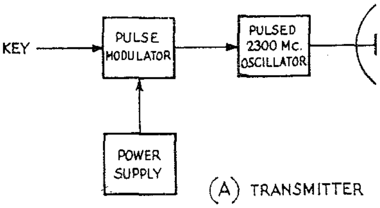
PULSE COMMUNICATION ON 2300 MC.

Amateur microwave communication with simple oscillator-type transmitters, using amplitude and frequency modulation requires a wide frequency band, as such oscillators are highly unstable under modulation. The receiver must necessarily be broad-band, and therefore inefficient. Transmitter efficiency is poor, and the power output with tubes generally available is very low. While much good work has been done this way, and it is still useful in many instances, something better is needed if the full potential of the microwave region is to be realized.

The usual alternative, crystal control and narrow-band receiving techniques, effects a very great improvement in communications range, but it entails considerable effort and financial outlay. The pulse system described here, developed by John T. Zimmer, W2BVU, and Robert F. Guba, W1QMN,[15] represents a desirable compromise between these two extremes. Stability requirements are no greater than with the simple oscillator approach, yet the communications range approaches that of narrow-band c.w., with cost and complication far below the narrow-band method.

Pulse is a wide-band mode inherently, so it is permitted only in the microwave region, where amateur assignments are wide enough to accommodate it. The technique set forth in this condensation of the W2BVU-W1QMN *QST* series is applicable to the amateur bands from 2300 Mc. up, with the exception of the 10,000-Mc. band, where pulse is not permitted. What follows is merely the how-to-do-it treatment; the complete *QST* series is recommended to anyone interested in the advantages of pulse communication. An earlier discussion by Beers[17] is also highly worthwhile.



Equipment Requirements

A block diagram of a complete amateur pulse system is shown in Fig. 10-52. A code setup is shown; phone can be used with pulse, but keyed pulse is much simpler and more effective. The transmitter consists of a pulse-generating modulator and a simple oscillator for the r.f. Keying is in the pulse generator. The receiver has a conventional front end using a crystal mixer, with a local oscillator similar to that used for transmitting. The i.f. amplifier is broad-band. Then come the principal elements wherein the pulse receiver differs from one for a.m. or f.m.: the threshold detector and the p.r.f. filter.

Overall efficiency is high. The oscillator is the sole r.f. component, in marked contrast to the string of multipliers required for microwave crystal control. It uses a 2C43 lighthouse tube, a low-cost surplus item. Though the average-power output is about 2 watts, using a pulse length of one microsecond and a pulse repetition frequency (p.r.f.) of 1000 per second, a peak-power output of 2 kilowatts is possible.

The modulator's three tubes draw about 10 ma. at 1300 volts, and 20 ma. at 300 volts, to produce 6 kw. peak input. The oscillator assembly can be installed at the antenna, to keep down feedline losses, and the modulator at any convenient spot below, with only a coaxial cable between them.

The receiver local oscillator can be similar to that used for transmitting, though this much power is not needed. A 2C40 oscillator similar to one described in *QST* by W2RMA [16] was used by W1QMN and W2BVU. Surplus oscillators can be found by some scrounging, and the possibility of using an APX-6 oscillator with a diode multiplier should not be overlooked. The i.f. amplifier, threshold detector, filter and audio system are described herewith.

The antennas should be parabolic reflectors, preferably 4 feet in diameter or larger. Using two stations as shown, the existing 2300-Mc. DX record of 170 miles was achieved with one station like that in Fig. 10-53 at sea level and the other only 600 feet higher. Typical v.h.f. propagation conditions prevailed at the time.

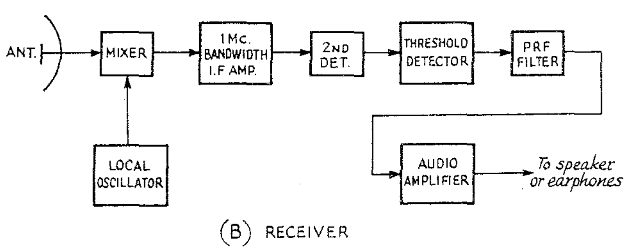


Fig. 10-52—Block diagram of a complete pulse communications system for the 2300-Mc. band. Communications range approximates that obtainable with narrow-band methods, with much simpler and less expensive equipment.

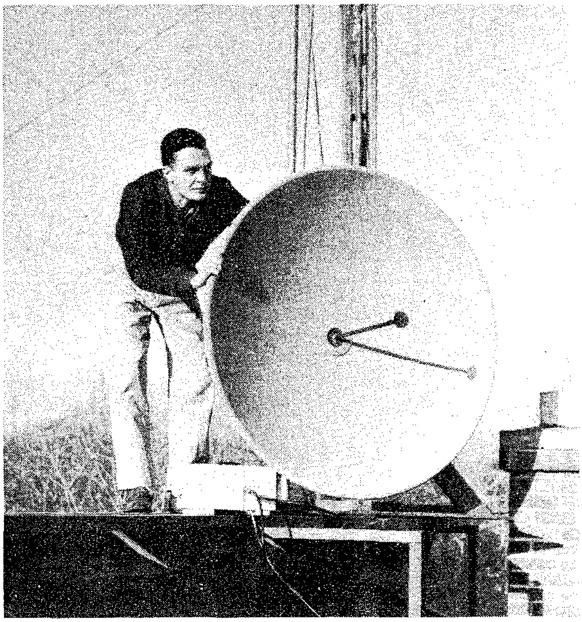


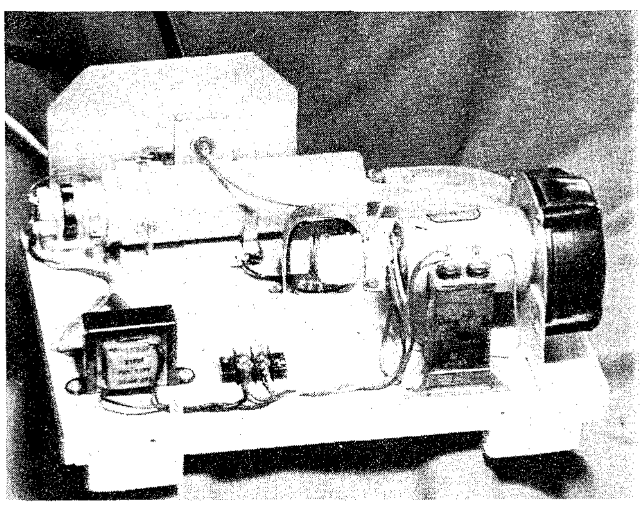
Fig. 10-53—W2BVU lines up his rooftop dish for a 2300-Mc. test beyond the visual horizon. Transmitter r.f. unit is in the weatherproof box at his feet. Reliable operating range approaches that on 144 Mc.

The Transmitter

In the r.f. unit, shown in Fig. 10-54 with its weather-proof cover removed, the oscillator is seen at the rear of the picture. A blower for cooling the oscillator, the 2C43 heater transformer and the pulse transformer are also visible. The only signal connection between the oscillator assembly and the pulse modulator, which may be placed at or near the operating position, is a coaxial cable to carry the high-voltage d.c. pulses from the modulator to the plate of the oscillator tube.

The oscillator is shown in cutaway form in Fig. 10-55, along with detail drawings of its component parts. A cylinder (G) mounted on the grid ring of the 2C43 lighthouse tube forms a coaxial line with the outermost cylinder (D) of the oscillator. This acts as an open-ended resonant tank circuit connected between the grid and cathode of the tube. Similarly, the same grid cylinder forms a resonant tank circuit between the grid and the plate. The feedback necessary for oscillation is obtained through the common opening at the ends of the coaxial tank circuits. Beyond this common opening, the plate line (A) is short-circuited to the outside cylinder, for r.f., by the cup-shaped choke assembly (B) mounted on the plate line. The outside cylindrical surface of this cup forms an open-ended coaxial line which, since it is exactly a quarter-wavelength long, appears as a very low impedance to r.f. inside the oscillator. Because of the way the grid and plate lines open into each other to produce feedback, the over-all circuit is called a re-entrant-cavity oscillator.

Fig. 10-54—The r.f. portion of the 2300-Mc. station is assembled on a wooden base that forms the bottom of a weatherproof box, for roof-top mounting. Output and modulator cables come in through fittings on the metal plate at the rear. Filament transformer in the foreground, pulse transformer between the blower and oscillator assembly. All holes in the box are screened to prevent entry of insects.



