CHAPTER NINETEEN

Ultra-High-Frequency Transmitters

The frequencies above 30 megacycles are generally called the ultra-high frequencies or the ultra-short wavelengths. Four amateur bands fall on frequencies above 30 Mc.; the 56 to 60 Mc., 112 to 116 Mc., 224 to 230 Mc., and 400 to 401 Mc. bands. Equipment designed for use in these frequency ranges is generally quite different from the equipment designed for use below 30 Mc. Hence, this chapter will deal with the practical design of transmitters for use within the limits of these bands.

The primary activity on the u.h.f. bands is telephony, although some i.c.w. and occasionally some c.w. is heard. On the 5-meter band (56 to 60 Mc.) radiophone transmitters are either crystal controlled or m.o.p.a. with a very high-Q self-excited oscillator and preferably at least one buffer stage. Modulated oscillators are not suitable for use on the 5-meter band, as the stability requirement set forth in the FCC regulations automatically rules them out. Frequency modulated transmission is, however, permitted in the range from 58.5 to 60 Mc., and on all frequencies within the bands above 60 Mc.

On 2½ meters (112-116 Mc.), 1¼ meters (224-230 Mc.), and ¾ meters (400-401 Mc.) the FCC is more lenient, and modulated oscillators are permitted in the interest of simplicity. However, some attempt at stabilizing the oscillator is usually made, and the advantages of m.o.p.a. transmitters are the same as on the low-frequency bands, when greatest simplicity is not needed. Oscillator stabilization is usually accomplished through the use of high-Q circuits, particularly in the grid circuit. High Q is obtained through the use of linear tanks (parallel rods or pipes) or by concentric tanks. The circuit Q is often increased still further in the grid circuit by tapping down on the quarter-wave grid line for the grid connection to the tube.

Portable and mobile operation on frequencies above 112 Mc. can be accomplished with a minimum of equipment through the use of transceivers, or combined transmitter-receivers; these have been described in the previous chapter.

Chapter Subdivisions. In order to classify the types of equipment used on the ultra-high frequencies and the micro waves, this chapter will be subdivided into the following divisions: Oscillators and M.O.P.A. Transmitters, Crystal Controlled Transmitters and U.H.F. Amplifiers, Frequency Modulation Transmitters, and Micro-Wave Transmitters.

OSCILLATORS AND M.O.P.A. TRANSMITTERS

The majority of the equipment to be shown under this heading will be of the simple oscillator type, since this type of equipment is quite adequate for experimental 112- and 224-Mc. communication. However, when greater frequency stability is desired, it is always advisable to place an amplifier or frequency multiplier between the oscillator and the final amplifier which is to be keyed or modulated. Some of the newer u.h.f. triodes such as the HK-24, 35TG, HY-75, and 1628 can be operated quite efficiently as push-pull triplers and will allow quite satisfactory neutralization in a push-pull amplifier when the conventional cross connected neutralizing circuit is used. Single ended amplifier stages can be neutralized most satisfactorily by the *coil* or *inductive* neutralization circuit shown under *Transmitter Theory.* The "coil" in this case can best be a short section of closely spaced open-wire line to resonate to the operating frequency by the grid-to-plate capacity.

U.H.F. Push-Pull Beam Tubes. Within the last few months several excellent push-pull u.h.f. beam tubes have made their appearance: 829, 815, etc. These tubes make excellent push-pull r.f. amplifier stages at 56, 112, and 224 Mc. and they have the advantage that, if the input circuit is properly shielded from the output, no neutralization will be required.

112-Mc. Equipment

20-Watt HY-75 Oscillator. This little transmitter was primarily designed to replace the final amplifier stage of a ten-meter mobile transmitter and to be modulated by the speech and modulator system which was originally used with the ten-meter transmitter. It consists of an HY-75 ultra-audion oscillator with conventional coil-and-condenser tank circuit. A concentric pipe or parallel rod oscillator would undoubtedly give greater stability, but with a low capacity, high transconductance tube the stability has been found sufficiently good with the tank circuit shown. The only precautions that need be taken in the construction of the transmitter is to make sure that all r.f. leads are as short as possible, that all parts are mounted rigidly, and that good u.h.f. insulation be used where it is in contact with high potential r.f. The tuning condenser should be of the ultra midget type, and it should be wired so that the rotor goes to the grid. The exact number of turns for the tank coil will depend somewhat on the physical layout and particular make of components chosen. Some pruning may be required on the coil. It should hit the band when the tuning condenser is about half meshed. Observe that both rotor and stator are hot to ground, both to d.c. and r.f.

The tube socket is not exposed to r.f., and may be of the inexpensive wafer type. It is important that the tube be mounted in a vertical position for good filament life.

Figure 1 shows a back view of the oscillator. It has been mounted upon this small chassis so as to take up as little space as possible when placed alongside the modulator system for the mobile ten-meter transmitter. Normal operation of the oscillator will be with 300 volts at about 80 ma. on the plate. If desired, the power input may be raised to 425 volts at 80 ma. to give about 35 watts input. The circuit diagram of the oscillator is shown in figure 2.

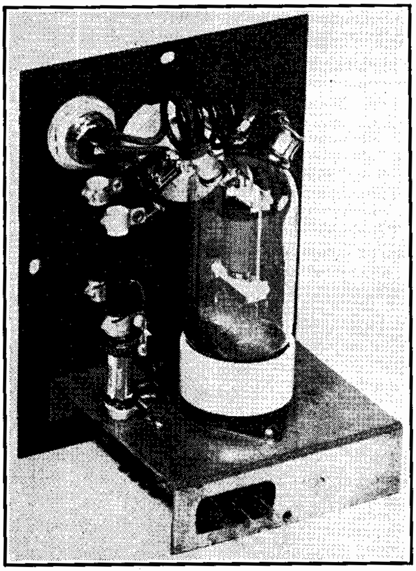


Figure 1.
20-WATT 112-MC. OSCILLATOR.
This diminutive oscillator will take 35 watts input on 112 Mc., and will deliver quite a substantial signal on the band. The tube clips are connected to the tank condenser by means of narrow copper ribbon. A one-turn link at the grid end of the tank connects to a coaxial cable connector.

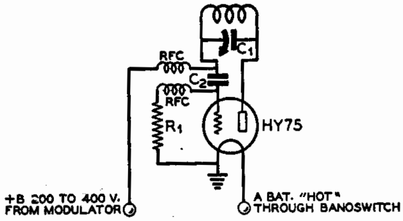


Figure 2.
SCHEMATIC OF THE HY-75 112-MC. OSCILLATOR.

C_1—15-$\mu\mu$fd. sub-midget condenser
C_2—.0001-μfd. midget mica
RFC—U.h.f. choke
R_1—2500 ohms, 1½ watts
Coil—4 t. no. 14 enam., ½" dia. spaced to hit band

Inexpensive 8-Watt Oscillator and Modulator. For the amateur who wishes to build an inexpensive low-power station transmitter for 112 Mc., the unit shown in figure 3 and diagrammed in figure 4 is ideal. It uses inexpensive tubes throughout, is built upon a breadboard, and has a quite respectable power output capability.

The oscillator is built on a baseboard measuring 5 x 23 x ¾ inches. The two rods

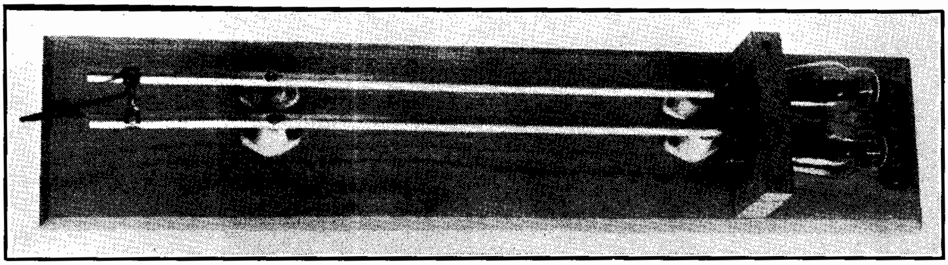


Figure 3.
112-MC. BREADBOARD OSCILLATOR USING PUSH-PULL TRIODES.
The oscillator is built breadboard fashion, with connections made directly to the tube prongs. The linear tank circuit permits comparatively high efficiency and gives an output of 8 to 10 watts. A suitable modulator and power supply are shown in figure 4. 6P5-GT's or 7A4's may be substituted for the 76's shown if desired; it will be necessary to lengthen the rods about one-half inch with the 6P5-GT's and 7A4's.

are each 15½ inches long, of either copper or aluminum ⅜ inch o.d. tubing. They are supported on 1½-inch standoff insulators, placed as shown.

The "stock" supporting the tubes is made from a block of wood measuring 4¼ x 2½ x ¾ inches. The grain should run the long way of the block. Holes are drilled just large enough to take the bases of the tubes, their centers 1⅝" apart and ⅞" from one of the 4¼" edges. Now with a ripsaw, cut the length of the block parallel to the long edges, through the centers of the two socket holes. The tubes will be held firmly, with a viselike grip, when two screws are run down through the assembly and into the baseboard 5 inches from one end of the latter.

This method of mounting the tubes, and soldering direct to the tube prongs, permits shorter leads than could be obtained with any type socket, as even socket terminals represent objectionable lead length at this frequency.

Bakelite tube bases show rather high losses at 2½ meters, but it is possible to reduce these losses by putting two hacksaw slots in the base of each tube, between the plate and grid prongs. Be sure to saw all the way through the base (about 1/16"), but don't go any farther or you may saw into the glass tip that seals the stem of the tube.

The grid coil is soldered directly to the grid prongs of the tubes, which should be mounted with the grid prong (the isolated prong) upward. The coil consists of 5 turns of no. 14 enamelled, spaced to approximately ⅝". The exact spacing constitutes tuning of the grid circuit. The carbon resistor which serves as a grid leak is mounted vertically between the grid coil and the wood "stock." The top of the resistor is soldered to the center turn of the grid coil (top of the coil) and the other resistor lead is soldered to the jumper which connects the two 76 cathodes.

The sliding jumper for the plate tank is constructed by soldering together two of the older type grid clips which just slip over a ⅜" diameter. These make firm contact to the rods, and can be slid along by pressing upon the two "tongues" while attempting to slide them. The lead from this jumper runs underneath the baseboard *midway between the two tank rods* to prevent unbalancing of the circuit.

Tuning. The oscillator is tuned by placing the shorting bar 14½ inches from the plate end of the plate tank rods. With the antenna disconnected, squeeze the grid coil in and out until the oscillator draws 50 ma. It should be possible to draw small sparks from the plate end of the rods with the tip of a lead pencil, indicating oscillation. The antenna is now coupled to the plate tank by means of hairpin link, the coupling being adjusted until the oscillator draws 60 ma. Tighter coupling should not be used, as the life of the 76's will be greatly shortened if they are allowed to draw over 60 ma. for any length of time. The output under these conditions will be very close to 8 watts.

The microphone jack, MIC, must be of the closed circuit (shorting) type. Otherwise the low voltage by-pass condenser C_1 will be blown when the microphone plug is removed.

100-Watt 75T Resonant-Line 112-Mc. Oscillator. Figures 5 and 6 illustrate a concentric line controlled 112-Mc. oscillator using a 75T, which will put out approximately 100 watts of stabilized r.f. on any frequency in the 112-116 Mc. amateur band. A short concentric line, which is resonated to the operating frequency by means of a 35-$\mu\mu$fd. midget variable, acts as the frequency deter-

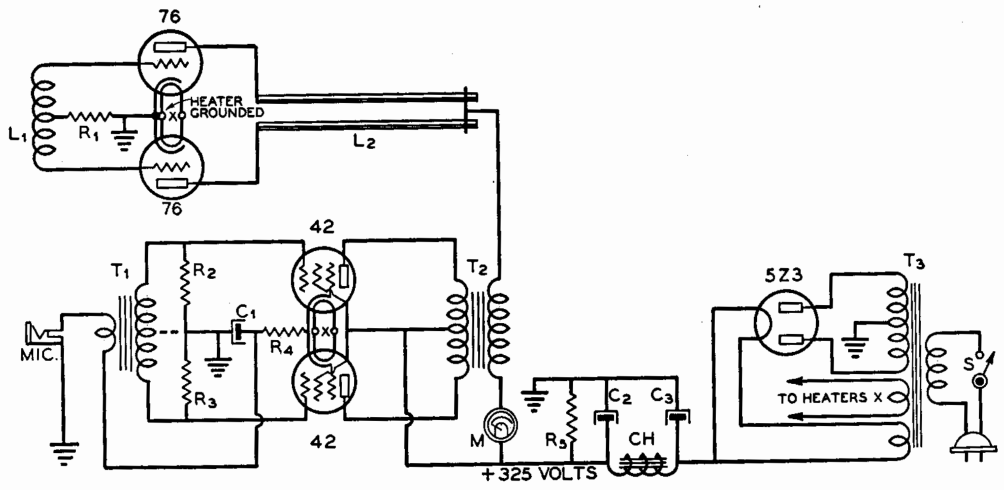


Figure 4.
WIRING DIAGRAM OF THE ECONOMY 112-MC. TRANSMITTER.

