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QST Issue: Jun 1963
Title: Solid-State SSB Transceiver, A
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Compact Unit for the 14-Mc. Band

A Solid-State S.S.B. Transceiver

BY BENJAMIN H. VESTER,* W3TLN

Although this unit was constructed for the 14-Mc. band, the author points out that the design is readily applicable to other bands. Good stability results from the use of crystal control in the two oscillator circuits, the VXO principle being used to obtain the desired tuning range.

For some years, I've had a hankering to try my hand at a transistorized s.s.b. transceiver. Being somewhat prejudiced toward the single-conversion approach with a relatively high i.f., I've had to wait until the transistor art boiled out some good units for use in the h.f. region. At the same time, miniature low-voltage capacitors and other components have been developed and are now readily available at low prices. After surveying a recent wholesale flier, I decided the prices were now reasonable enough to start building. For reasons which are somewhat fuzzy now, I settled on 20 meters as the best band, although the design is suited to other bands as suggested later.

The basic arrangement of this transceiver is almost identical to that of the tube model described earlier,[1] the key features being (a) use of a high-frequency crystal filter to allow single conversion and (b) use of a VXO for the tunable oscillator. The transmit-receive switching is accomplished manually with a miniature wafer switch which interrupts the B+ to stages which are inactive for the mode in use.

With an eye toward future installation in my Volkswagen, I restricted myself to a single 6-volt power supply. As will be noted, this somewhat limits the amount of d.c. stabilization one can use, and also limits the power output obtainable.

Receiver Front End

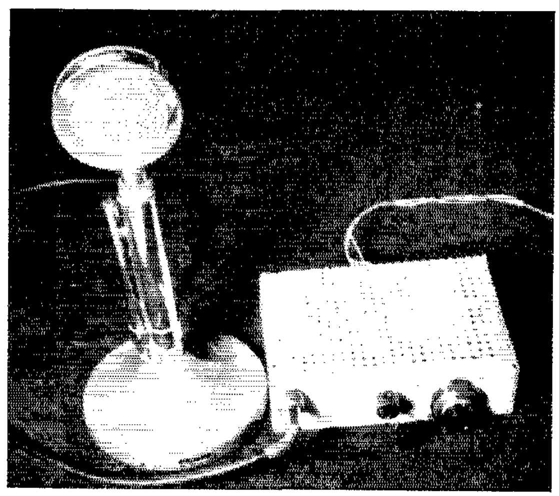
The schematic starts in Fig. 1. The r.f. amplifier, Q_1, is in a standard neutralized grounded-emitter circuit with double-tuned input. With the poor intermodulation characteristics of transistors, as much selectivity as practical should be inserted "up front." L_1 and L_4 are wound on separate link-coupled powdered-iron toroids with an electrostatic shield between them. The whole r.f. stage is mounted in one of the Command-set i.f. cans with the two capacitors therein being used to tune L_1 and L_4. L_2 and L_3 are each a single turn which is slid around the toroid until proper coupling is obtained; *i.e.*, until a passband of about 500 kc. is obtained. The electrostatic shield is the same shielding disk found in the i.f. cans.

The collector coil, L_5, is wound on a CTC LS-9 coil form. The LS-9 is a completely-shielded, ferrite-loaded form which is quite small. Having a group of these forms salvaged from a surplus military receiver, I used them throughout the unit. A small, tunable coil like this is, of course, a key factor in achieving miniature design.

The receiver mixer, Q_2, is conventional, capacitor C_4 being chosen empirically to give the maximum mixer efficiency. L_7 and L_8 are wound on another LS-9 form with the appropriate impedance step-down for the crystal filter which follows in Fig. 2.

VXO

The VXO with transistors is slightly different from the tube type. The crystal operates in its



This complete 14-Mc. transistor transceiver is contained in an enclosure measuring 5 by 7 by 2 inches. The vernier tuning dial controls the VXO frequency by adjustment of C_5. Of the two smaller knobs to the left, the lower one operates the transmit-receive switch, while the upper one is the r.f. gain control.

* 601 Wallerson Road, Baltimore 28, Maryland.

[1] Vester, "Mobile S.S.B. Transceiver," *QST*, June, 1959.