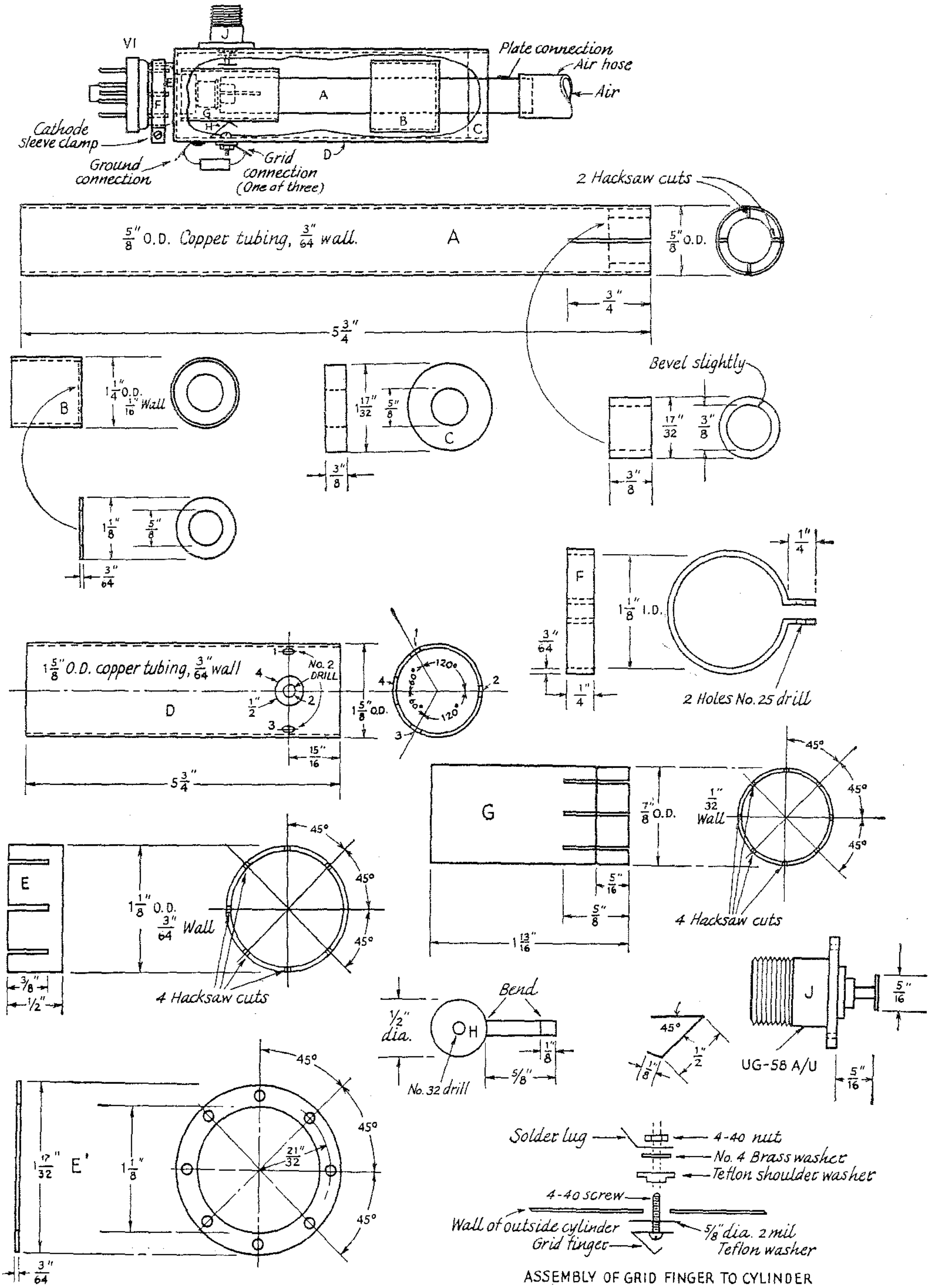


Fig. 10-55—Cut-away drawing of parts of the pulsed oscillator. A—plate line and contact; B—plate choke assembly, 1¼ inches long; C—plate line insulator; D—outside cylinder; E—cathode sleeve; E'—cathode end disk; F—cathode sleeve clamp; G—grid cylinder; H—grid contact finger (3 required); J—output probe (modified UG58A/U receptacle with thin disk attached). All parts except H and C are copper or brass. Cylinders are standard copper pipe diameters. H is thin beryllium copper.

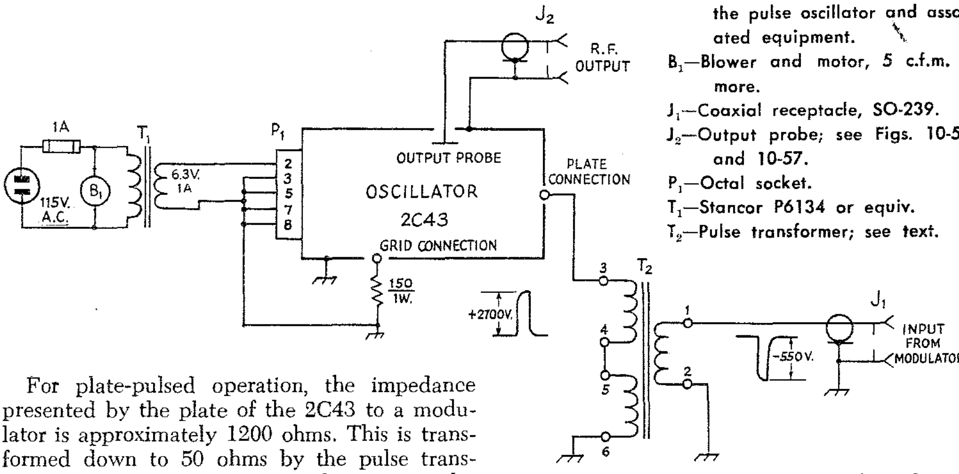


Fig. 10-56—Schematic diagram of the pulse oscillator and associated equipment.

B_1—Blower and motor, 5 c.f.m. or more.

J_1—Coaxial receptacle, SO-239.

J_2—Output probe; see Figs. 10-55J and 10-57.

P_1—Octal socket.

T_1—Stancor P6134 or equiv.

T_2—Pulse transformer; see text.

For plate-pulsed operation, the impedance presented by the plate of the 2C43 to a modulator is approximately 1200 ohms. This is transformed down to 50 ohms by the pulse transformer, T_2 in Fig. 10-56. Since the output pulse of the modulator is negative, the pulse transformer is also required to invert the polarity of the pulses. The voltage applied to the plate of the 2C43 when it is pulsed is between 2500 and 3000 volts. The peak plate current is two to three amperes, depending on the particular tube used.

Construction of a pulse transformer is described below, but it is likely that a suitable transformer can be found on the surplus market. Any pulse transformer rated for a few microseconds pulse length and a secondary voltage of at least 2500 volts, and having a primary-to-secondary voltage or turns ratio of roughly 1:5, should work satisfactorily.

Re-entrant Cavity Oscillator

The oscillator can be made from standard-size tubing available in plumbing-supply stores. Desirable tools are an electric drill, Greenlee punches, a tubing cutter, and a propane torch. All necessary dimensions are given in Fig. 10-55. The following comments indicate the proper sequence for assembling the complete cavity.

Outside Cylinder, D: Be sure to remove all burrs around holes 1, 2, and 3, as the d.c. grid connections are made here. Hole 4 can be made with a ½-inch punch if care is taken not to deform the tubing.

Plate Contact and Plate Line, A: The plate contact is made from ½-inch diameter brass rod. Wrap a 1/64-inch copper shim, ⅜-inch wide, around the rod and press fit the rod into one end of the plate line. Solder in place. Next, drill a ⅜-inch hole in the center of the brass rod and then cut two slots with a hacksaw. Remove all burrs and bevel the inside edge of the plate contact to facilitate insertion of the 2C43 plate terminal.

Plate Choke Assembly, B: The outside diameter of the choke ring should fit snugly within the choke cylinder, and the hole in the ring should fit snugly about the plate line. Insert the ring on one end of the choke cylinder, making sure it is flush with the end of the cylinder, and solder. Position the choke assembly as shown in Fig. 10-55, with the *inside* of the closed end of the choke 4 1/16-inch from the plate end of the line. Make sure that the choke cylinder is concentric with the plate line and then solder in place. To prevent previously-soldered connections from remelting, a dampened rag should be wrapped about these joints before the torch is applied. Position the plate-line insulator, C, on the plate line. The outside diameter of the insulator should make a snug but movable fit inside the outside cylinder.

