kc. I-F Channel for.............. 30
Beam Power Amplifiers (See "Medium
  and High Power R-F Amplifiers")
Blanketing...................................286, 302, 305
Bleeder Resistor..200
Blocked-Grid Keying.. 13
Break-In Keying......................... 12, 61, 67, 69
Bridge Rectifier.......................................203, 204
Broadcast Interference......................................301
Broadside Antenna Arrays....................258, 260
Butterfly Circuit, Use in Transmitter........162

C

Calibrator, Crystal Controlled.............. 58, 67
Capacitance Measurement..............................241
Characteristic Impedance, Feeder........270, 281
Choke Considerations......................................200
Choke, Filter..200
Choke Input..203
Choke, Swinging..200
Circuit:
  Bridge Rectifier..................................203, 204
  FM Modulator.................................. 63, 85, 97
  Noise Limiting..135
  Phase Inverter.............................169, 188, 194
  Phase Modulation............................ 63, 85, 97
  Push-Pull R.F..111

Rectifier 203
Class B Amplifier, R.F. 116
Class B Modulator 180, 182, 185
Clickless Keying Methods 13
Clipping, Speech 98, 142, 167
Close-Spaced Directional Array 264
Coaxial Line, Use for Harmonic Reduction 103, 127, 292
Coaxial-Line Input Circuits for Receiver 36, 150
Coil, Loading 253
Colinear Antenna Design Chart 259
Colpitts Oscillator 71, 73, 76
Control Circuits, Transmitter and Receiver 22
Control of Transmitter Plate Supplies 18
Contactors and Relays, Use of 9
Converters:
Broad-Band 33
Crystal-Controlled 33
Mobile 147
28-Mc. 33
144-Mc. 38
Counterpoise 253
Coupler, Antenna 103, 127, 295
Coupler, Pi-Section 297
Coupling:
Antenna to Receiver 17, 36, 150
Antenna to Transmitter....103, 127, 295, 297
Crystal:
Calibrator 58, 63, 67
High Frequency 33, 162
Oscillators 33, 49, 58, 71
Crystal Calibrator, Use in Exciter 58, 63
Crystal Oscillator Keying 46
Crystal Oscillator Tuning Procedure 85

D

Degenerative Feedback Amplifier 169, 188
Delta-Matched Antenna 251, 268
Dipole 251
Dipole Antenna, Stacked 258
Directive Antennas 255
Double Extended Zepp 259
Doublet Antenna 250
Driving Mechanism, Antenna Rotating 282
Dynamotor, PE-103A 141, 161

E

Efficiency Modulation 198
Electrical Length 249
Electrostatic Shield 107, 227
Elements, Rotatable Antenna 265
Elimination of Harmonics 292
Elimination of Interference 286, 301
End-Fed Antennas 249, 262
End-Fire Directivity 261, 264
Exciters and Low Power Transmitters 46
Exciter Design 46, 58
Exciter Blocking for Break-In 16, 61, 67
Exciters (See also "Oscillators and Crystal Oscillators"):
20-Watt Transmitter/Exciter 46
Two-Tube All-Band Transmitter/Exciter 49
One-Tube V-F-O Unit 51
40-Watt C-W Exciter/Transmitter 55
15-Watt All-Band V-F-O Exciter Unit 58
De-Luxe All-Band FM-CW Exciter Unit 63
Exciter/Transmitter for 10 and 6 71
All-Band 257B Exciter/Transmitter 73
All-Band 4-65A Exciter/Transmitter 76
Single-Sideband Exciter/Transmitter for 75 85
Singe-Sideband Exciter/Transmitter with 807's 91
FM Exciter Unit for 3.9 Mc. 97