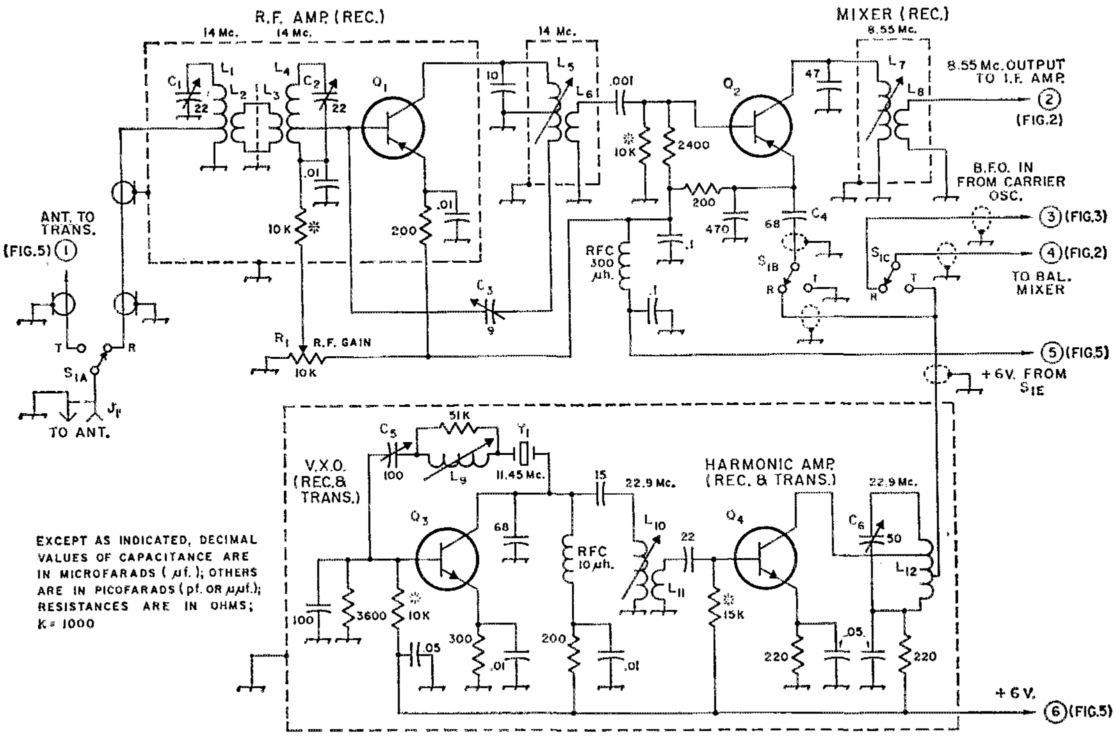


Fig. 1—VXO and high-frequency receiver circuits. The 22.9-Mc. VXO signal mixes with a 14.35-Mc. incoming signal to produce an 8.55-Mc. i.f. signal. On transmit, the 22.9-Mc. signal is transferred to the balanced diode mixer of Fig. 2. Fixed capacitors of decimal value are miniature ceramic or paper with a minimum rating of 6 volts. Others are NPO ceramic or dipped silver mica. Resistors are ¼ watt. Resistors marked with asterisks are bias resistors (see text).

C_1, C_2—Air trimmer from Command-set i.f. cans.

C_3—0.1–9-pf. trimmer, or "gimmick."

C_4—Nominal value; see text.

C_5—Air variable (Hammarlund APC-100B).

C_6—Ceramic trimmer.

J_1—Phono jack or chassis-mounting coax receptacle.

L_1—40 turns, tapped at 2 turns from ground end, on powdered-iron toroid (Stackpole D-1 iron) ½-inch outside diameter, ¼-inch inside diameter, circular cross section (Henry L. Crowley Co., West Orange, N. J., part No. C-2776).

L_2—Single turn on L_1; see text.

L_3—Same as L_2, wound on L_4.

L_4—Same as L_1, tapped at 4 turns.

L_5—21 turns of double-strand No. 34 enameled (bifilar-wound) on CTC LS-9-5S shielded ferrite-slug form. Finishing end of one strand is connected to starting end of other strand to form center tap; two remaining ends connected to circuit as shown.

L_6—3 turns over L_5.

L_7—25 turns on CTC LS-9-4S shielded ferrite-slug coil form.

L_8—6 turns over ground end of L_7.

L_9—48 turns close-wound on 1-inch ceramic iron-slug form (National XR-60 form).

L_{10}—Inductance 3.5 µh., scramble-wound on CTC PLST-2C4L/N iron-slug form.

L_{11}—4 turns over ground end of L_{10}.