Cathode Sleeve Assembly, E: The slots should be cut in the cathode sleeve before it is cut from the tubing stock. Before cutting out the cathode end disk, E′, mark the position of the eight air holes but do not drill these holes until after the disk is otherwise finished. Exact inside and outside dimensions of the disk should be tailored to provide a snug fit with the cathode sleeve cylinder and the outside cylinder. Fit the end disk inside the outside cylinder, making sure that the surface is flush with the end of the cylinder, and then solder in place. Fit the cathode sleeve inside the end disk, as shown, making sure the end of the sleeve is flush with the inside surface of the end disk. It is important that the cathode sleeve be concentric with the outside cylinder. Wrap the outside cylinder with a damp rag and solder the sleeve to the end disk. To secure a snug fit to the cathode surface of the 2C43, bend the ends of the slotted sleeve inward or file out the

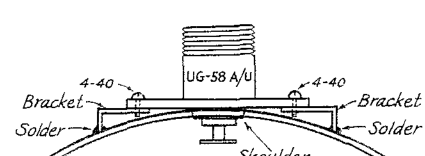


Fig. 10-57—Mounting of the output probe on the outer cylinder of the 2300-Mc. oscillator.

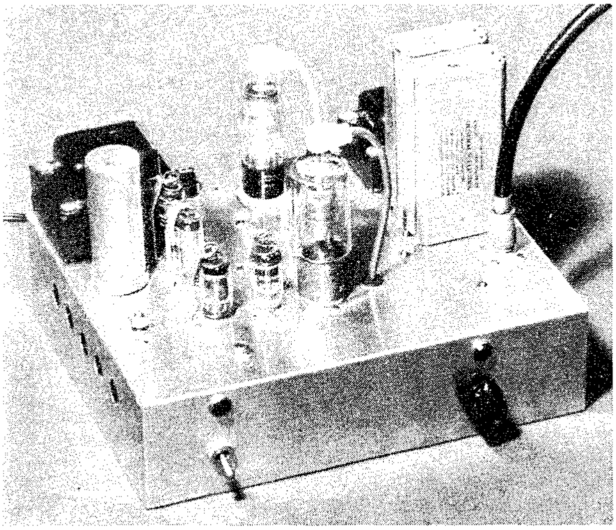


Fig. 10-58—Pulse modulator and power supply. The 3C45 hydrogen thyraton is the large tube near the center of the chassis. The pulse-forming network is located beneath the blank area of the chassis, between the thyraton and the output cable. The latter runs to the remote oscillator assembly, Fig. 10-54.

inside diameter of the sleeve. This will depend on tubing wall tolerances. The sleeve clamp is then made so as to grip the 2C43 firmly after it is inserted into the cavity.

Grid Cylinder, G: The tubing ideally suited for this part is the type used in a hot-water baseboard-heating converter. It is important for proper operation of the cavity that the tubing wall be thin. Score a groove 5⁄16-inch from one end with a tubing cutter to form a shoulder on the inside of the tube against which the 2C43 grid disk will butt. This operation has to be performed with care so as not to cut through the tubing. Next, cut the slots as indicated. The fingers thus formed are then bent inward slightly until a firm clasp on the grid contact of the 2C43 is achieved.

Output R.F. Probe, J: Mount the probe in the ½-inch hole of the outside cylinder, making sure that it makes a snug connection in the

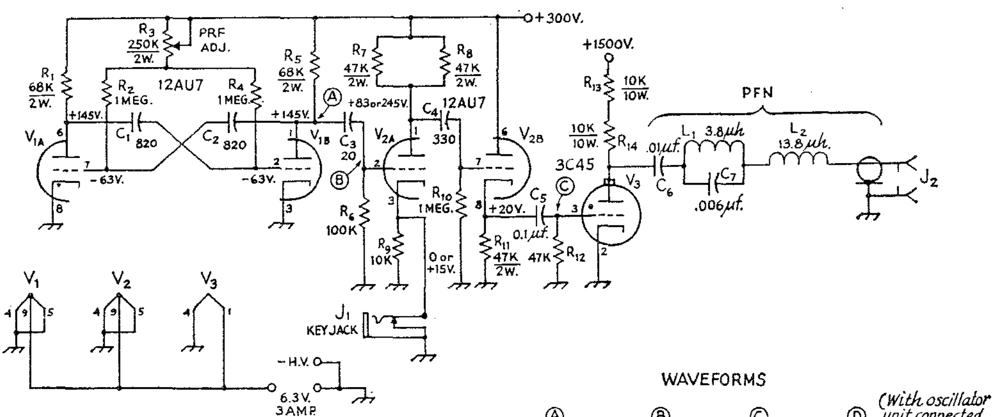
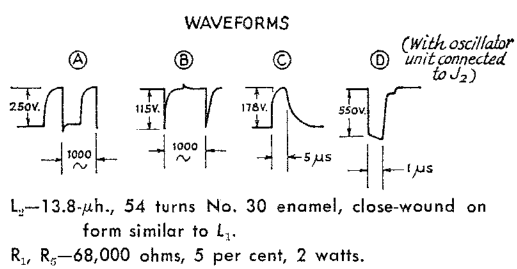


Fig. 10-59—Schematic diagram and parts information for the modulator. Values of parts are plus-or-minus 20 percent, unless specified. Output from J_2 goes to the pulse transformer in the r.f. unit.



C_1, C_2—820-pf., 600-volt, 5 per cent, silver mica.
C_3—20-pf., 600-volt, 10 per cent ceramic
C_4—330-pf., 600-volt, 10 per cent mica.
C_5—0.1-µf., 400-volt paper.
C_6—0.01-µf., 2000-volt mica.
C_7—0.006-µf., 1500-volt mica.
J_1—Closed-circuit jack.
J_2—Coaxial receptacle, SO-239.
L_1—3.8-µh., 28 turns No. 24 enamel, close-wound on 3⁄8-inch diam. form about 1 inch long.
L_2—13.8-µh., 54 turns No. 30 enamel, close-wound on form similar to L_1.
R_1, R_5—68,000 ohms, 5 per cent, 2 watts.
R_2, R_4, R_{10}—1 megohm, 5 per cent, ½ watt.
R_3—250,000-ohm, 2-watt potentiometer.
R_6—100,000 ohms, ½ watt.
R_7, R_8, R_{11}—47,000 ohms, 2 watts.
R_9—10,000 ohms, ½ watt.
R_{12}—47,000 ohms, ½ watt.
R_{13}, R_{14}—10,000 ohms, 10 watts.

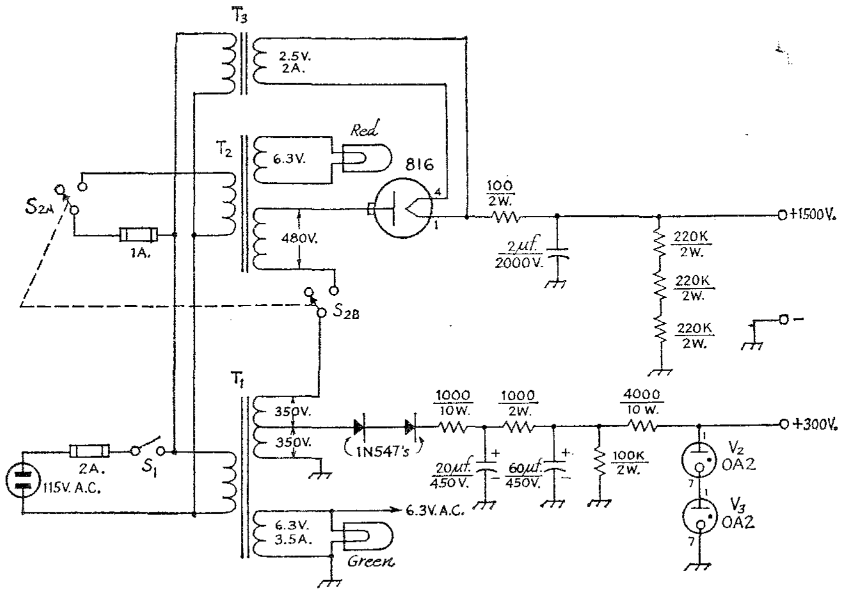


Fig. 10-60—Schematic diagram and parts information for the power-supply portion of the modulator. Components are not critical, and any supply capable of delivering 1500 volts at 10 ma. and 300 volts at 20 ma., and 6.3 volts at 3.5 amp., may be substituted. Capacitors with polarity shown are electrolytic.

S_1—S.p.s.t. toggle switch.
S_2—D.p.d.t. wafer switch.
T_1—Thordarson 24R04-U or equiv.
T_2—Thordarson 24R00-U or equiv. Do not use high-voltage center tap.
T_3—Stancor P4082 or equiv.

hole, flush against the surface of the cylinder. Two small right-angle brackets should be tailor-made to secure the r.f. connector. Two 4-40 tapped holes are made in each bracket for attaching the connector to the brackets. This assembly is shown in Fig. 10-57.

Grid Contact Assembly: The Teflon shoulder washers can be hand cut from ¼-inch rod stock using a sharp knife. When the grid contacts are assembled, check to see that the three grid fingers touch the grid cylinder when it is inserted into the cavity. The wire used to interconnect the external solder lugs of the grid contacts should be well insulated and kept clear of the outside cylinder, since peak grid potentials of several hundred volts are produced during operation.

