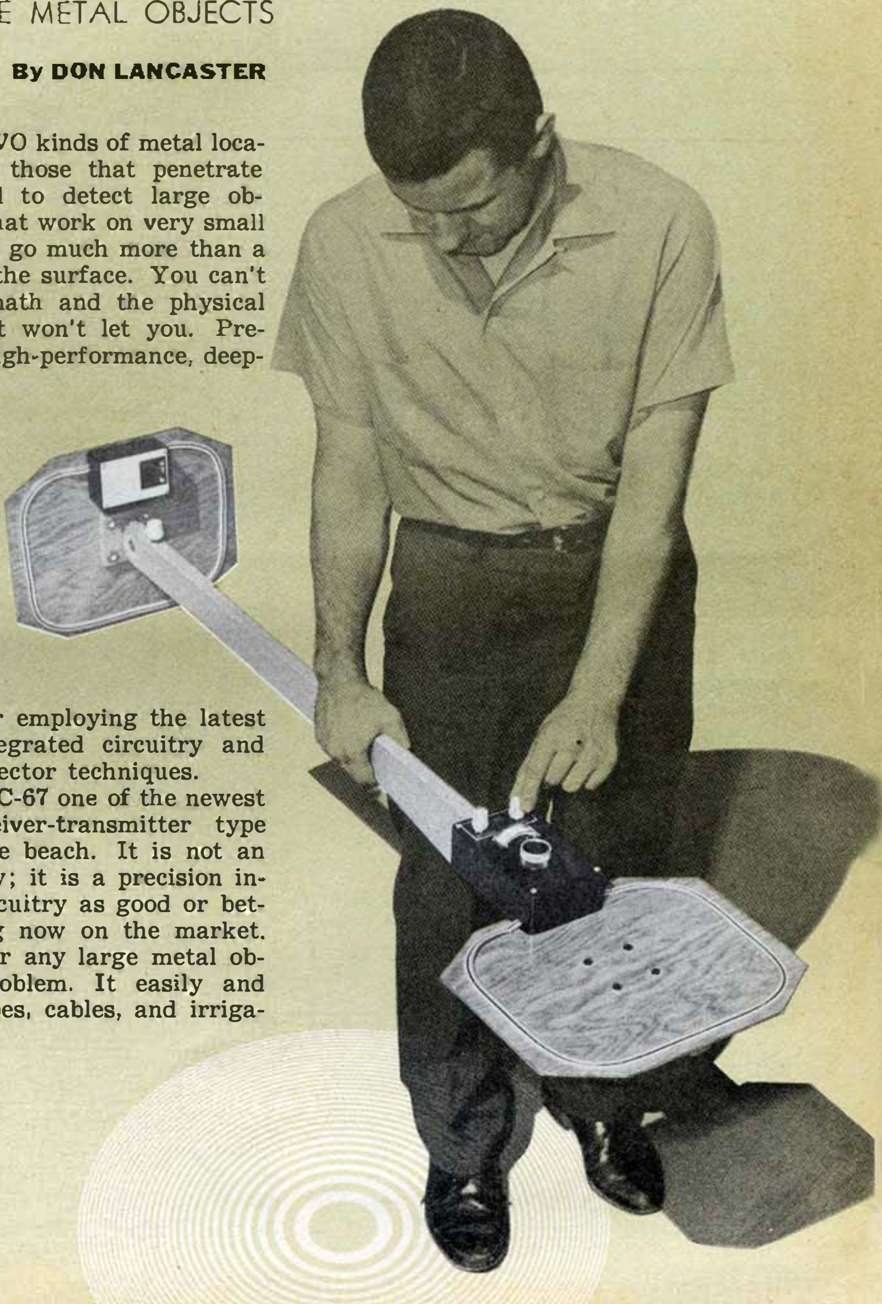
BUILD

IC-67 Metal Locator

SOLID-STATE, PRECISION INSTRUMENT OF ADVANCED DESIGN DEEPLY PENETRATES THE EARTH TO LOCATE METAL OBJECTS

By DON LANCASTER



THERE ARE TWO kinds of metal locators available: those that penetrate deep underground to detect large objects; and those that work on very small objects but do not go much more than a few inches below the surface. You can't have both—the math and the physical laws involved just won't let you. Presented here is a high-performance, deep-type metal locator employing the latest in solid-state integrated circuitry and military mine detector techniques.

You'll find the IC-67 one of the newest and hottest receiver-transmitter type locators to hit the beach. It is not an experimenter's toy; it is a precision instrument with circuitry as good or better than anything now on the market. You can use it for any large metal object detection problem. It easily and strongly spots pipes, cables, and irriga-

COVER STORY

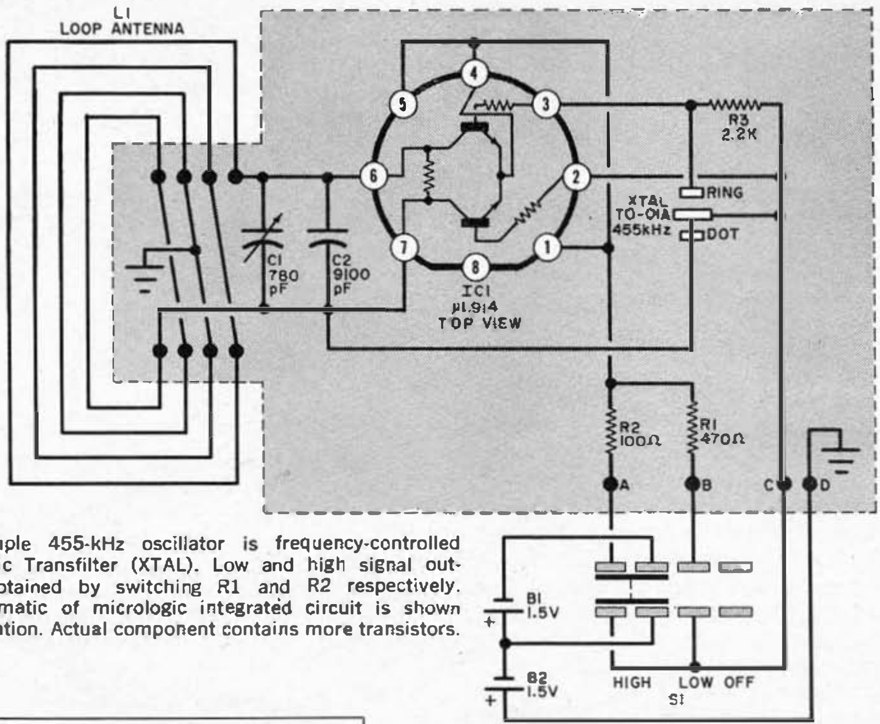


Fig. 1. Simple 455-kHz oscillator is frequency-controlled by a ceramic Transfilter (XTAL). Low and high signal outputs are obtained by switching R1 and R2 respectively. Partial schematic of micrologic integrated circuit is shown for simplification. Actual component contains more transistors.