Note: Above coils are close-wound with No. 34 enameled wire.

L_{12}—12 turns No. 24, ½-inch diam., 32 turns per inch (B&W 3004 Miniductor), tapped at 4 turns and 7 turns from ground end.

Q_1, Q_2—2N700, or similar u.h.f. p.n.p. transistor (see text).

Q_3, Q_4—2N706, or similar u.h.f. n.p.n. silicon transistor (see text).

R_1—Linear-taper control.

S_1—Subminiature ceramic rotary switch, 2 sections, 5 poles, 2 positions (Centralab PS-117, 1 pole and 1 position not used). See Figs. 2 and 5 for remaining poles.

Y_1—11.45-Mc. crystal.

series-resonant mode instead of parallel resonance. The VXO crystal, Y_1, was one of several given to me by W3BWK; its fundamental frequency (11.450 Mc.) was half of the desired frequency (22.9 Mc.), so some harmonic selection and amplification was necessary. This was not quite so easy as with pentode tubes, and another transistor, Q_4, was required. Prior to putting in this stage, with its associated tuned circuits, the 11.45-Mc. signal leaking into the receiver mixer was enough to allow high-power teletype signals just below 20 Mc. (11.45 + 8.55 = 20 Mc.) to be heard in the receiver. If you can get a crystal whose fundamental is at 22.9 Mc., you can avoid the extra stage.

Of course, the tuning range of the VXO depends on the inductance of L_9. I put on just enough turns to make the VXO cover the most

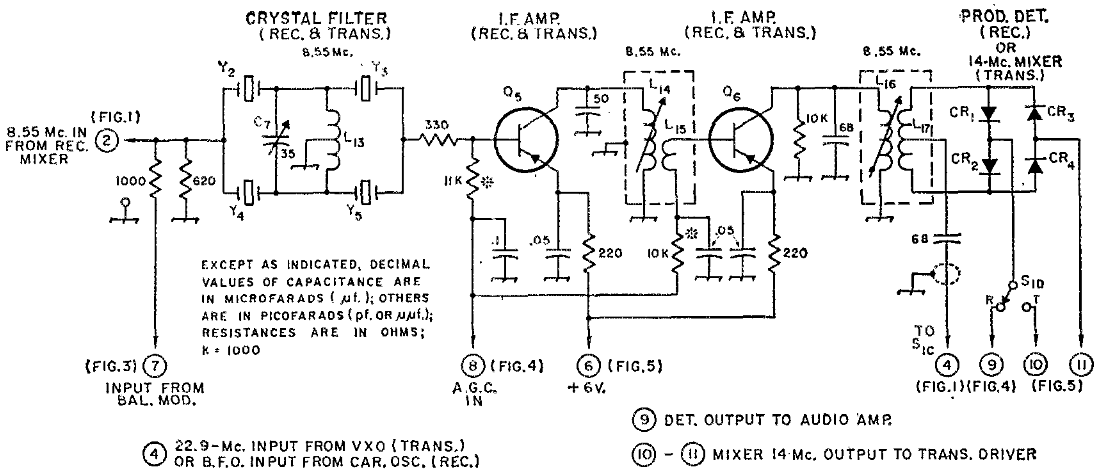


Fig. 2—8.55-Mc. i.f. circuit. On receive, the diodes in the output circuit operate as a product detector, the carrier oscillator (Fig. 3) serving as the b.f.o. On transmit, the 8.55-Mc. suppressed-carrier signal from the balanced modulator (also Fig. 3) passes through the crystal filter which strips off the unwanted sideband. The remaining sideband passes through the i.f. amplifier to the diode network, which now operates as a balanced mixer, where it mixes with the 22.9-Mc. VXO signal to produce a 14.35-Mc. signal for the transmitter (Fig. 5). Fixed capacitors of decimal value are miniature ceramic or paper with a minimum rating of 6 volts. Others are NPO ceramic or dipped silver mica. Resistors are ¼ watt. Asterisks identify biasing resistors (see text).

C_7—Ceramic trimmer (Centralab 827D).

CR_1, CR_2, CR_3, CR_4—Germanium diode (CK706, 1N34A or equivalent.)

L_{13}—20 µh., center-tapped, bifilar-wound on ¾-inch ferrite toroid core, and connected as described for L_5. Cores available from same source as L_1. See references 1, 2.

L_{14}—21 turns on CTC LS-9-4S, shielded ferrite-slug coil form.