The Pulse Modulator

Much of the modulator, Fig. 10-58, is conventional power-supply circuitry. Any supply capable of providing 10 ma. at 1500 volts and 20 ma. at 300 volts could be substituted for that shown in Fig. 10-60. The actual pulse-generating circuitry uses three tubes: two 12AU7s and a 3C45. The latter is a hydrogen thyratron available on the surplus market.

The p.r.f. is generated in the modulator, Fig. 10-59, by V_1, in a multivibrator circuit, a square-wave oscillator which has reasonably good frequency stability. It can be adjusted over a small frequency range by means of R_3. Thousand-cycle square waves appearing at the plate of V_{1B} are differentiated by a short-time-constant coupling network, C_3R_6, to produce impulses at the grid of V_{2A}. Positive and negative impulses are produced when the voltage of the square wave is rising and falling, respectively. Since the voltage at Pin 1 of V_{1B} falls faster than it rises during the square wave, a larger negative impulse is generated. This negative impulse becomes the positive trigger for firing the thyratron, V_3, after having been amplified by V_2. The operating conditions for V_2 are arranged to suppress the undesired positive impulses appearing at the first grid. V_{2A} can be keyed in its cathode circuit. When the key is closed, the stage is a conventional pulse amplifier, and the negative impulses on the grid (point B) produce positive pulses at the plate. These are applied to the grid of the thyratron by V_{2B}, a cathode follower. When the key is open, sufficient self-bias is developed across R_9 to prevent the pulses from triggering the thyratron.

The thyratron acts as a high-speed switch, closed by the trigger pulses whenever an output pulse is to be produced. The one-microsecond length of the actual output pulses of the modulator is determined by the pulse-forming network (p.f.n.) in the plate circuit of the thyratron. To create each output pulse, C_6 is first charged to almost 1500 volts by the power supply, acting through resistors R_{13} and R_{14}, L_1, L_2, and the transmitter load resistance of 50 ohms (connected to J_2). When the thyratron is fired, it becomes almost a short circuit from its plate to ground so that the energy stored in C_6 of the p.f.n. begins to discharge through the load, which is then effectively in series. The p.f.n. acts as a delay line in such a way that, one microsecond after the thyratron fires, it causes the voltage across the thyratron to be reduced to zero. When this happens, the thyratron becomes an open circuit again, and C_6 begins recharging in preparation for the next pulse. The charging resistors R_{13} and R_{14} are large enough in value so as not to affect the action of the circuit when pulses are actually produced.

The pulse-forming network has a characteristic impedance of 50 ohms which, when working into a 50-ohm load, causes the output pulses to have an amplitude equal to approximately one half the power-supply voltage. This low impedance permits a coaxial cable, such as RG-8/U, to be used to conduct the pulses to a remotely-located oscillator.

Modulator and Power Supply Layout

The modulator and its associated power supplies are constructed on a 10 × 12 × 3-inch aluminum chassis as illustrated in Fig. 10-58. The power-supply section requires no special layout or critical wiring technique, other than observing insulation requirements in the high-voltage section. Transformers T_1 and T_2 are interconnected as a means of generating high voltage with readily obtainable components. Before wiring the transformer secondary high-voltage leads permanently into the circuit, check the phasing of the high-voltage windings to make sure they are aiding, not bucking.

Winding the Pulse Transformer

The winding of the pulse transformer is similar to winding a heater transformer for 60-cycle operation. The differences are the type of core used and the amount of insulation needed between the windings. The core, specially fabricated for use in pulse circuits to minimize the high-frequency eddy-current losses, can be purchased from Arnold Engineering Co., Marengo, Illinois, or through one of their many sales offices. The full description of the core is Arnold 2-mil. Silectron "C" core, part No. AL-12. Data for winding the transformer and a cross-sectional view are shown in Fig. 10-61.

Since winding wire directly on the core initially is very impractical, a wooden mandrel should be made having the same cross-section dimensions as the core. After clamping the mandrel in a vise, cut a strip of cardboard approximately 0.025 inch thick (such as used in a tube carton), 1⅛ inches wide, and wrap it tightly around the mandrel. Overlap the ends ¼-inch and cement the ends together. The cardboard form prevents the windings from collapsing when removing the coil from the mandrel. This permits easy insertion of the core. Before winding, precut 1⅛-inch wide strips of Teflon from 2-mil sheet stock. Wrap two layers of Teflon around the form, securing the ends with short strips of masking tape. Next, center a 2-inch long strip of masking tape, sticky side up, across the form and wind 50 turns of No. 26 enameled copper wire over the tape. Fold the ends of the tape over the winding, thus securing the end turns. Continue with steps E, F, G, H, and J as listed in the winding-data diagram. Start all windings at the same end of the form and wind in the same direction. Label the ends of each winding according to Fig. 10-61 to facilitate wiring the transformer into the circuit.

When the winding is completed, slip the cardboard form supporting the winding stack off the mandrel and insert the core. Tape tightly around the periphery of the core with vinyl electrical tape to butt the ends of the core pieces together. Apply a finishing coat of coil varnish to the windings and the transformer is complete.

Operation

Attach a dummy load, made by paralleling five 270-ohm 2-watt composition resistors, across the modulator output jack, J_2. Set the p.r.f.-adjust control, R_3, in the center of its range, and insert a key in J_1. Turn on the heaters and 300-volt supply with switch S_1, and check the voltages in the circuit against the values given on the schmeatic. The dual voltages on Pins 1 and 3 of V_2 correspond to key-closed and key-open conditions. If the voltages agree approximately, turn on the high-voltage supply with S_2, making sure the key is open. Measure the high voltage at the power supply. It should be between +1300 and 1500 volts d.c. With the key closed, the 3C45 should ionize with a purple glow, indicating that it is being triggered properly. One should also hear a faint 1000-cycle tone. After five minutes of operation,

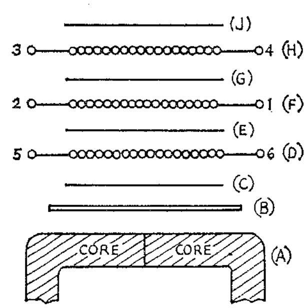


Fig. 10-61—Pulse transformer construction.
A—Core; Arnold Eng. Co. No. AL-12.
B—Cardboard form.
C—2 layers 2-mil Teflon sheet.
D—50 turns No. 26 enam.
E—4 layers 2 -mil Teflon sheet.
F—20 turns No. 22 enam.
G—4 layers 2-mil Teflon sheet.
H—50 turns No. 26 enam.
J—4 layers 2-mil Teflon sheet, followed by 3 layers masking tape.

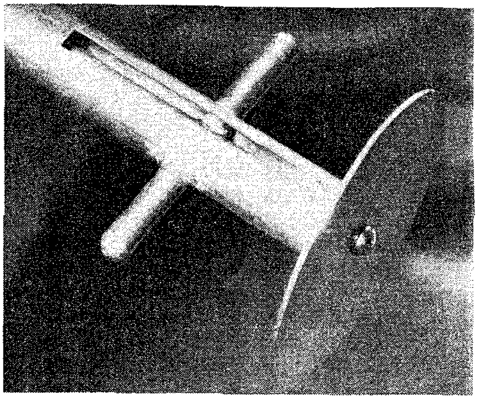


Fig. 10-62—Close-up view of the dipole and reflector assembly. For constructional details see text and Fig. 10-63.

turn off the high voltage and touch the dummy load. It should be hot, as 6 to 7 watts of average power is dissipated. For those amateurs who have a fairly good oscilloscope, waveforms are also given at four points in the circuit as a check-out aid.

Operating the Transmitter

Before connecting the cavity into the circuit, make sure that the 2C43 is seated securely and the plate-line contact is fully engaged with the 2C43 plate terminal. Connect the blower to the plate line with a short length of plastic hose and attach the heater, cathode, grid, and plate connections according to the schematic, Fig. 10-56. Connect the oscillator to the modulator with RG-8/U cable. At K1JIX, a 50-foot cable connects the modulator in the shack to the oscillator on the roof, next to the antenna. Apply 115 volts a.c. to the oscillator unit and check for air flow at the cathode end of the cavity. Allow the cathode of the 2C43 at least 60 seconds to come up to temperature before turning on the pulse modulator. When the modulator high voltage is turned on and the key is closed, one should immediately hear the pulse transformer "sing" at the p.r.f.

A simple check for r.f. output can now be made by touching a neon lamp to the center conductor of the output jack, J_2. A second check is to connect the dipole feed to the oscillator with a 5-foot length of RG-8/U or RG-9/U cable and hold a neon lamp near the dipole. The lamp should glow brightly in both cases. Between 1000 and 2000 watts peak-power output can be obtained, depending on the condition of the 2C43, the degree of coupling by the r.f. probe, and the amplitude of the pulse applied to the 2C43 plate. If output indication such as described above is produced, it is likely that the output power is at least 1000 watts. It was found that silver plating of the entire cavity assembly increased the cost considerably but did not result in any measurable increase in power out.

