Lab Notes

The ETI-566 Metal Detector Revisited

This project, published in the April 1980 issue, has proven to be pretty popular amongst experimenters who have clamoured for more complete construction details. Your patience is herewith rewarded!

IT SEEMS from correspondence that this project has been popular amongst experimenters. We have been asked to give more details on the unit and/or alternative construction etc. There have also been problems with component supply, particularly the coils. This Lab Notes gives details, for the experimenter, of alternative construction arrangements, coil details and suggestions on different configurations to make the unit more sensitive to small objects.

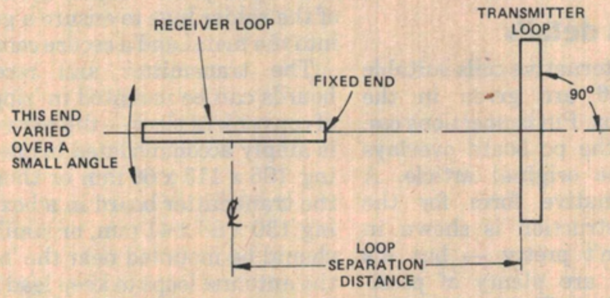


Figure 1. **The 'Induction Balance' principle employed in the ETI-566**

Notes on the principle of operation

First of all, to be able to experiment with the construction of the instrument, it is useful to know something of the principle of operation. As explained in the original article, the unit employs an *induction balance* technique. As illustrated in Figure 1, the transmitter antenna loop and the receiver antenna loop are located with their planes at right angles and a small distance apart. This provides the minimum induction of the signal from the transmitter loop into the receiver loop as there is minimum magnetic coupling between the two. To permit accurate alignment, the receiver antenna loop can be varied over a small angle.

The transmitter puts out a pulsed signal at 20 kHz. The pulsing is principally to provide a modulated signal for the receiver that may be demodulated and put through a speaker or headphones for the convenience of the operator. The pulse repetition frequency may be set to some convenient pitch in the audio range between about 200 Hz and 1.5 kHz.

The alignment of the antennas is adjusted such that, with no metal object within the field of the instrument, there is minimum (or no) received signal.

The receiver is tuned to the *third* harmonic of the transmitter, i.e.: 60 kHz. This provides better sensitivity than if it were tuned to the transmitter at 20 kHz. It seems to work like this: the transmitter is deliberately designed to have a considerable harmonic content in its output. The inductive coupling between the antenna loops is greater at the third harmonic than it is at the fundamental frequency, but ground penetration is better at 20 kHz than 60 kHz as the ground resistivity increases with frequency. The transmitter antenna loop is oriented vertically to give maximum ground penetration of the transmitted signal and maximum induction into buried metal objects.

With the instrument near the ground, the effect of the ground on the field patterns of the two antennas will result in some distortion of their fields but this can be compensated for by realigning the receiver antenna for a null (minimum signal).

When a buried metal object is encountered, eddy currents induced in the object will cause a distortion in the field pattern of the transmitter antenna. As the antenna is tightly coupled to the oscillator, this will also bring about a distortion in the field pattern of the antenna at the harmonic frequencies. This will increase the coupling between the transmitter and receiver antenna loops and a signal will be heard in the receiver.

Metal objects buried close to the surface will affect the field pattern of both antennas, but deeply buried objects will primarily influence the transmitter antenna field.

The 'depth sensitivity' of the instrument is dependent on a number of ▶

Lab Notes

LEFT: 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.