TRANSMITTER PARTS LIST

B1, B2—AA 1.5-volt penlight cell. (2 required)
C1—170-780 pF trimmer capacitor
C2—9100-pF polystyrene capacitor (Mallory type SX, ± 5%; do not substitute)
IC1—µL914 epoxy dual gate (Fairchild)
L1—9" x 11" loop (1-turn four-conductor flat cable, 16 AWG, (formed from 37" of Belden 8476 or similar)
R1—470-ohm, ¼-watt carbon resistor
R2—100-ohm, ¼-watt carbon resistor
R3—2200-ohm, ¼-watt carbon resistor
S1—D.p.3-t. slide switch (Wirt G-128 or similar)
XTAL—TO-01 A Transfilter (Clevite)
*1—1¼" x 2½" printed circuit board***
1—4" x 2⅞" x 1 9/16" plastic case and cover (Harry Davies #220 or similar)
1—Battery holder (Lafayette 99R6331 or similar)
Misc.—Dialplate, hardware, PC terminals (12), staples, wire, solder, etc.*

Note: IC1 and XTAL are available from Semiconductor Specialists, 5700 W. North Ave., Chicago, Ill. 60639.

*,**See Receiver Parts List

tion valves buried as deep as seven feet, making it a top instrument for construction or landscape work. As a treasure finder, a silver dollar *in air* can produce a noticeable output, but when it comes down to the practical matter of reliably finding buried objects, a coffee can is probably the best you'll be able to do.

Integrated circuits and low battery voltages as well as low power drain go hand in hand; only six penlight cells are used. A fully automatic zero-cost battery-tester feature is included. No headphones or dangling cords are required; a small sonic module easily provides a loud audio output from a very high gain receiver. A "crystal" stabilized transmitter in a CW broadcast system is used. An output meter and a choice of two transmitter power levels help locate the "treasure." Four controis run the instrument, and the entire project weighs in at only five pounds.

Most important, you get some features not found on commercial units. A signal expander circuit lets you reject all the background noise and signal variations to permit you to concentrate on what you're looking for. At the same time, the signal from deep targets is sharpened to enable you to precisely pinpoint deeply buried objects.

Total semiconductor cost is $4.50, but the final bill will probably amount to about $40—split $35 for components and $5 for lumber. This is about one-quarter to one-ninth the cost of comparable commercial instruments.

While not intended as a beginner's project, the circuit is not too difficult to build and the parts are easy to get. Pay particular attention to the parts list and construction details; certain changes could cause trouble. A parts kit is available (see Receiver Parts List) or you can assemble your own parts.

How It Works. Essentially this instrument is nothing more than a receiver and a transmitter equipped with loop antennas. Loop antennas are very directional—two of them at right angles to each other provide practically zero signal coupling. But a metal object in the vicinity of the two antennas will upset a null condition and give you an output signal. Energy transmitted from the vertical rear transmitter loop is "reflected" by the object to the horizontal front receiver loop. Both loops must be rigidly connected and at least one of them precisely adjustable to null the no-target coupling.

The *transmitter* (Fig. 1) consists of a loop antenna driven by a 455-kHz oscillator. A dual micrologic integrated circuit (*IC1*) forms a push-pull CW oscillator when feedback is cross-coupled by a ceramic Transfilter (*XTAL*). As output power depends in part upon emitter current, a high or a low output level can be obtained simply by switching *R1* or *R2* into the circuit.

The *receiver* is a three-stage TRF type, followed by a detector, a signal expander, a meter, and sounder device. The receiving loop resonates at 455 kHz, picks up the signal from the transmitter and drives the r.f. amplifier (*IC1*). Transformer *T1* also resonates at 455 kHz, and couples the amplified signal to *IC2* for further amplification; *T2* similiarly provides coupling to *IC3*. (See Fig. 2.)

The amplified output of *IC3* is transformer-coupled by *T3* to a conventional diode detector (*D1*). A d.c. voltage appears across *R4* and *C10* which is a function of the signal strength. To obtain signal expansion, the output voltage across *R4* and *C10* is added to the voltage across *R9* and part of the *Expansion* control *R7*, and applied to the base of a special, high gain transistor (*Q1*) to increase current flow through the meter and the sounder, which serve as visual and audible indicators.

If the expansion voltage is large, *Q1* operates as an ordinary linear amplifier, and all target and clutter signals are equally amplified. On the other hand, if the expansion voltage is very small, *Q1* stays "off" unless a very strong signal is received. In this mode, only the peaks of the strongest signals reach the output, which "sharpens" target positioning and rejects background noise and clutter.

For intermediate settings of the *Expansion* control, the nonlinear operation of *Q1* amplifies the *stronger* signals more than the *weaker* ones, and "expands" the target signals at the expense of the clutter. Simply adjust the *Expansion* control to optimize results for each location.

Total receiver r.f. gain is on the order of 30,000, which is considerably more than the gain of an average AM radio. The gain of *IC1* and *IC2*, and hence overall gain, is controlled by *Gain* control *R6*.

Construction. No metal locator will work properly with a sloppy, loose or out-of-square frame. For topnotch operation, the frame *must* be absolutely rigid; the loop assemblies must be precisely at right angles; and there must be a means for smoothly adjusting the null between the two loops. Otherwise, "straight-through" transmitter energy will come booming through the receiver and completely "swamp" any target signals. Extra time spent on the frame will be more than made up by improved performance.

The main frame should be made from a quality piece of ¾" kiln dried maple, or plywood, as shown in Fig. 3. A ⁷⁄₁₆" dado blade, if available, makes child's play out of the rear slot; otherwise, just use repeated cuts and fence settings on a table saw to get the same result. Do not drill the ¾" pivot hole just yet.