The remaining and most difficult part of the procedure is checking the oscillator frequency. There are at least three ways that this may be done: (1) a wavemeter, (2) a slotted line or Lecher wires, or (3) the companion receiver. The simplest way is to use a wavemeter. Several types of these are available on the surplus market. The authors acquired a surplus type 402-B coaxial wavemeter. The third method consists of using the companion receiver and calibrating it by means of harmonics from a lower frequency source. Possible sources are a grid-dip meter operating in the u.h.f. range, a 220- or 420-Mc. transmitter, or a 1215-Mc. equipment such as the APX-6.

The operating frequency of the oscillator constructed using the dimensions given here was found to be 2333 Mc. The frequency can be shifted 50 Mc. higher by shortening the grid cylinder length from 1$\frac{13}{16}$ inches to 1$\frac{3}{4}$ inches, or lower, by sliding the plate line outward on the plate terminal.

Antenna System

The antenna feed is designed for operation at a center frequency of 2360 Mc., where a wavelength is exactly 5 inches. Details of the feed are shown in Figs. 10-62 and 63. It is basically a dipole radiator, fed from a rigid coaxial line having a characteristic impedance of 50 ohms. The disk is a reflector, so there is little forward radiation from the dipole, and the main lobe of the radiation pattern is centered on the direction from which the coaxial line approaches. A parabolic dish antenna can therefore be illuminated with radiation by using the coaxial line to support the feed at the center of the dish.

The manner in which the microwave energy is coupled to the dipole elements from inside the line is interesting. Two half-wavelength slots are cut in opposite sides of the outer con-

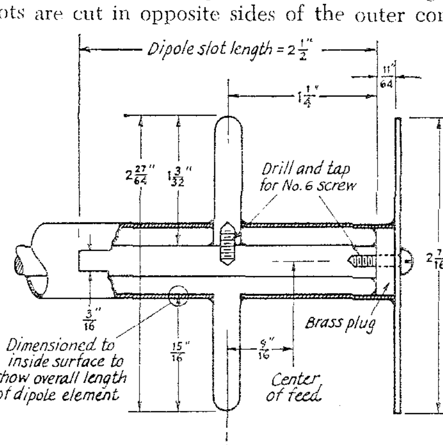


Fig. 10-63—Dimension drawing of the dipole and reflector assembly. Rigid coaxial line, left, extends to the parabolic dish reflector, and is terminated in a coaxial fitting in back of the dish. Inner conductor and dipole are ¼-inch diameter.

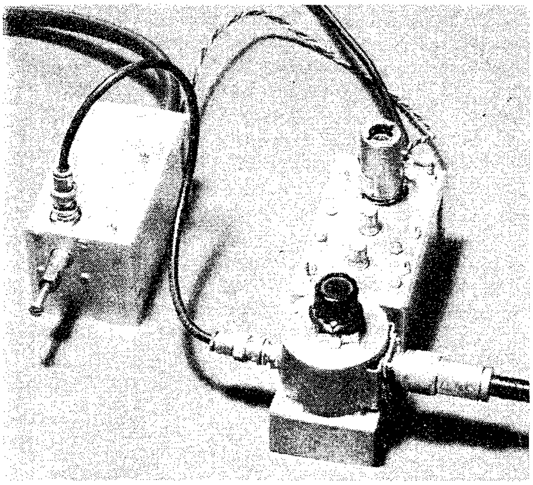


Fig. 10-64—Front end of the 2300-Mc. receiver. The box at the left contains the local oscillator. The mixer is the cylindrical assembly in the right foreground, with the cable from the antenna entering from the right. The i.f. preamplifier is just to the rear of the mixer. Knob on the top of the mixer is a tuning adjustment which was found to be unnecessary.

ductor of the coaxial line, extending back from the closed end. A short circuit is placed between the inner and outer conductors at the mid-point of these slots. This causes an r.f. potential difference between opposite sides of the inside of the line, which is transferred to the outside of the line by the slots. The dipole elements are excited by this r.f. potential difference. Although the short circuit inside the line is formed by an extension of one of the dipole elements, the dipole element and the short are electrically independent.

The effective origin or center of the radiation from the feed is located between the dipole and the disk as shown by the arrow in Fig. 10-63. To properly illuminate a parabolic antenna, the feed should be mounted so that this spot is at the focal point of the parabola.

Although dimensions are given to a 64th of an inch, errors of this amount should not affect performance noticeably. It is important, however, that each dipole element extend exactly the same distance beyond the outside surface of the coaxial line.

The outside conductor of the coaxial line is a standard size of copper water tubing. Its length depends on the size of the parabolic reflector with which it is used. The inside dimensions of the coaxial line make it convenient to mount a "type N" connector (UG-58A/U, as used for the transmitter r.f. probe) on the input end. When this is done, the center conductor is shortened somewhat with respect to the outer conductor (so as to keep the tapped hole in the side of the center conductor lined up with the dipole), drilled in the center to fit over the center conductor of the connector, and tapered or rounded off, as are the ends of the dipole elements.

In assembling the feed, first solder the center conductor to the connector. Two or three washers made from polyethylene foam or Teflon are then placed at intervals along the center conductor, to keep it in the middle of the outer conductor. The outer conductor is then slipped over it, and the longer dipole element screwed on the inner conductor. It may help to solder the No. 6 screw in place in the dipole element beforehand. The disk and brass end plug are then mounted on the end of the center conductor and the shorter dipole element inserted. (The hole in the outer conductor for this element should be made slightly undersize to give a force-fit). At this point, the assembly is complete, and all metal-to-metal joints (including that of the outer conductor with the N connector) should be soldered, using a propane torch. The inside joints of the feed are accessible for soldering through the slots. Finally, the external lengths of the dipole elements should be checked to see that they are the same; if one is longer, it can be filed down to match the other.

Pulse Reception

A block diagram and brief description of the pulse receiver were given earlier. The receiver as shown in Fig. 10-52 is complete; nothing is needed but earphones or a speaker to do an effective job in pulse reception. Reasonably good reception is possible without the special threshold detector and p.r.f. filter included here.

The r.f. portion consists of a cavity mixer and a one-tube local oscillator. These and a 3-stage

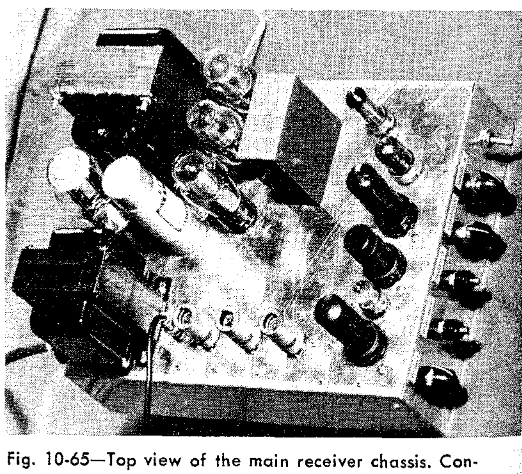


Fig. 10-65—Top view of the main receiver chassis. Controls are for i.f. gain, video gain, threshold stability, audio gain, audio bandwidth and power on-off, reading from bottom up. The first row of tubes are the video and audio stages. Power supply components are at the rear, and the i.f. amplifier stages are the three small shielded tubes in a row at the edge of the chassis. A bottom plate is required to shield the i.f. from stray 30-Mc. signals.

i.f. preamplifier are shown in Fig. 10-64. The mixer is a 1N21-series diode, in a quarter-wave resonant coaxial cavity made from standard-sized copper tubing. The 2C40 local-oscillator design was obtained from a *QST* article by W2RMA.[16]

The main i.f. amplifier, the threshold detector, p.r.f. filter, audio amplifier and power supply are constructed on a $10 \times 12 \times 3$-inch chassis. This assembly, Fig. 10-65, can be remotely located from the front-end assembly, and interconnected with it by means of a coaxial cable for the i.f. signal and a power cable for the B-plus and heater voltages.

The over-all i.f. amplifier has a center frequency of about 30 Mc., though any frequency from 20 to 60 Mc. is satisfactory, provided that a bandwidth of about one megacycle can be maintained. A low-noise design with Nuvistor cascode input is used here, but it should be possible to adapt surplus i.f. amplifiers with good results.