L_1—5 turns no. 14 enameled, ½" dia., spaced to approx. ⅝" (see text)
L_2—Copper or aluminum tubing "linear tank," each element ⅜" dia., 15½" long, spaced 1¼" center to center (see text)
C_1—25-μfd. 25-volt electrolytic
C_2, C_3—Single "dual 8-μfd." electrolytic, 450 w.v.
R_1—7500 ohms, 1 watt
R_2, R_3—200,000 ohms, 1 watt
R_4—400 ohms, 10 watts
R_5—50,000 ohms, 2 watts
T_1—High ratio sing. button mike trans. (see text)
T_2—Class-B output transformer for 6N7, 6A6, 53, etc. to class-C load
T_3—350 v. each side c.t. at 110 ma.; 5 v. at 3 amp.; 6.3 v. at 2 amp.
CH—10 to 30 hy., 110-ma. filter choke
M—0-100-ma. milliammeter
MIC — Closed circuit jack for microphone

mining element; output power is taken from a self-resonant coil in the plate circuit.

The concentric line itself is 12 inches long and 2⅞ inches inside diameter (3" o.d. with 1/16" wall), and the inner conductor is 13¼ inches long and ¾ inches in diameter. Both pieces which make up the line are cut from standard lengths of thin-wall copper water pipe. To make up the line first the inner conductor is soldered to the center of a piece of 20-gauge copper sheet about 3½ inches square with the aid of a small alcohol torch and a soldering iron. Then the outer conductor is slipped over it and also soldered in place. Considerable heat is required to do the soldering, but if the work is placed on a block of wood as insulation, a small alcohol torch *and* a conventional electric soldering iron will do the job quite easily. The wood will be thoroughly charred when the work is finished but it will have served its purpose. Asbestos would probably be better but wood will be satisfactory.

A hole is drilled in both the inner and the outer conductor 2¼ inches up from the base on the line. Then another hole is drilled in the center of the base so that a wire may be run through it, through the inner conductor, and then through the hole 2¼ inches up through both the inner and outer conductor to connect to the grid of the tube. This wire is by-passed immediately to ground and one side of the filament of the 75T as it leaves the base of the line.

The plate coil consists of three turns of no. 12 wire 1¼ inches in diameter and 2 inches long. The upper end of this coil is by-passed to the concentric line by means of a .0001-μfd. 5000-volt mica condenser. This plate coil was found to resonate over the entire 2½-meter band with the plate-to-ground capacity of the 75T and the distributed capacity of the circuit.

With the circuit constants shown the grid condenser will tune the oscillator to the center of the 2½-meter band when it is about half meshed. About 30° rotation of the condenser will cover the band. Approximately 100 watts output may be obtained from the oscillator at 1250 plate volts and at a plate efficiency of 50 to 65 per cent.

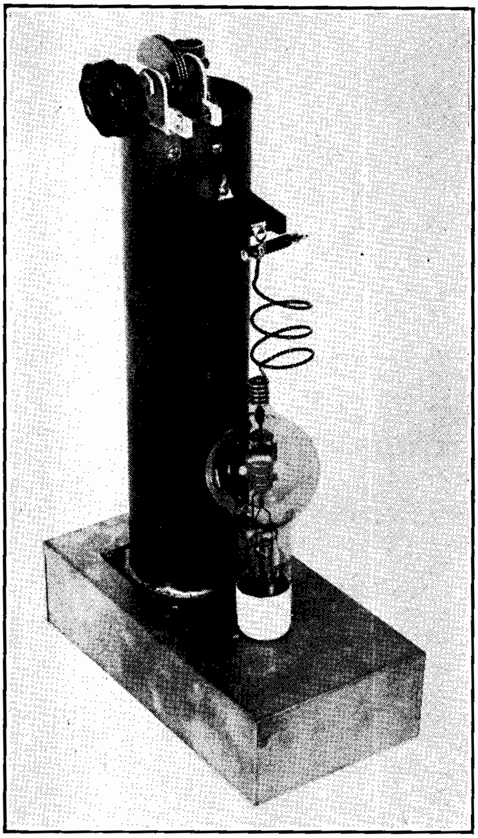
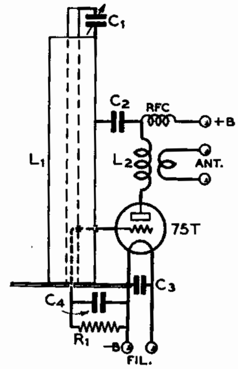


Figure 5.
CONCENTRIC-LINE 75T OSCILLATOR.
This concentric-line oscillator with a 75T gives good stability and a quite reasonable power output on the 112-Mc. band.

Figure 6.
SEMI-SCHEMATIC OF THE 75T OSCILLATOR.



C_1—35-$\mu\mu$fd. midget variable
C_2—.0001-μfd. 5000-volt mica
C_3—.003-μfd. midget mica
C_4—.0005-μfd. 1000-volt mica
R_1—5000 ohms, 10 watts
L_1—Concentric grid line—see text
L_2—Resonant plate coil and link—see text

224-Mc. Equipment

Within the last few months a great deal of interest has been centered on the 224-Mc. band due to the peculiar conditions which exist upon it, and due to the fact that, for a given amount of power, greater signal strength is obtainable over an optical path than with use of any of the lower frequencies.

A 2-Watt 7A4 Oscillator. Figure 7 shows a 224-Mc. oscillator using a 7A4 which can be used either as a transmitter to give about 2 watts output, or as a superregenerative detector to feed an audio amplifier as a receiver. The unit as shown, and as illustrated in the circuit diagram, is set up as a low-power 224-Mc. oscillator. For this use the grid leak R should be 7500 ohms and should be connected between the grid of the 7A4 and ground. For the proper method of tuning this oscillator to a given frequency in the 1¼-meter band through the use of Lecher wires, see the chapter *U.H.F. Communication.*

As an oscillator the plate voltage on the 7A4 should be limited to 250 volts and the plate current should not be greater than 30 ma. The resting plate current of the oscillator, unloaded, will be about 18 to 20 ma.; when the circuit is loaded to 30 ma. about 2 watts may be taken from the antenna coupling link.

The plate hairpin of the oscillator is made from no. 10 bare copper wire (actually no. 10 enamelled wire from which the enamel has been scraped); it is bent into a narrow hairpin with about 3/32″ spacing between the wires. The length from the turn on the loop where the plate voltage connection is made to the plate of the tube is 4½″. The length along the other side of the loop from the plate voltage connection to the grid *condenser* is 3¼ inches. Quite a wide adjustment in frequency may be obtained by varying the spacing between the wires in the hairpin. Decreasing the spacing *increases* the frequency, and increasing the spacing decreases the frequency of oscillation. It is quite simple to vary the frequency of oscillation from about 180 Mc. up to 230 Mc. merely by making a comparatively small adjustment in the spacing from just over ⅛″ to 3/32″.

To convert the oscillator into a superregenerative detector it is only necessary to remove the 7500-ohm resistor that goes from the grid to ground and then to place a 500,000-ohm resistor directly across the grid condenser. Making the return of the grid leak to positive high voltage in this manner greatly

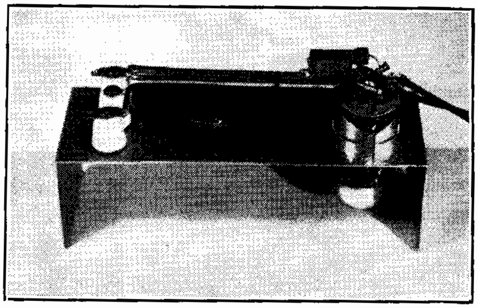


Figure 7.
2-WATT 224-MC. OSCILLATOR.
This simple and inexpensive oscillator may be used either as a low-power transmitter on the 1¼-meter band or, by a slight circuit alteration, as a 224-Mc. band superregenerative receiver.

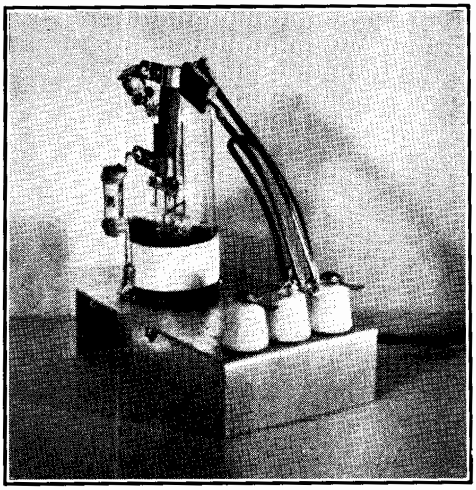


Figure 9.
8-WATT HY-75 224-MC. OSCILLATOR
This small HY-75 transmitter is ideal for the amateur who wishes a medium-power 1¼-meter oscillator for both fixed station and portable use.

increases the output of the tube when operating as a detector, as compared to when it is returned to ground. Note that it is necessary to have the .003-μfd. by-pass condenser from the plate return to ground for the tube to superregenerate.

An HY-75 8-Watt Oscillator. Another 224-Mc. oscillator using a hairpin as the resonant line is illustrated in figure 9 and diagrammed in figure 10. The lead lengths from the center of the hairpin to the plate of the HY-75 and to the grid condenser are the same as for the 7A4 oscillator just described. An r.f. choke has been used between the grid and the grid leak because of the comparatively low value of resistance of this leak resistor. It was not required in the 7A4 oscillator because of the considerably higher grid-leak resistance. A grid-leak resistance from 3000 to 4000 ohms has been found to be best for the HY-75 in this circuit.

The operating voltage on the HY-75 should be from 275 to 300 volts. The unloaded plate current of the oscillator will be about 30 to 35 ma. and it can safely be loaded to 75 or 80 ma. before excessive plate heating takes place. With this value of power input, the output will be from 8 to 10 watts.

A Push-Pull HY-75 Oscillator. The unusual parallel-rod push-pull oscillator shown in figure 11 and diagrammed in figure 12 has proven to be quite a satisfactory source of power for experiments in the 224- to 230-Mc. amateur band. A parallel-rod line is used as the frequency controlling element and a small self-tuned coil is used in the plate circuit.

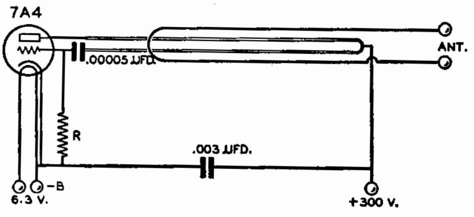


Figure 8.
SCHEMATIC OF THE SIMPLE 7A4 224-MC. OSCILLATOR.
The resistance R should be 7500 ohms for operation of the oscillator as a transmitter. For operation as a superregenerative detector, R should be removed and a 500,000-ohm resistor placed across the grid condenser. The plate circuit of the 7A4 may then be fed into a conventional audio amplifier.

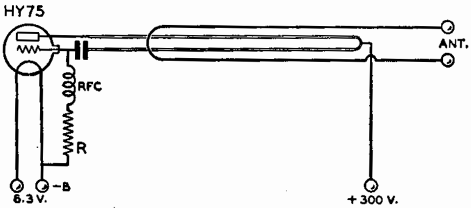


Figure 10.
SCHEMATIC OF THE HY-75 224-MC. OSCILLATOR.
The grid leak R should have a resistance of about 3000 ohms for normal use. The grid condenser should have a value of .00005 μfd.

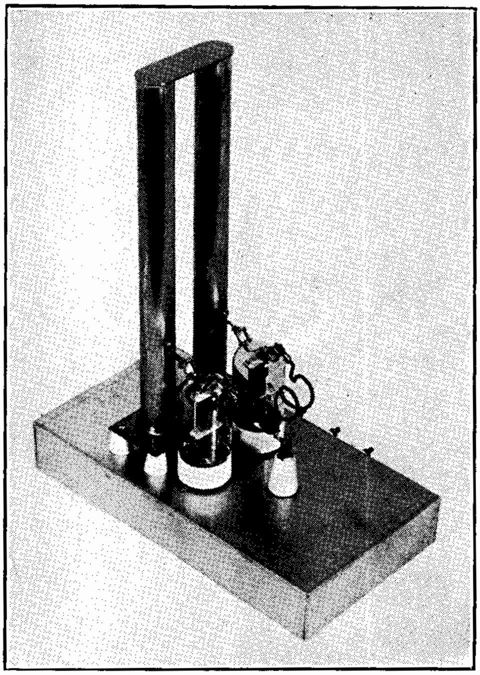


Figure 11.
PUSH-PULL 224-MC. HY-75 OSCILLATOR.