L_{15}—4 turns wound over ground end of L_{14}.

L_{16}—24 turns on CTC LS-9-5S iron-slug form.

L_{17}—8 bifilar turns, wound over L_{16} and connected as described for L_5.

Note: Above coils are close-wound with No. 34 enameled wire.

Q_5, Q_6—Same as Q_1.

S_1—See Fig. 1.

Y_2, Y_3—8550.3-kc. crystal.

Y_4, Y_5—8551.5-kc. crystal.

active part of the s.s.b. portion of the band with the slug all the way out. With the slug advanced to a preset stop, the VXO tunes all the way down to the bottom end of 20. There is some loss in v.f.o. stability at this setting, but with the "cool" transistor circuits, the stability is still as good as that of a number of commercial receivers.

I.F. Filter and Amplifier

The crystal filter (Fig. 2) has been covered before [1,2]; capacitor C_7 and coil L_{13} are chosen to resonate approximately (disconnected from the circuit) at the passband frequency of the filter. Adjustment of C_7 and the slug of L_7 (Fig. 1) can then be made to optimize the filter passband.

The i.f. amplifiers, Q_5 and Q_6, are conventional, with coils wound on LS-9 forms being used for interstage coupling. These stages were not neutralized, and some intentional interstage impedance mismatch was used to keep the circuits noncritical.

The diodes fed by Q_6 serve both as a product detector for receiving and as the transmitter mixer, where the 8.55-Mc. i.f. signal and the 22.9-Mc. VXO signal are mixed to produce 14-Mc. output. The diodes are in a balanced arrangement so that both the VXO and the 8.55-Mc. signals are suppressed when transmitting. The diodes are garden-variety germanium with no particularly good balance requirements on them.

[2] Arnold and Allen, "Some New Ideas in a Ham-Band Receiver," *QST*, May, 1960.

Carrier Oscillator and Balanced Modulator

The carrier oscillator and balanced modulator (Fig. 3) are conventional, and are both stuffed into the same Command-set i.f. can to contain the carrier leak-through. Both the fixed and variable capacitors already mounted in the i.f. can are used. L_{18} and L_{19} are wound on another miniature powdered-iron toroid which is supported by plastic tape wrapped around two of the posts in the i.f. can. Crystal Y_6 is similarly supported on the other two posts. C_9 was tried on both ends of the balance pot to obtain the best carrier suppression.

The audio amplifier used in the receiver could have been switched into use as a microphone amplifier, of course, with some small saving in parts. The additional switch contacts required didn't justify it with the parts and space I had available. As shown in Fig. 3, the addition of a feedback path around the microphone amplifier is a handy technique for generating a tone for both tune-up and c.w. operation.

Receiver Audio and A.G.C.

The audio amplifier (Fig. 4) was built around a couple of transformers I salvaged from a hearing aid, and transistors from the junk box. Anyone

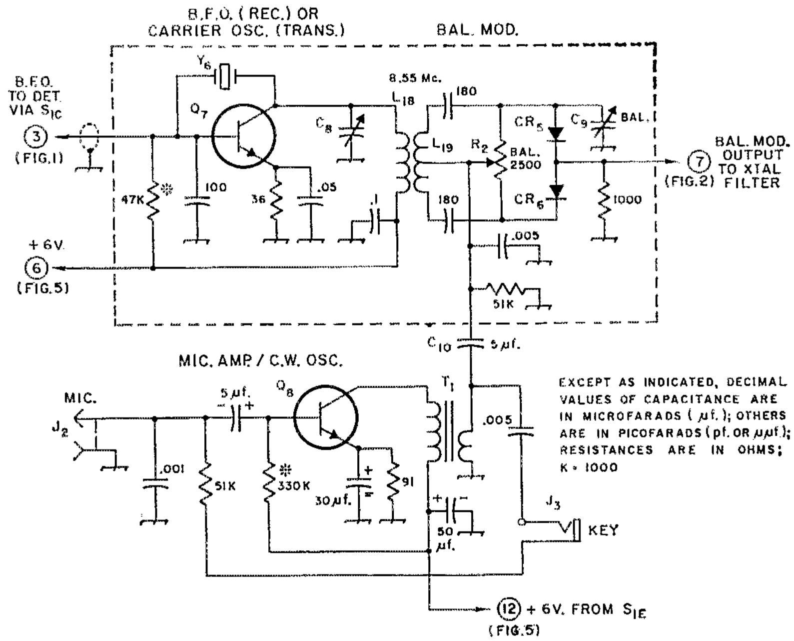


Fig. 3—Carrier-oscillator (b.f.o.), balanced-modulator, and transmitter audio circuits. A feedback, circuit is provided to cause the microphone amplifier to oscillate for c.w. operation. Fixed capacitors of decimal value are miniature ceramic or paper. Except as listed below, others are NPO ceramic or dipped silver mica, except where polarity indicates electrolytic. All capacitors have a minimum rating of 6 volts. Fixed resistors are ¼ watt. Biasing resistors are identified by asterisks; see text.