F

Faraday Screen (Shield) 107, 227
Feedback, Degenerative, Use of 169, 188
Feeder Losses 270, 281
Feeders, Antenna 270, 281
Feeding the Antenna 251, 263, 266
Filter:
Choke Considerations 199
Choke-Input 201
Chokes 200
Circuit Considerations 201
Circuits 201, 203
Double Section 201
High-Pass 288
Line 294, 306
Low-Pass 127, 297, 308
Pi-Section 297, 308
R-C 202
Flat-Top Beams 261
FM 63, 85, 97
Franklin Antenna (Colinear) 259
Frequency:
Calibrators 58, 67
Conversion (to wavelength) 249
Converters 33, 38, 147
Modulation, Generation of 63, 85, 97
Multipliers 46, 49, 162
Relation to Wavelength 249
Resonance, Antenna 249
Frequency Measurement:
50-Kc. Oscillator as Calibrator 63
100-Kc. Oscillator as Calibrator 58
Frequency Modulation 63, 85, 97
Frequency Modulation Transmitters.... 63, 97
Frequency Multipliers, Broad Band 63
Full-Wave Rectification 203

G

Generation of Harmonics 102, 292
Generator Whine, Suppression of 146
Glow-Discharge Voltage Regulator....201, 214
Grid Bias Pack Considerations 205, 212
Grid Controlled Rectifiers 209
Ground Resistance 254
Grounded Antennas (Marconi) 252
Grounded Grid Amplifier 116
Grounds 253

H

H (Lazy) Antenna....260
Half-Wave Radiators....248
Half-Wave Rectifiers....203
Harmonic Distortion....169, 188
Harmonic Elimination....292
Harmonic Suppression....292
Hertz Antenna....249
High-Frequency Converters.... 33, 38, 147
High-Level Splatter Suppressor....168
High Powered Amplifiers....108
Horizontal Directivity....255
Horizontal Pattern vs. Vertical Angle....255

I

I-F Amplifier Alignment.... 32
I-F Amplifier Noise Silencers....135
I-F Channel, 175-Kc. for BC-348.... 30
Ignition Noise Suppression....146
Impedance:
  Antenna....251, 266
  Characteristic Surge....270, 281
  Johnson Q Matching Section....252
  Load, for R-F Amplifier....297
  Matching (See also "Antennas")....252, 266
  Transmission Line....270, 281
Input Choke....203
Input Power Control.... 10
Interference Classifications....286, 290, 302
Interference Elimination....286, 301
  Blanketing....286, 302
  Electrical Noise....135, 145
  Image 307
  Key Clicks (See "Keying")
  Radiotelephone Interference....290, 303
  R-F Filters....127, 288, 297, 308
  Wavetraps....287, 302
Inverse Feedback....169

K

Keying:
  Blocked Grid.... 13
  Break-In.... 12, 61, 67, 69
  Cathode 46
  Circuits.... 12, 61, 67, 75
  Click Elimination.... 12
  Grid 13
  Screen-Grid 13
Kraus Flat-Top Beam....261

L

Lazy H Antenna....260
Length, Antenna....249
Limiter, Audio.... 98, 142, 167
Limiting (Noise) Circuits....135
Line, Transmission....270, 281
Linear Amplifier.... 85, 116
Loading, Transmitter....298
Losses, Feeder....270, 281
Low-Frequency Parasitics....305
Low-Level Speech Clipping.... 98, 142, 167
Low-Pass Filter....127, 297, 308
Low-Power Transmitters and Exciters.... 46

M

Marconi Antenna....252, 253
Matching Section, Q....252
Matching Stubs....251, 261
Measurement of Capacitance....241
Measuring Equipment....236
Medium and High Powered Amplifiers....103
"Millisec" Relay, Use with Break-In.... 18
Mobile Communication....134
Mobile Antennas....143
Modulation:
  Amplitude 166
  Circuits for FM.... 63, 85, 97
  Equipment 166
  Frequency (Armstrong).... 63, 85, 97
  Phase.... 63, 85, 97
  Phase Inverter Circuit....169, 188
  Splatter Suppressor....168
Modulator Operating Conditions....174, 181, 187, 194
Modulators 166
Multi-Band Exciter.... 49, 58, 63
Multiple-Stacked Broadside Arrays....260
Multi-Wire Doublet Antenna....252, 267

N

Noise-Limiting Circuits....135
Noise Factor.... 37
Noise Silencers....135
Noise Suppression, Vehicular....145
Non-Inductive Resistor for Rhombic Termination....256, 282

O

Open Wire Lines....270
Operating Conveniences.... 7
Optimum Angle of Radiation....255
Oscillator:
  Audio One-Tube....238
  Clapp.... 51, 55
  Colpitts.... 71, 73, 76
  Crystal Calibrator.... 58, 63
  Crystal Controlled.... 49, 58, 71
  Permeability Tuned.... 58, 63
  Stability 53
  Variable Frequency, One-Tube.... 51
Outlet Strips.... 9

