Project 566

Pipe and cable locator

Finding ring-pulls, bottle tops and assorted junk is fine with your 'garden variety' metal detector, but if you need to find important things like water pipes, phone cables or giant gold nuggets ... you're a candidate for this project.

Phil Wait

The completed instrument. The handle is secured by bolts, to which the knobs are attached, which pass through the handle into threaded receptacles in the case panels. The handle for general use is 1120 mm long overall. We also tried a shortened handle, 610 mm long, which improves sensitivity to small objects, but decreases ground penetration. The webbing strap is an optional refinement, used to lower the unit towards the ground to improve penetration.

THIS INSTRUMENT can be used to locate metal objects buried at considerable depths. Whilst the title, Pipe and Cable Locator, suggests a purely pragmatic use – that of locating buried pipes and cables in order to avoid damaging same when excavating for some reason, the instrument can be used for the same sorts of activities the more familiar metal detectors (or 'treasure hunters') are employed – prospecting. Whilst in the form described here it will not detect the presence of small metal objects – coins, small-sized rubbish or hopefully, small gold nuggets – it will detect larger objects buried up to several metres below the surface, opening up a whole new avenue, perhaps, of mineral or treasure prospecting.

Our pipe and cable locator employs an induction balance technique, where a transmitter and receiver each have the plane of their antennas aligned at a right angle, the receiver picking up a minimum of the transmitted signal until a metal object, brought within the field of the antennas, distorts the field, producing a strong signal in the receiver.

Design

The transmitter and receiver are housed in two plastic cases which have an integral antenna attached around the lip of each. Each antenna loop consists of an aluminium extrusion bent to fit the lip of the case, one loop mating with the other so that the two cases may be clipped together, making the instrument into a single unit for transportation.

The handle has three bolts passing through it, each having a knurled knob on the 'upper' side, as can be seen in the photograph. The handle attaches to the transmitter via a threaded receptacle set into the V-groove in the dividing piece in the case (see photographs). The receiver is attached via two threaded receptacles set into the front panel.

When the two units are mounted on the handle they are positioned such that the planes of the loop antennas are at a right angle. This ensures minimum coupling between them. To permit accurate alignment, one screw is spring loaded – the one attached to the black knob at the forward end of the receiver – and this permits the angle of the receiver to be adjusted over a small range.

The transmitter is quite simple. It consists of an RF oscillator, operating at about 100 kHz, arranged such that it switches itself on and off at about 800 Hz, thus providing a modulated signal.

The receiver seems somewhat more complex, but is quite simple in principle – it has one stage of tuned RF amplification followed by an untuned, direct-coupled amplifier and a class B detector. The bursts of transmitted RF picked up by the receiver are demodulated by the class B detector and fed to a simple audio amplifier.

The class B detector is 'off' until a signal is received. The signal will turn it on, the collector current of this stage (Q5) varying with signal strength. Thus, a meter in series with Q5's collector load serves as a signal strength indicator.

A sensitivity control is arranged to vary the gain of the tuned RF stage and the following amplifier.

Construction

The cases are made of impact-resistant plastic, while the handle is made from an aluminium pipe. The hardware for this project is manufactured by Aegis Pty Ltd who will be making it available to kit suppliers (see Shoparound on page 71 for more details).

The antenna loops are each pop-riveted to the case rims. Connections to the break in each loop are made via solder lugs secured under the pop rivets at these points – this can be seen in the internal photograph of the receiver.

The best place to start is to familiarise yourself with the hardware. The details should be fairly clear from the accompanying pictures. The panels for the transmitter and receiver may be cut from a piece of masonite. The dimensions may be obtained from the inside measurements of the cases. The various cutouts (see the photographs) around the edges should be carefully marked and either cut with a fine fret saw or filed out. The position of the holes through which the securing screws pass should be carefully marked and drilled to a suitable clearance diameter.

Two threaded receptacles have to be mounted on the receiver front panel — these take the bolts on the handle which secure the receiver to the handle, the 'forward' one being spring-loaded to allow the angle of the receiver to be adjusted. These threaded receptacles must be accurately mounted on the centre-line of the panel so that the receiver antenna loop is correctly positioned with regard to the transmitter.