C_8, C_9—22-pf. air trimmer from Command-set i.f. can.
C_{10}—Ceramic or paper.
CR_5, CR_6—Same as CR_1.
J_2—Microphone connector.
J_3—Miniature open-circuit phone jack; both sides must be insulated.
L_{18}—60 turns No. 34 enameled, close-wound on toroid form same as described for L_1.
L_{19}—10 bifilar turns over L_{18}, wound and connected as described for L_5.
Q_7—Same as Q_3.
Q_8—2N170 or similar.
R_2—Linear control.
T_1—Subminiature interstage audio transformer, 4:1 turns ratio, low-impedance winding in output.
Y_6—8553.0-kc. crystal.

considering building a unit like this would do well to copy the audio circuits from Priebe's excellent receiver article,[3] or buy one of the packaged units available from Lafayette Radio.

The a.g.c. rectifier and amplifier feed directly off the output transformer. As can be seen, this will provide a.g.c. to maintain the same audio level at all times. Having only enough panel space for a single gain control, I chose to make it an r.f. gain control. Of course, the audio level that the a.g.c. tries to hold could be adjusted by running R_3 to a potentiometer similar to the r.f. gain control. The "hang" action of this a.g.c. is not as good as with similar tube circuits, but it seems to be a reasonable compromise with miniaturization since it uses only four tiny parts.

Transmitter Output Stages

The transmitting amplifier, Q_{13}, in Fig. 5, is a straightforward Class A stage. The "final," Q_{14}, is a high-frequency silicon switching transistor which is run Class B. with the emitter grounded directly. The bias resistor, R_4, must be empirically chosen for any particular transistor to give a static collector current of 3 to 5 ma. Since the switching transistor has a very low collector-saturation resistance, it has considerable peak-current capability and makes an excellent s.s.b. linear amplifier.

Constructional Details

The general layout of components is shown in the photographs and the sketch of Fig. 6. As already noted, the miniature LS-9 coil forms are used wherever practical, with fixed miniature mica capacitors added for resonant tanks. Additional shielding is provided by using the two Command-set i.f. cans for critical circuits, and by enclosing the complete VXO in the smallest-size Minibox. The remainder of the r.f. circuits are mounted on subchassis made of copper-clad perforated boards. Since many of the components connect to ground, they can be soldered directly to the board, providing a good low-inductance path. These boards are very easy to work with and simplify construction and assembly considerably.

The filter crystals squeeze in between the r.f. amplifier can and an under-chassis shield, and are held in place with a drop of glue. C_7 is a Centralab

[3] Priebe, "All-Transistor Communications Receiver," *QST*, February, 1959.

