All-Transistor Walkie-Talkie for 28 Mc.

A Practical Portable

BY ROBERT G. THOMAS,* W3QZO

THE value of a walkie-talkie in emergency communications is certainly far more important than its role as an electronic curiosity. Therefore, when the design of a walkie-talkie is contemplated, first consideration should be given to factors affecting long and reliable service, communications range, and operating convenience. All too often the tendency in the past has been to minimize the importance of these factors for the sake of compactness, resulting in a design that is "cute" but has little practical value. Micro-powered transmitters combined with broad-band superregen receivers typify this class. This is not to say that compactness should be given no consideration at all — certainly it is an important factor in portable gear — but the temptation to sacrifice dependability for size reduction should be resisted.

Naturally, any portable equipment designed today should exploit the efficiency of transistors wherever possible. Transistors suitable for receiving circuits at 30 Mc. and higher have been available for some time but with power ratings so low that their use in portable transmitters of reasonable output has not been practical. The recent introduction of the Texas Instruments 2N1143, with a maximum collector rating of 750 milliwatts and cutoff frequency of 480 Mc., has made it possible to build a portable transmitter with respectable output at a reasonable price, even for the two-meter band.

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This is the receiver end of the W3QZO walkie-talkie. The speaker behind the circular cutout can be turned on or off with the slide switch beside it. The vernier dial is for receiver tuning, and the other knob is on the combined volume control and power switch. The small aluminum tabs on top of the box at each end are for a carrying strap.

Not so tiny that performance is compromised but small enough to carry anywhere, this self-powered station is full of interesting ideas like combining a homemade converter with a cheap b.c. set to get a good-working double superhet. This model is for 10 meters, but there's no reason why it couldn't be adapted to 6 or 2.

Frequency and Form Factor

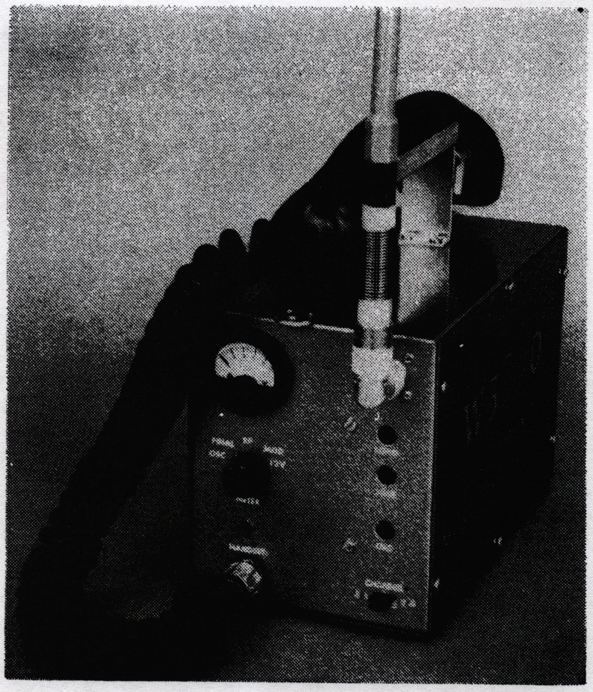
Ten meters was selected for the rig described here principally because of the activity promoted on that band in the Philadelphia area by the Phil-Mont Mobile Radio Club. This group has an active program providing communications for sporting events, parades, and civil emergencies. Past experience by members has shown that a portable rig is most convenient to use when it employs a telephone-type handset in conjunction with a case containing transmitter, receiver, batteries and antenna. This is in contrast to the single-unit handie-talkie configuration in which all components, including the antenna and microphone, are mounted on a single box which must be held near the head of the operator when in use.

The preferred arrangement offers several advantages over the single-unit approach: When operating at a fixed position, it is far more convenient to manipulate a single handset than a complete transmitter, receiver and antenna assembly. Since the size of the case is then of secondary importance, large batteries may be used with a corresponding increase in service life. When operating while on foot, the case is easily carried at the operator's side by means of a strap slung over his shoulder. In this instance, the case provides a stable base for the antenna and handset cradle, leaving both of the operator's hands free when not transmitting. A loudspeaker is also provided so the operator is not forced to continually hold the handset to his ear during receiving periods. This feature has proved invaluable for net operations where the operator does more listening than transmitting. It also heightens interest for any spectators in the vicinity by allowing them to hear both sides of the QSO.

What Kind of Receiver?

When it comes to receivers, there are several possibilities. The simplest, of course, would be a superregen. The main reason for rejecting this type is its poor selectivity, not to mention problems dealing with radiation, capture effect (strong signals "taking over"), rushing noise on standby, and the need for a regeneration control in order to realize maximum sensitivity. A superhet with a superregenerative detector might provide satisfactory performance on six or two meters, but in view of conditions encountered on the 10-meter band, nothing short of a full conventional superhet will provide the desired performance. This requirement is actually not as bad as it may seem at first, since a receiver of this type can be assembled very simply by using one of the many low-priced transistor broadcast receivers coupled to the output of a crystal-controlled converter. Coverage of the ham band is then accomplished by tuning the b.c. set.

The broadcast receiver shown in the photographs was obtained in kit form from one of the large mail-order houses for about $13, less transistors. Although it does not have an r.f. stage, it does have an air dielectric tuning capacitor, push-pull audio output, and a self-contained speaker. Similar receivers, completely assembled, are now available for less than $20. Regardless of the type of receiver used, it should be thoroughly tested on the broadcast band before attempting to use it with a converter so that any tendency toward instability may be eliminated by suitable circuit modifications.



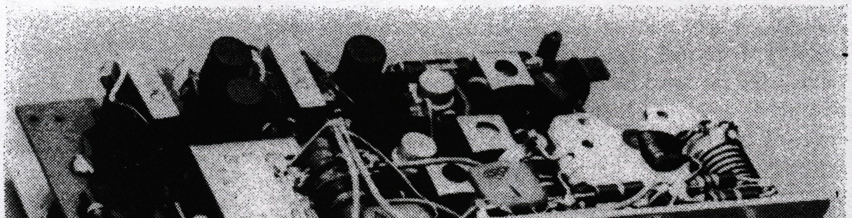
The walkie-talkie as seen from the transmitter end. The three holes under the homemade base-loaded whip allow access to the tuning and loading capacitors. The slide switch selects either of two crystals. All currents of interest, plus the battery voltage, can be checked with the meter and switch on the left. Microphone, audio output and push-to-talk connections to the handset are made through the jack at the lower left.

Converter Circuitry

The converter design (see Fig. 1) is based on an RCA data sheet for "drift" transistors. It consists of a 2N1396 r.f. amplifier, 2N1396 mixer and 2N384 crystal-controlled oscillator, all stages using the common-emitter configuration. C_1 and C_2, in addition to resonating L_1 to the signal frequency, form a capacitive voltage divider that matches the antenna impedance to the input circuit. The position of the tap on L_1 is selected to provide optimum signal transfer consistent with reasonable loading of the tuned circuit by Q_1. Similarly, the collector is tapped down on interstage coil L_2, but the relatively high output impedance of the grounded-emitter amplifier does not require a tap as far down as on the input coil.