The holes for the meters and switches and the receiver's speaker and sensitivity pot should be drilled out last of all. The position of these components is not all that critical, but follow the general placement indicated in the photographs. Alternatively, Scotchcal front panel artwork may be available (check your supplier) and placement of these components may be taken from the artwork. Radio Despatch Service in Sydney will make up Scotchcal front panels to order.

Construction of the electronics can follow. All components in each unit are mounted from the front panel.

The transmitter is quite simple, using only one active component. The pc board is mounted on the back of the battery test meter to simplify the mechanical construction. Start by assembling the pc board as shown, taking care with the electrolytic capacitors and the transistor. This unit has been specially designed around a germanium transistor and a silicon type *cannot* be substituted.

The pc board has been designed to accept a variety of trimmer capacitors and two different types of pot cores, one a Philips type, the other from Neosid. Both are manufactured by Aegis Pty Ltd. You will see two different circles of holes in the board. The innermost circle accepts the Philips pot core pins, the outermost, the Neosid type. Run the wires to the switch, battery and the loop antenna, keeping the wires to the loop as short as possible to avoid any stray radiation upsetting the field pattern. Twist them lightly.

The meter on the transmitter is only used as a battery indicator and may be more expensive than you wish. It can however be replaced by a LED if the value of R3 is reduced to about 1 kohm. This will increase the current drain from the battery but should not be a problem. If you stick with the meter, either a 100 μA, 200 μA or 1 mA movement can be used by choosing the value of R3 to be 100 k, 47 k, or 10 k respectively. In this case, you will have to mount the pc board on the front panel with standoffs.

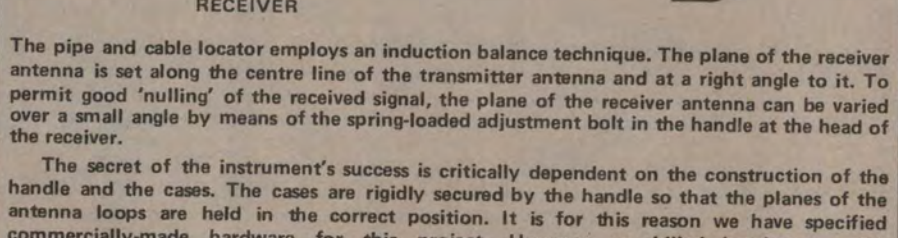
The receiver is quite a bit more complex than the transmitter but as all the components are mounted on the pc board it shouldn't prove too difficult. Watch out for the orientation of the electrolytic and tantalum capacitors. Again, the pc board has been designed to accept a variety of trimmer capacitors and either the Neosid or Philips pot cores.

The meter shown is a 200 μA type. However, if it is unavailable a 100 μA movement can be used. If you do this, increase the value of R17 to 10 k and R18 to 100 k. Note that R18 is mounted off the pc board between the meter test button (PB1) and the power switch (SW1). Keep the leads to the loop as short as possible and well away from the speaker leads. The pc board is mounted behind the meter and held off the front panel with standoffs as shown in the photograph.

Tuning up

After the two units are assembled the oscillator must be adjusted for correct operation and the transmitter and receiver set to the same frequency. Lay the two units on a table about a metre apart and turn them on. By advancing ▶

Overall views of the completed receiver and transmitter. The antenna loops are made to fit together so that the instrument may be made into a single case for transporting. The clips and carrying straps are 'dress up' options. The V-groove visible in the transmitter panel is where the handle sits.



The pipe and cable locator employs an induction balance technique. The plane of the receiver antenna is set along the centre line of the transmitter antenna and at a right angle to it. To permit good 'nulling' of the received signal, the plane of the receiver antenna can be varied over a small angle by means of the spring-loaded adjustment bolt in the handle at the head of the receiver.

The secret of the instrument's success is critically dependent on the construction of the handle and the cases. The cases are rigidly secured by the handle so that the planes of the antenna loops are held in the correct position. It is for this reason we have specified commercially-made hardware for this project. However, a skilled handyman, with imagination, could fashion suitable hardware from wood and chipboard. The antenna loops have to have very low resistance, hence a metal strap is necessary.