Flush-mount three #10 Teenuts (washer-shaped metal fastener about ¾" in diameter, with three large fangs on outside and *10-32* threads on the inside) on the frame as shown. Put a dab of glue under each Teenut. The pilot hole for the Teenut on the rear end of the frame should go all the way through, into the

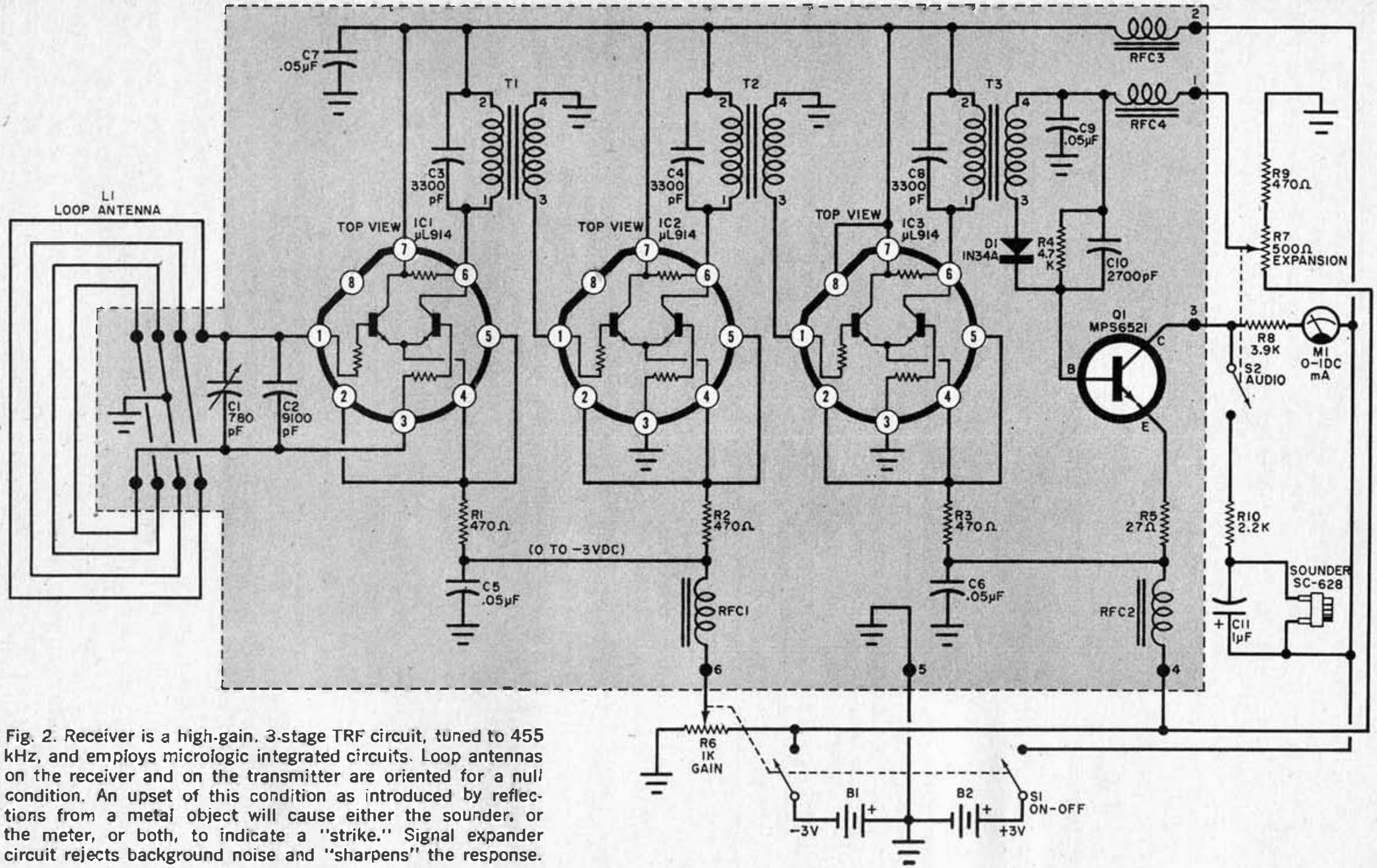


Fig. 2. Receiver is a high-gain, 3-stage TRF circuit, tuned to 455 kHz, and employs micrologic integrated circuits. Loop antennas on the receiver and on the transmitter are oriented for a null condition. An upset of this condition as introduced by reflections from a metal object will cause either the sounder, or the meter, or both, to indicate a "strike." Signal expander circuit rejects background noise and "sharpens" the response.

RECEIVER PARTS LIST

B1, B2—AA 1.5-volt penlight cells (4 required)
C1—170-780 pF trimmer capacitor
C2—9100-pF polystyrene capacitor (Mallory type SX, ± 5%; do not substitute)
C3, C4, C8—3300-pF ceramic capacitor, 10% tolerance (Vitramon VK33; do not substitute)
C5, C6, C7, C9—0.05-µF miniature Mylar capacitor, or paper
C10—2700-pF ceramic capacitor
C11—1-µF, 6-volt electrolytic capacitor
D1—1N34A diode
IC1, IC2, IC3—µL914 epoxy dual gate (Fairchild)
L1—9" x 11" loop (1-turn, four-conductor flat cable, 16 AWG, formed from 37" of Belden 8476 or similar)
M1—0-1 d.c. milliammeter (Emico Model 13, edgewise-type, or similar)
Q1—MPS6521 transistor (Motorola; do not substitute)
R1, R2, R3, R9—470-ohm, ¼-watt carbon resistor
R4—4700-ohm, ¼-watt carbon resistor
R5—27-ohm, ¼-watt carbon resistor
R6—1000-ohm linear carbon potentiometer with d.p.s.t. switch S1
R7—500-ohm linear carbon potentiometer, with push-pull s.p.s.t. switch S2
R8—3900-ohm, ½-watt carbon resistor
R10—2200-ohm, ½-watt carbon resistor
*RFC1, RFC2, RFC3, RFC4—10 turns 34-AWG enameled magnet wire on Ferroxcube K5-001-00/3B shielding bead; do not substitute****
S1—D.p.s.t. switch on R6
S2—S.p.s.t. push-pull switch on R7
Sounder—6-28 volt d.c. audio sonic alarm module (Mallory or Sonalert SC628)
*T1, T2, T3—36 turns 34-AWG enameled magnet wire on Indiana General "Q-1" CF101 core, bifilar-wound; do not substitute****
*1—3⅜" x 2⅝" printed circuit board***
1—6¼" x 3¾" x 1⅞" plastic case and cover (Harry Davies #240 or similar)
1—Battery holder (Lafayette 99R6331 or similar)
Misc.—Knobs (2), PC terminals (14), staples, dialplate, hardware, wire, solder, etc.*

*Metalphoto dialplate set (1 for receiver and 1 for transmitter); both available for $1.50 from Reill's Photo Finishing, 4627 N. 11 St., Phoenix, Ariz. 85014, postpaid in USA.