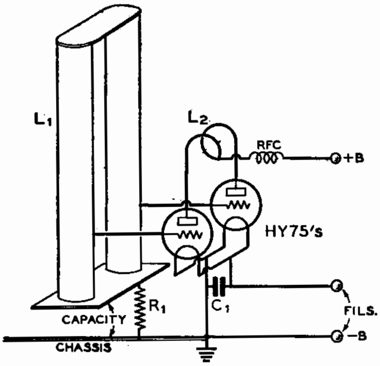


Figure 12.
SEMI-SCHEMATIC OF THE PUSH-PULL 224-MC. OSCILLATOR.

C_1—.003-μfd. midget mica
R_1—5000 ohms, 10 watts
L_1—Half-wave parallel-rod line
L_2—2 turns 5/8" dia., 1" long
RFC—6 turns hookup wire, 1/4" dia.

The resonant line is made up of two 7/8 inch, thin-wall copper pipes spaced 7/8 inch, 9½ inches long overall, and connected together both at the top and bottom to act as a half-wave line instead of the more common quarter-wave arrangement. The base for the line is a piece of 20-gauge sheet copper 1¾" by 4" which is mounted above the 9½" by 5" by 1½" chassis by means of one-half inch standoff insulators.

The capacity to chassis of the copper base plate acts as a by-pass for the center of the parallel-rod line. The copper plate can be proven to be acting normally as a by-pass since its center will be quite cold to r.f. One of the standoffs which supports the copper plate is of the feedthrough type and has the grid leak connected between its lower end and the grounded side of the filaments of the tubes.

The power output of the oscillator as shown is 20 to 25 watts with 450 volts on the plates of the tubes. The plate efficiency is approximately 40 per cent with the half-wave line in the grid circuit as shown. The plate efficiency was somewhat less than this until the original quarter-wave grid line was replaced with the capacity-shortened (grid-to-ground capacity) half-wave line.

50-Watt 225-Mc. 829 M.O.P.A. Transmitter. Figures 13 and 14 illustrate a very interesting 225-Mc. transmitter of quite respectable power handling capabilities. This transmitter is particularly interesting in the fact that it is an oscillator-amplifier affair instead of being merely an oscillator as are most transmitters for this high a frequency. The fact that the final stage is an amplifier indicates that it is quite possible to double down to a frequency as high as 225 Mc. for crystal controlled or frequency modulation transmission and still be able to find an arrangement which will be capable of operating as an amplifier at this extremely high frequency. As a matter of fact, the 829 amplifier stage operates with a plate efficiency of about 60 per cent when fully loaded, and requires a driving power of less than five watts actual output from the preceding stage.

The 829 tube itself is particularly designed for operation as an r.f. amplifier for frequencies above 50 Mc. It consists of a pair of beam tetrodes with a total plate dissipation of 40 watts mounted inside an envelope in which lead length has been made a primary consideration. The tube has no base, the terminal leads for the tube elements being brought out to tungsten rods which extend through the glass bottom plate of the envelope.

The socket for this tube is also very interesting and it, in addition, is particularly designed for u.h.f. use. The photographs give a good general idea of its construction: all the leads which are normally cold, heaters,

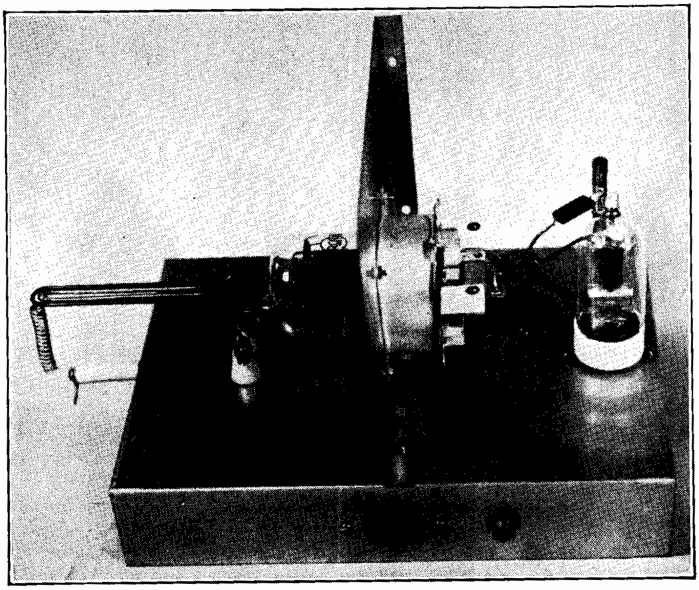


Figure 13.
TOP VIEW OF THE 829 M.O.P.A. 225-MC. TRANSMITTER.

cathode, and screens, are brought out through large terminal clips which have built-in mica by-pass capacitors. Then, the grid leads to the two elements within the envelope are brought out to a separate mycalex arbor which is supported away from the base of the socket by means of small ceramic pillars.

The general layout of the HY-75 oscillator which is used as the exciter for the 829 can be seen in the top view photograph. The oscillator circuit is an ultra-audion, with a combination resonant line and coil in the plate circuit. The lead from the plate extends about 1½″ and the lead from the grid condenser about ½″ and then they are crossed over to form a one-turn coil. Another one-turn coil is interwound with this and connected to the two grid terminals on the 829 socket. The schematic diagram, figure 15, gives a general idea of the arrangement of these two circuits but it does not indicate graphically the fact that the two one-turn coils are interwound—at least in as much of a manner as two one-turn coils can be interwound.

If desired, the frequency of the HY-75 oscillator may be controlled by a quarter-wave concentric line, in the same general fashion as the frequency of the 75T 112-Mc. oscillator is controlled. The grid of the HY-75 should be tapped up a short distance from the bottom of the capacity loaded line, and the plate return made to the side of the line in the same manner as the 75T oscillator described previously. An alternative arrangement would be to use the HY-75 as a frequency doubler from the 112-Mc. band for crystal controlled or FM transmission. The plate and grid circuits of the 829 amplifier would be the same as shown, and the plate tank of the HY-75 would be returned to ground with the 112-Mc. excitation fed to the grid.

The normal plate voltage of the 829 is 400 volts, the screen voltage is 200 volts, and the grid bias should be 35 to 45 volts. The grid current of the 829 as shown is about 8 to 9 ma. through a 4000-ohm grid leak. The amplifier operates very satisfactorily with a

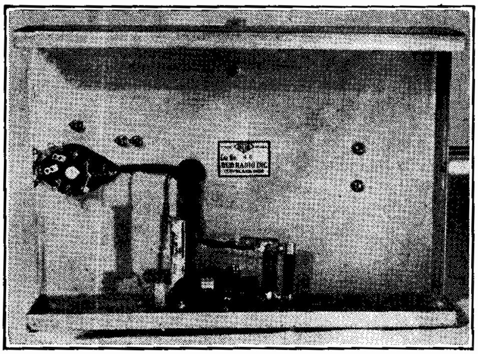


Figure 14.
BOTTOM VIEW OF THE 829 TRANSMITTER.

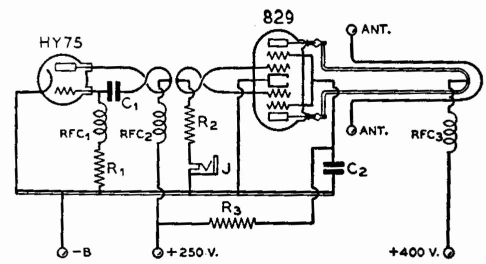


Figure 15.

SCHEMATIC OF THE HY-75, 829 224-MC. TRANSMITTER.

C_1—.00005-μfd. midget mica
C_2—.0005-μfd. midget mica
R_1—7500 ohms, 1 watt
R_2—4000 ohms, 1 watt
R_3—7500 ohms, 10 watts
RFC_1—Midget u.h.f. choke
RFC_2—12 t. hookup wire, 1/4" dia.
RFC_3—15 t. no. 14, 1/8" dia.
Coils and lines—See text

plate current of 200 ma., and the plate current may be run as high as 240 ma. if the full rating of the tube is to be used. The output at 200 ma. plate current (400 plate volts) is about 40 watts; at 240 ma. plate current it is about 50 watts.

The total length of the no. 10 bare wire tank circuit is 4¼″ from the plate seals of the tube to the end of the hairpin. The spacing between wires is ⅛″ for about 3″ until the wires spread out to make soldered connection to the plate clips of the 829. The actual plate clips are small hard copper spring clips of the type supplied with HK24 tubes to make the plate connection to them. The plate line is resonated to the frequency of the oscillator by sliding the line back and forth on the tungsten rods that come out of the 829 envelope as the plate connections. The type of plate clips shown are particularly suited to this application since they slide back and forth comparatively freely on the plate lead rods.

CRYSTAL-CONTROLLED U.H.F. TRANSMITTERS

Crystal control provides the same advantages of excellent frequency stability and reliability on the u.h.f. bands that it does on the lower frequencies. However, due to the relatively greater difficulty of getting amplifier and frequency multiplier stages into operation on the higher frequency bands, crystal control is not widely used except in the case of more elaborate transmitters. High-frequency crystals have made their appearance on the market, but due to their inherent instability, high temperature coefficient, and lack of ruggedness, they have fallen into disuse, and, in fact, have been discontinued by some manufacturers. Hence, for most amateur work, the highest practical operating frequency for the crystal is 7300 kc. From this comparatively low frequency a rather large number of doublers are required to get down to the u.h.f. bands. However, through

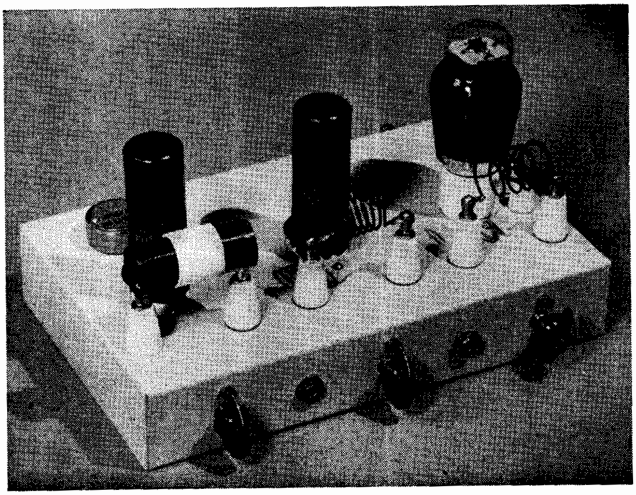


Figure 16.

THREE-STAGE 20-WATT CRYSTAL-CONTROLLED 56-MC. EXCITER UNIT.

A 6L6 oscillator on 7 Mc. drives a 6L6G quadrupler, which in turn drives a T21 doubler to 56 Mc. Power output may be taken from any of the three stages by means of a coupling link.

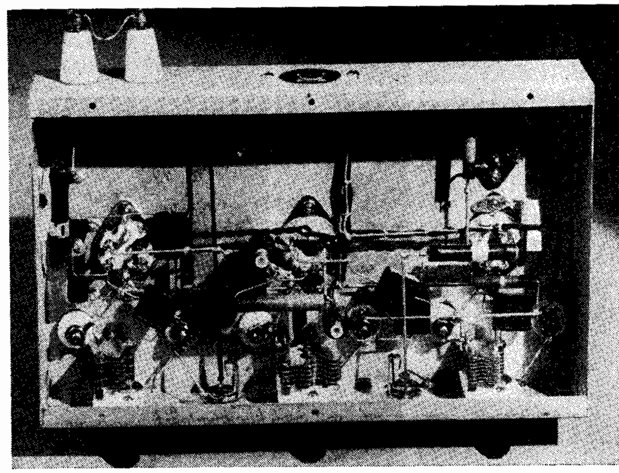


Figure 17.
UNDER-CHASSIS VIEW OF THE 56-MC. R.F. UNIT.

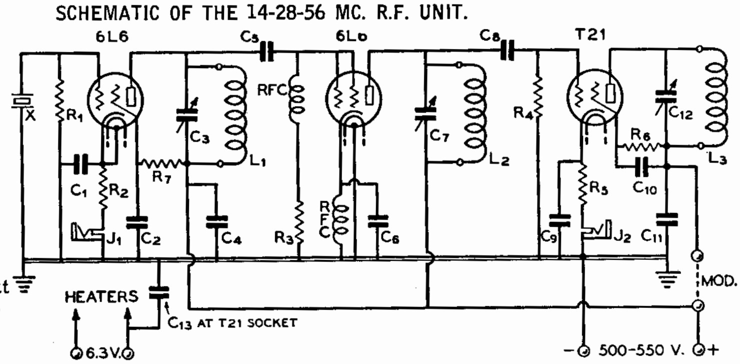
the use of beam tetrodes, it is possible to obtain comparatively good operation from triplers and quadruplers, thus simplifying the frequency multiplication problem.