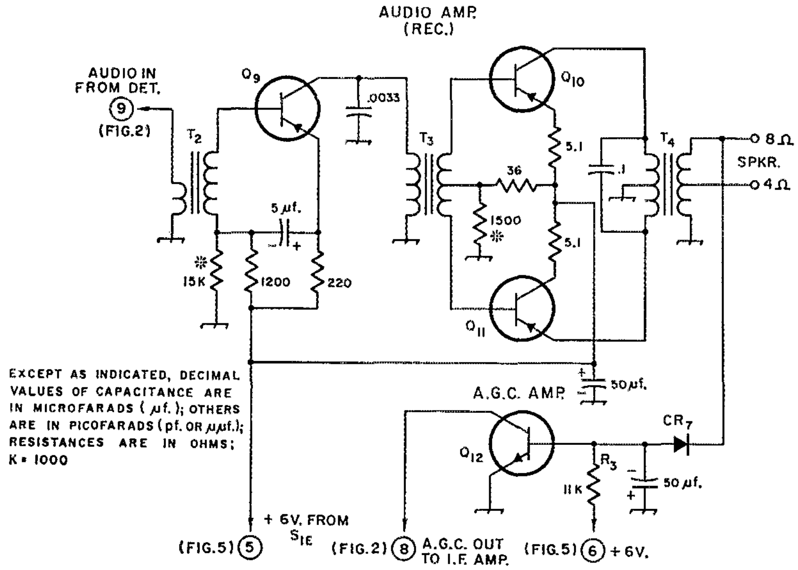
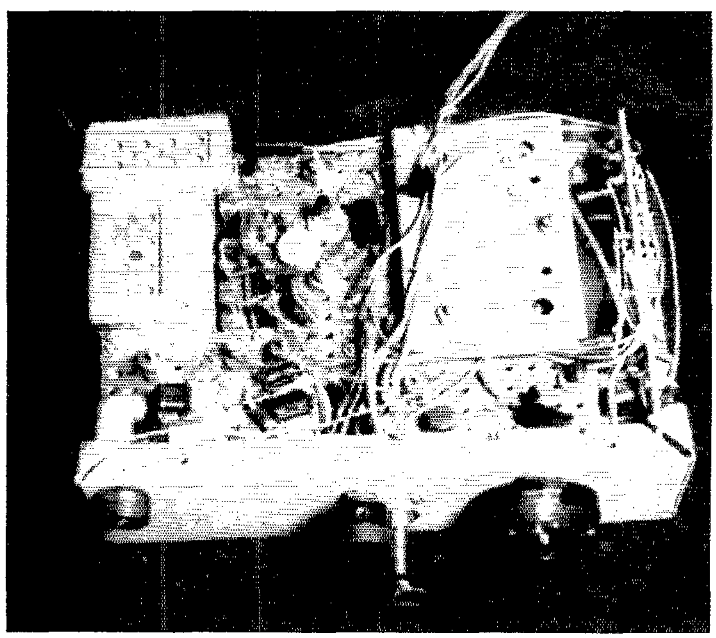


Fig. 4—Receiving audio circuit. An a.g.c. signal is obtained by rectifying and amplifying a signal taken from the audio output. Capacitors of decimal value are miniature ceramic or paper. Others are electrolytic. Boty types have a minimum rating of 6 volts. Resistors are ¼ watt. Bias resistors are identified by asterisks; see text.

CR_7—Silicon junction diode, 50 p.i.v., 1N599 or equivalent.
Q_9—2N653 or similar.
Q_{10}, Q_{11}—2N586 or similar.
Q_{12}—Same as Q_8.
R_3—See text.
T_2—Same as T_1; low-impedance winding in output circuit.
T_3—Subminiature interstage transformer, 4:1 turns ratio, secondary center-tapped.
T_4—Transistor output transformer, 400 ohms, c.t., to 8.4 ohms, tapped at 4 ohms (Thordarson TR-22).

type 827 ceramic trimmer capacitor. When Y_2 and Y_3 are placed end to end, the mounting-hole spacing of the capacitor matches the spacing of adjacent pins of the two crystals. The capacitor is slipped over the crystal pins for support. L_{13} is glued in place close to the capacitor. Other parts which are too heavy to be supported by their leads are glued in place.

To make assembly and disassembly possible with the crowded chassis, a number of captive nuts were used, fastened to the chassis and mounting brackets with epoxy (a two-tube mix-



Top view of the transceiver. The two rectangular speakers in the upper left-hand corner are flat dynamic microphones taken from junked hearing aids. The microphone-amplifier board is immediately to the rear of the microphone connector. It is mounted on top of the can containing the carrier oscillator. The basic chassis is a standard 5 × 7 × 2-inch unit with back apron sawed off.