The interstage coupling circuit, C_3L_2, has a high L/C ratio to achieve a bandwidth great enough so that no retuning is necessary across the entire 10-meter band. R_1, R_2 and R_3 furnish stabilizing bias for Q_1.

The oscillator may be placed either above or below the signal frequency. One point to keep in mind with any double-conversion superhet using a broadcast receiver for a tunable i.f. is that image rejection diminishes as the b.c. set is tuned toward the low end of its range. Therefore, the oscillator frequency should be selected so that the end of the ham band used most often is heterodyned to the high end of the broadcast band. Operation at W3QZO is almost exclusively on the high end of 10, generally on the Phil-Mont



The receiver consists of a transistor broadcast set constructed on the printed wiring board in the background and a crystal-controlled converter. Converter components are mounted on the side of the chassis in the foreground. From left to right are the crystal (and behind it, oscillator coil L_5L_5), oscillator transistor Q_3, mixer output transformer L_3L_6, mixer Q_2, interstage coil L_2, r.f. amplifier Q_1, and input coil L_1.

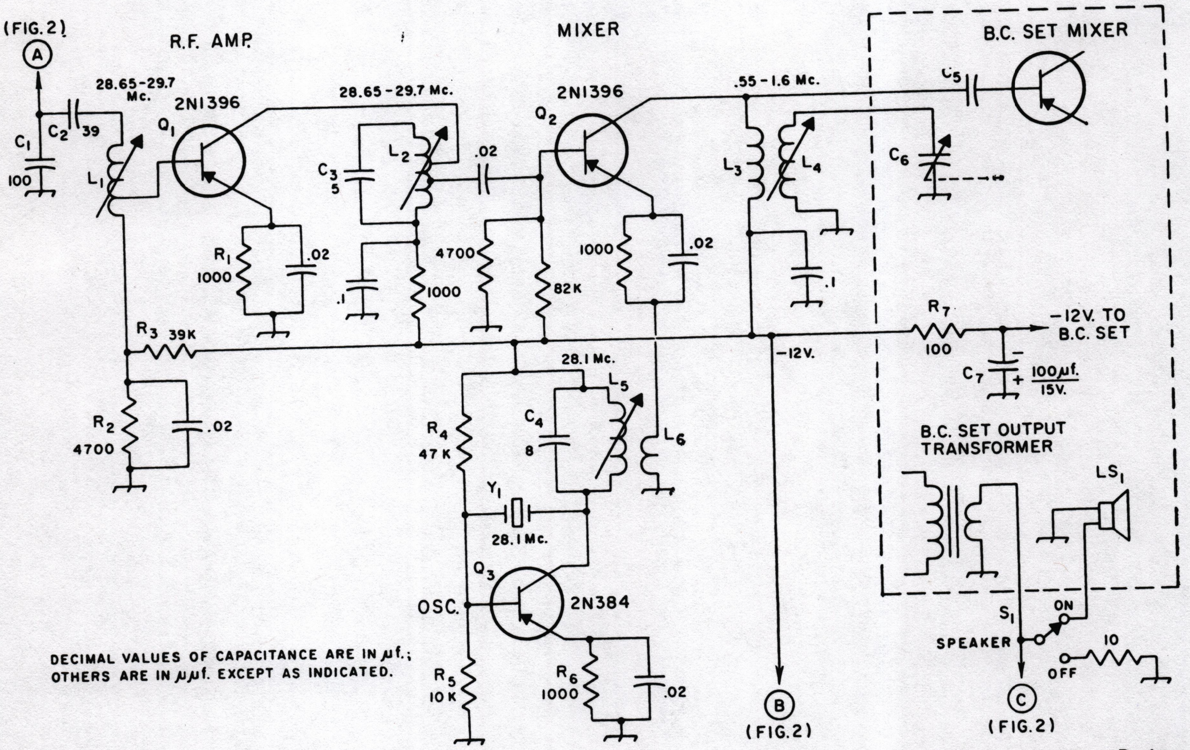


Fig. 1—Circuit diagram of the crystal-controlled converter used with a transistor b.c. set for 10-meter reception. Resistances are in ohms, and resistors are ½-watt composition. Capacitors are 50-volt disk ceramic except as specified below.

C_1—100-μμf. mica.
C_2—39-μμf. mica.
C_3—5-μμf. tubular ceramic.
C_4—8-μμf. tubular ceramic.
C_5—Part of b.c. set, originally connected to loop-stick antenna.
C_6—Mixer tuning capacitor (part of b.c. set).
C_7—100-μf. 15-volt electrolytic.
L_1—10 turns No. 26 enam., wound 16 turns per inch on ⅜-inch diam. iron slug-tuned form (CTC PLS5/B, Miller 4400); tap 2 turns from bottom.
L_2—Like L_1, but 10 turns close-wound and tapped 2 and 8 turns from bottom.
L_3—24 turns No. 29 enam., random-wound on top of L_4.
L_4—About 300–800 μh., slug-tuned (North Hills P-120-J, Miller 4412).
L_5—Like L_1, but 20 turns close-wound and not tapped.
L_6—⅔ turn No. 26 enam. on cold end of L_5.
LS_1—Speaker of b.c. set.
R_1—R_7 inc.—See text.
S_1—S.p.d.t. slide switch.
Y_1—28.1-Mc. overtone type.

net frequency of 29.493 Mc. An oscillator crystal on 28.1 Mc. places this frequency at 1393 kc. on the b.c. receiver and allows coverage of all but the lower 150 kc. of the 10-meter phone band.

The oscillator circuit is analagous to the Pierce, with a third-overtone crystal in the feedback path from collector to base. R_6 provides temperature stabilization and bias for protection of the transistor in the event that oscillation stops. R_4 and R_5 are part of the stabilizing network and furnish forward base bias to ensure starting. Oscillator output is link coupled to the emitter of the mixer, Q_2. The small link provides adequate current for proper mixer operation without introducing excessive degeneration in the mixer emitter circuit, thereby maintaining satisfactory conversion efficiency.

Signals amplified by the r.f. stage are capacitively coupled from a low-impedance tap on L_2 into the mixer base. The mixer output, appearing across L_3, is fed via C_5 to the input of the b.c. receiver. C_5 originally connected to a tap on the loop-stick antenna, which must be removed. The section of the variable capacitor in the b.c. set that formerly tuned the loop antenna is now used to resonate L_4, which is coupled to L_3. The mixer collector circuit is thus made to track with the oscillator in the b.c. receiver for maximum selectivity and rejection of interference. The physical size of L_3L_4 should be quite small, to inhibit pickup of local broadcast stations. It was necessary to add a decoupling network, R_7C_7, in the 12-volt lead of the b.c. set to prevent motorboating. These components are mounted in an unused area of the printed wiring board.