20-Watt Crystal Controlled 14, 28, 56 Mc. Transmitter or Exciter. The crystal controlled 56 Mc. r.f. unit illustrated in figures 16 and 17 and diagrammed in figure 18 uses conventional circuits and low cost parts. With but three stages and a 7-Mc. crystal, it supplies 20 husky watts of crystal controlled, 56-Mc. or 28-Mc. r.f. For phone operation the output stage may be modulated by a 25-watt modulator. As an exciter it has sufficient output to drive a 56-Mc. final stage to 200 watts input.

The chassis measures 12 x 7 x 2 inches. As can be seen from the photographs, the tubes are evenly spaced along the center of the chassis. Each plate coil is directly in front of the tube with which it operates. The tank condensers are mounted on the front lip of the chassis directly below their respective coils. Small jack type feed-through insulators are used to support the plug in coils and at the same time to provide connections to the condensers. Banana plugs on the coils allow quick and easy band change.

Inasmuch as each tuned circuit is on a different frequency, placing the coils in line along the front of the chassis does not have any adverse effect on the operation of the unit.

Figure 18.
SCHEMATIC OF THE 14-28-56 MC. R.F. UNIT.



C_1, C_2—.01-μfd. paper
C_3—75-μμfd. midget
C_4—.005-μfd. mica
C_5—100-μμfd. mica
C_6—50-μμfd. mica
C_7—50-μμfd. midget
C_8—.001-μfd. mica
C_9—.002-μfd. mica
C_{10}, C_{11}—.001-μfd. mica
C_{12}—15-μμfd. midget, double spaced
C_{13}—.001-μfd. mica
R_1—25,000 ohms, 1/2 watt
R_2—400 ohms, 10 watts
R_3—25,000 ohms, 10 watts
R_4—150,000 ohms, 2 watts
R_5—600 ohms, 10 watts
R_6—30,000 ohms, 10 watts
R_7—100,000 ohms, 1 watt
RFC—2.5-mh. r.f. chokes
J_1, J_2—Closed-circuit jack
Coils—see coil table

Underneath the chassis, parts are placed where convenience dictates. The T21 stage has all its ground return connections made to the feed-through insulator which is at the cold end of the plate tank. While this does not enhance the appearance of the unit, it aids in eliminating coupling in the various ground return circuits.

Two feed-through insulators at the rear of the chassis are provided for the connections from the modulator. If the unit is used as an exciter or c.w. transmitter, these terminals are simply shorted together.

The second 6L6 acts either as a doubler or quadrupler, depending upon the crystal frequency and desired T21 output frequency. Thus with a 40 meter crystal, 10 or 5 meter output is obtainable from the T21. With an 80 meter crystal, either 20 or 10 meter output is obtainable from the T21.

With the meter plugged in the cathode circuit of the T21 the total plate, screen and grid current is shown. This gives a false indication as to the plate current "dip" of the stage, which is about 15 milliamperes lower than the cathode current would indicate.

For optimum performance, the T21 stage should be loaded to approximately 90 milliamperes. At this input, the output is approximately 20 watts.

No antenna coupling circuit has been provided as the type of coupling circuit will depend upon the antenna used. Any of the usual capacitive, inductive or link-coupling circuits will be suitable, however. When used as an exciter, the unit should be link coupled to the next stage.

COIL TABLE

All coils have small, banana type plugs spaced 2½ in. 80 and 40 m. coils are wound on bakelite tubing: 20, 10 and 5 m. coils are self-supporting.

80 OSC.
37 turns no. 22 d.c.c. on 1 inch form.

40 OSC. OR DOUBLER
22 turns no. 22 d.c.c. on 1 inch form.

20 DOUBLER
13 turns no. 14 enam. 1 in. dia. spaced to 1½ in.

20 FINAL
17 turns no. 14 enam. 1¼ in. dia. spaced to 1½ in.

10 QUADRUPLER
6 turns no. 14 enam. 1 in. dia. spaced to 1 in.

10 FINAL
8 turns no. 14 enam. 1 in. dia. spaced to 1¼ in.

5 FINAL
4 turns no. 14 enam. ⅞ in. dia. spaced to 1¼ in.

Note: 40 meter coil serves either as osc. coil or doubler coil.

Medium Power 56-Mc. Amplifier. By using tubes having close element spacing, yet low interelectrode capacities, and a plate tank condenser especially designed for u.h.f. service, it is possible to construct a medium power 56-Mc. amplifier that will exhibit good efficiency without resorting to the use of parallel rods in the plate circuit.

Such an amplifier is illustrated in figure 19. It utilizes a pair of HK24's in push pull, and the efficiency is as good as that obtained with commonly used equipment on the 14-Mc. band. With proper coils, the amplifier could also be used on 28 and 14 Mc., but as it was expressly designed for 56 Mc. work, the coils are not of the plug in type. By fastening the plate coil directly to the condenser stator lugs, losses are minimized.

About 20 watts excitation are required, this amount of excitation permitting approximately 175 watts input on phone or 225 watts input on c.w. The T21 exciter of figure 18 is ideally suited for use with this amplifier, the excitation being sufficient so long as the coupling link between exciter plate coil and amplifier grid coil is not too long. The losses are high at 56 Mc. in a twisted pair line, even in a good line. EO-1 cable makes the best coupling line, and it should be not more than 18 inches long unless reserve excitation is available to compensate for the losses in the line.

A conventional, resistor-biased circuit is used with circuit balance provided by a grounded-rotor grid condenser. Plate voltage is fed to the center of the plate coil through a u.h.f. choke. Since the circuit is balanced by grounding the rotor of the grid condenser, it is possible to let the rotor of the plate condenser "float," thus increasing the allowable plate voltage for a given condenser spacing. No filament by-pass condensers are used, as they were found to be unnecessary. Mechanically, the amplifier differs somewhat from the usual push-pull stage and the mechanical layout will therefore be discussed in greater detail.

Construction Details. An 11 x 7 x 2-inch chassis allows ample room for all the components except the filament transformer, which is mounted externally.

The plate condenser is one designed for u.h.f. use. The stator terminals are arranged so as to allow an extremely compact neutralizing condenser assembly. This condenser is mounted on its side with the stator terminals

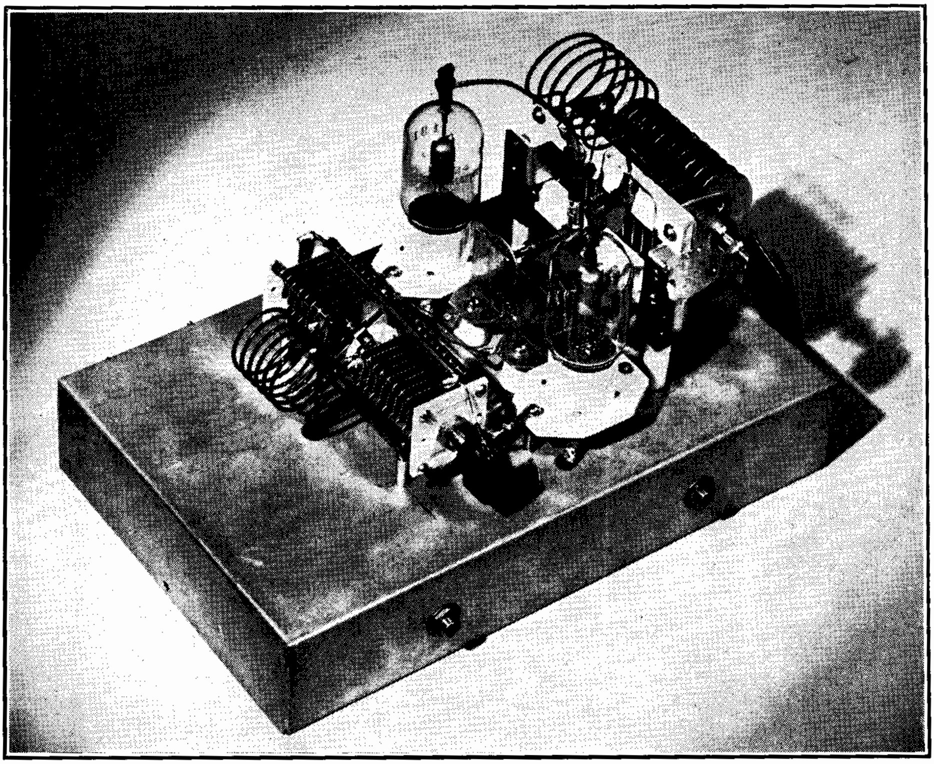


Figure 19.
125-WATT 56-MC. AMPLIFIER.

Extreme simplicity characterizes this 56-Mc. amplifier stage. The neutralizing condensers may be seen between the tubes. All components with the exception of the grid resistor are above the chassis.

toward the tubes. Two angle brackets and small standoff insulators serve to hold the condenser above the chassis. Mounting the condenser in this manner permits short plate leads to the upper stator terminals. The plate coil, 6 turns of no. 14 wire $1\frac{1}{4}$ inches in diameter, is spaced so as to mount directly on these upper terminals.

Two small discs of aluminum, 1 inch in diameter and 1/16 inch thick, are used for the movable plates of the neutralizing condensers. Each of these plates has a flat-headed 6-32 screw through its center. The screws are held in place by nuts on the back of the discs. The heads are filed smooth with the surface of the discs. The edges of the discs are rounded with a fine-tooth file to prevent corona losses.

Two pieces of hollow rod, threaded with a 6-32 tap are mounted on the lower stator terminals of the plate condenser. The screws through the discs are screwed into these rods and neutralizing adjustments are made by running the screws in or out of the threaded rods, thus changing the spacing between the circular plates and the stationary plates, which are simply small rectangular pieces of aluminum mounted on standoff insulators.

The grid coil is 6 turns of no. 14 enamelled wire $1\frac{1}{8}$ inches in diameter and $1\frac{1}{8}$ inches long. This condenser tunes with its plates about one-third meshed. Both ends of the rotor are grounded for the sake of symmetry.

The amplifier should not be operated for any length of time with the load removed, as the heavy r.f. field within the plate coil will heat and melt the soldered connection at its center. With the tank circuit loaded however, no trouble of this kind will be experienced.

By slightly exceeding the plate voltage rating and operating the two tubes at 1750 volts, an output of slightly over 200 watts is obtained from the amplifier at the normal plate current of 150 ma. for the two tubes. For

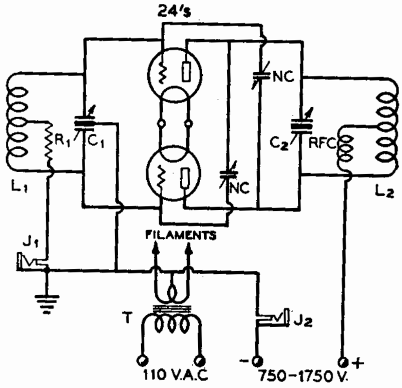


Figure 20.

125-WATT HK-24 U.H.F. AMPLIFIER

C_1—30-μμfd. per section midget
C_2—35-μμfd. per section, 4500-volt spacing
R_1—3000 ohms, 10 watts
J_1, J_2—Single closed circuit jacks
T—Filament transformer, 6.3 v., 6 a.
NC—See text
L_1, L_2—See text
RFC—U.h.f. choke

modulated operation, the plate voltage should be lowered to 1250 volts, however. Two jacks, J_1 and J_2, are provided for reading the grid and plate current. A one-turn link is used between the amplifier and the exciter and the grid current is adjusted to 50 milliamperes under load by varying the coupling.

250-Watt Linear Tank Amplifier. By cross neutralizing a push-pull linear tank u.h.f. oscillator, a highly efficient u.h.f. amplifier results. Linear tanks are advantageous in power amplifiers not for reasons of frequency stability, but to provide an inexpensive, highly efficient tank circuit having high impedance and low losses. For this reason a linear tank is ordinarily used only in the plate circuit of an amplifier, a grid coil being satisfactory for the grid tank when very high Q is not required for the sake of stability.

The 56-Mc. amplifier of figures 21 and 22 will deliver over 250 watts with good efficiency, and requires approximately 35 watts excitation. The excitation may be furnished by a stabilized push-pull HK-24 linear tank oscillator using parallel rods in the grid circuit with the grid connections made one quarter of the way up from the voltage node. Or it may be furnished by an HK-24 or HK-54 doubler tube being fed from 28-Mc. excitation either as a crystal controlled amplifier or as an amplifier for an FM transmitter.

It will be noticed that the rods not only are bent back upon themselves, but that the spacing between the two rods is not uniform. This has no detrimental effect upon the efficiency of the tank, and permits a compact arrangement. The rods are of half-inch aluminum tubing, each slightly over three feet long, and bent and mounted as shown in figure 22. The position of the shorting bar is adjustable, and the tank is resonated by sliding the bar along the rods with a piece of dry wood until minimum plate current is obtained. The shorting bar is then clamped firmly by tightening the screw.

The husky, four-inch ceramic pillars which support the rods also support two of the small aluminum plates used for neutralizing.

The grid coil consists of 6 turns of no. 14 wire, 1 inch in diameter and spaced to 1¼ inch. The coil is soldered directly to the stator terminals of the grid condenser.