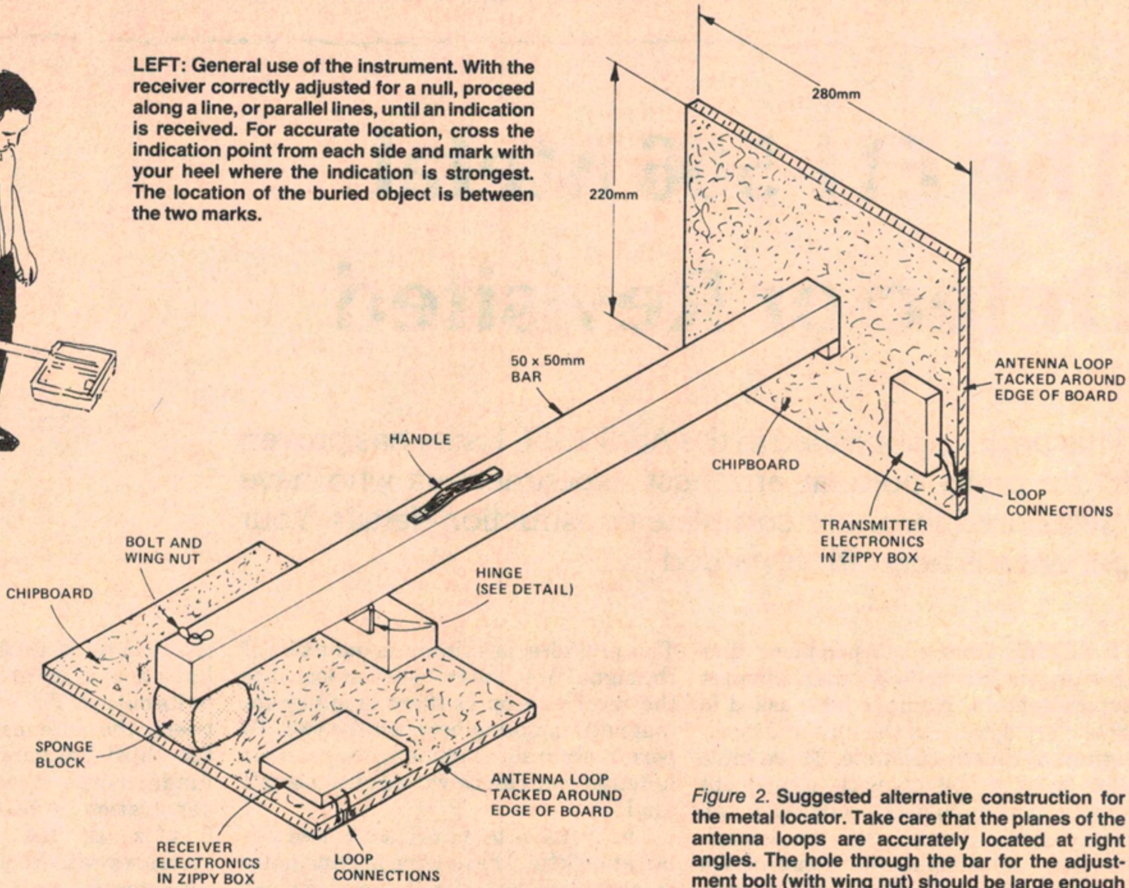


Figure 2. **Suggested alternative construction for the metal locator. Take care that the planes of the antenna loops are accurately located at right angles. The hole through the bar for the adjustment bolt (with wing nut) should be large enough to clear the bolt when the receiver baseboard is fully angled towards the bar.**

factors — primarily the 'loop separation distance' (see Figure 1), the size of the antenna loops, the power of the transmitter and the sensitivity of the receiver. Ground mineralisation also affects sensitivity and penetration.

The ability of the instrument to detect small objects depends largely on the loop separation distance and the size of the loops. Smaller loops and closer spacing improve the unit's sensitivity to small objects, but at the expense of penetration.

Constructed to the dimensions illustrated, a football-sized object can be detected at depths as great as two to five metres, depending on ground mineralisation and how long it has been buried. Small diameter pipes can be readily detected at depths of one metre below ground level.

As a matter of interest, the principle of operation is some 50 years old! Following the April article a reader sent us a clipping from a popular electronics magazine, describing a similar instrument, published in the 1930s!

Alternative construction details

Full details of alternative coils suitable for the ETI-566 are given in the accompanying box. Pin connections can be taken from the pc board overlays published in the original article. A suggested alternative form for the mechanical construction is shown in Figure 2. It ain't pretty — but it's practical! There are plenty of possibilities — which we'll leave to your ingenuity — but keep the basic principles in mind.

Two pieces of chipboard, 15 - 19 mm thick, serve as bases to mount the antenna loops. The latter are made from aluminium (or copper — if you can afford it!), as shown in Figure 3, and tacked around the edge of each board. The connections to the loops should be as good as you can make them to ensure low resistance contact. Solder lugs pop-riveted to the edge of the loops at the 'break' make good connection, or you could use pk screws and solder lugs — with shakeproof washers on both sides of the solder lugs to ensure a good 'bite' into the metal and a secure connection.