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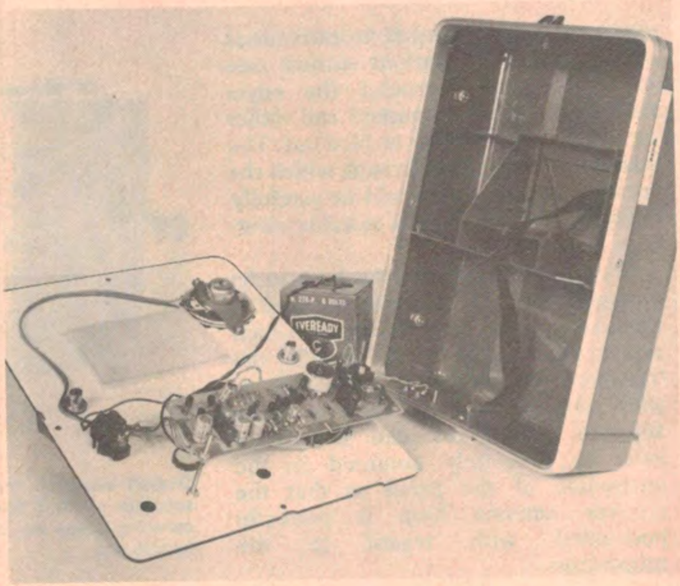
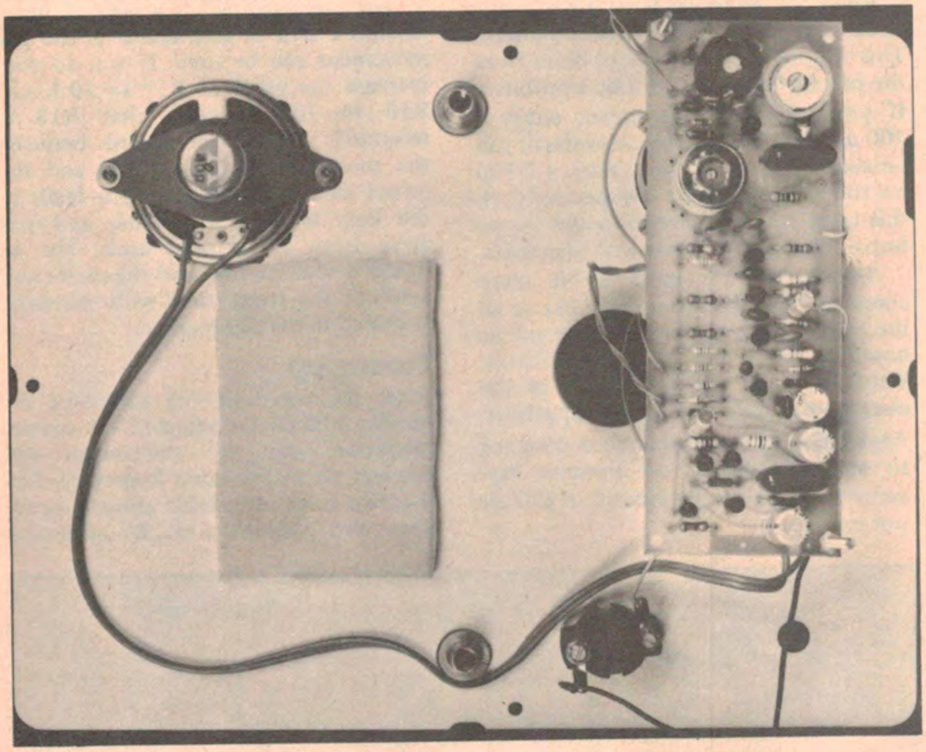