The combination of threshold detector and p.r.f. filter is effective in detecting pulses barely exceeding the noise level at the output of the second detector. The threshold detector uses a multivibrator circuit, as shown in Fig. 10-66, and works as follows: V_3 and V_4 comprise a one-shot or monostable multivibrator, producing a single square output wave only when triggered by V_1, a video amplifier which also inverts the polarity of the positive output of the second detector. Negative noise peaks and pulses are therefore applied to the grid of V_4 by way of V_2 and C_4. R_2 is adjusted so that V_3 is normally cut off and V_4 is conducting. When a negative peak from V_1 cuts off V_4, the multivibrator "flips," and V_3 conducts for a time before returning to the original conditions. Duration of the positive pulse at the plate of V_4 is determined by C_4 and the 1.5-megohm grid ressistor of V_4. For values given, the pulse out of the multivibrator is about 35 microseconds long.

The amplitude of the negative pulse required to trigger V_4 can be varied by means of R_2. This control and the video amplifier gain control, R_1, therefore serve as threshold level adjustments. The multivibrator threshold is set so that, in the absence of a pulsed signal, it is triggered by noise peaks several times per sec-

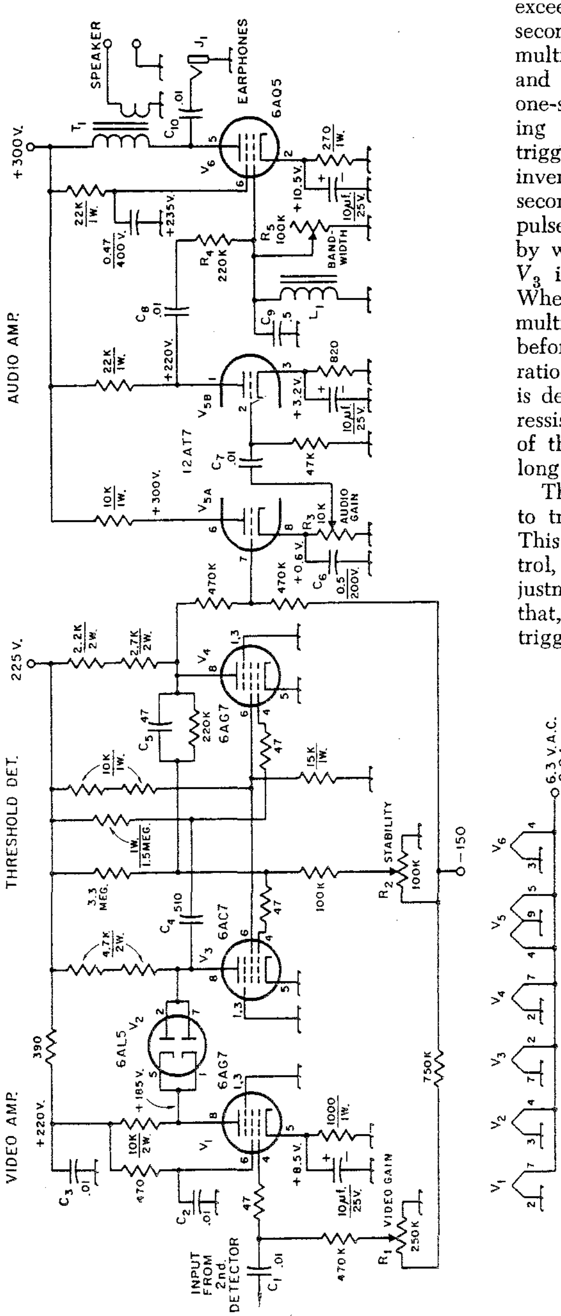


Fig. 10-66—Schematic diagram of the video amplifier, threshold detector and audio stages. Resistors are ½ watt, 10 per cent tolerance, unless specified. Decimal values of capacitance are in μf., others in pf., unless specified. Those marked with polarity are electrolytic.

C_1, C_2, C_3, C_7, C_8, C_{10}—Paper or ceramic, any tolerance.

C_4, C_5—Mica, 10 per cent.

C_6—Paper, 20 per cent.

C_9—0.5 μf.; see text.

J_1—Phone jack.

L_1—50-mh. high-Q toroid (Freed F-1755). See text.

R_1, R_2, R_3, R_5—2-watt potentiometer.

R_4—See text.

T_1—Audio pentode output transformer (Stancor A3822).

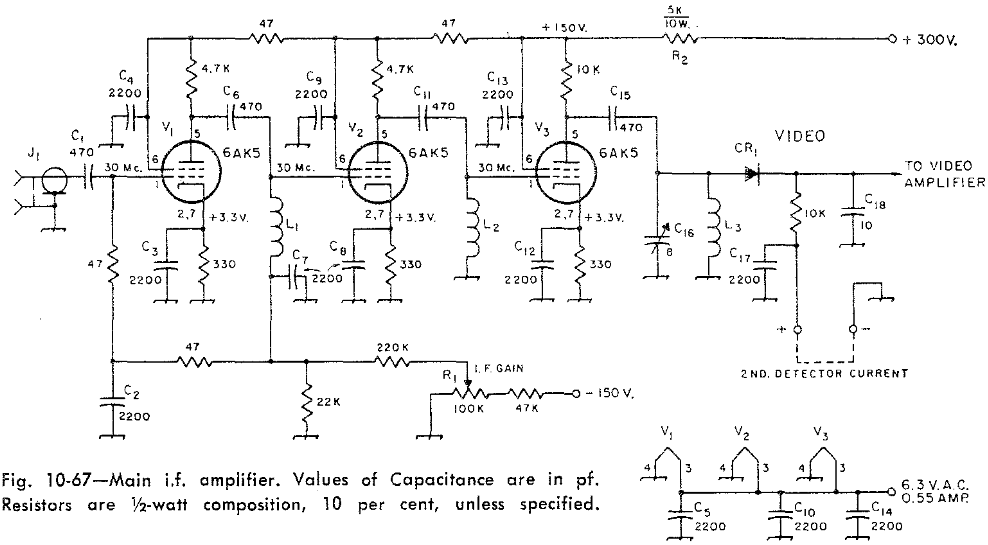


Fig. 10-67—Main i.f. amplifier. Values of Capacitance are in pf. Resistors are ½-watt composition, 10 per cent, unless specified.

C_1–C_{15} incl.; C_{17}—ceramic disk.
C_{16}—1-8-pf. cylindrical trimmer (Erie 532B).
C_{18}—10 pf., 10 per cent, mica.
CR_1—Chystal diode, 1N60, 1N67, 1N295 or equiv.
J_1—Coaxial receptacle, BNC type.
L_1, L_2, L_3—2.2 μh., 32 turns No. 24 enam., close-wound on ¼-inch diam.
R_1—2-watt potentiometer.
R_2—5000 ohms, 10 watts, wire-wound.

ond. When even a weak signal appears, there is a pronounced increase in the triggering rate. When a moderately strong signal with the correct p.r.f. appears, a noise-free tone is produced at the output of the p.r.f. filter. Difference between the signal and no-signal output conditions is quite distinct, and the effect is similar to that of a squelch circuit. With freedom from a constant level of background noise, searching for weak signals is relatively easy on the ears.

The three stages following the threshold detector make up a very narrow-band audio amplifier centered at 1000 cycles. Most of the selectivity is provided by a 1000-cycle filter formed by inductor L_1, resonating with C_9, between V_5 and V_6. A small but important amount of filtering is provided in the cathode circuit of V_{5A}. Capacitor C_6 removes undesired high-frequency components of the multivibrator square wave, so that they will not overload the following triode amplifier. The *LC* filter uses a high-*Q* toroid to obtain an audio bandwidth as small as 10 cycles. The result is that unless the square waves produced by the threshold detector-multivibrator have a p.r.f. of exactly 1000 cycles, there is little output from the audio amplifier. The net effect of these circuits is a signal-to-noise ratio somewhat comparable to that obtained with narrow-band c.w. on lower frequencies.

The Main I.F. Amplifier

The main receiver chassis is seen in Fig. 10-65. It is recommended that this general arrangement be used, but exact wiring details are not important except in the case of the i.f. amplifier circuitry. The three i.f. amplifier stages, Fig. 10-67, are in a line along the lower side of the chassis, with the input stage toward the left where there is little neighboring wiring. The second detector is near the video amplifier. In order to reduce cost, identical fixed inductors are used to tune each stage. The exact frequency is not important, so long as each is tuned to the same frequency. Since the coils resonate with the capacitance of the interstage wiring and the input and output capacitances of the tubes, the wiring layout between each pair of tubes must be identical. Similarly, the coils should be identical, though it is not important exactly how they are wound. The wiring of the plate circuit of the last stage is not critical, as a variable capacitor, C_{16}, allows for differences in circuit capacitance.

The *Q*, and therefore the bandwidth, of each i.f. stage is determined by the plate load resistance (in the output stage, the detector load resistance appears in parallel with the plate load). For a value of 4700 ohms, the *Q* is 10, so the bandwidth of each stage is about three megacycles. Over-all bandwidth, including the preamplifier, approaches one megacycle, but it will depend on alignment.