The plate choke consists of 50 turns of no. 20 d.c.c. close wound on a ceramic pillar insulator ½ inch in diameter. Very little r.f. voltage appears at the shorting bar, and the choke has little work to do; however it is advisable to incorporate it in order to insure proper circuit balance.

About 350 watts output may be obtained by raising the plate voltage to 1750 volts. The value of grid resistor should be increased about 50 per cent and greater excitation power will be required. At this plate voltage it is necessary to keep the tubes loaded evenly and the tank circuit in exact resonance. If the higher value of plate voltage is used, it is advisable first to tune up at reduced voltage.

FREQUENCY MODULATION TRANSMITTERS

Frequency modulation or FM transmission is destined to be one of the major uses of the ultra-high frequency bands. The u.h.f. bands are wide enough so that the wide band of frequencies required for FM are amply contained. In addition, a practically infinitesimal amount of modulating power is required to modulate an FM transmitter, regardless of its power output, and, a last advantage, frequency multipliers, or class C or class B amplifiers may carry FM r.f. since the amplitude of an FM signal is constant. However, a complete explanation of the theory and practice of FM has been given in *Chapter Nine,* so this section will be devoted entirely to the description of equipment designed for FM transmission.

FM transmission is permissible on all amateur frequencies above 58,500 kc.; that is, it is permitted from 58.5 to 60 Mc., 112 to 116 Mc., 224 to 230 Mc., and above 300 Mc. The equipment to be described is designed for operation on the 112-Mc. band, but it can just as

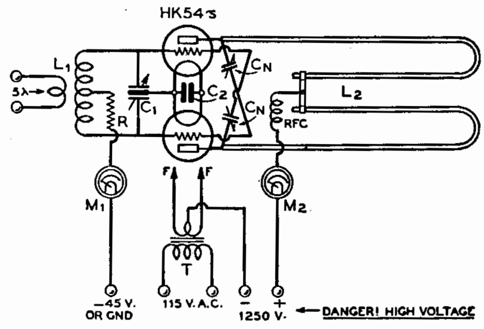


Figure 21.
SCHEMATIC OF HK-54 LINEAR TANK AMPLIFIER.

C_1—30-μμfd. per section, double-spaced midget
C_2—.002-μfd. mica
L_1, L_2—See text
R—3000 ohms, 25 watts if no fixed bias; 2000 ohms if 45 v. fixed bias.
M_1—0-100 ma. d.c.
M_2—0-500 ma. d.c.
T—5 v. 10 amp. fil. trans.

easily be operated on any other frequency assigned to FM transmission simply by changing the frequency of operation of the various frequency multipliers and then using a final amplifier on the desired band.

75-Watt 112-Mc. FM Transmitter

This transmitter consists of two units, exclusive of power supplies, the exciter which ends up in a HK-24 doubler to 38 Mc., and the final stage which uses a pair of HK-54's as a push-pull tripler to 114 Mc.

Exciter Lineup. The use of a power push-pull tripler as the output stage of the transmitter required that the exciter end up with a stage operating on 38 Mc. for an output frequency of 114 Mc. There are a large number of oscillator frequencies which in conjunction with various combinations with doublers, triplers, or quadruplers will yield the desired output frequency. However, since it was desired to use an HK-24 as a doubler in the output stage of the exciter and thus do away with neutralizing worries, the excitation requirements seemed to call for two doubler stages between the oscillator and the exciter output stage.

The original design of the exciter called for 6L6's in the doubler stages. The 6L6's looked all out of proportion driving the diminutive HK-24, however, so 6F6's were substituted to "see what would happen." Nothing happened except that the tube cost went down considerably—the output as indicated by the grid current to the HK-24 remained the same.

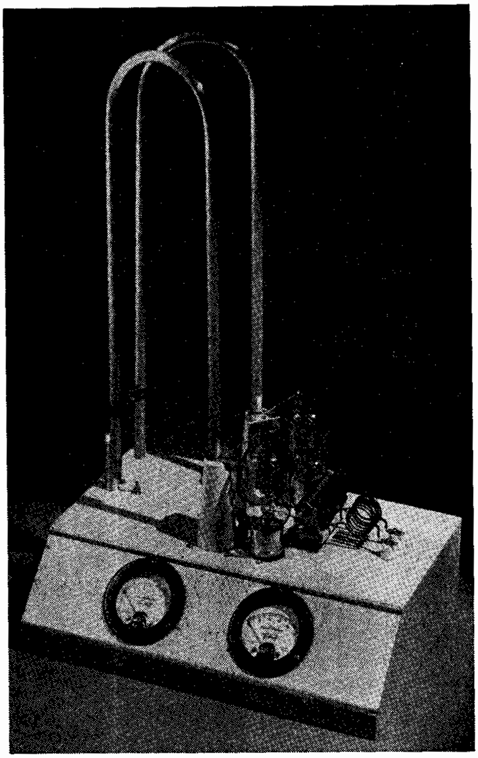


Figure 22.
FOLDED LINEAR TANK 56-MC. 250-WATT AMPLIFIER.
An inexpensive yet compact and highly efficient tank circuit for this HK54 amplifier is had by folding back on itself a quarter-wave stub made of half-inch aluminum tubing.

The Frequency Modulated Oscillator. The oscillator is also a 6F6. It is arranged as a conventional e.c.o. with impedance coupling to the following stage. Omitted from the diagram is a 25,000-ohm, 2-watt series dropping resistor to the oscillator screen. The output obtained across the plate r.f. choke is not great, but it is sufficient to excite the following doubler to full output. A moderate amount of capacity across the oscillator tank coil is provided by a 75-μμfd. midget variable in parallel with a 100-μμfd. zero temperature coefficient ceramic condenser. With the coil specified in the diagram caption the capacity required to hit 4750 kc. in the oscillator is about 160 μμfd., 100 μμfd. of this being supplied by the fixed condenser, of course.

The two doubler stages following the oscillator are quite conventional. The two stages are identical with the exception of tank

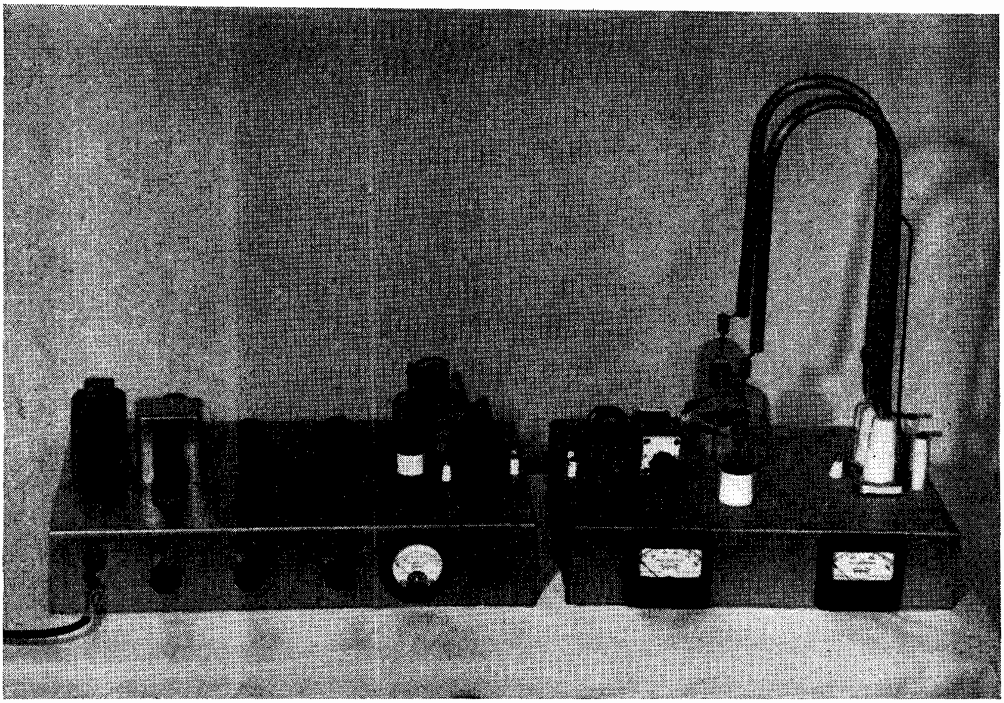


Figure 23.
THE 75-WATT 112-MC. F.M. TRANSMITTER.
The transmitter proper is constructed on two chassis. The exciter unit on the left puts out frequency modulated r.f. at 38 Mc. which is tripled to 114 Mc. by the push-pull 54 output stage at the right.

circuits and grid leaks. R_9, the grid leak for the first stage is a 100,000-ohm 1-watt unit while R_{10} in the second stage has been made a 150,000-ohm 2-watt resistor to allow for the increased excitation available at this point. Cathode bias is also used on both stages to provide a measure of safety in case the excitation should inadvertently be removed. A common series screen resistor R_{16} is used on both 6F6 doubler stages. A point leading to smooth, "bug-free" operation of these doubler stages is the use of the no. 1 terminal on the sockets as the ground point of the by-passes associated with each stage. The plate blocking, screen by-pass, and cathode by-pass condensers for each stage are grounded through the shortest possible lead to this point. The use of .003-μfd. "postage-stamp" mica condenser permits the length of the leads to be kept to a minimum.

The HK-24 exciter output doubler to 38 Mc. is also conventional. Here again care has been taken to bring the r.f. ground returns to a common point on the tube socket. A lug under one of the socket mounting screws serves as the ground point in this case.

The Speech System. Every effort has been taken to reduce hum modulation in the transmitter shown. The amount of undesirable modulation taking place is directly related to the amount of impedance in the reactance-tube grid return circuit, since the grid will pick up hum in proportion to its impedance to ground. Shorting this grid return to ground (across C_5) should give a "p.d.c." note if the reactance tube is operating properly. The grid impedance to ground has been kept to a minimum through the use of a 500-ohm output transformer at T_2. With a crystal microphone the cascaded 6N7 speech amplifier will provide a peak undistorted audio output of 25 volts across the 500-ohm winding. This amount of voltage is sufficient to operate the modulator over the complete linear portion of its characteristic. Any amount of swing desired up to the full 800 kc. of which the rig is capable may be had by adjusting the speech gain control, R_{22}.

The Push-Pull Tripler Final. Due to the difficulty in obtaining a short, direct ground return in single-ended stages, push-pull frequency multipliers are almost universally

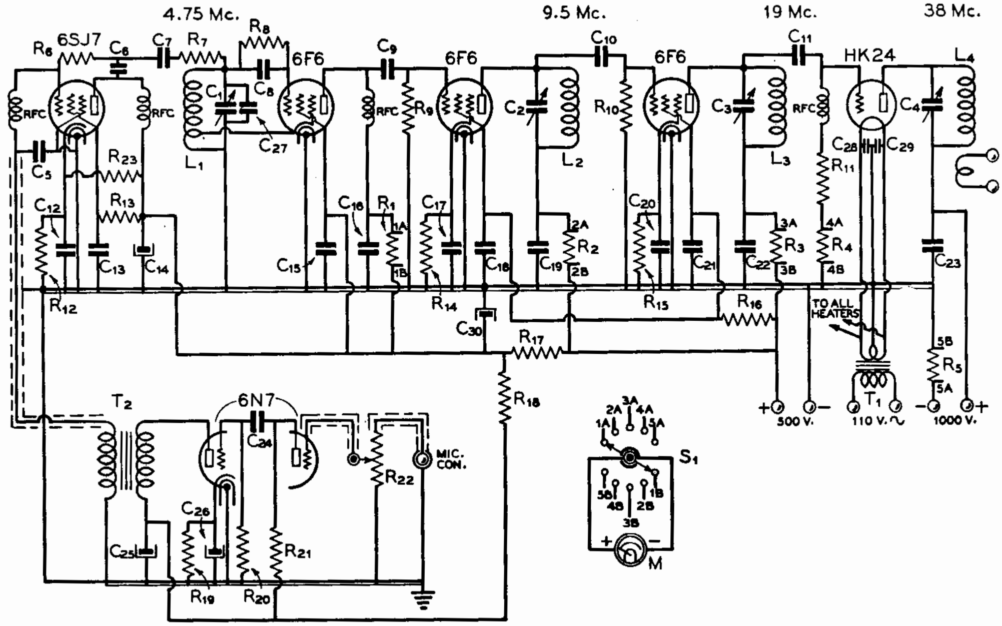


Figure 24.
WIRING DIAGRAM OF THE F.M. EXCITER.