Transmitter and Modulator

The r.f. portion of the transmitter is quite simple, consisting only of an overtone crystal oscillator and a common-base amplifier. Before arriving at this arrangement, diagrammed in Fig. 2, all manner of oscillator-multiplier-buffer combinations were tried, but all suffered in various degrees from low efficiency, excessive complexity and inadequate drive capabilities.

The only difference between the converter local oscillator and the transmitter oscillator is that the bias network of the latter is designed to operate the transistor at the higher power level needed to drive the final amplifier. The input to the transmitter oscillator is approximately 200 mw. Although a receiving-type transistor such

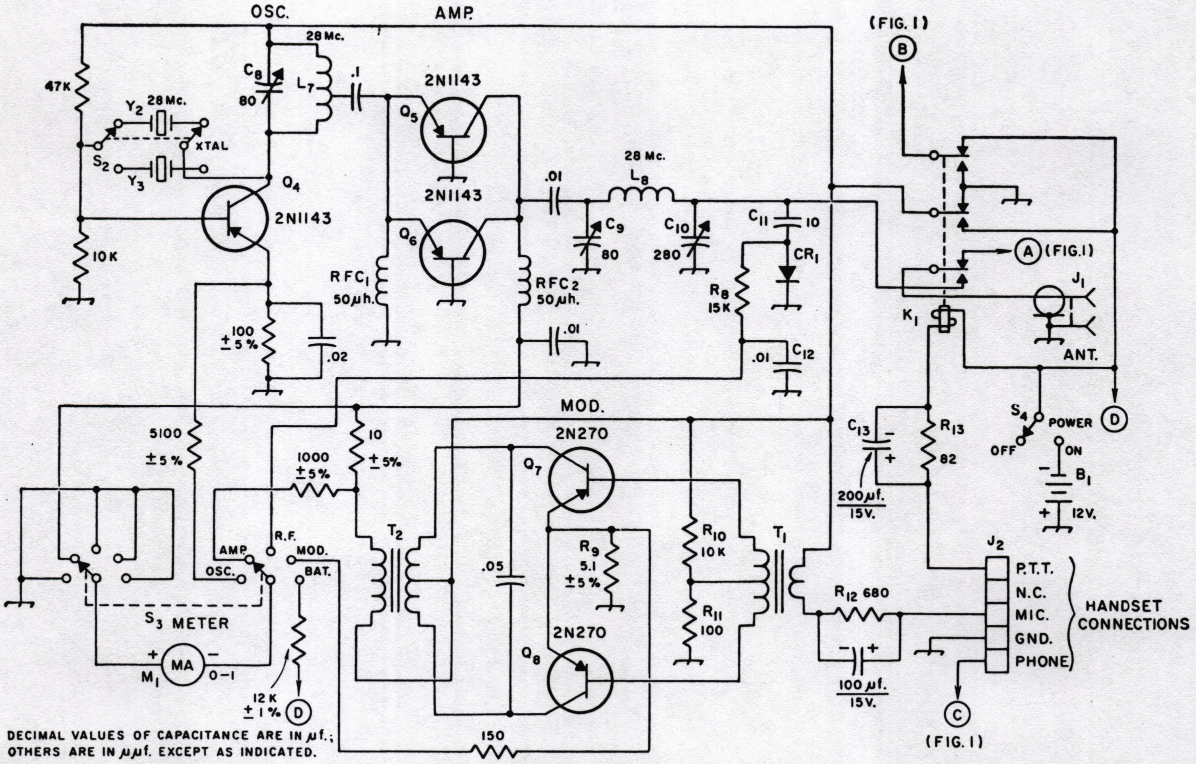


Fig. 2—Diagram of the walkie-talkie transmitter, modulator and switching circuits. Resistances are in ohms, and resistors are ½-watt composition. Capacitors marked with polarity are electrolytic; others are 50-volt disk ceramic except as specified.

B_1—2 6-volt lantern batteries with coil spring contacts (Burgess F4H) in series.
C_8, C_9—5–80-μμf. mica trimmer.
C_{10}—25–280-μμf. mica trimmer.
C_{11}—10-μμf. tubular ceramic.
C_{12}—0.01-μf. disk ceramic.
C_{13}—200-μf. 15-volt electrolytic.
CR_1—1N34 or equivalent.
J_1—Coax receptacle (SO-239).
J_2—Miniature 5-pin receptacle (Amphenol 126-218).
K_1—3p.d.t. subminiature relay, 12-volt coil (Potter & Brumfield KM14D).
L_7—11 turns No. 20 tinned ⅝-inch diam., 16 t.p.i. (B & W Miniductor 3007 or Airdux 516T); tapped 6 turns from bottom end.
L_8—Like L_7 but 7 turns and not tapped.
M_1—0–1 d.c. milliammeter, miniature type.
R_8–R_{13} inc.—Composition.
RFC_1, RFC_2—50 μh. (National R-33 or similar).
S_2—D.p.d.t. slide switch.
S_3—Subminiature ceramic rotary, 2 poles, 5 positions, 1 section, nonshorting (Centralab PS-105).
S_4—Part of volume control (see text).
T_1—Driver transformer, 500 ohms c.t. to 5000 ohms c.t. (Stancor TA-4); use half of primary.
T_2—Output transformer, 500 ohms c.t. to 200 ohms (Thordarson TR-66).
Y_2, Y_3—10-meter overtone type.

as a 2N1396 might be used in this application, its collector dissipation would be running too close to maximum for good reliability. Therefore, a 2N1143 was used here, allowing a generous margin of safety. The tank coil, L_7, is tapped at the point that provides optimum power transfer to the final-amplifier input.

The final amplifier uses two parallel-connected 2N1143 transistors in a common-base amplifier. This configuration does not produce quite as much power gain as a common-emitter amplifier. It is inherently stable, however, and requires no neutralization or tricky tuning, even though it is operating straight through. Collector current flows only when the stage is driven, providing automatic protection in the event of oscillator failure. A pi network matches the collector impedance to the load. Sufficient range is provided by the mica tuning and loading capacitors, C_9 and C_{10}, to match most likely-to-be-encountered whip antennas or transmission lines. The collector is shunt fed through RFC_2. RFC_1 provides a d.c. ground return for emitter current. Power input to the final is about 0.75 watt. The transmitter tuned circuits are broad enough so that no retuning is required for frequency shifts up to ±150 kc.

There is dubious theoretical advantage in paralleling common-base amplifiers; nevertheless, doing so increased the output substantially, and it was thus felt to be worthwhile. The same two transistors in push-pull would probably produce more output than is presently obtained, but lack of time has prevented experimentation along these lines. Such a possibility should be considered by anyone developing this type of equipment.