The following parts are available from DEMCO, Box 16297, San Antonio, Tex. 78216:

**Etched and drilled circuit boards (1 for receiver and 1 for transmitter) both for $3.50

***RCF and transformer kit consisting of 4 beads and 3 toroid cores with necessary lengths of magnet wire, $2.50

Complete kit of parts, including Teenuts, less lumber, dialplates, and batteries, $35.00. All prices postpaid in USA.

slot. The boards to hold the transmitter and receiver, also shown in Fig. 3, can be cut from ¼-inch plywood.

Cut two flanges and the pivot from a small piece of 7⁄16" maple as shown in Fig 4. Flush-mount four Teenuts on each flange. Glue the front flange into the 3" notch in the front of the main frame. The Teenuts on the flange should be on the bottom side. Be certain the flange is centered and square. Use clamps for the glue job. Insert and glue the pivot into the rear flange.

The pivot and flange assembly should be sanded to a smooth fit in the slot on the main frame. There should be no wobble or side play. After careful alignment, drill the ¾" hole through the pivot and frame at the same time. Cut and insert a ¾" length of ¾" dowel. Secure with a dab of glue at one end only. Be sure that no glue gets into the pivot assembly to restrict movement.

Steel-wool all the woodwork and apply a coat or two of clear varnish. Keep the slot clear of varnish. After the final coat is thoroughly dry, assemble the microbalance as shown in Figs. 5 and 6.

Use a 3"-long *10-32* machine screw, a compression spring, and protecting washers. You may have to try several springs to get just the right length and tension. You can redrill and tap a knob equipped with a setscrew for a ⅛" shaft to go over the top end of the long screw, and secure it in place with the setscrew. Rotating the knob rotates the pivot, which in turn rotates the transmitter board with respect to the receiver board. Each full turn of the knob represents 0.8 degree of transmitter tilt.

Fasten the transmitter and receiver boards to the main frame with four *10-32* ⅝"-long machine screws. If you use knurled head or thumbscrews for this purpose, you will be able to remove the boards to facilitate carting and storage. Certain special jobs of tracking pipes, or triangulating for depth measurements, can be more readily accomplished with this disassembly feature.

Metal cases should not be used to house the transmitter or the receiver on this type of metal locator as they would cause field-pattern distortion. Low-cost plastic instrument cases are suitable. Be sure to have all the electronic parts on hand and plan their layout before actual assembly is begun. External component dimensions may vary and you may have to make some allowances.

Drill the cases as shown in Figs. 7 and

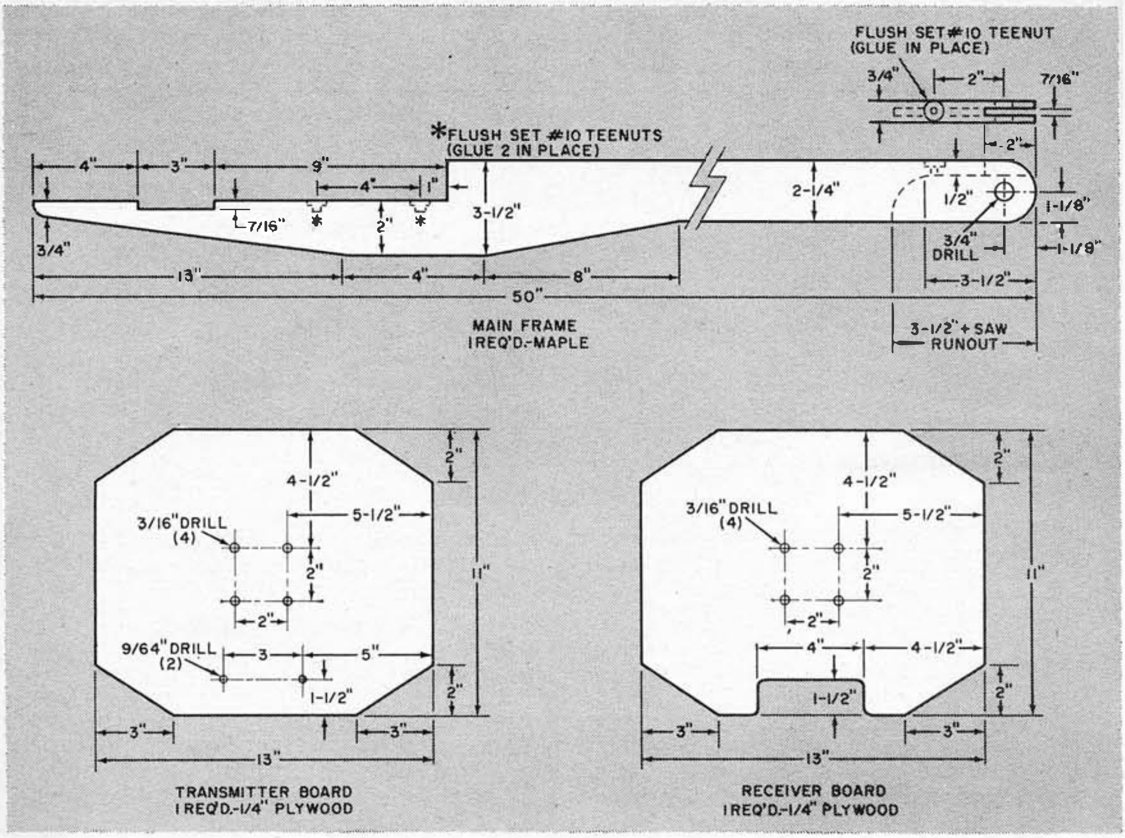
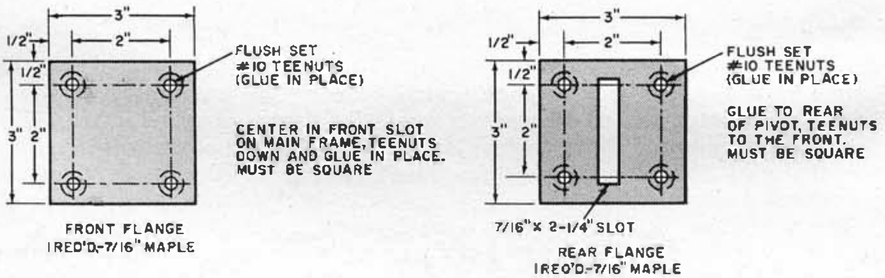