C_1—75-μμfd. midget variable
C_2—35-μμfd. midget variable
C_3—25-μμfd. midget variable
C_4—20-μμfd. variable, .070" spacing
C_5, C_6, C_7—.003 μfd. mica
C_8—.0001-μfd. mica
C_9—.0001-μfd. mica
C_{10}, C_{11}—.00005 - μfd. mica
C_{12}—.01-μfd. 400 volt tubular
C_{13}—.003-μfd. mica
C_{14}—8-μfd. 450 volt electrolytic
C_{15}, C_{16}, C_{17}, C_{18}, C_{19}, C_{20}, C_{21}, C_{22}—.003-μfd. mica
C_{23}—.002-μfd. 2500 volt mica
C_{24}—.02-μfd. 400 volt tubular
C_{25}—8-μfd. 450 volt electrolytic
C_{26}—10-μfd. 25 volt electrolytic
C_{27}—100-μμfd. zero temperature coefficient ceramic
C_{28}, C_{29}—.003 - μfd. mica
R_1, R_2, R_3, R_4, R_5—50 ohms, 1 watt
R_6—100,000 ohms, ½ watt
R_7—2500 ohms, 1 watt
R_8—60,000 ohms, 1 watt
R_9—100,000 ohms, 1 watt
R_{10}—150,000 ohms, 2 watts
R_{11}—25,000 ohms, 10 watts
R_{12}—1000 ohms, 1 watt
R_{13}—50,000 ohms, 1 watt
R_{14}, R_{15}—500 ohms, 10 watts
R_{16}—15,000 ohms, 10 watts
R_{17}—5000 ohms, 20 watts
R_{18}—10,000 ohms, 1 watt
R_{19}—2000 ohms, ½ watt
R_{20}, R_{21}—50,000 ohms, ½ watt
R_{22}—1 megohm potentiometer
R_{23}—50,000 ohms, ½ watt
Note: for oscillator screen resistor, see text.
S_1—Two section, 5 position "Ham-switch"
T_1—6.3 volts, 10 amps.
T_2—Triode plate to 500-ohm line
RFC—2½ mh.
M—0-150 ma.
L_1—17 turns of no. 22 d.c.c. wound to a length of ⅞ inch on 1¼" dia. form. Cathode tap 6 turns from ground end.
L_2—20 turns no. 14 enam. 1" dia., 1⅝" long
L_3—15 turns no. 14 enam. ¾" dia. 1-⅜" long
L_4—10 turns no. 10 enam. 1" dia., 2½" long

used in u.h.f. equipment above 60 Mc. The push-pull arrangement is inherently balanced to ground so that no r.f. current flows in the external plate-to-ground circuit. Even harmonics cancel out in the push-pull output circuit but it is possible to obtain fair efficiency (considering the frequency) at the third harmonic.

The tripler stage grid circuit is arranged for link coupling to the exciter output tank. The split-stator grid condenser, C, (figure 25) has its rotor grounded to aid in establishing circuit balance. The ground connection does not need to be particularly short as the balance between the two tubes is so close that a very slight amount of r.f. current flows in the lead. Grounding the rotor to the most convenient point on the chassis will serve the purpose. The parallel-rod plate tank used is the best and least expensive way of ob-

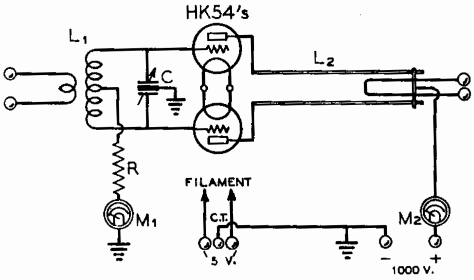


Figure 25.
SCHEMATIC OF THE PUSH-PULL TRIPLER TO 114 MC.

C—50-μμfd. per section, midget
R—20,000 ohms, 20 watts
L_1—8 turns no 14 enam. 1" dia., 1¼" long
L_2—Linear plate tank, see text
M_1—0-100 ma.
M_2—0-300 ma.

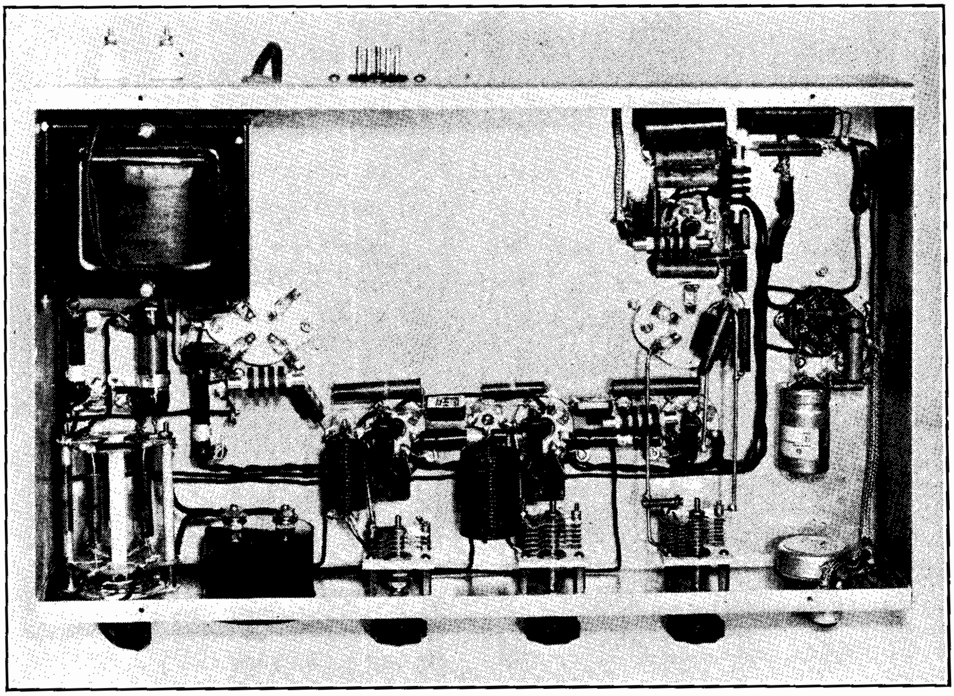
taining good tank circuit efficiencies at 114 Mc.

Meters are provided in the plate and grid circuit of the output stage so that an accurate check on the operation may be kept at all times. There is no need to place the plate meter in the negative lead to this stage since the large exposed plate tank should be sufficient warning to the operator to keep his hands a safe distance from the stage at all times.

Tuning Procedure. If an accurately calibrated receiver which tunes to 4750 kc. is available, no difficulty should be experienced in getting the transmitter tuned up. The oscillator is simply set to this frequency and the following doubler stages in the exciter tuned to resonance with the tripler output stage disconnected. Exciter meter readings should be about as follows: oscillator plate, 30 ma.; 9.5-Mc. doubler plate, 28 ma.; 19-Mc. doubler plate, 28 ma.; HK-24 grid, 12 ma.; HK-24 plate unloaded, 20 ma.; HK-24 plate loaded, 75 ma. These figures are for 500 and 1000 volt power supplies.

When the transmitter as a whole is being tuned up for the first time it is best to apply about 500 volts to all stages until one becomes familiar with the transmitter's operation. The correct coupling to the output stage grid is about as shown in the photograph of the complete transmitter; the link coil should be pushed about two-thirds of the way into the HK-54 grid coil for maxi-

Figure 26.
UNDER-CHASSIS VIEW OF THE EXCITER.



mum power transfer. With the lowered voltage applied to the transmitter and the tripler grid circuit tuned to resonance and the shorting bar on the plate rods down against the standoff insulators, a screwdriver with a *well insulated* handle may be used to determine the resonant point on the plate rods. The screwdriver should be pressed firmly against both rods and slid along from the power supply end toward the plates. Resonance will be indicated by a sharp drop in plate current as the screwdriver passes over the proper point. This point will probably be from one to three inches up the rods from the power supply end. If resonance is not found until the screwdriver is to within 6 or 8 inches of the plate ends of the rods it is an indication that the rods are too short, as the resonance point 6 or 8 inches away from the plates is that for the fifth harmonic of the grid frequency, or 190 Mc.

When resonance has been found by the screwdriver, the shorting bar should be placed at this position and tightly clamped to the rods. The shorting bar may be moved back and forth a short distance in either direction to insure that the resonance point has been correctly determined, making sure to remove the plate voltage each time the shorting bar is touched.

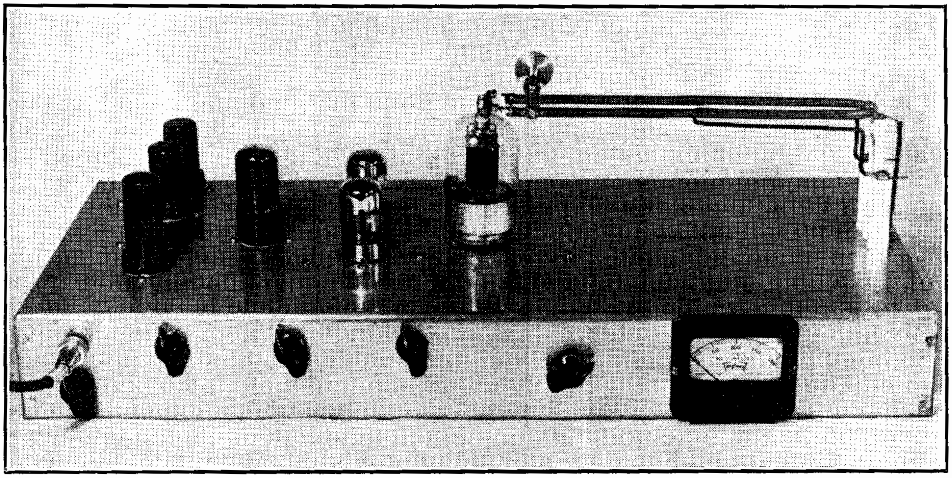
Final Operating Conditions. After the shorting bar has been properly located full plate voltage may be applied to the transmitter and the currents in the tripler stage checked. These should be: grid current—25 ma.; plate current unloaded—125 ma. A 75-watt lamp bulb connected across the antenna terminals should glow at about normal brilliancy when the coupling hairpin is adjusted so that the transmitter is loaded to 225 milliamperes. This indicates that the tripler efficiency is approximately 30 per cent, which is about normal at these frequencies. The 150-watt difference between input and output would seem to indicate that the plate dissipation of the tubes was being considerably exceeded. However, the criterion in matters such as this is the plate temperature of the tubes, and their color does not seem to indicate that their 50-watt plate dissipation is being exceeded. Undoubtedly the 50-watt discrepancy between the total power loss and the plate dissipation can be accounted for in radiation and resistance losses in the plate tank.

50-Watt FM Transmitter

The transmitter illustrated in figures 27 and 28 and diagrammed in figure 29 has an output of 50 watts, frequency modulated, at 112 Mc. Except for the 500-volt, 250-ma. power supply, the transmitter is all located on the single 10″ by 23″ by 3″ chassis.

The Exciter Stages. The exciter section of the transmitter, which includes those stages

Figure 27.
TOP VIEW OF THE 50-WATT F.M. TRANSMITTER.
The three tubes in the row on the left edge of the chassis are, front to back: the 6F6 oscillator, 6SJ7 reactance tube, and 6SC7 speech amplifier. Then comes the 6V6-GT doubler to 38 Mc. and the push-pull 7A4 tripler to 112 Mc., followed by the 50-watt output tube and its tank circuit. Note the manner in which the plate circuit tubing condenser has been soldered to the plate rods.



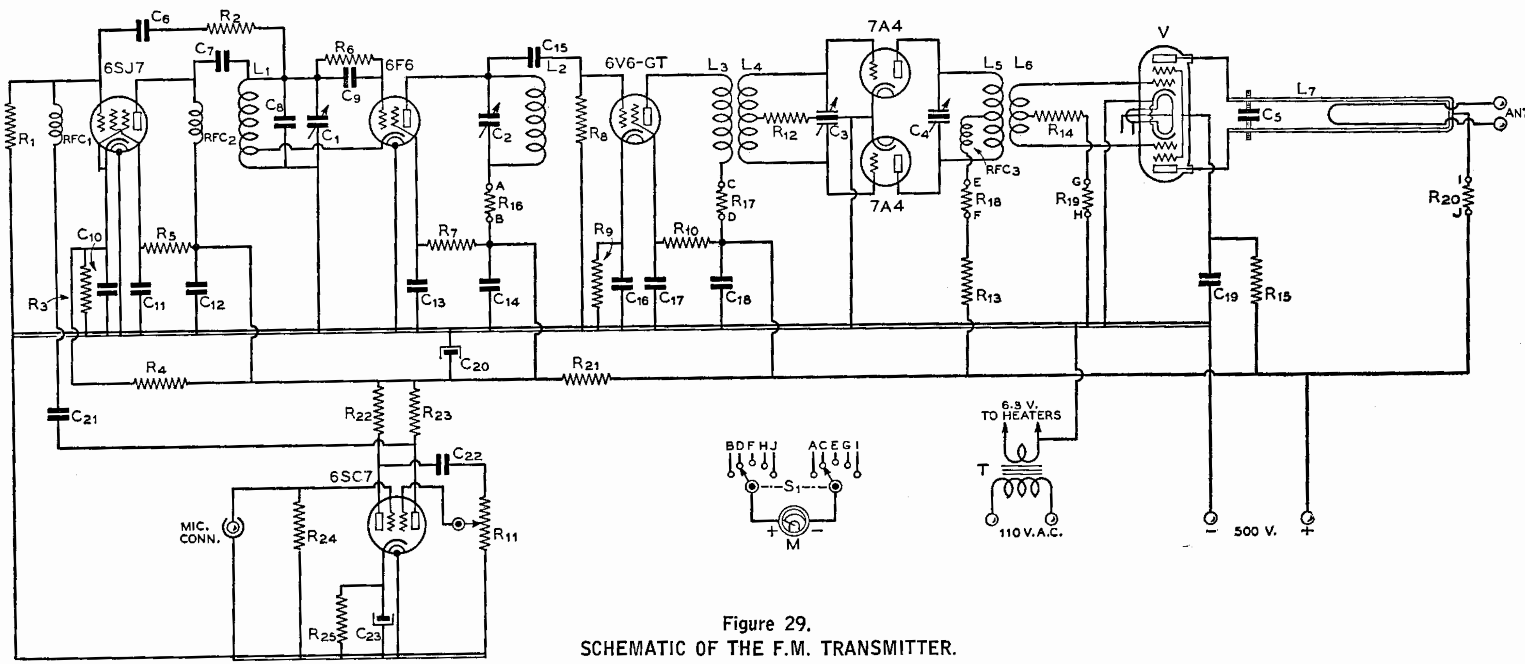


Figure 29.