The modulator consists of two 2N270 transistors, Q_7 and Q_8, in a Class B push-pull amplifier. Stock transistor-type transformers are used for input and output coupling. R_{10} and R_{11} supply a small amount of forward bias to reduce crossover distortion. R_9 is inserted in the common-emitter return to reduce the possibility of thermal runaway. Sufficient output is available from the carbon microphone element of a surplus TS-13-E handset to fully drive the modulator without any need for additional amplification. Button current is regulated by R_{12}.

Metering and Switching

A miniature 0–1-ma. meter is used with appropriate multipliers and shunts for measuring several voltages and currents. Oscillator emitter current, final collector current, relative r.f. output, modulator emitter current, and battery voltage can all be metered according to the setting of S_3. A peak detector connected to the transmitter output rectifies the r.f. which is then filtered by R_8C_{12} and applied to the meter. The r.f. output and modulator current scales are arbitrary. Full scale on the oscillator and final-amplifier ranges corresponds to 50 and 100 ma., respectively. In the battery check position, full-scale deflection indicates 12 volts.

Push-to-talk operation by means of a switch on the handset contributes to convenient, snappy operation. It is accomplished with a miniature three-pole relay that switches the antenna and the collector supply voltage when energized by a butterfly switch built into the TS-13-E handset. The d.c. switching contacts in the relay are arranged to eliminate feedback resulting from slow decay of the supply voltage when going between receive and transmit.

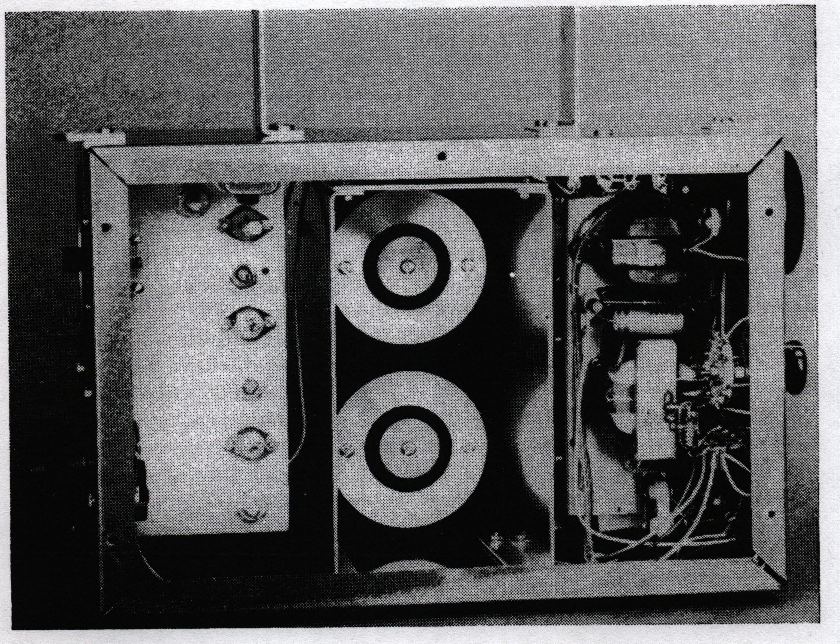
A paradox often encountered in transistor gear is that a control device may consume more power than the total useful output from the equipment. This is avoided to some extent in the case of the push-to-talk relay by two expedients. First the restoring spring is over-stretched somewhat to weaken its tension, thus reducing the coil current required for pulling in and holding the relay armature. Second, a network consisting of R_{13} and C_{13} is placed in series with the relay coil. When the coil circuit is initially closed, pull-in current is normal; because the large capacitance of C_{13} cannot charge quickly, it effectively short-circuits R_{13}. When C_{13} becomes fully charged, current is reduced by the presence of R_{13} in series with the coil, but by this time the relay is closed and requires only a small holding current. Thus, while transient operation is unchanged, the steady-state power consumption is cut almost in half.

Construction

The converter chassis is a piece of aluminum about 5 inches high bent into an "L" shape 3¼ inches on one leg and 2⅞ inches on the other. One hole of the diameter required for the speaker and another for clearing the variable-capacitor shaft are drilled in the longer leg. Additional small holes are also drilled in this leg for screws which fasten the chassis to the b.c. receiver printed wiring board. A strip of brass is riveted across the chassis between the speaker and shaft holes. Two holes drilled and tapped through this double layer of strip and chassis take screws used for fastening the completed receiver assembly to the main box. Self-tapping screws can be used if riveting facilities are not available.

Converter components are mounted on the other leg of the "L" chassis near its edge, to avoid interference with b.c. set components. Small parts are wired point-to-point, using miniature insulated turret standoff terminals where required.

As seen in one of the photographs, the transmitter is built on a second "L"-shaped aluminum chassis about 5 inches high. One leg of the "L" has notches at the corners to clear the crystal socket assembly and coax antenna jack. Modulation and microphone transformers are mounted on



The walkie-talkie with one side cover removed. The receiver compartment is on the left, the homemade battery box is in the center, and the transmitter section is at the right. The rings and disks on the far side of the battery box make contact with coil spring terminals on the batteries. This view shows the transformer side of the transmitter chassis, the meter switch wiring, and the crystal sockets mounted on the slide switch in the lower right corner.

one surface of this leg, and the mica tuning capacitors on the other surface. All transistor sockets are mounted on the other leg of the "L." A small shield separates the oscillator and final circuits. As in the converter, all small components are wired directly, using miniature insulated standoff terminals where necessary.

A heat sink for the output transistors is made from 1¾ × 1¼ × ¼-inch piece of aluminum. Two 21/64-inch holes, spaced the same distance as the transistor sockets, are drilled through the aluminum. These holes fit over the transistors which are secured lightly with set screws. The capacitance between the heat sink and the chassis makes up part of the total tuning capacitance in the final-amplifier collector circuit.

The receiver and transmitter are mounted at opposite ends of a 5 × 6 × 9-inch utility box. The receiver assembly is fastened with two screws that pass through the box into the tapped holes in the receiver chassis. The speaker grille, a small piece of perforated metal, is sandwiched between the chassis and the inside surface of the box where it is held firmly when the mounting screws are tightened. The only precaution necessary when mounting the receiver is to ensure that the tuning capacitor shaft lines up with the bushing on the miniature vernier knob (Lafayette F-348). The volume control and switch unit supplied with the b.c. receiver will probably be of the printed wiring variety and not lend itself to panel mounting. It should be removed and a standard 5000-ohm control and s.p.s.t. switch combination mounted on the end of the box. Wires are then run from the new unit to the former connection points. The switch is wired into one battery lead as shown in Fig. 2. In addition, leads to the audio-output transformer secondary and the speaker are connected to the speaker switch, S_1.