Fig. 3



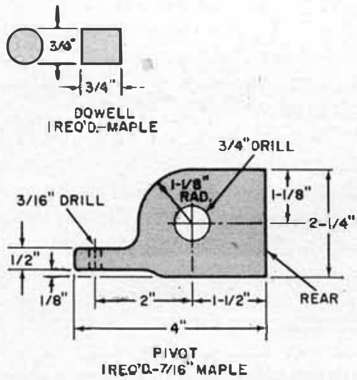
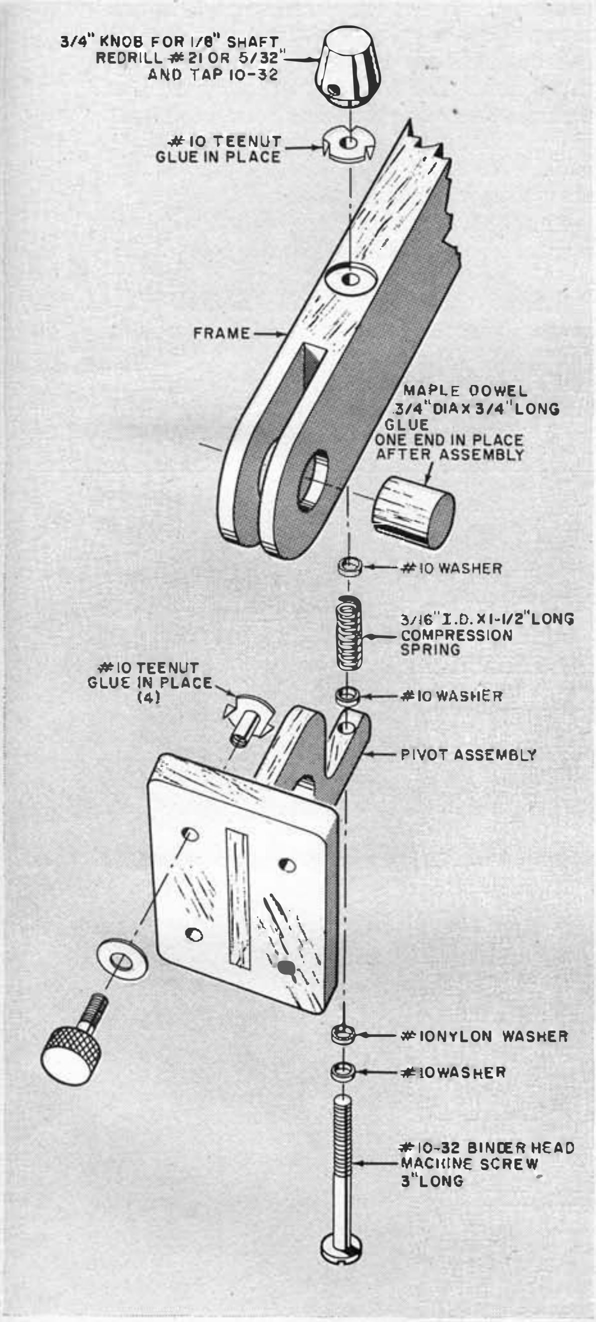


Fig. 3. As in any precision instrument, all parts must be made to fit squarely and securely. Exact contour of frame and boards is not critical, but do maintain relative positions and distance between boards. The less metal hardware, the better. Use maple or other hard, high-quality wood for frame.

Fig. 4. Insert and glue the pivot into slot on the rear flange. Rear of pivot should be flush with back side of flange as shown in Fig. 5. The 3/4"-hole should be drilled through the frame and pivot assembly at the same time. Position the pivot assembly as accurately as possible before drilling.

Fig. 4



FRAME PARTS LIST

1—Beam: 50" x 3½" x ¾" maple
2—Antenna boards: 13" x 11" x ¼" plywood
1—Pivot: 4" x 2¼" x 7/16" maple
2—Flanges: 3" x 3" x 7/16" maple
1—Dowel: ¾"-diameter x ¾"-long maple
11—Teenuts: 10-32 x ¾" diameter
1—Machine screw: 10-32 x 3" long, binder head
1—Knob: ¾" diameter for ⅛" shaft, with setscrew
1—Spring, compression: 3/16" i.d. x 1½" long, 6 turns
4—Thumb screws: 10-32 x ¾"
3—Washers: #10 metal
5—Washers: #10 nylon
4—Machine screws: 10-32 x ¾"
Misc.—Glue, varnish, steel wool, etc.

Fig. 5. The microbalance assembly (left) should work freely, but not sloppily. One complete turn of the knob is equal to 0.8 degree of transmitter tilt.

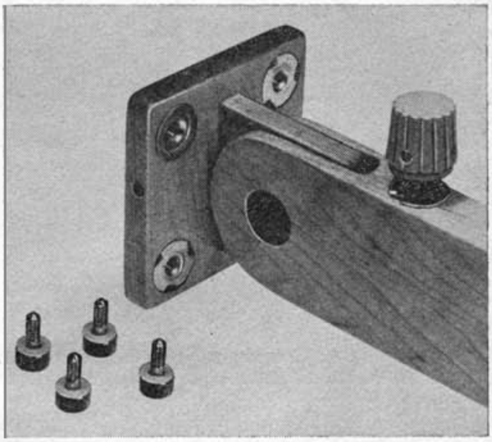


Fig. 6. Use of knurled-head bolts or thumb screws facilitates the removal of the transmitter board for storage, and to solve certain locating problems.

8, but do this carefully to avoid damage. A rotary file will save you time on the two big holes in the receiver. Glue nylon nuts over the holes in the case, as indicated, and keep the threads and the hole clear. Insert a metal screw while the gluing job is in progress, and then remove the screw before the glue sets. Metal nuts can be used if you have difficulty locating the nylon type.