Variable inductors could be used for each stage, to avoid the need for careful layout and permit exact alignment. A small coil such as the Miller type 5403, 1.6 to 2.8 μh., should work well, or similar surplus slug-tuned coils could be used. An inductance of the proper value will resonate at 30 Mc. with a 12-pf. capacitor.

P.R.F. Filter

The toroid, L_1 in Fig. 10-66, has a *Q* of approximately 200 by itself, and effective circuit

Q of about 100, due to loading by R_4 and R_5. A Freed F-804 ($6.60) would give a Q of 70, and be entirely adequate. Suitable toroids may be available on the surplus market. Qs as low as 20 to 30 would still give good results. Inductance values other than those given can be used by changing R_4 and R_5 in the same proportion. Example: if the inductance is increased 10 times, to 0.5 henry, R_4 becomes 2.2 megohm and R_5 1 megohm.

Capacitor C_9 is actually several capacitors in parallel. A 0.47-μf. capacitor is used with enough 0.01-μf. or 0.0047-μf. capacitors in parallel to resonate the toroid to exactly 1000 cycles. These capacitors should be low-loss types, to preserve circuit Q.

Mixer

Crystal diodes of the 1N21 series have letter suffixes from A to F, each giving progressively lower noise figure and costing more. Very satisfactory results have been achieved with the inexpensive 1N21C. Mounting of the mixer to the preamplifier is important, as the diode forms part of the amplifier input circuit. The mixer cylinder must be well grounded to the preamplifier chassis, so that it will not act as an i.f. pickup loop and cause the amplifier to oscillate.

Construction details of the microwave mixer and a cutaway view of the complete assembly are given in Fig. 10-68. Following is the sequence for assembling the mixer. Attach the center rod to the end disk with the hole, using a 6-32 screw, and solder with a propane torch. Attach the receptacle that receives the pin end of the 1N21 diode to the center rod. This is a demountable base, made for reversible-case cartridge-type diodes, and is available from any manufacturer of microwave diodes. A substitute can be made from ¼-inch brass rod 7/32 inch long, drilled out 3/32 inch at the center. Slot it for most of its length with a thin saw blade, and bend the fingers in slightly so that it will make good contact to the diode pin. Clamp the base in the notch on the center rod, and solder the connection, being careful not to fill in the slots with solder. Attach this assembly to the outside cylinder, and align the 9/32-inch hole in the cylinder wall with the crystal receptacle on the center post, using a crystal diode. Clamp securely, and solder the end disk to the outside cylinder. Clamp the other end disk to the top of the cylinder and solder securely.

To mount the l.o. connector, center and clamp the nut supplied with the UG-1094/U connector over its hole, and solder, being care-

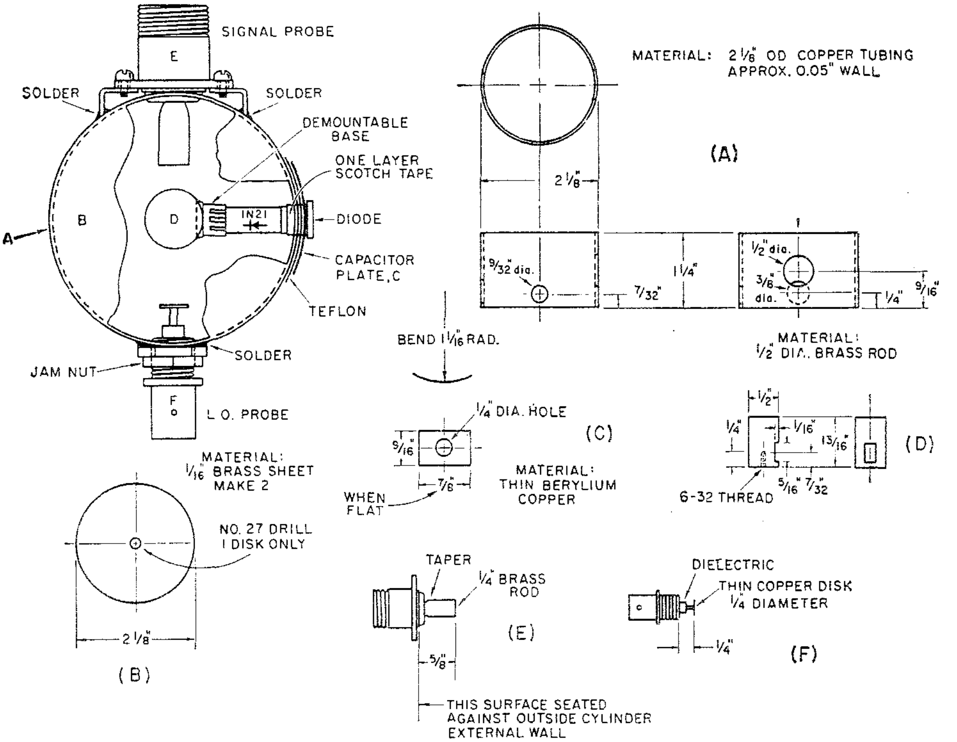


Fig. 10-68—Cutaway view of the crystal-mixer assembly, with details of individual parts. As may be seen from Fig. 10-64, the mixer cavity is mounted adjacent to the end of the i.f. preamplifier. The head of the diode, and its external bypass capacitor, project through a rectangular hole cut in the end of the preamplifier case. A ¾ by ¼-inch spring finger on a standoff insulator makes contact to the diode, to take off the 30-Mc. i.f. output.

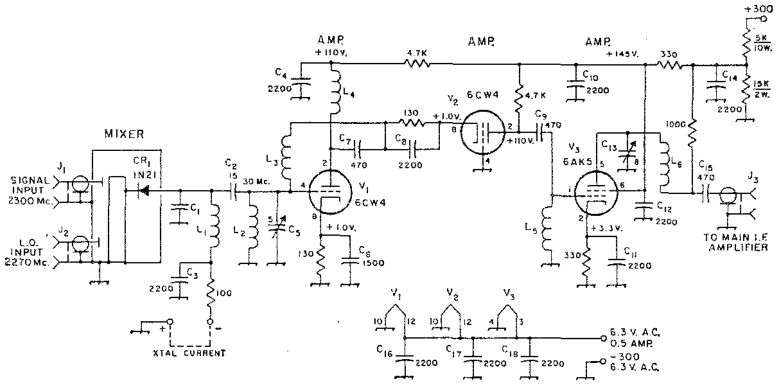


Fig. 10-69—2300-Mc. crystal mixer and 30-Mc. i.f. preamplifier. Capacitors are ceramic disk, (CD Tinymike) values in pf., 20 per cent, unless specified. Resistors are ½-watt composition.

C_1—Bypass capacitor built onto mixer assembly; see Fig. 10-68.
C_3, C_4, C_8, C_{10}, C_{11}, C_{12}, C_{14}, C_{16}, C_{17}, C_{18}—2200-pf. ceramic disk ,CD Tinymike LT0D22).
C_7, C_9, C_{15}—470-pf. ceramic disk (CD Tinymike L10T47).
C_2—15 pf., 10 per cent, mica.
C_5—5-pf. cylindrical trimmer (Erie 532A).
C_6—Critical lead length; see text. (CD Tinymike L10D15)
C_{13}—8-pf. cylindrical trimmer (Erie 532B).
CR_1—1N21-series crystal diode; see text.
J_1—Coaxial receptacle, UG-58/U (Type N).
J_2, J_3—Coaxial receptacle, UG-1094/U (Type BNC).
L_1—22μh., plus or minus 10 per cent (Delevan 1537-44).
L_2—1.3 μh., 21 turns No. 24 enam., close-wound on ¼-inch diam. form.
L_3—22 μh., 65 turns No. 32 enam., close-wound on ⅜-inch diam. form; see text.
L_4, L_5, L_6—2.2 μh., 32 turns No. 24 enam., close-wound on ¼-inch diam. form.

ful not to flow solder into the nut threads. The l.o. probe can then be screwed in or out, to adjust the injection level. A second nut threaded onto the probe can be used to lock it in position, once the desired level is obtained. This and the method of attaching the signal probe to the cylinder are shown in Fig. 10-68.

The mixer is attached to the preamplifier by two brackets. A clearance hole is first cut in the wall of the preamplifier chassis, large enough to clear the crystal bypass capacitor, C_1, which is assembled later. Details of the bracket depend on the chassis used for the preamplifier. Before mounting the crystal diode, cut a piece of 2-mil Teflon sheet slightly larger than the crystal bypass plate. Carefully cut a true ¼-inch hole in the center of the dielectric. Wrap a layer of Scotch tape around the base of the diode to prevent it from shorting against the wall of the outside cylinder. Slide the capacitor plate and the Teflon sheet over the diode. Insert it into the mixer cavity and seat the diode flange firmly against the capacitor plate. Tape the capacitor plate to the outside cylinder so that the crystal can be removed without disturbing the capacitor. A small beryllium spring finger mounted on a standoff insulator holds the crystal in place, and serves as the i.f. signal connection.