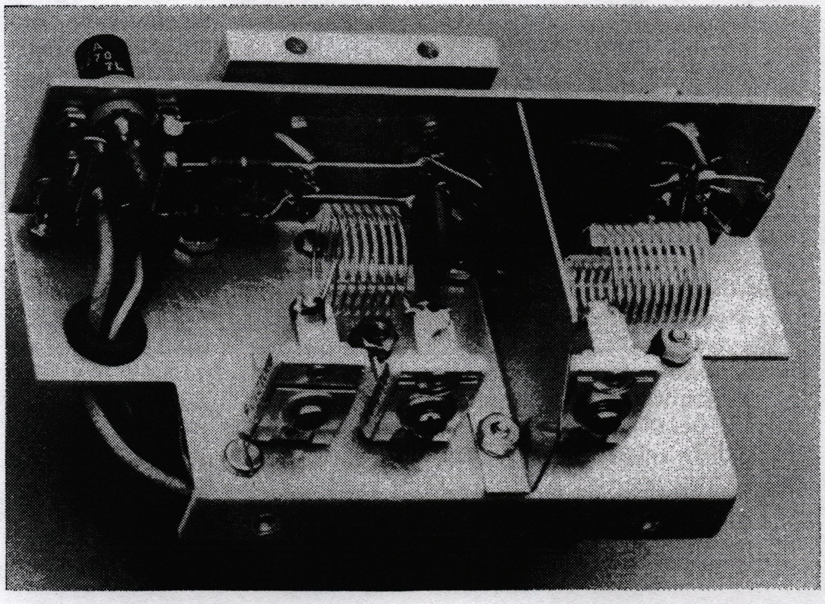
The transmitter is mounted at its end of the box by means of a narrow flange on one side of the chassis. Holes in the end of the box line up with the three variable capacitors, providing access for tuning. The meter, meter switch and crystal switch are mounted on the transmitter end of the box. The crystal sockets are mounted by soldering their terminals directly to the switch terminals. The complete crystal switch and socket assembly is then mounted in a corner of the box with two short leads connecting the switch to appropriate points in the oscillator circuit. Most metering components are mounted on a terminal strip below the meter switch.

Between the transmitter and receiver is a box constructed of aluminum for housing two lantern-type batteries that come equipped with coil-spring terminals. The interior view shows one end of the battery box open for receiving the batteries. At the other end of the box there is a bakelite plate to which disk and ring terminals are attached with small screws. These screws also hold solder lugs on the other side of the bakelite plate for making connection between the walkie-talkie circuits and the battery box. The disks and rings are cut out of 1/32-inch brass with a hole cutter.

To change batteries it is only necessary to remove a side cover of the walkie-talkie, tilt the box to eject the old batteries, and slip new batteries in place. Compression of the battery spring terminals and a sponge-rubber pad inside the side cover automatically compensate for dimensional variations and ensure good contact. Haywire, loose connections, and the possibility of getting polarity mixed up are completely eliminated.

A combination carrying handle and handset cradle made of aluminum is mounted centrally on the top of the box. For carrying ease, a surplus web strap with swivel snap connectors at each end may be fastened to the small aluminum brackets screwed to each end of the walkie-talkie.

Small disks of ⅛-inch sheet rubber are cemented to the bottom of the box near the corners to prevent marring surfaces on which the unit is placed. Using this material rather than conventional rubber feet eliminated screws that would



The transmitter subassembly. The shield partition separates the oscillator section on the right from the amplifier components on the left. One edge of the aluminum heat sink which fits over the 2N1143 amplifier transistors is visible just above the L-shaped chassis. The sockets for the modulator transistors are on the far left, and the audio transformers are mounted on the other side of the chassis and hidden in this view.

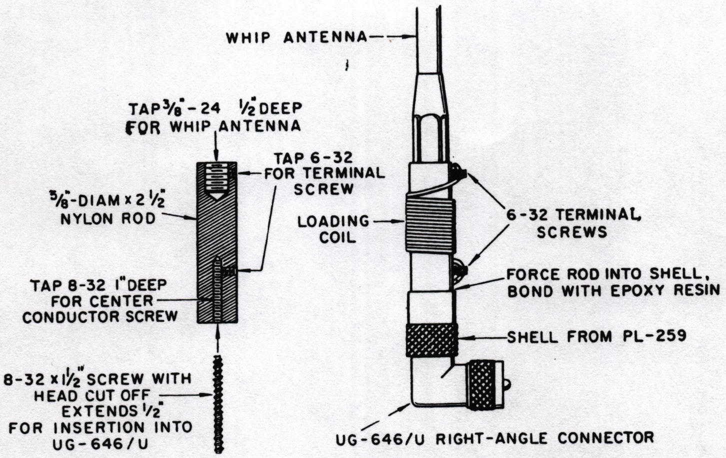


Fig. 3—Construction of the base-loaded whip used with the walkie-talkie. Tighten the 6-32 screws against the whip and the 8-32 center conductor screw. Then cut the heads off both terminal screws and use them to hold the ends of the coil. The inductance of the coil should be adjusted for resonance with the particular whip used.

have protruded into the box and interfered with various components.

Making the Antenna

The antenna shown in the photographs was made from a surplus Fiberglas helical whip for 40 Mc. A loading coil at the base lowers the resonant frequency of the whip to 29 Mc. Construction details are shown in Fig. 3. The coil form is made from a 2½-inch length of ⅝-inch-diameter nylon rod, drilled and tapped at one end to receive the whip. The other end is tapped for an 8–32 screw. The outer shell from a PL-259 coax plug is screwed onto a UG-646/U right-angle connector and the form is jammed into the end of the shell. Epoxy resin is used to cement the nylon in place. The 8-32 screw projecting from the end of the coil form rod makes contact with the center conductor of the right-angle fitting. Small screws fitted radially at the top and bottom of the coil form make contact with the whip and 8-32 screw, respectively, and also serve as terminals for the loading coil. Similar construction may be used with other whips; the only requirement is that the loading coil be adjusted with a grid-dip meter for resonance near the desired operating frequencies. The finished assembly is simply screwed onto the coax jack on the rig.

Adjustment

Start off by using a grid-dip oscillator to set all the tuned circuits in both converter and transmitter to the proper frequencies. Then apply power to the converter and b.c. set and check to see that Q_3 is oscillating, using the g.d.o. as an indicating wavemeter. At this point, you should be able to hear signals (or a signal generator) and peak up L_1, L_2, L_4 and L_5 for maximum output. Rock the b.c. set tuning capacitor and adjust L_4 for proper tracking over entire range.

The transmitter is tuned by simply adjusting C_8, C_9 and C_{10} for maximum output as indicated by the built-in r.f. voltmeter. The oscillator-emitter and amplifier-collector currents are checked for reference only; they are typically 20 and 60 ma., respectively.

How Far Will It Work?