Two plastic battery holders for four AA cells are also cemented in place---one in the receiver, and one in the transmitter. Solder a lead to an appropriate eyelet or conductor on the receiver's battery holder to provide a "center tap," to give you a center-tapped 6-volt supply. On the transmitter's battery holder, connect the two bottom conductors together and a lead for a center tap, to provide a center-tapped 3-volt supply. Only two cells are used for the transmitter. You could use a 2-cell battery holder for this purpose, but the 4-cell holder permits easier access.

If the cases come through without

covers, use any suitable insulated material. A piece of 1/16" fiberglass is suitable. Add a dialplate to obtain a finished appearance, and to identify the controls.

Electronic Package Construction. *Note: Due to the exceptionally high receiver gain, it is important that an exact duplicate of the prototype PC board be used, and that the exact core materials and winding instructions are followed for the transformers and r.f. chokes. Failure to do so will almost certainly result in receiver instability and bandwidth problems.*

The r.f. chokes are wound on ferrite beads. Start with about 12" of 34-AWG enameled magnet wire, and wind 10 turns equally spaced toroidal-fashion around the bead. Keep the wire tight and the turns neat. Do not nick the wire on the bead edge. After winding, cut each end to 1/4" length and strip the enamel back 3/16". Sand your way down to shiny bare copper, and tin the leads.

The transformers are only slightly more difficult. Start with 10 feet of 34 AWG enameled magnet wire. (Do not substitute.) Fold the wire in half and twist it until you get about 12 turns per inch. Guard against kinks, nicks, and abraided insulation. Now, using this bifilar wire, wind *exactly* 36 turns on a

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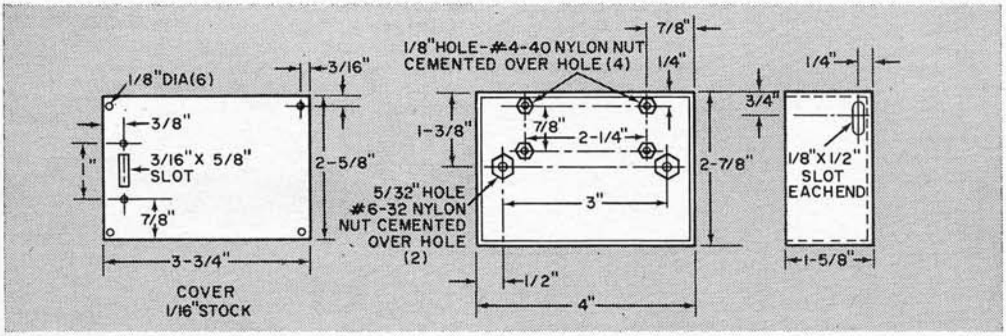


Fig. 7. Use a small plastic box to house the transmitter. Do not employ any more metal hardware than is absolutely necessary. A metal case will distort field pattern uniformity.

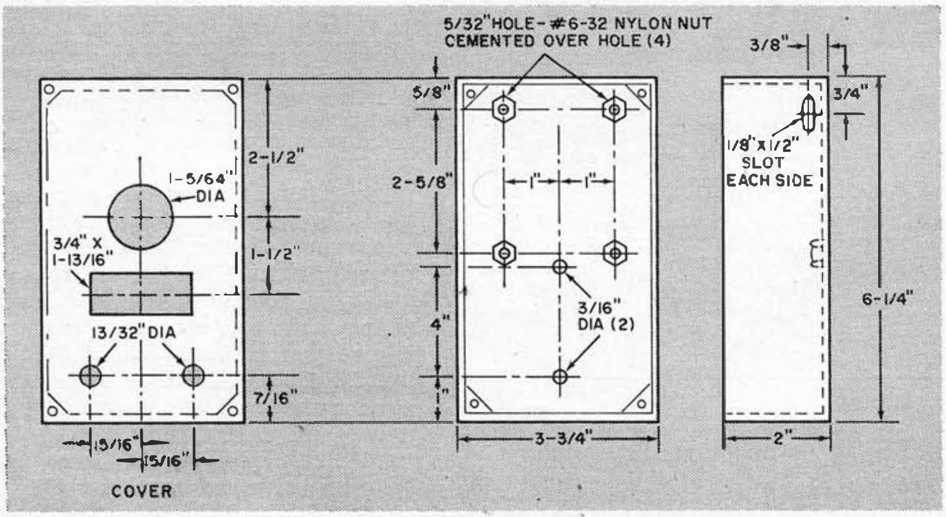


Fig. 8. Receiver housing is also made of plastic; work slowly and carefully when drilling or cutting. Slots in side of box should be large enough to accept antenna without bending or bunching conductors.

IC-67 METAL LOCATOR

(*Continued from page* 48)

CF101 core. Work your way evenly around the core until you near the end of the first layer. Leave a small gap on the core, with no wire in it. Then begin a second layer, working your way back to the beginning, and so forth. Keep your turns neat, tight, and sequential.

After counting out the 36 turns, cut the leads to ¼″ and strip and tin to 3/16″, just as you did on the r.f. chokes. There should be four leads. Use an ohmmeter to identify each pair of wires. Also check for shorts between windings and the core.

Circuit boards are available, but if you want to make your own, follow the actual size layouts shown in Figs. 9 and

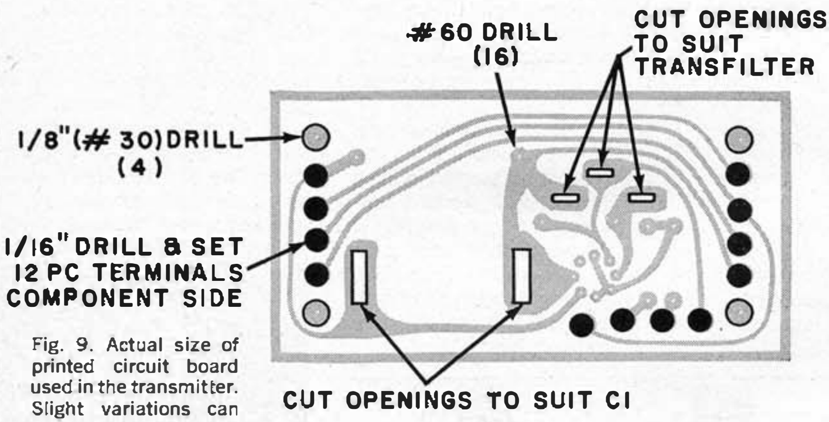


Fig. 9. Actual size of printed circuit board used in the transmitter. Slight variations can be made to accommodate parts which are of different size, but avoid any excessive variation in either size or layout of the components.