SCHEMATIC OF THE F.M. TRANSMITTER.

C_1, C_2—50-μμfd. midget variable

C_3—50-μμfd. per section

C_4—25-μμfd. per section

C_5—Midget circular plate neut. condenser mounted on plate rods

C_6, C_7—.003-μfd. midget mica

C_8—.0001-μfd. zero coeff.

C_9—.0001-μfd. midget mica

C_{10}, C_{11}, C_{12}—.003-μfd. mica

C_{13}, C_{14}—.003 - μfd. mica

C_{15}—.00005-μfd. mica

C_{16}, C_{17}, C_{18}—.003-μfd. mica

C_{19}—.0003-μfd. silver mica

C_{20}—8-μfd. 450-volt elect.

C_{21}—.01-μfd. 400-volt tubular

C_{22}—.005-μfd. mica

C_{23}—10-μfd. 25 - volt elect.

R_1—500,000 ohms, 1/2 watt

R_2—50,000 ohms, 1/2 watt

R_3—1000 ohms, 1/2 watt

R_4—60,000 ohms, 1 watt

R_5—100,000 ohms, 1/2 watt

R_6—50,000 ohms, 1/2 watt

R_7—25,000 ohms, 1 watt

R_8—100,000 ohms, 1 watt

R_9—600 ohms, 10 watts

R_{10}—25,000 ohms, 1 1/2 watts

R_{11} — 500,000 - ohm potentiometer

R_{12}—10,000 ohms, 1 1/2 watts

R_{13}—5000 ohms, 10 watts

R_{14}—10,000 ohms, 1 1/2 watts

R_{15}—25,000 ohms, 1 1/2 watts

R_{16}, R_{17}, R_{18}, R_{19}, R_{20}—100 ohms, 1 watt

R_{21}—5000 ohms, 10 watts

R_{22}, R_{23} — 250,000 ohms, 1/2 watt

R_{24}—1 megohm, 1/2 watt

R_{25}—1000 ohms, 1/2 watt

RFC_1, RFC_2—2.5 mh. 125 ma.

RFC_3—U.h.f. choke

T—6.3-volt 10-ampere trans.

M—0-200 d.c. milliammeter

L_1—12 t. no. 18 d.c.c. 1" dia. 1" long

L_2—13 t. no. 14 enam., 5/8" dia. 1" long

L_3—8 turns hookup wire inside L_4

L_4—8 turns no. 14 enam. 7/8" dia. 1 1/4" long

L_5—4 t. no. 14 enam. 5/8" dia. 3/4" long

L_6—2 turns hookup wire wound with L_5

L_7—20" 1/4" copper tubing bent into a hairpin with 1" center - to - center spacing

V—815 dual beam tetrode

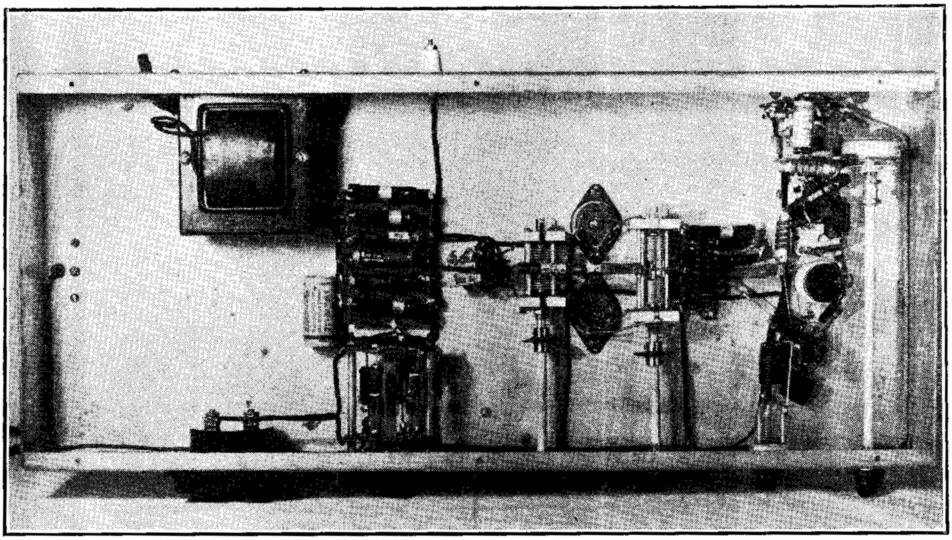


Figure 28.
UNDER-CHASSIS VIEW OF THE 50-WATT F.M. TRANSMITTER.
The filament transformer for the entire rig is shown in the left rear. The meter switch is mounted, with the resistors between its sections, directly in front of the resistor tie plate for the rig.

preceding the output stage, employs standard receiving tubes throughout and is distinguished by the lack of unusual or "trick" circuit arrangements. The frequency modulated oscillator is a 6F6 operating at low plate and screen voltages to assure minimum frequency drift. The grid circuit of this stage is tuned to 9.5 Mc., and the plate circuit to the second harmonic, or 19 Mc.

Excitation from the oscillator stage is carried through a small coupling condenser to the grid of the following doubler, which is a 6V6-GT. To reduce the number of tuned circuits in the transmitter, the plate circuit of the doubler stage is tuned only by being closely inductively coupled to the grid circuit of the following stage. The close coupling required for proper operation of this type of circuit is achieved by locating the 6V6-GT plate coil, L_3, inside the following grid coil, L_4. There are no rigorous requirements in the choice of the tube used in the doubler stage, and a 6V6 or 6L6 may be substituted for the 6V6-GT, if desired, without making any circuit changes. If the plate voltage to the doubler stage is lowered somewhat, a 6F6 may be used. The doubler output frequency is 38 Mc.

Following the doubler stage is a tripler to 114 Mc. employing push-pull 7A4's. Circuit balance in this stage is provided by grounding the rotor of the split stator grid condenser. It is not necessary to ground the rotor of the plate tank condenser in this stage. No harm will be done, however, if the type of plate condenser used makes grounding the rotor more convenient than insulating it.

Tests with an experimental version of this transmitter showed the necessity of placing the tuned input circuit of the tripler directly in the grid circuit, rather than the more conventional method of capacity coupling from a balanced, tuned plate circuit in the preceding stage. With the latter type of circuit the tripler stage is prone to oscillate while with the circuit shown in the diagram there is no tendency toward oscillation or instability.

By itself, the exciter section of the transmitter forms a complete, inexpensive, low power 112-Mc. transmitter with an output of 5 to 7 watts, and if the constructor is interested in a transmitter in this power class he could well choose the exciter of the 50-watt transmitter.

Output Stage. The 50-watt output stage utilizes an 815 tube, which has two beam tetrodes, each of somewhat lower power rating than an 807, in a single envelope. Excitation to the 815 is obtained by a two-turn coupling coil pushed between the center turns of L_5. The excitation is adjusted by pushing the coupling coil in and out of L_5—too much coupling will overload the tripler and reduce the excitation and output in the final amplifier, while too little coupling will reduce the excitation and output. It is a simple matter to adjust the excitation properly by observing the output from the transmitter.

The final plate tank circuit consists of a U-shaped piece of ¼-inch copper tubing measuring 9½ inches on each leg, with the two legs separated 1 inch. Tuning of the linear tank circuit is accomplished by varying the spacing between the plates of a small condenser at the plate ends of the tank circuit. The condenser plates and their supporting strips were taken from a small neutralizing condenser originally intended for neutralizing a 6L6. The plates and the supporting metal were removed from the insulator assembly which originally served as a mounting for the condenser and the metal strips were soldered to the tank circuit with the aid of a small alcohol torch.

The antenna coupling "hairpin" is made up of a length of no. 10 enamelled wire supported by two standoff insulators which also serve as terminals for connecting the antenna feeders. The antenna coupling is varied by bending the coupling hairpin toward or away from the plate tank.

Modulator and Speech Amplifier. The frequency modulator uses a conventional reactance tube circuit. The theory of operation of this type of circuit is described in Chapter 9. Partially fixed bias on the reactance tube is provided by resistor R_4, which bleeds a constant amount of current through the reactance tube bias resistor, R_3. Varying amounts of positive and negative d.c. voltage may be applied across the grid resistor, R_1, to determine whether the frequency varies linearly each side of the "carrier" frequency when the control voltage is varied. Non-linearity may be corrected by changing the value of R_4. In the transmitter shown, the resistor value specified in the diagram caption gave a linear voltage-frequency characteristic. For a 50-kc. swing under modulation at 112 Mc. the modulator should be linear over a range of slightly more than 4 kc. at the oscillator frequency.

A single 6SC7 dual triode is used as a two-stage speech amplifier. This tube provides considerably more voltage gain than is necessary to give a 50-kc. swing, when a crystal microphone is used. The 6SC7 may be replaced by a low gain triode (6C5, 6J5, etc.) if a low output single-button microphone or a double-button microphone is used. High output single-button microphones (telephone type) may be coupled directly into the reactance tube control grid by a microphone transformer, with the gain control, R_{11}, replacing the fixed grid resistor R_1.

Construction. As the photographs show, all of the wiring except the 815 plate circuit is below the chassis. The oscillator, modulator and speech amplifier circuit occupy the space toward the left edge of the chassis. The stages following the oscillator are placed along the center line of the chassis, with each circuit placed as close to the preceding one as possible, since short leads are of prime importance in the high and ultra-high-frequency stages. In each of the stages following the oscillator, all ground returns are brought, through separate leads, to a single point on the tube socket.

Operation. To place the transmitter into operation, 250 to 300 volts should be applied to the "+500" terminal and the oscillator first tuned to 9500 kc., as indicated by a conventional receiver. After the oscillator grid circuit has been set to the correct frequency, the oscillator plate circuit and following stages should each be tuned to resonance as indicated by minimum plate current. It will be found that tuning the oscillator plate circuit to the second harmonic of the grid circuit frequency will change the oscillator frequency slightly, and it may be necessary to retune the grid circuit after the plate circuit has been resonated. After the complete transmitter has been tuned up, the antenna may be connected and the full 500 volts applied.

Typical current readings, at resonance, are as follows: Oscillator plate—15 ma.; doubler plate—35 ma.; tripler plate—40 ma.; final amplifier grid—3 ma.; final amplifier plate—150 ma.

Although it is not to be recommended except for extremely short periods of time, a check on the operation of the output stage may be made by removing the loading and observing the minimum plate current. If the stage is operating correctly the plate current will be approximately 30 ma. at resonance without load.

MICROWAVE TRANSMITTERS

Microwaves are generally considered as being those whose wavelength is less than one meter (frequencies greater than 300 Mc.). Microwaves are generated by means of *magnetrons, electron-orbit oscillators* and *regenerative oscillators.* Microwaves are used by broadcast stations for remote pickup, by amateurs and experimenters and for occasional telegraph and telephone communication such as the British channel-spanning system. The technical problems encountered in this field are numerous, yet new tubes designed for microwaves have simplified many of these problems and have been instrumental in increasing the usefulness of the band.

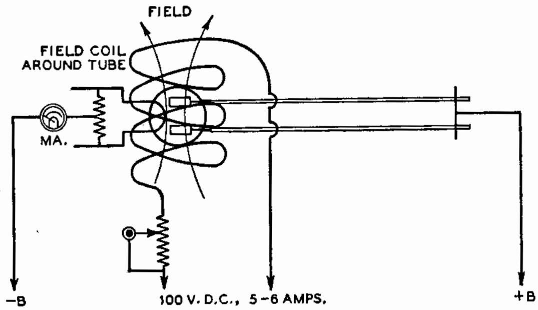


Figure 30.
SPLIT-ANODE MAGNETRON
MICRO WAVE OSCILLATOR.