Above left

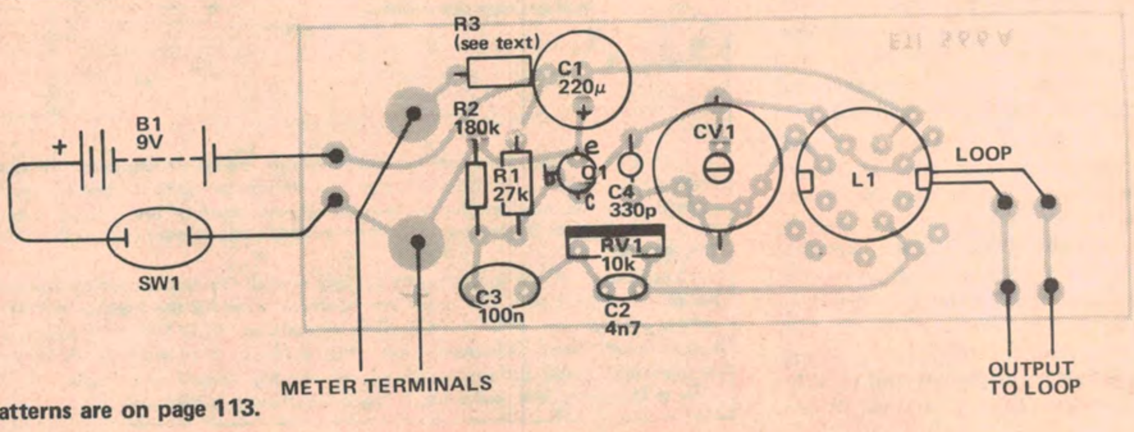
Internal view of the transmitter. We used a pull-on/push-off switch, but an SPST toggle switch will do as well. The pc board we mounted on the rear of the meter, using the terminals to support it. If you elect to dispense with the meter, the pc board may be mounted on a couple of standoffs. The panel is secured with three screws. The case shown here is from an old unit, the cases to be supplied will have a different appearance but function in the same way.

Above right

General view inside the receiver. The receiver and transmitter antenna loops were secured with pop rivets. Each loop has a 'break', with pop rivets securing the loop ends to the case. Under each of these pop rivets is a solder lug making the antenna connection. The transmitter antenna connection is the same.

Left

All the receiver components are mounted from the front panel. The two threaded receptacles — to accept the bolts on the handle — can be seen near the centre of each side of the panel. These must be accurately located along the centre line of the panel. The panel is secured to the case by four screws. The piece of sponge helps to secure the battery. The small cutouts visible on the panel edges provide clearance for the pop rivets securing the loop.



The pc board patterns are on page 113.

the sensitivity control a tone may come from the speaker. If not, adjust the trim pot in the transmitter and the tone should appear. Set the trim pot for a maximum reading on the receiver meter. The oscillator is now working correctly.

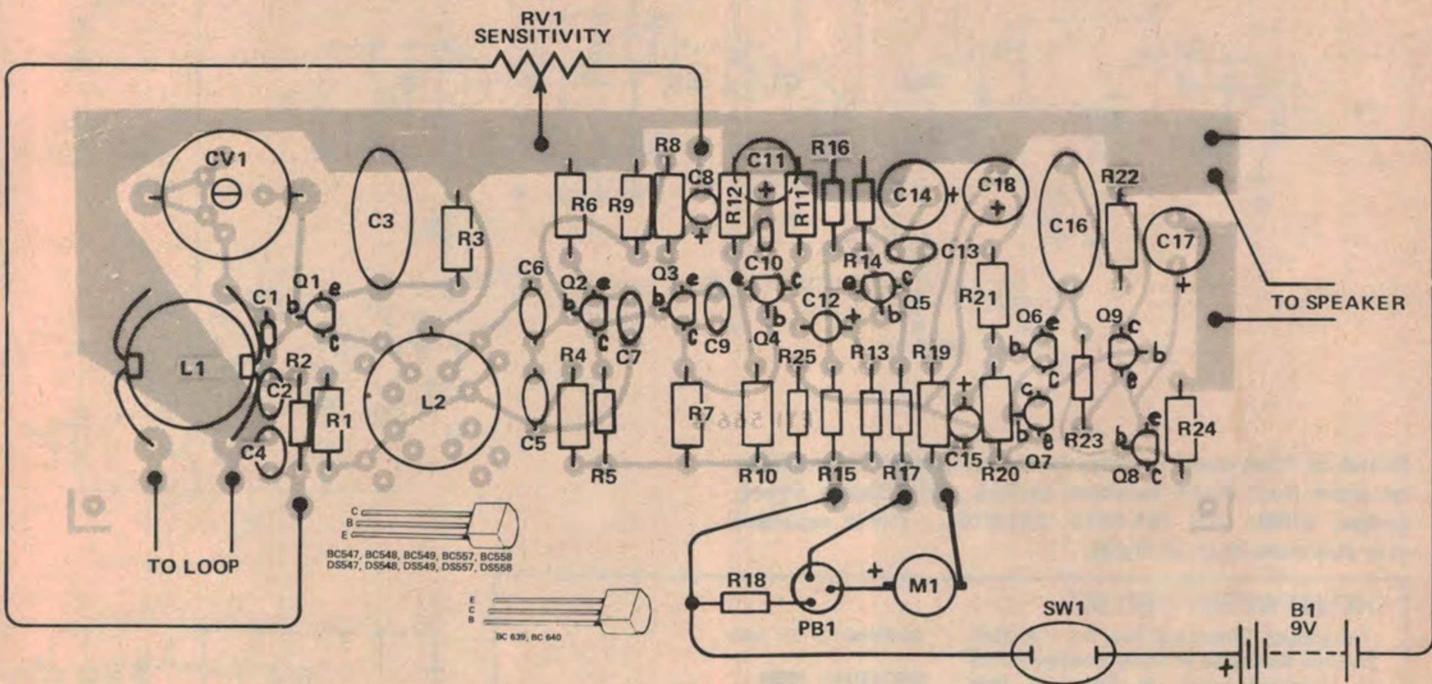
The two units now have to be set to the same frequency. The exact frequency is unimportant so long as they're the same. Lay the two units about two metres apart and set the trimmer capacitor and pot core adjustor on L2 in the *receiver* to half adjustment. Adjust the trimmer in the *transmitter* for a peak in the receiver meter, and then go back to the *receiver* and adjust the trimmer and pot core for a peak in the reading. Be careful when adjusting the pot core not to strain the thread, as it is very fragile.