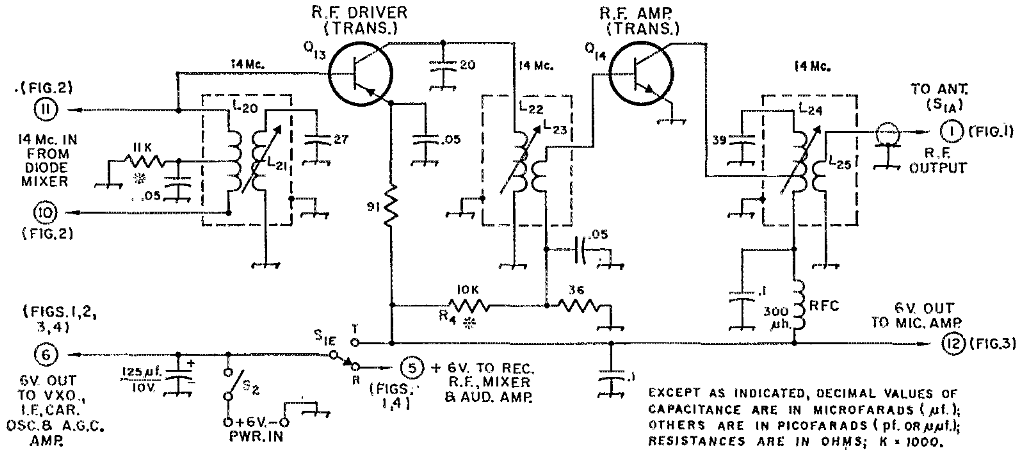


Fig. 5—Transmitter output circuits. This section receives 14-Mc. drive from the diode balanced mixer of Fig. 2. Capacitors of decimal value are miniature ceramic; others are NPO ceramic or dipped silver mica, except polarity indicates electrolytic. Capacitors have a minimum rating of 6 volts. Resistors are ¼ watt; asterisk indicates bias resistor see text

L_{20}—4 bifilar turns, center-tapped, wound over L_{21} and connected as described for L_5.
L_{21}—21 turns on CTC LS-9-5S iron-slug form.
L_{22}—21 turns on CTC LS-9-4S iron-slug form.
L_{23}—6 turns wound over ground end of L_{22}.
L_{24}—16 turns on CTC LS-9-5S iron-slug form, tapped at 4 turns from low-potential end.
L_{25}—6 turns wound over low-potential end of L_{24}.
Note: Above coils are close-wound with No. 34 enameled wire.
Q_{13}—Same as Q_1.
Q_{14}—Same as Q_3.
R_4—Nominal value, see text.
S_1—See Fig. 1.
S_2—S.p.s.t. slide or toggle switch.

ture is now available in most hardware stores). The cover was made from perforated aluminum sheet with the corners folded over and epoxyed together. After filing the corners smooth, several coats of spray paint were added to give a fairly professional-looking cover.

Components

Up to now, we have ignored the types of transistors used. The audio-transistor choices were made straight from my particular junk box. If your junk box is emptier, the Japanese units with matching transformers are an excellent choice.

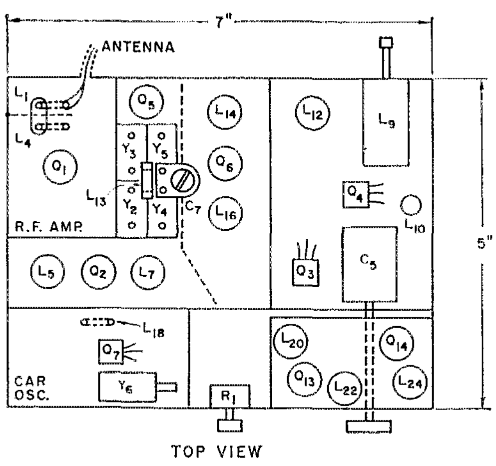


Fig. 6—Sketch showing lay-out of principal components.

For Q_1, Q_2, Q_5, Q_6 and Q_{13}, I used some available 2N700s. The 2N1742 will serve in these circuits with essentially the same performance, and is somewhat cheaper. For Q_3, Q_4, Q_7 and Q_{14}, I used 2N706s. Actually, Q_{14} is the only stage that requires a silicon transistor of this quality. Any of the u.h.f. transistors will serve for Q_3, Q_4, and Q_7. In fact, if these circuits are adapted for p.n.p. transistors, the 2N1742 will work fine.

Regardless of what transistor is used for each stage, it is wise to adapt each stage's bias resistor (all bias resistors are identified with asterisks) to the particular unit to give a collector current equal to that recommended for the transistor used. The 2N1742, for example, will require a bias resistor of considerably higher value.