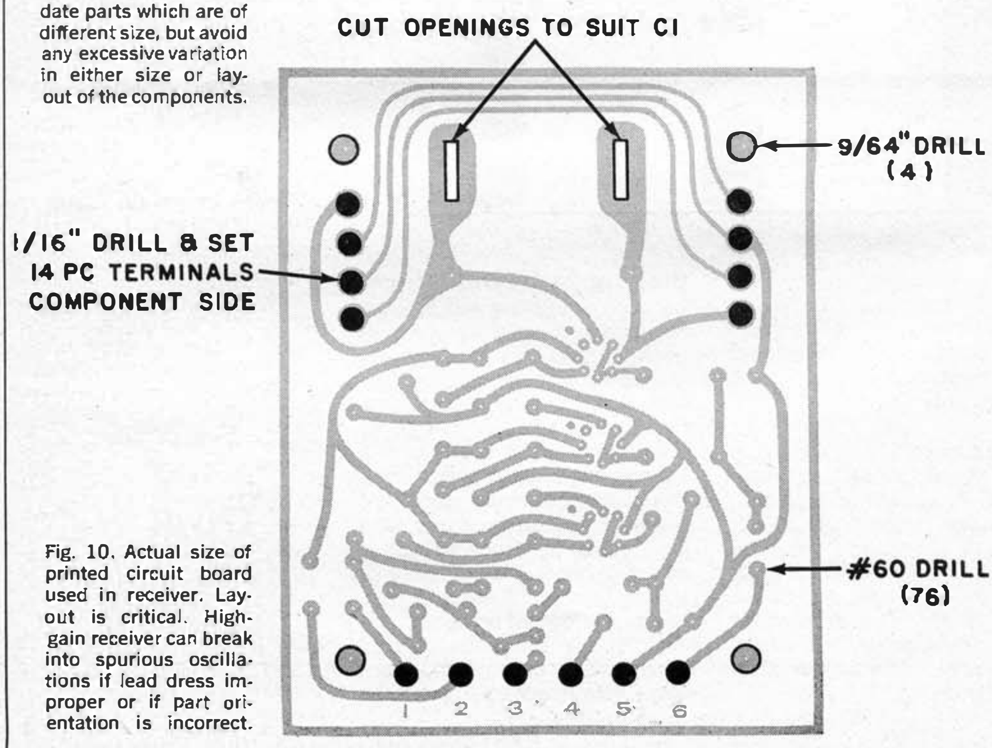


Fig. 10. Actual size of printed circuit board used in receiver. Layout is critical. High-gain receiver can break into spurious oscillations if lead dress improper or if part orientation is incorrect.

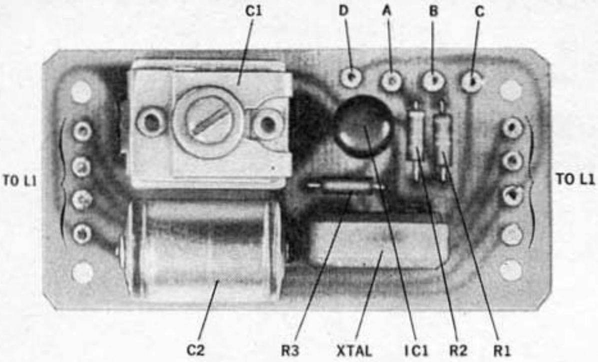
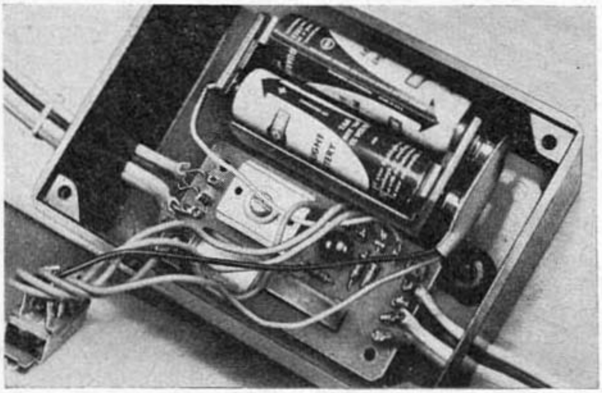


Fig. 11. Components are mounted on transmitter board. Note that pin numbers on IC1 run counterclockwise when you're looking at the top of the component.



10. Mount the components as shown in Figs. 11 and 13. Do not substitute capacitors; those called for have the proper "Q" and tolerance. The transformers and chokes are held in place by their leads. After the initial checkout, you can further secure them with a dab of coil dope.

Controls with switches mounted on them are used to simplify operation of the receiver. The *Gain* control carries on/off switch *S1*, and the *Expansion* control has a push-pull s.p.s.t. switch (*S2*) mounted on its back, as shown in Fig. 14.

Wiring should present no serious problems. Use several colors of wire and double-check all connections. Route all six receiver leads through a single piece of ⅜" sleeving to keep the receiver orderly and prevent spurious oscillation.

The two loop antennas are identical and are made out of a 37-inch length of four-conductor 16-AWG flat cable, and shaped into a 9" x 11" rectangle. It is important that both loops be exactly the same (in size and shape).

It is not possible to simply bend the cable—you'll have to gradually work or mold it into shape with your hands. The cable must lie flat on the board, so work the cable by alternately bending and flattening as you go. You can best do this on a flat table. Temporarily add a bit of tape in the center of the cable, to mark the center, and work your way towards each end from the middle.

Staple the loops to their respective boards. Remove just enough excess cable (the same amount from each loop) to accommodate the receiver and transmitter terminal spacing. The loop ends are stripped and soldered into place. The loop leads must go to the antenna terminals in sequential order. They will do this naturally if your cable lies flat.

Initial Checkout. Insert the receiver batteries and turn both the *Gain* and *Expansion* controls all the way down. Pull out the *Pull Audio* switch. Bring up the *Expansion* control until the meter reads 0.4 mA. The audio should cut in initially around 0.3 mA. Now bring the gain up. The meter reading should increase only slightly. If it jumps up, you have oscillation problems, which can usually be cured by more careful lead dress. If necessary, try rotating the transformers slightly.