During the tuning precedure it will be necessary to adjust the sensitivity control for a convenient meter reading. Be careful not to move the cases as this will change the coupling between them, giving a false variation in the meter readings.

How to use it

Condensed instructions have been included on the receiver front panel artwork as a handy reference.

Hold the instrument by the centre of ▶



PARTS LIST - ETI - 566B

Resistors .... all ½W, 5%

R1	4k7
R2	10k
R3	1k
R4	33R
R5	82k
R6	680R
R7	12k
R8	15k
R9	6k8
R10	5k6
R11	33k
R12	22k
R13	10k
R14	220k
R15	150R
R16	10k
R17	4k7
R18	47k (see text)
R19	2k2 (see text)
R20, R21	1M
R22	56R
R23	2k2
R24	470R
R25	150R

Capacitors

C1	330p styroseal
C2	4n7 styroseal
C3	470n greencap
C4	22n greencap
C5	4n7 styroseal
C6	270p styroseal
C7	22n greencap
C8	10u 16V electro
C9	22n greencap
C10	10n greencap
C11	4u7 16V electro
C12	1u tantalum
C13	22n greencap
C14	47u 16V electro
C15	10u 16V electro
C16	470n greencap
C17	100u 16V electro
C18	47u 16V electro

Variable

RV1	1k linear pot
CV1	150p or 100p variable capacitor

Inductors

L1	Aegis S284 pot core
L2	Aegis S282A pot core

Semiconductors

Q1—Q3	BC549, BC109
Q4, Q5	BC559, BC179
Q7	BC559, BC179
Q8	BC639
Q9	BC640

Miscellaneous

M1 - Moving Coil Meter 40mm x 48mm, University TD-48 or similar (see text); SW1 - SPST toggle or pull switch; PB1 - SPST momentary push button; SP1 - Eight ohm speaker approx 55mm dia.; Aegis box to suit, nine volt battery type 276P, ETI 566 pc board, knob, standoffs.

PARTS LIST - ETI 566A

Resistors .... all ½W, 5%

R1	27k
R2	180k
R3	see text
RV1	10k trimpot

Capacitors

C1	220u electrolytic
C2	4n7 greencap
C3	100n greencap
C4	330p styroseal or silver mica
CV1	150p compression trimmer