The transmitter and receiver pc boards can be mounted in 'zippy' boxes of convenient sizes — the receiver board is amply accommodated in one measuring 196 x 113 x 60 mm or thereabouts, the transmitter board in a box measuring 130 x 68 x 41 mm, or similar. They should be mounted near the 'breaks' in the antenna loops to keep lead length to the loops as short as possible. Twist the leads.

The wooden bar which holds the two chipboard antenna bases could be a length of 50 x 50 mm dressed western red cedar (to minimise warping). Alternatively, you could us a length of square-section aluminium tubing. Overall length of the bar should be about one metre for best depth penetration with this arrangement (the original project used a handle measuring 1120 mm). However, there is plenty of room to experiment. All wooden parts should be sealed and painted or given several coats of 'Estapol' or similar clear lacquer finish to preserve them from the effects of the weather. Do this prior to final assembly.

The hingeing arrangements for the receiver antenna baseboard are shown in Figures 2 and 3. An 80 mm length of 50 x 50 mm dressed timber is chamfered as indicated and fixed to an edge of the receiver baseboard, in the centre. A hole is drilled in the middle of the opposite side, just smaller than the outside diameter of a ¼" Whitworth nut. The nut is forced into this hole. A corresponding hole is drilled in the bar. A ¼" Whitworth bolt, 6" (150 mm) long, with a wing nut screwed up to the head, is passed through the bar and into the nut in the receiver baseboard. A block of sponge rubber serves as a 'spring'. The diagram in Figure 2 makes it all clear.

A brass hinge is fixed to the chamfered block and the underside of the bar, as illustrated in Figure 3.

The transmitter baseboard is mounted flush on the end of the bar. Note that this end must be cut as square as possible. The underside of the bar is 60 mm above the *horizontal* centre line of the baseboard. Fix the baseboard to the bar with a single long wood screw. This allows you to rotate the transmitter antenna to achieve correct alignment. The small block shown under the bar, against the transmitter baseboard, is glued in place after the antenna is aligned. ▶