Set the transmitter a few feet away from the receiver, and switch it to *Low*. The receiver should immediately swing off scale and the audio volume should increase. Decrease the *Gain* control on the receiver to obtain a meter reading of 0.7 mA, and adjust the trimmer capacitor in the receiver and in the transmitter to peak the response.

To be sure that your metal locator is at optimum sensitivity, perform these three tests. First, have someone hold the receiver while you hold the transmitter (antenna loops) *parallel* to the receiver, and walk away slowly. Key the transmitter on and off with the switch, as you walk. In the *High* position, there should still be a discernable receiver output beyond 50 feet; in the *Low* position, you should easily get a range of about 25 feet.

Second, assemble the locator, hold the beam sideways (receiver loop facing the horizon), turn the *Gain* up, and adjust the microbalance for a null reading (minimum). Approach a chain-link fence, a truck, or other large metallic body; the meter should show an output when you get within nine feet of the object, and should swing off-scale at seven feet.

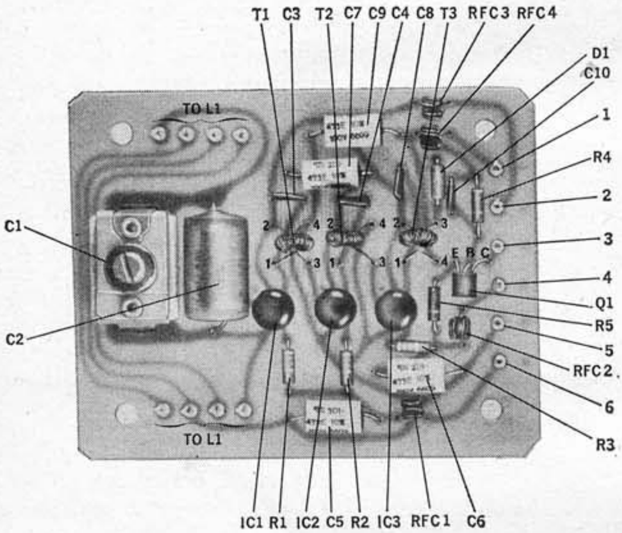


Fig. 12. Component layout in the receiver is critical. You may have to slightly rotate or bend the transformers towards or away from the board to prevent unwanted oscillations. Reverse leads on T3's secondary when connecting it to the board as shown.

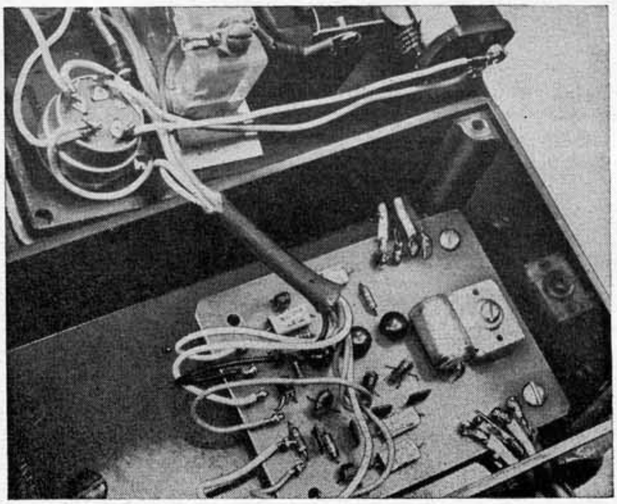


Fig. 13. All r.f. stages in receiver resonate at 455 kHz. Trimmer capacitor tunes the antenna. This is one project where you must stick as close as possible to instructions and not make parts substitutions or compromises.

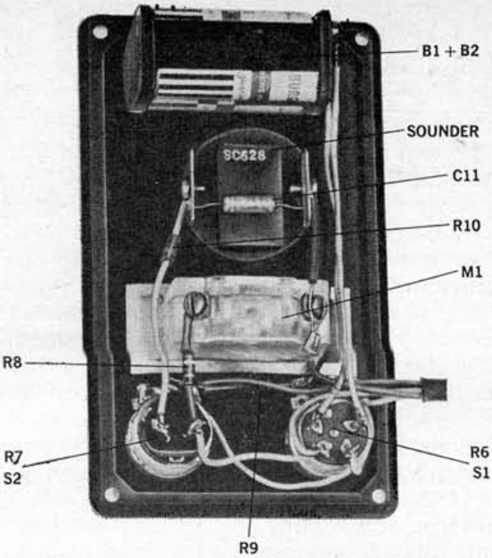


Fig. 14. Sounder, meter controls, and batteries are all mounted on cover of receiver. While most of the space is accounted for, layout is not cluttered.

Third, set the locator on a wooden stool (outdoors) and adjust the microbalance slightly off the null position with the *Gain* control at maximum. Hold a silver dollar or similar-sized piece of metal 4" above and centered on the receiver loop. As you rotate the coin slowly, it should produce at least one division of meter variation.

If any of these tests fail, you'll have to "ring" out the circuit with a good oscilloscope and an r.f. signal generator to find the stage or stages which are either off resonance or malfunctioning. All stages should peak at 455 kHz. You can check the receiver response independent of the receiving loop simply by shunting the loop with a 10-ohm resistor and injecting a signal.

Operating Hints. Become familiar with your instrument and its behavior with known objects before attempting any treasure hunts. Try some sample targets—cookie sheets, pots, coffee cans, water pipes, etc.

You'll find that the microbalance control is best set at *one-half turn clockwise* from the null position to give you maximum sensitivity to changes in field pattern. Any time you change the operating height, you'll have to readjust this control. Normally, you can carry the instrument at arm's length, but for deepest penetration, you should hold it closer to the ground. Once you have located a target, keep backing down the *Expansion* control until your target is just barely detectable—to obtain the sharpest possible "outline."

To find the exact position of a target, approach it from several directions and average out the results. With proper use of the *Expansion* control, you should be able to pinpoint a target to within a few inches. When tracing pipe, always cross the pipe at right angles to get a distinct response. For unknown targets, cover an area first East-West, then North-South, traveling slowly and steadily, and repeating the "dosage" at two-foot intervals.

To test your batteries, turn the *Expansion* control all the way up. The receiver batteries are good if the meter reads at least 0.8 mA. Replace the transmitter batteries if the signal "drops out" in the *Low* position at any time.

Happy hunting. -30-