Semiconductors

Q1	AC128

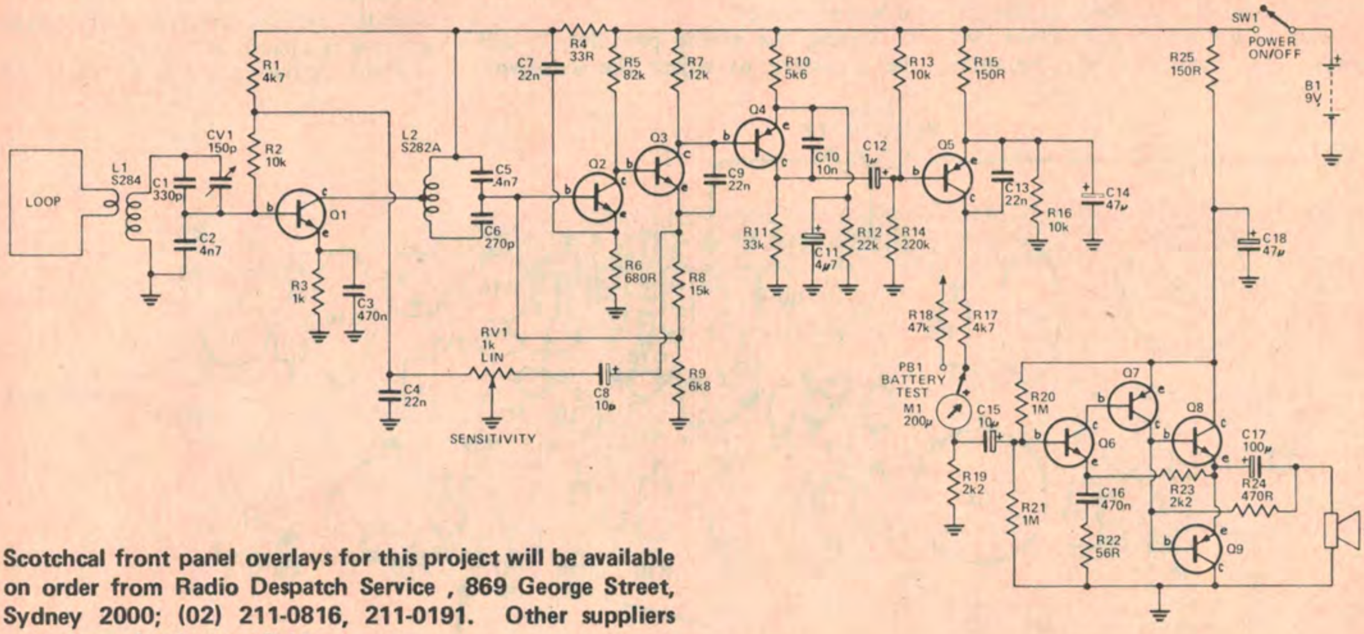
Miscellaneous

ETI-566A pc board; L1 - Aegis S283B; battery, 9V 276P Eveready, transmitter case, front panel; M1 - see text, nuts, bolts and special handle (see 'Shoparound' on page 71 for details on the hardware).

the bar with the receiver in front of you. The instrument should be held at arm's length, parallel to the ground. The operator's body should be midway between the two units. Wind the adjusting screw fully in (clockwise), and turn the two units on; Advance the sensitivity control to about ¾ range and a tone should appear. Wind the adjusting screw out (anti clockwise) until the tone disappears and continue turning the adjuster in the same direction until a slight indication is shown on the meter. The instrument is now ready to operate.

Walking over a buried object will cause a meter deflection and a sound from the speaker. Make sure when you are adjusting the instrument that there are no buried objects, cars, fences or pipes nearby to upset the balance.

To accurately pin-point the location



Scotchcal front panel overlays for this project will be available on order from Radio Despatch Service , 869 George Street, Sydney 2000; (02) 211-0816, 211-0191. Other suppliers may also make them available.

HOW IT WORKS – ETI 566

The general principle of how the induction balance technique of metal location works is explained earlier in the text. This description will be confined to the electronics.

TRANSMITTER 566A

Transistor Q1 is operated as a self-modulating RF oscillator. To provide RF output, Q1 and the tuned circuit – L1, C4, CV1 – are connected as a modified Hartley oscillator operating at around 100 kHz. The feedback has been arranged so that the oscillator "squeggs" at a frequency around 800 Hz, modulating the transmitted signal.

After power is applied, the circuit will oscillate at the frequency determined by the tuned circuit and C2-C3 will charge up via the rectifying action of the base-emitter junction of Q1. When this is sufficient to reverse bias the b-e junction of Q1, the RF oscillation will cease and C2-C3 will commence to discharge (via the bias resistors and RV1). Eventually, Q1 will turn on again and RF oscillation will commence once again and the whole process will repeat.