P

Parallel Resonance in Power Supply....202
Parasitic Elimination....126, 289
Peak Current....199
Peak Limiters, Audio.... 98, 142, 167
Peak Limiters, Noise....135

Phantoms 304
Phase Inverter....169, 188
Phase Modulation, Systems for.... 63, 85, 97
Phased Antennas....258, 260
Phonograph Equalizer, Reluctance
  Pickup 180
Pi Section Antenna Coupler....297
Pi Type Filter....127, 297, 308
Positive Peak Modulation....168
Power Amplifiers:
  A-F 166
  R-F (See also "Transmitters, Final
    Amplifiers") 102
Power Control Systems.... 7
Power Input Control, Transmitter.... 10
Power Supplies....198
  Low Drain, 200 volts at 50 ma....206
  Miniature, 100 volts at 6 ma....237
  Regulated Grid Bias....212
  Thyratron Controlled....209
  Variable Voltage....209
  Voltage Regulated, 400 Volts 250 Ma...214
  350 volts at 110 ma....207
  400-volt 250-Ma....213
  600/750-Volt 200-Ma....214
  100-Watt Voltage Regulated....214
  1250-Volt 250-Ma. Power Supply....218
  1750/2000-Volt 300-Ma. Supply....235
Power Supply:
  Current Rating Considerations....199
  Filter System Resonance....202
  Grid-Bias Supplies....205, 212
  R-C Filters....202
  Ripple Calculation....201
  Voltage Regulation....201, 214
Power Systems.... 8
Powerstat 10
Push-Pull Amplifiers, Audio....169
Push-Pull R-F Circuits....111
Push-Push Doubler....162

Q

Q Antennas....252
Q Bars....252
Quarter-Wave Antenna, Mobile....143
Quarter-Wave Antenna Trans-
  former 252, 268
Quarter-Wave Matching Stub....251, 263

R

Radial Ground....253
Radiation Resistance....251, 266
Radiation, Angle of....255
Radiation, Antenna....248
Radiation, Broadside....258, 260
Radiation, End-Fire....261, 264
Radiation, Suppression of Harmonic....292
Radio Frequency Amplifiers
  (See also "Transmitters")....102
R-C Filters....202
Receiver:
  Adjustment.... 27, 32
  Alignment.... 33, 36, 42, 150
  Construction.... 25, 147
  Operation with Break-In.... 17
  Regenerative 25
  Superheterodyne Converter.... 29, 33, 38
Receivers:
  Two-Tube Regenerative.... 25
  Superheterodyne Converter.... 29, 33
  175-Kc. I-F Channel for BC-348.... 30
  Broad-Band 28-Mc. Converter.... 33
  144-Mc. Converter with Triode Tubes.... 38
  Inductively Tuned ("Inductuner")
    Converter 41
  Mobile Converter for 10 and 75....147
Rectifier and Filter Circuit Con-
  siderations 199
Rectifier, Bridge Type....203, 204
Rectifier, Circuits....203
Rectifier, Grid-Controlled....209
Rectifier Protection Circuit.... 10
Rectifier Rating (Discussion)....199
Regenerative Crystal Oscillator 49, 71, 73, 76
Regenerative Receiver.... 25
Relays and Contactors.... 9
Relay, "Millisec".... 18
Resistance, Radiation....251, 266
Resistors, Bleeder....200
Resistors, Rhombic Terminating....256, 282
Resonant Trap Circuit....287, 302
R-F Amplifiers (See also "Transmitters") 102
Rhombic Antenna....256, 280
Rotatable Antennas....264, 270, 275