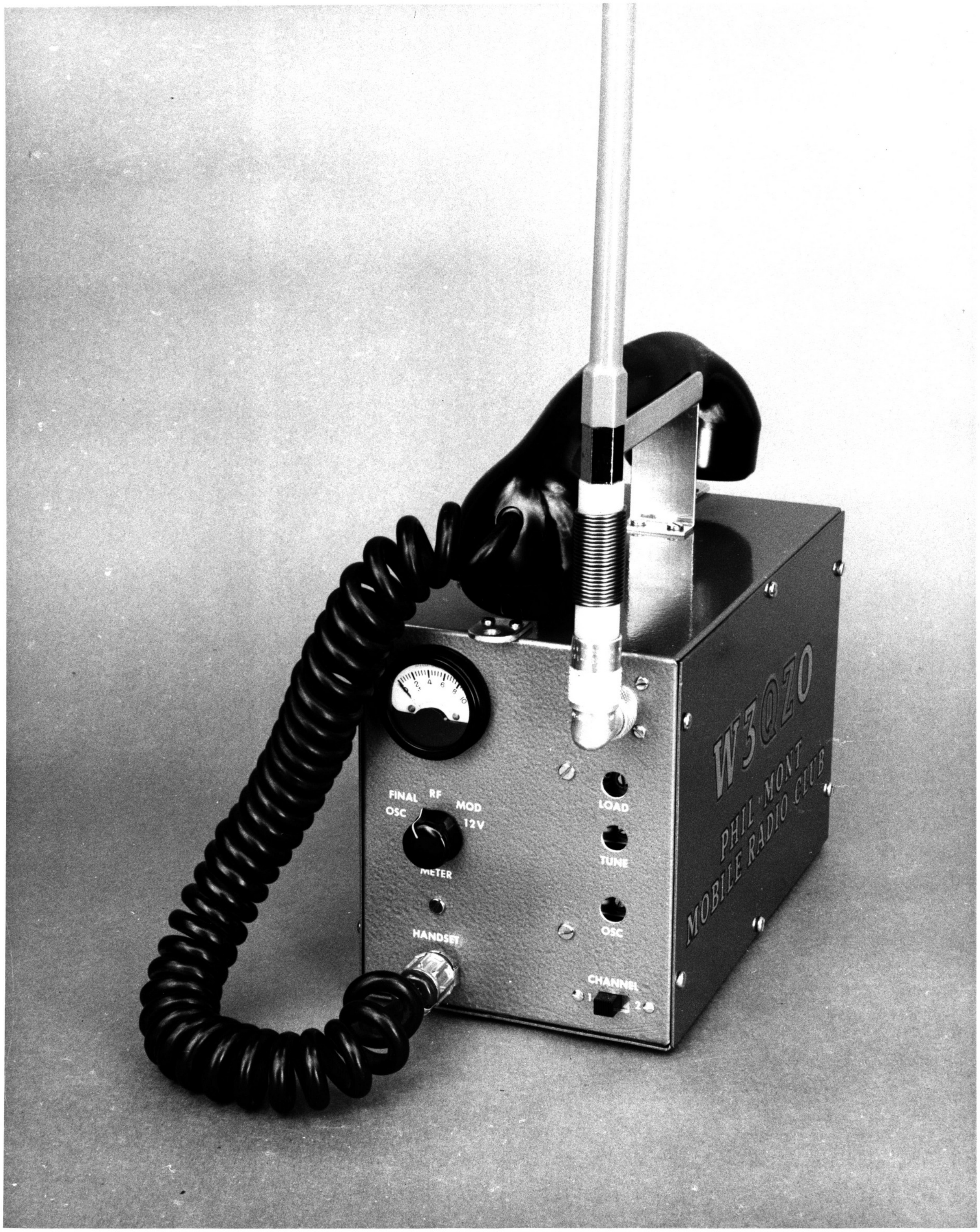
In field use the walkie-talkie has demonstrated the desirable, though often frustrating, characteristic of a receiving range which is far greater than its transmitting range. Distances consistently covered from a field location over average terrain are limited by transmitter power to about two miles to a mobile in motion and five miles to a fixed station. Good locations will extend the range. For example, stations about twelve miles away are worked consistently from inside an apartment building at the author's QTH, using only the whip antenna shown in the photographs. Needless to say, TVI is not a problem with this rig!

Receiver sensitivity equals that of typical commercial communications sets, ground-wave range being on the order of 30 or 40 miles with the whip. While the selectivity does not stack up with that obtained with exotic i.f. systems, it has been more than adequate for conditions encountered so far. Shielding provided by the metal box prevents b.c. signals from leaking directly into the broadcast receiver, but there is a tendency for h.f. commercial stations to cause cross-modulation in the input stage. A more sophisticated input circuit with a band-pass network might eliminate this problem, but it has not been serious enough so far to warrant such a complication.

It would be nice at this point to include a discussion of battery life, but after four months of use the original cells show no sign of deterioration. The average receiver drain is only 18 ma., and even considering the 130-ma. total load on transmit it appears that one set of batteries can be counted on for about a year of normal use, after which they should be replaced on general principles anyway. Since the batteries cost only 72 cents each, the operating cost is negligible — something that cannot be said for tube equipment of a similar nature.

This walkie-talkie has been described not with the thought that it will be copied but rather to relate a few ideas that may assist others with similar projects. Regardless of mechanical or circuit details, rigs of this type share one characteristic: They all provide unlimited enjoyment for their owners.