The transmitter signal is coupled to the loop antenna via a winding on L1. The trimpot, RV1, provides control over the feedback. The meter is used both as an on/off indicator and a battery level indicator. An LED may be substituted as explained in the text.

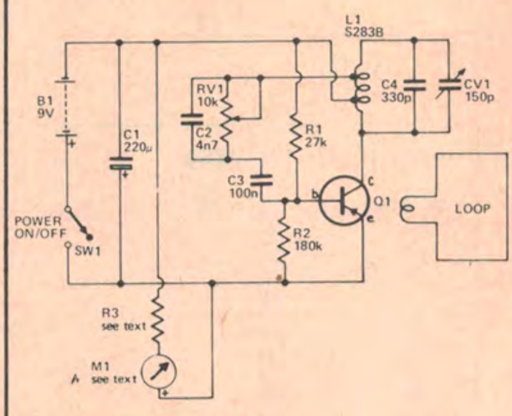
RECEIVER 566B

This consists of a single tuned RF amplifier stage followed by a broadband, direct-coupled amplifier and a class-B detector. A simple audio amplifier provides output to a loudspeaker.

The receiver antenna loop is coupled to the first tuned circuit, L1, via a link winding. The base of Q1 is impedance-matched to the tuned circuit via a capacitive 'tap'. The collector of Q1 is matched to the second tuned circuit, L2, by tapping down the coil.

A three stage broadband, direct-coupled amplifier follows L2. The base of Q2 is impedance matched to the second tuned circuit by a capacitive tap once again. Some negative feedback is provided by C7. Sensitivity is varied by simultaneously varying the base bias of Q1 and the emitter bypassing at Q3. Gain is maximum when the wiper of RV1 is at the end connected to C8.

Transistor Q5 is biased so that it is not quite turned on. When a signal appears at the end of the amplifier chain (collector of Q4), Q5 will turn on, the base-emitter junction rectifying the signal, the modulation then appearing at the collector. As the signal strength increases, Q5 will turn on harder, thus the collector current may be used as an indication of signal strength.



Resistors R17 and R19 (plus the meter) form the collector load of Q5. Audio is tapped off via C15 and passed to the audio amplifier.

The audio amplifier employs a complementary-symmetry output stage (Q8, Q9), transistors Q6 and Q7 being configured as a modified Darlington driving stage. The frequency response is 'peaked' with the RC network of C16 and R22. Feedback from the output to the input is provided by R23 and feedback around the output stage is provided by R24. Any small speaker having an impedance between 8 ohms and 40 ohms may be used.

of an object, cross it from each side and with your heel, mark the position on the ground where the signal is strongest. The object will be located mid-way between the two heel marks.

Something can be learnt about the shape of an object by passing over it from different directions. Obviously a pipe will be easy to identify because it will run along the ground for a long way. Other objects will appear more symmetrical.

Careful operation of the sensitivity control can help accurately locate an object. Having located something with the instrument set at the normal settings (as described above) reduce the sensitivity a small amount and repeat your crossing of the location. The signal will be heard over a much smaller distance. This method is useful for separately locating closely adjacent pipes.

Greater depth penetration can be obtained by lowering the instrument to the ground by means of a strap attached to the handle. One is shown with the instrument in the photograph on the first page of this article. The instrument is first adjusted as per normal, then lowered to the ground as close as you can go without upsetting the receiver indication. The instrument should be held so that the receiver is angled a little downward. It may be necessary to reduce the sensitivity slightly.

The best way to get used to the instrument is to experiment with known buried objects. You will note that objects which are only at a shallow depth give a maximum indication when they are directly beneath the receiver. Objects buried more deeply give a maximum indication when they are about midway beneath the transmitter and receiver.

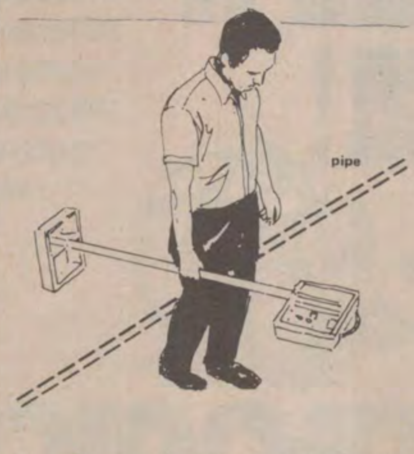
The two units may be operated separate from the handle to locate the direction of a pipe, lateral pipes and bends. The accompanying diagrams show how to use the instrument in this mode.