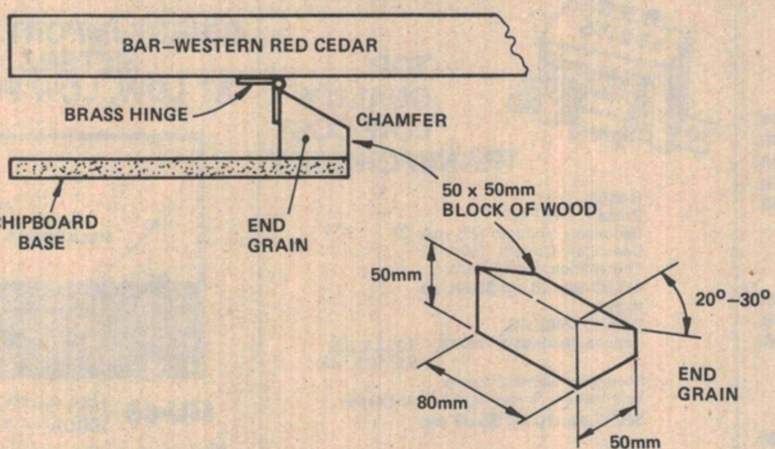


Figure 3. **Hingeing arrangement for the receiver antenna baseboard.**

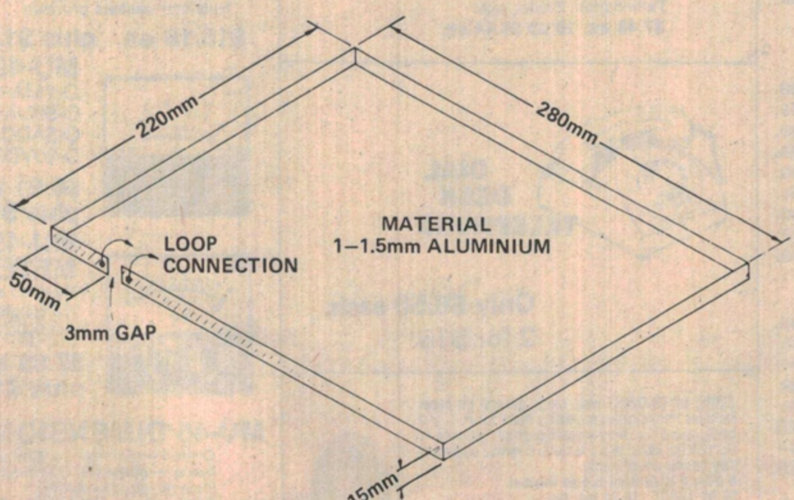
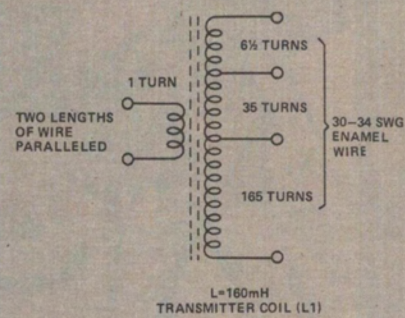


Figure 4. **Dimensions of the antenna loops. The 'break' for the loop connections need not necessarily be as indicated here, but could be located at a corner or midway along one side.**

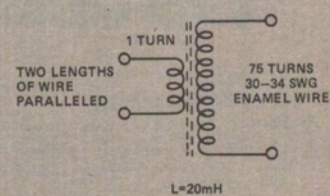


ETI-566A (Tx) — L1

Inductance — 160 mH. Wound on pot core assembly, primary and secondary turns and tappings as illustrated above. Pot core is Philips type P18/11, 3H1 material, ungapped with two-section bobbin, can and tag plate.

Part Numbers

Pot core —	4322 020 2150
Bobbin —	4322 021 30280
Can —	4322 021 30530
Tag plate —	4322 021 30450

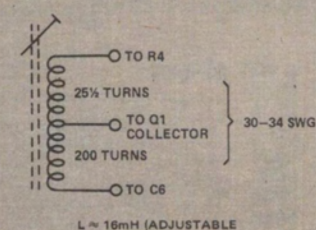


ETI-566B (Rx) — L1

Inductance — 20 mH. Wound on pot core assembly, turns of primary and secondary as illustrated above. Pot core, Philips type, P18/11, 3H1 material, ungapped with two-section bobbin. This assembly is bolted to the pc board through the central hole.