The author wishes to acknowledge the many suggestions offered by W2HBE during the development of the transmitter r.f. circuit. QST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MOBILE RADIO CLUB
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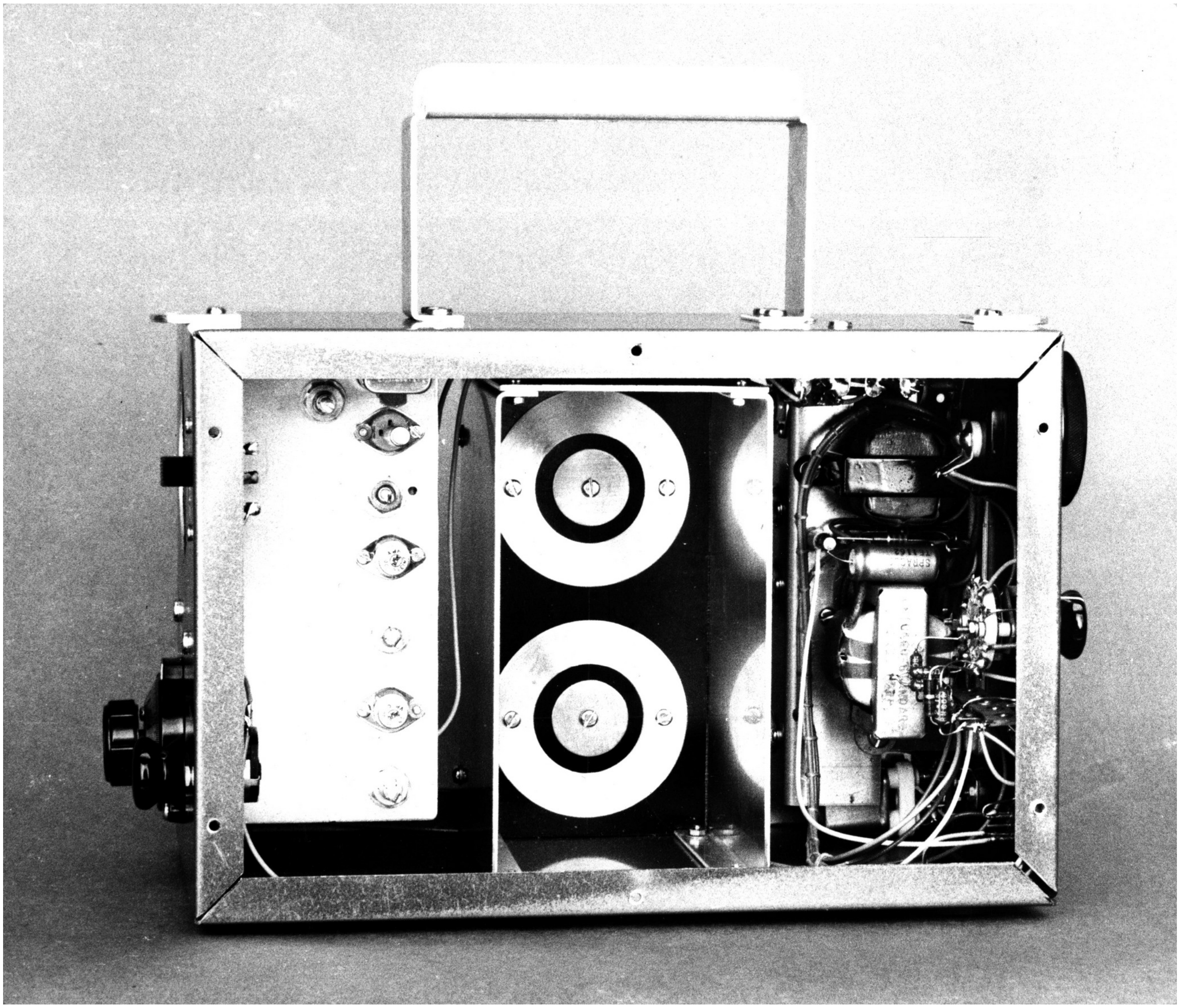