Newly buried objects can be difficult to locate as they give a poor indication. The detectability of an object improves with time as the soil surrounding the object compacts and corrosion improves the soil conductivity.

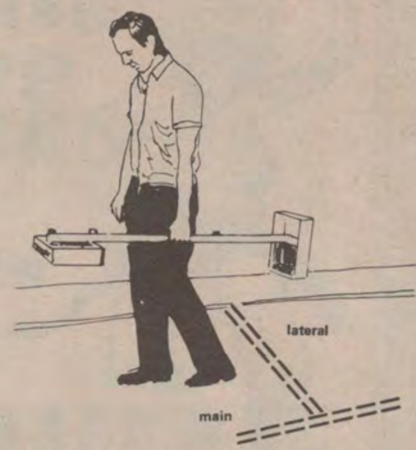
When operating in conductive soils (heavily mineralised), you will need to reduce the sensitivity and adjust the null as previously outlined.

As with any instrument, it takes practice and experience to be able to use it effectively. ●

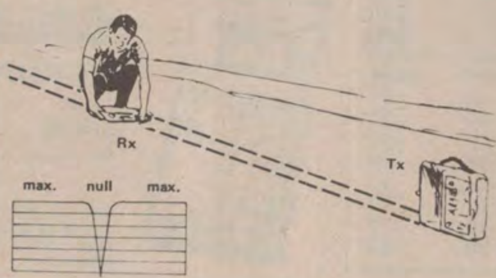
LOCATING PIPES AND CABLES



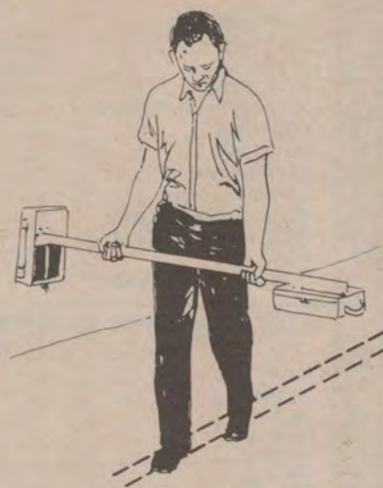
General use of the instrument. With the receiver correctly adjusted for a null, proceed along a line, or parallel lines, until an indication is received. For accurate location, cross the indication point from each side and mark with your heel where the indication is strongest. The location of the buried object is between the two marks.



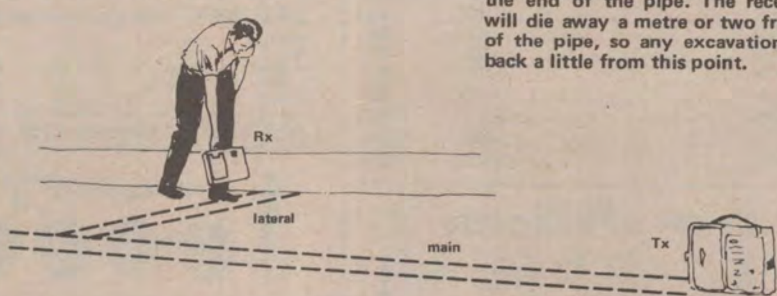
Locating a lateral pipe that joins onto a main. Having determined the direction the main runs, walk parallel to it, several metres away. Lateral pipes will produce an indication in the receiver.



Locating the direction a pipe runs using the separated transmitter and receiver. The transmitter is stood up such that the plane of the antenna runs roughly in the pipe's expected direction. With the receiver held horizontal, go about 10 metres away and pass the receiver back and forth to find a null. A very sharp null will be found. The position of the minimum pinpoints the centre line of the pipe. Moving the transmitter and receiver successively along the line determined will locate the full course of the pipe.



Locating the end of a pipe. Having determined the position of the pipe, hold the instrument as shown — the received signal will be quite strong until you pass the end of the pipe. The received signal will die away a metre or two from the end of the pipe, so any excavation should be back a little from this point.



Locating a lateral pipe with the receiver and transmitter separated. Using this method, with the receiver held vertical, a peak indication is obtained over the location of the lateral pipe. Bends can also be found in this manner.