S

Screen-Voltage Keying.... 13
Separate Bias Supply....205, 212
Shield, Electrostatic....107, 227
Shielding 293
Single-Ended Amplifiers....103, 107, 108, 116
Single-Sideband Equipment:
  Balanced Modulators.... 84, 92
  150-Watt Transmitter for 3.9 Mc.... 85
  Multi-Band Transmitter with
    Four 807's.... 91
  Phase-Shift Networks.... 86, 92
  Sideband Selection.... 87
  Theory 82
Slotted Line Measurements....242
Smoothing Choke....200
Soldering 47
Spacing, Rotatable Antenna Element....266
Speech Amplifiers....166
Speech Clipping....98,142,167
Speech and Modulation Equipment....166
Splatter Suppressors, High Level....168
Spray-Shield Tubes....306
Spurious Emissions....286, 289, 305
Stacked Dipole Antennas....258
Standard Push-Pull Amplifier....111
Standing Wave Indicators....241
Static, Wheel, Suppression of....146
Station Control Systems.... 7, 10, 12
Sterba Curtain Antenna Array....260
Superheterodyne Interference....307

Superheterodyne Converters 29, 33, 38, 41, 147
Supply, Bias........205, 212
Suppression, Harmonic........290, 292
Suppression, Noise, Vehicular........145
Suppressor, Parasitic........157, 289
Suppressor, Splatter, High Level........168
Surge Impedance, Transmission Line 270, 281
Swinging Choke........200

T

Terminating Resistor, Rhombic Antenna 256, 282
Test and Measurement Equipment........236
  Bridge-Type Standing-Wave Indicator....243
  Grid-Dip Meter........239
  Miniature Power Supply........237
  One-Tube Sine-Wave Audio Oscillator 238
  Standing-Wave Indicators........241
  Twin-Lamp Standing-Wave Indicator....244
  Twin-Lamp with Meter Indicator........245
Thyratron Tubes, Application in Power Supply........209
Transformer, Auto........ 10
Transmission Lines........270, 281
Transmission Speed, Radio Waves........248
Transmitter Construction........219
Transmitter Power Input Control........ 10
Transmitters:
  Adjustments to Eliminate Interference....289
  Antenna Coupling........103, 127, 295, 297
  Bandswitching 55, 58, 63
  Bias Supplies........212
  Complete:
    200-Watt All-Band........219
    Compact Kilowatt C-W........227
    400-Watt AM-FM-CW........234
    Beginners C-W Transmiter........ 46
    Two-Tube All-Band Low Power........ 49
    40-Watt C-W with V.F.O........ 55
    See also "Exciter Units"........ 46
  Construction 219
  Control, Power Input........ 10
  Exciters 46
  Final Amplifiers (See also "Transmitter Construction"):
    Shielded 807 Amplifier........103
    4-65A Single-Ended Amplifier........107
    4-125A Single-Ended Amplifier........108
    Push-Pull Standard Amplifier........111
    Single-Ended 35TG Amplifier........114
    Grounded-Grid 304TL Amplifier......116
    One-Kilowatt P-P 250TH........120
    One-Kilowatt P-P 4-250A........123
    Shielded 4-400A Kilowatt........127
  Frequency Modulation........ 63, 85, 97
  Harmonic Generation........102, 292
  Keying 12, 61, 67, 75
  Mobile 134, 152
  Parasitic Oscillations........126, 157, 289
  Power Input Control........ 10
  Power Supplies........198
Tuned Doublet........250
Tuned Feeders........250, 263
Tuning Crystal Oscillators........ 49, 58, 71, 85
Two-Section Filter........200
Two-Wire Doublet Antenna........252, 267
Two-Wire Open Line........270

V

V Antenna........256
Vacuum Tube Keying........ 13, 61, 67, 69
Variable Frequency Oscillator, One Tube.... 51
Variac, Use of........ 10
Vehicular Noise Suppression........145
V-F-O Exciter........ 51, 55, 58, 63
Voice-Frequency Filter........180
Voltage Control, Transmitter........ 10
Voltage-Regulated Power Supply........214
Voltage-Regulator Circuit........216
Voltage Regulator Hash, Suppression of....146
Voltage Regulator Tubes........214

W

Water Pipe Ground........254
Waveform:
  Peaked 167
  Power Relations in........167
  Speech, Clipping 97, 167
Waveform Distortion, Audio........167
Wavelength 248
Wavelength-Frequency Conversion........249
Waves, Standing........241, 266
Wave Trap........287, 302
Wheel Static, Suppression of........146

Y

Y-Match, Antenna........268
Yoke Match for Rotary Arrays........268

Z

Zepp Antennas........249
Zepp, Feeders for........270