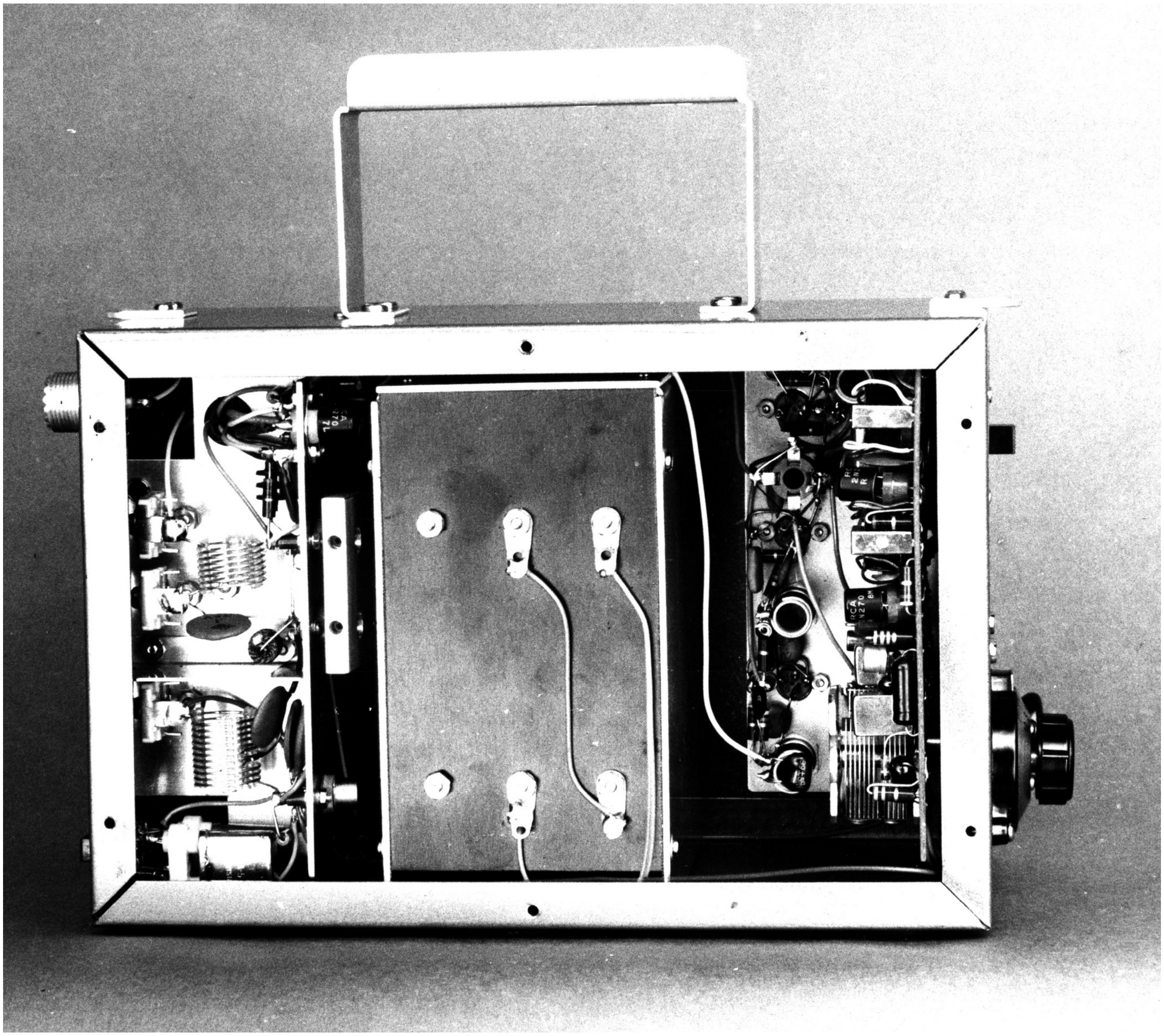

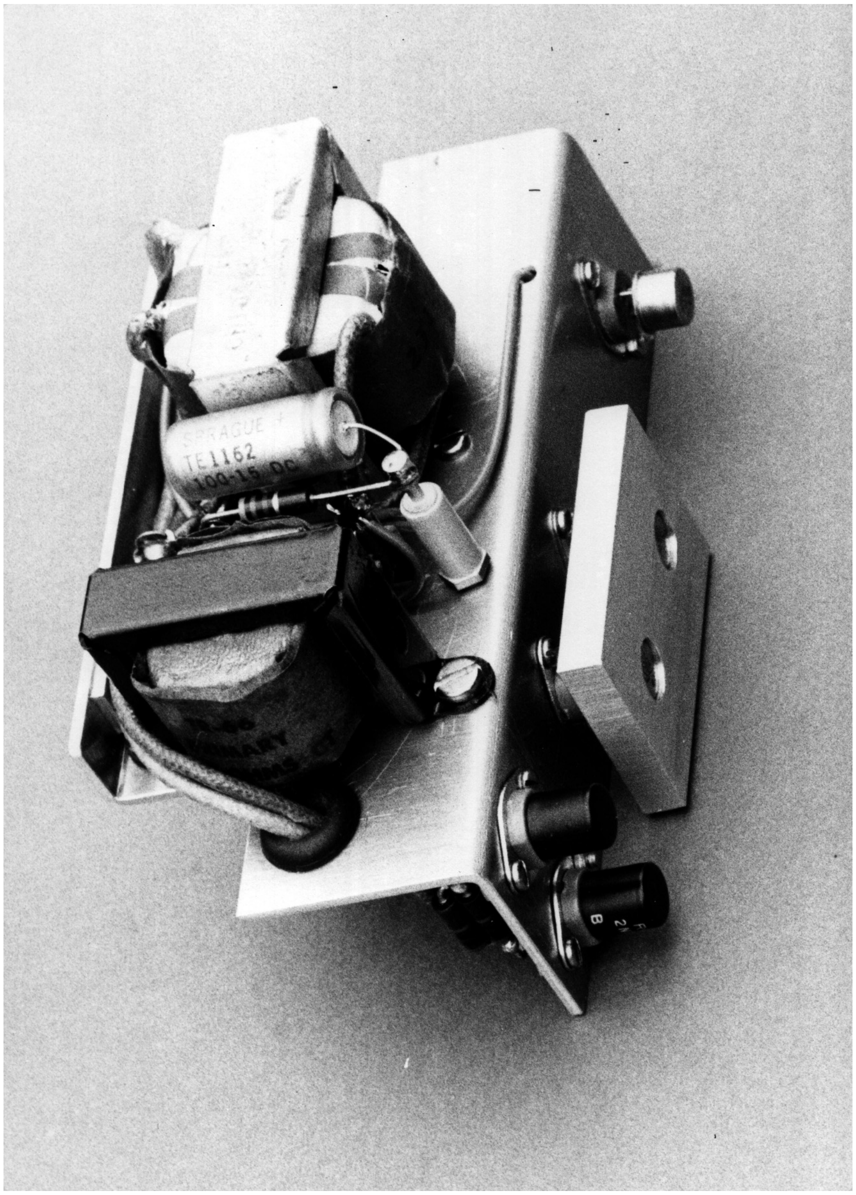
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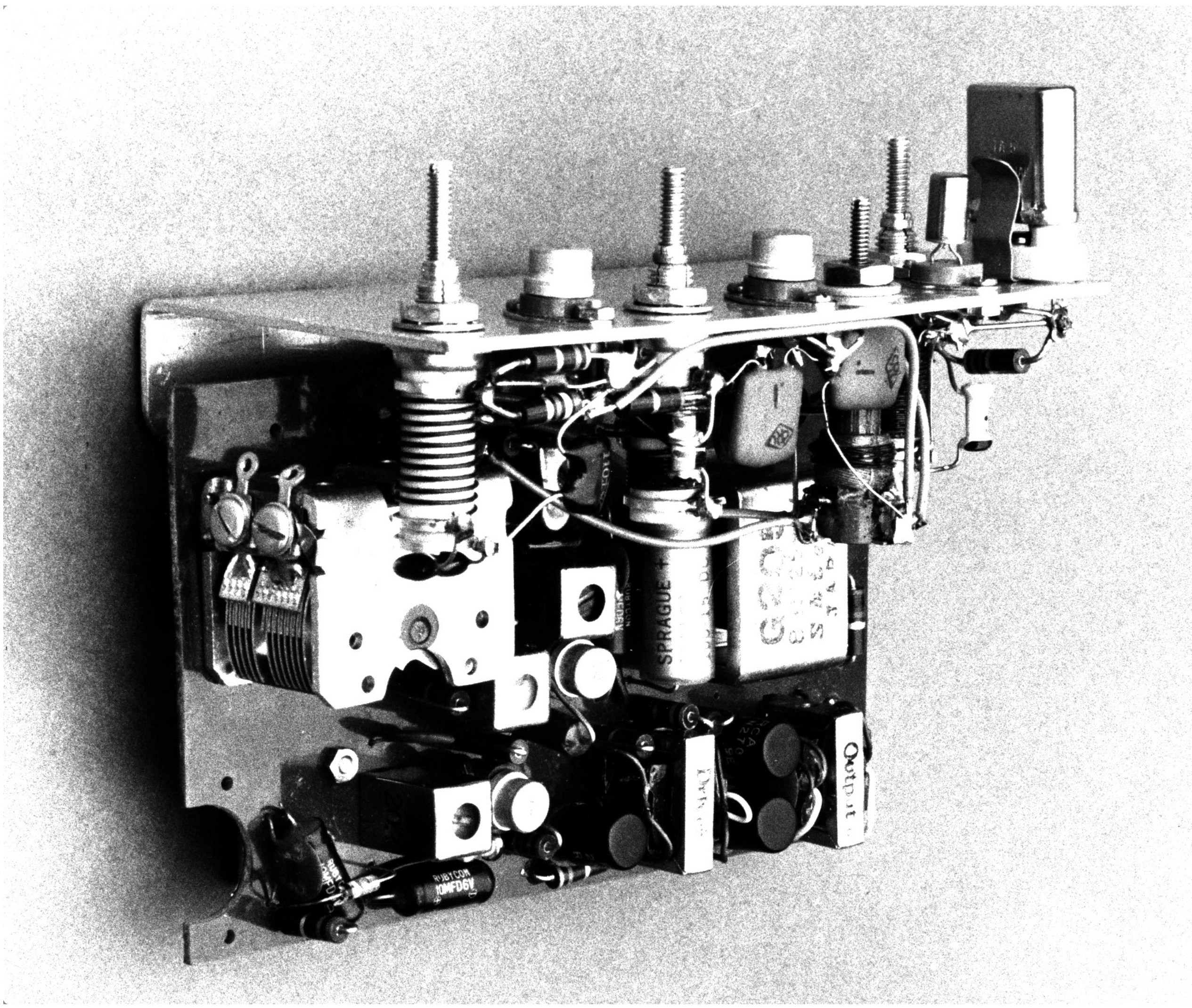
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