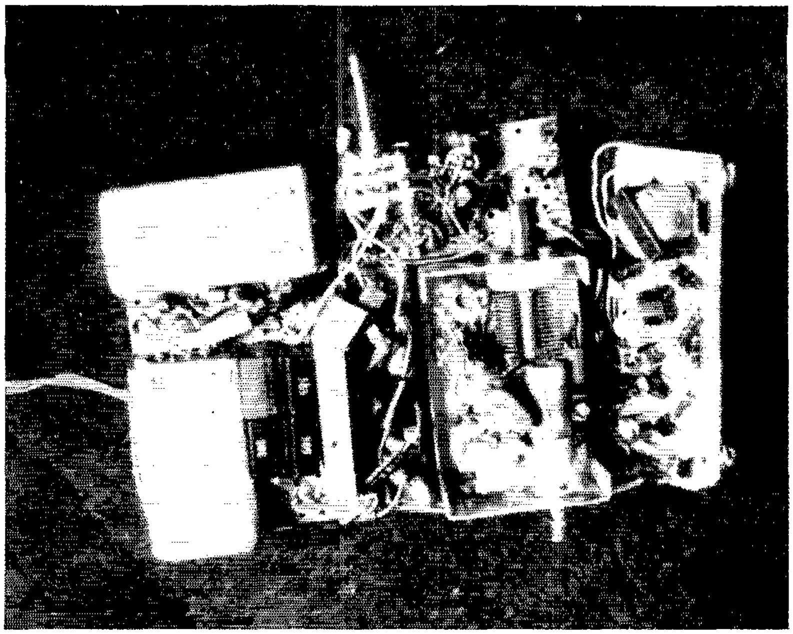
Actually, there is little to be gained by neutralizing the receiving r.f. amplifier if a 2N700 is used. However, if a lower-frequency transistor is used, neutralizing may yield a sizable increase in gain.

The electrolytic capacitors used throughout were obtained from the C-923 assortment and the ceramic bypasses from the AS-510 assortment, both from Olson Radio. These are good-quality Japanese parts and quite cheap.

The transmit-receive switch is the latest Centralab subminiature wafer switch.

Other Bands

It is pretty obvious that by rewinding a few coils and using different VXO crystal, you can adapt the unit for operation on other bands. The carrier oscillator, i.f. circuits, and audio circuits remain as is. The VXO frequency should



Bottom view of the transceiver. The VXO is in the Minibox to the right of center. The carrier oscillator and balanced modulator are in one of the shielding cans to the left. The other, adjacent to the four crystals of the i.f. filter, contains the receiver r.f. stage. The receiver audio section is assembled on the perforated board to the right.

be chosen to be 8.55 Mc. *above* the highest frequency to be covered so as to get maximum tuning range. Of course, L_{10} and L_{12} must be rewound to resonate at the new VXO frequency. Similarly, L_1, L_4, L_5, L_{21}, L_{22}, and L_{24} must be rewound to resonate on the new band. The same approximate turns ratios should be used for each transformer.

Results

With all such rigs, some mention of results is in order. First, the receiver is stable and selective, but is not very good as far as intermodulation is concerned. This is one respect in which transistors are inferior to tubes. The audio quality is limited by the small speaker. (I always demonstrate it with an external speaker.) On transmit, the carrier suppression is 45-50 db., and the other sideband is about 40 db. down. Local reports indicate that the signal is clear and clean. Since the "final" runs a puny 250 mw. p.e.p., I haven't worked much DX (Florida, Louisiana, Nebraska, and similar), but it is a dandy "local" rig. It's been running off a 6-volt lantern battery for several months now. It has made several trips cross country in my briefcase, and provided an excellent way to keep in touch with what the 20-meter s.s.b. gang is up to

Of course, I intend to add a linear amplifier to bring the transmitter up to a reasonable output, but haven't definitely decided yet whether to succumb to tubes or wait for the price break on high-power h.f. transistors. QST

Strays

WA6PMZ lost a roll of movie film — it not coming back from the processor. But someone found it on the street (the mail man dropped it?), ran it through their projector, spotted the call letter license plates, and returned the film.

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VE1PV and VE1ZZ have been conducting some underground transmission tests on 1823 kc. First VE1ZZ took a 50-watt transmitter and a receiver down to the 600-foot level of the Pugwash Salt Mine, and worked VE1PV at the surface with signals loud and clear. While he was down there, VE1ZZ heard many low frequency stations (10 to 500 kc.) with good strength. Later equipment was taken down to the 1150-level, and again excellent communication was established with the surface. On this second test the subsurface transmitter was of one-watt power. At the 1150-foot level, the surface transmitter was more than 7000 feet away, with a 35-foot layer of salt water in between. Other hams participating in the tests were VE1NV, VE1AFY, and VE1AIJ.

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You a coin collector? So is DJ0CL, and he'd like to hear from you. Walter Snyder, 17a Karlsruhe/Baden, Karl-Schremppstrasse 37, Germany.