Local Oscillator

Both oscillators described by W2RMA have been constructed and used with the receiver described here, with good results. Several other approaches are open, the most obvious being to use the oscillator from a surplus microwave unit. A few such possibilities are mentioned later. The transmitter oscillator and local oscillator of the APX-6 immediately suggest themselves for this application with a diode multiplier. Such an oscillator could be located at the operating position and connected to a varactor mounted in the mixer at the antenna. This arrangement could be quite simple, as only a milliwatt or less power is required for l.o. injection at 2300 Mc.

I.F. Preamplifier

The i.f. amplifier has a noise figure of only slightly more than 1 db., due mainly to the Nuvistor cascode input stages. Low-loss coils at L_1, L_2 and L_3 in Fig. 10-69 are important, as is the small value of coupling capacitance, C_2. This transforms the low impedance of the crystal up to the higher value which is optimum for the 6CW4 at 30 Mc. A critical value of cathode bypass is used for C_6. This should be wired into the circuit with ¼-inch leads, to tune out the cathode lead inductance of the first stage. L_1 can be made like L_3, if desired.

The three tubes of the preamp should be arranged in line, with components mounted close to the tube sockets they serve. Lead lengths should be kept to ½ inch or less. The 6CW4—6AK5 wiring should be like that of the main i.f. amplifier. Since the preamp makes an extremely sensitive 10-meter front end, a shielded chassis such as a Minibox, and a 6AK5 tube shield, should be used. The dropping resistors and bleeder in the B-plus circuit are arranged so that the supply voltage will not be excessive during warm-up periods.

Operation

Before reception is attempted, the l.o. injection, i.f. amplifier and threshold detector should be checked out. Operate the main receiver chassis first, without the preamplifier or local oscillator connected. Before applying power, set the i.f. and video gain controls at maximum (fully clockwise) and the remaining potentiometers fully counterclockwise. After turning on power, the VR tubes should light up in a few seconds, and the voltage after R_2, Fig. 10-67, should read about 150, as soon as the heaters warm up. Other voltages should read about as given.

Connect a speaker or earphones to the output, turn the audio gain and bandwidth controls fully clockwise, and turn the i.f. and video gain controls fully counterclockwise. As the stability control is turned up slowly, a popping sound should be heard, followed by a weaker squeal, whose pitch varies with rotation. Leave the stability control set just below where the popping is first heard.

The main i.f. amplifier can be aligned with a signal source such as a grid-dip oscillator, using a few inches of wire in the input BNC connector as an antenna. Connect a milliammeter in the second detector circuit, as indicated in Fig. 10-67. Place the bottom cover on the chassis, and turn the i.f. gain full on. The 30-Mc. signal source should be coupled to the input so as to give about 1-ma. output current. Without changing input coupling, tune the signal source until a frequency is found which gives the highest current when the output stage is peaked by adjusting C_{16}. This is the center frequency of the response of the three stages together, and is about 31.5 Mc. for the receiver shown.

Next, connect power to the i.f. preamp and the local oscillator, but do not connect the l.o. or i.f. signal cables. Check the cathode voltages of the preamp. With the preamp and mixer completely assembled, connect the preamp to the main receiver with a 50-ohm cable, and tune the signal source to the center frequency of the main i.f. amplifier. With a few inches of wire connected to the signal-input jack of the mixer, peak C_5 and C_{13} to the i.f. signal, with the meter showing about 1 ma. Move the signal source away, or use a 2300-Mc. signal later, to peak C_5 accurately.

To check mixer operation, remove the jumper from the crystal-current meter terminals on the preamp, and connect a 1-ma. meter with the polarity shown. Decouple the l.o. probe, J_2, from the mixer cavity as far as possible, and connect a short coaxial cable from the l.o. Adjust the l.o. output for 0.3- to 0.8-ma. crystal current. Increase injection by threading the l.o. probe farther in, if necessary. When the proper level is obtained, lock J_2 in place with the jam nut. The meter can be removed and the jumper replaced.

The receiver is now ready for use on 2300 Mc. It will be found that front-end thermal noise is capable of continuously triggering the threshold with the video and i.f. gain at maximum. The most sensitive condition for weak signals is with the i.f. gain near maximum and the video gain turned down until the threshold is triggered on noise peaks a few times per second. The i.f. gain control is then used for minor adjustment of the triggering rate. It should not be left turned down for long periods, as the B-plus voltage after the main i.f. dropping resistor, R_2, will be excessive in this condition. No trouble has been experienced with this, but if it becomes a problem it can be eliminated through the use of a VR-150 regulator after R_2.

The final step is to check the tuning of the p.r.f. filter, by varying the transmitter p.r.f. and watching for the peak in audio output.

Conclusions

It should be emphasized that this description is only one of many possible approaches. The equipment could be improved in many ways, and could be adapted to 3300 Mc. with only minor modification. There are also many intriguing possibilities in the large amount of surplus radar pulse equipment now available. Some useful equipments are listed below:

APR-4, with tuning head TN-54 Radar receiver 2150 to 4000 Mc. Noise figure poor. L.o. in tuning head.

APR-5A Radar receiver, 1000 to 5000 Mc., in one assembly. Noise figure probably poor.

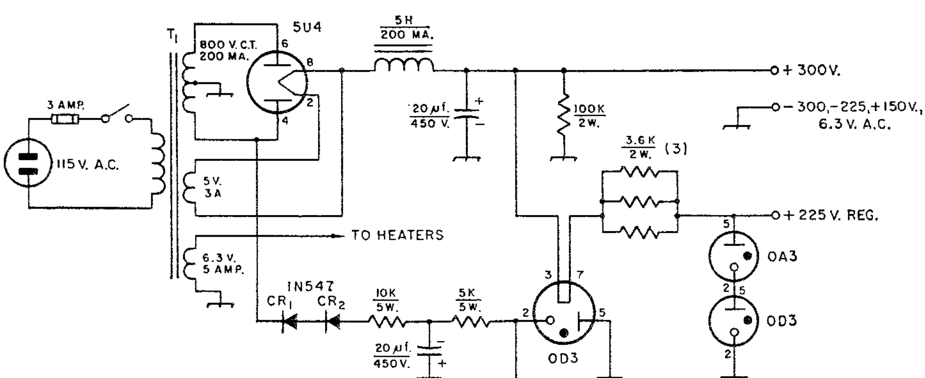


Fig. 10-70—Power supply for the 2300-Mc. receiver. Capacitors are electrolytic, polarity as indicated. T_1—Stancor 8412, or equivalent.

APR-9 with tuning head TN-128 Radar receiver, 1000 to 2600 Mc. Noise figure poor. L.o. in tuning head.

APG-5 or APG-15 Radar for B-29 tail gun, 2700 to 2900 Mc. Has pulsed 2C43 transmitter and 2C40 l.o., in cavities similar to those described in this series. Probably convertible to 2300 Mc. without too much difficulty.

2J39 Integral-magnet magnetron. 9-kw. peak power output, 3267 to 3333 Mc.

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Peterson, "Practical Gear for Amateur Microwave Communication," June, 1963, *QST*.

5650 Mc.:

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10,000 Mc.:

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Conversion of the APX-6 for 1215 Mc., September, 1960, and February, 1961.

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Scott and Banta, "Using the Helical Antenna on 1215 Mc., July, 1962.

Troetschel, "Quad Helix for 1215," August, 1963.

"Wireless Lecher Wires," Cover and p. 10, September, 1948, *QST*.

For those amateurs who wish to acquire a more basic understanding of microwave circuits and techniques, the following low-cost publications are available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Generation and Transmission of Microwave Energy, Cat. No. D101.11:11–673. 204 pp., ill. Price, $1.00.

Microwave Techniques, Cat. No. D211.2:M58. 188 pp., ill. Price, 55 cents.

Microwaves and Waveguides, Cat. No. D211.2 M58/2. 56 pp., ill. Price, 25 cents.

Radar Electronic Fundamentals, Cat. No. N29.2: R11/3. 474 pp., ill. Price, $1.50.

Radar System Fundamentals, Cat. No. N29.2: R11/2. 394 pp., ill. Price, $1.25.

Radar Circuit Analysis, Cat. No. D301.7:52–8. 480 pp., ill. Price, $5.25.

Pulse Techniques, Cat. No. D101.11:11–672. 102 pp., ill. Price, 55 cents.

Most of these are training manuals used by the armed services. They are clearly written, with numerous illustrations.