Special magnetron tubes delivering several watts output at extremely high frequencies are available for certain experimental purposes. Their main disadvantage for amateur work is that they are rather difficult to obtain. Also, a source of d.c. of large magnitude is required for the field electromagnet.

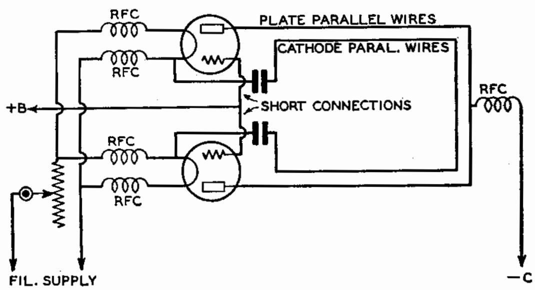


Figure 31.
KOZANOWSKI OSCILLATOR.

This type of u.h.f. oscillator requires the use of tubes having cylindrical elements, such as the HK-24 and 54, 35TG and 75T, 1628 and 852, and HY-75. Certain receiving tubes such as the 7A4, 955, etc. may also be used for lower power outputs. The grid dissipation of the tubes is the most important limiting factor on their power output.

The Magnetron Oscillator. The magnetron is a specially designed tube for very-short-wave operation. It consists of a filament or cathode between a split plate, as shown in figure 30.

A magnetic field is produced at the filament by means of a large external field coil which is energized by several hundred watts of d.c. power. Ultra-high-frequency oscillations are produced in the split plate circuit when this magnetic field is in the correct direction and of the proper intensity. A parallel-wire tuned circuit should be used for wavelengths below one meter. The frequency stability is not very good and it is difficult to obtain satisfactory voice modulation from magnetron oscillators.

Electron Orbit Oscillator. The range of oscillation in ordinary circuits is limited by time required for electrons to travel from cathode to anode. This transit time is negligible at low frequencies, but becomes an important factor below 5 meters. With ordinary tubes, oscillation cannot be secured below 1 meter, but by means of *electron orbit oscillators,* in which the grid is made positive and the plate is kept at zero or slightly negative potential, oscillation can be obtained on wavelengths very much below 1 meter.

Parallel-wire tuning circuits can be connected to these tube oscillators in order to increase the power output and efficiency. The tubes most suitable for this type of operation have cylindrical plates and grids, and their output is limited by the amount of power which can be dissipated by the grids. For transmitting, tubes such as the 35T, HK54, 852, etc., can be used in the circuit shown in figure 31, which is a modification of the circuit of figure 32. More output is obtained by using a tuned-cathode circuit instead of tuned-grid circuit. Modulation can be applied to either the plate or grid. The frequency stability is very poor.

Regenerative Oscillators. The introduction of RCA "Acorn" tubes made low power ½-meter regenerative oscillators practical. These tubes are more efficient than ordinary types for ultra-high-frequency work, and are available in several types in both 6.3 v. and 1.4 v. series. They are satisfactory for low-power transmitters and superregenerative receivers. The regenerative circuits are quite similar to those for longer wavelengths, except for the physical size of condensers and coils. The tube element spacing in these acorn tubes is made so small that electron transit time becomes a negligible factor for wavelengths above 0.6 meter.

Acorn tubes are also made in r.f. pentode amplifier types, both sharp cutoff and remote cutoff. However, these require concentric

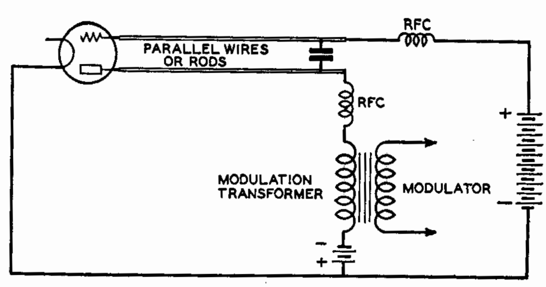


Figure 32.
BARKHAUSEN-KURTZ OR GILL-MORRELL OSCILLATOR.
As with all oscillators of the electron-orbit type, the grid dissipation will be very high and the oscillator tube should have cylindrical elements. This circuit may also be used as a detector for microwave signals, with the transformer feeding into an audio amplifier instead of being fed audio energy for modulation.

tank circuits below 2½ meters because at such high frequencies it is impossible, due to high losses, to obtain appreciable gain (high Q) with conventional tanks.

For higher power oscillators, special transmitting tubes designed for microwave work are offered by several manufacturers, notably Western Electric, Hytron, RCA, and Eimac. The HK24 also makes an excellent microwave tube when two are used in push-pull.

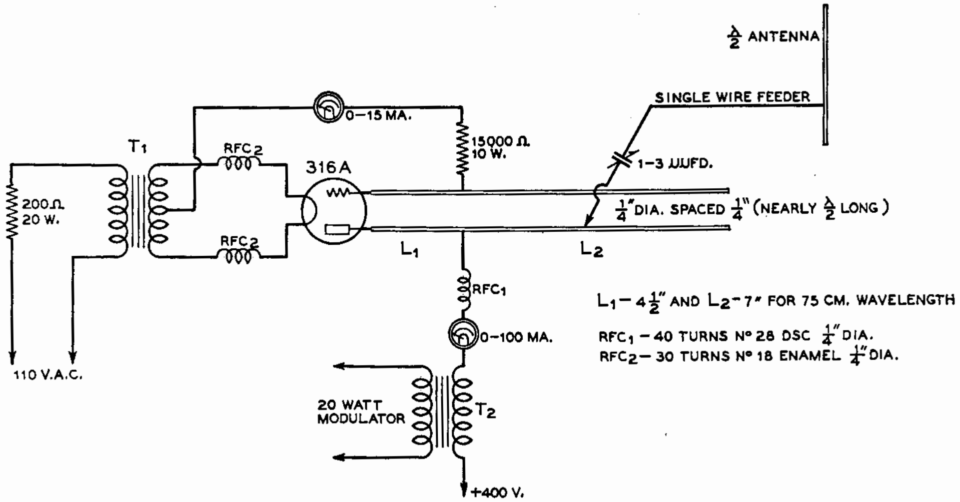
For maximum output at 2½ meters and shorter wavelengths, filament chokes are sometimes required. One way to avoid the necessity for filament chokes and at the same time increase the efficiency is to substitute a tuned filament circuit for the usual tuned grid circuit, by-passing the grids to ground.

Microwave regenerative oscillators are most efficient when linear tank circuits are used in place of coils, and when two tubes are used in push-pull. Maximum output and efficiency cannot be obtained with single-ended circuits.

3/4-Meter Parallel Rod WE-316A Transmitter. A large variety of circuits could be suggested for microwave operation, but the most simple of these is the one shown in figures 33 and 34. It consists of two parallel half-wave rods, spaced about ¼-inch apart, to provide a ¾-meter tuned circuit of fairly-high Q. The grid and plate of the tube are connected to the copper rods; this capacity causes the physical length to be less than a half wavelength. As can be seen from the photograph, the plate r.f. choke and the grid leak do not connect to the center of the rods, but rather across the voltage node. The distance between this point and the free ends of the rods is a quarter wavelength.

Filament r.f. chokes, or tuned filament leads, are desirable for operation below one

Figure 33.
400-MEGACYCLE NEGATIVE-GRID OSCILLATOR WITH WE-316-A.



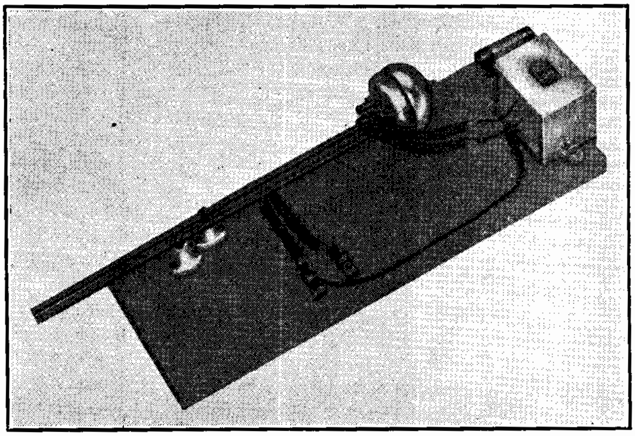


Figure 34.
WE-316A 400-MEGACYCLE OSCILLATOR.

meter because the filament is not strictly at a point of ground potential in the oscillating circuit. These filament chokes consist of 30 turns of no. 16 enamelled wire, wound on a ¼-inch rod, then removed from the rod and air-supported, as the picture shows. The length of these chokes is approximately 3 inches. A 200-ohm resistor is placed in series with the 110-volt a.c. line to the filament transformer in order to reduce the transformer secondary voltage from 2½ to 2 volts, because the filament of the tube operates on

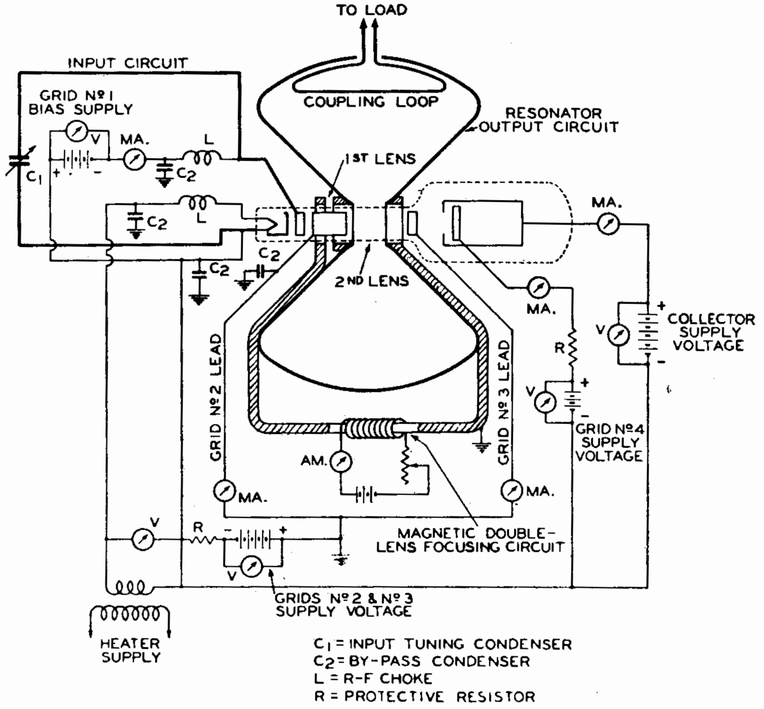


Figure 35.
OPERATING CIRCUIT FOR THE 825 AS A 500-MEGACYCLE AMPLIFIER.

2 volts at 3.65 amperes. This particular oscillator gave outputs in excess of 5 watts on ¾ meter, even when no filament r.f. chokes were used.

Operation of the Oscillator. This oscillator, when loaded by an antenna, draws from 70 to 80 milliamperes at 400 volts plate supply. The oscillator should be tested at reduced plate voltage, preferably by means of a 1000- to 2000-ohm resistor in series with the positive B lead, until oscillation has been checked. A flashlight globe and loop of wire can be coupled to the parallel rods at a point near the voltage node, in order to indicate oscillation. A thermo-galvanometer coupled to a loop of wire makes a more sensitive indicator, but the high cost of this meter prohibits its use in most cases.

A 15-inch antenna rod or wire can be fed by a one- or two-wire feeder of the nonresonant type. A single-wire feeder can be capacitively coupled to the plate rod, either side of the voltage node, through a small blocking condenser. If a two-wire feeder is employed, a small coupling loop, placed parallel to the oscillator rods with the closed end of the loop near the voltage node of the oscillator, will provide a satisfactory means of coupling to the antenna.

UHF Antennas are described in *Chapter* Twenty-one.

Microwave Amplifiers

It is extremely difficult to get into operation any type of amplifier circuit of the conventional type at a frequency greater than about 250 Mc. The main reasons for this difficulty have been the extremely high amounts of loading of the interelectrode capacitances, the high inductances of leads to elements, and the practical impossibility of obtaining a satisfactory neutralizing arrangement. Quite recently, however, RCA announced an entirely new type of amplifier arrangement which had been under development for quite a period of time. In the new circuit arrangement the output tuned circuit is inductively coupled to a stream of high-velocity electrons within a vacuum tube especially designed for the purpose. Since there is no coupling other than the purely inductive coupling between the electron stream and the output tank circuit, all the difficulties mentioned above have been averted.

A new vacuum tube especially designed for this service, the 825, has been placed upon the market. It is called an *inductive output amplifier* and is suitable for operation on frequencies above 300 Mc. Figure 35 shows a diagram of an inductive amplifier stage which is capable of delivering an output of 35 watts at a frequency of 500 megacycles.