Part numbers

Pot core —	4322 020 2150
Bobbin —	4322 021 30280



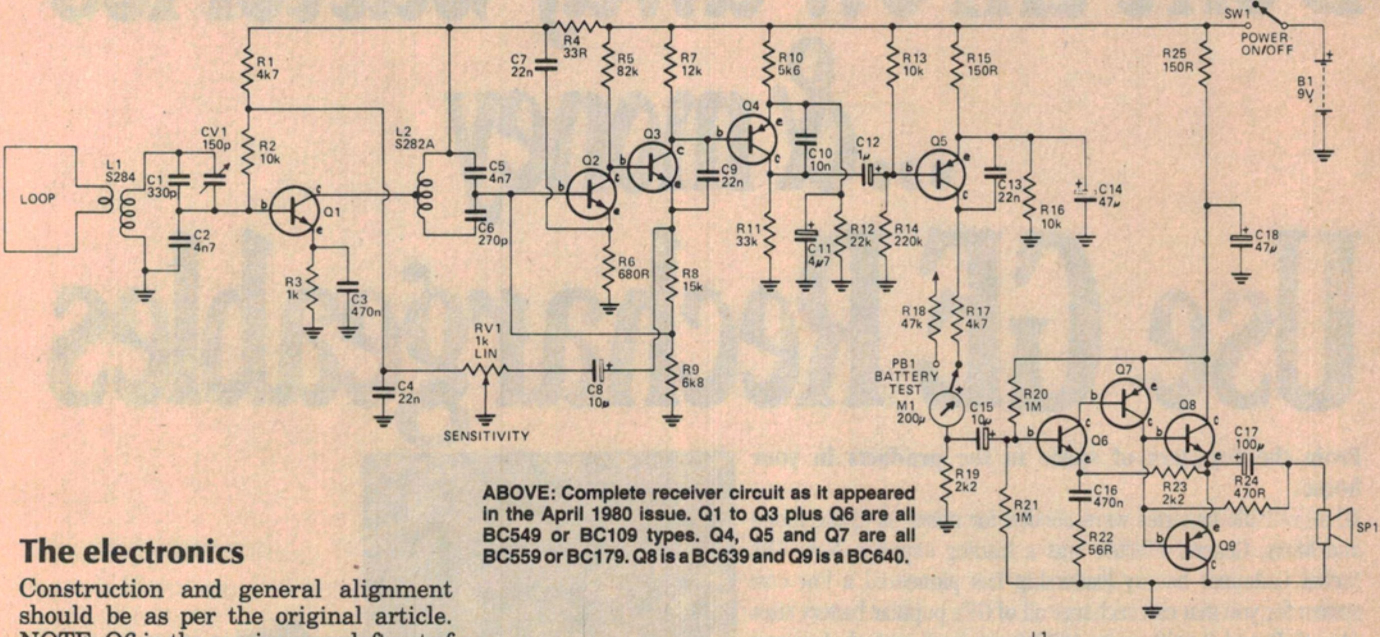
ETI-566B (Rx) — L2

Inductance — approx. 16 mH, adjustable. Wound on pot core assembly, turns and tappings as illustrated above. Pot core, Philips type, P18/11, 3H1 material (μe = 150), with single-section bobbin, adjuster (colour-coded white), can and tag plate.

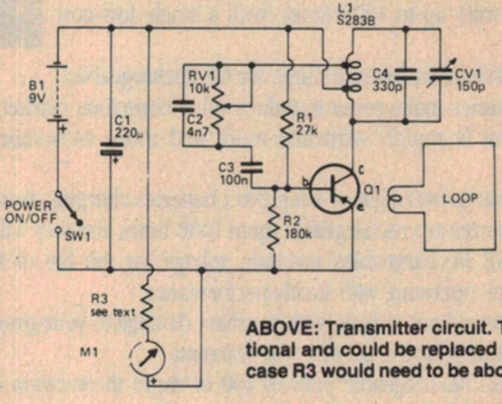
Part numbers

Pot core —	4322 022 24270
Adjuster —	4322 021 32130
Bobbin —	4322 021 30270
Can —	4322 021 30530
Tag plate —	4322 021 30450

Lab Notes



ABOVE: Complete receiver circuit as it appeared in the April 1980 issue. Q1 to Q3 plus Q6 are all BC549 or BC109 types. Q4, Q5 and Q7 are all BC559 or BC179. Q8 is a BC639 and Q9 is a BC640.



ABOVE: Transmitter circuit. The meter, M1, is optional and could be replaced with a LED, in which case R3 would need to be about 270 or 330 ohms.

The electronics

Construction and general alignment should be as per the original article. NOTE: Q6 in the receiver was left out of the original parts list — it is a BC549 or BC109. Coil details are given in the box on page 53. Note that, as these coils are jumble wound on the formers they will have greater self-capacitance than those specified for the original instrument. This will result in some variation in the tuning but there should be sufficient adjustment in the trimmer capacitors in the transmitter and receiver and the core adjuster in L2 in the receiver. If any difficulty is experienced, C4 in the transmitter and C1 in the receiver could be reduced to 270 pF each. In addition, C6 in the receiver could be reduced to 220 pF.

The trimpot (RV1) in the transmitter should be set at mid-point resistance prior to alignment and adjusted to produce a suitable pitch in the receiver after the initial alignment.

As for batteries, a No. 2362 or 2364 9V battery may be used in the receiver with the size box suggested, while a No. 2362 battery will fit in the box suggested for the transmitter. Alternatively, No. 216 size 9V batteries may be used, but they won't last too long with prolonged use. (Alkaline types in this size might be ok, though).

Antenna alignment

Following initial alignment of the electronics, the antenna baseboards can be attached to the bar and the transmitter antenna aligned. Standing well clear of metal objects (at least 5 - 6 metres) align the receiver baseboard such that it is parallel with the bar. Turn on both units and adjust the receiver sensitivity to obtain a convenient indication on the meter. Rotate the transmitter baseboard to get minimum received signal, adjusting the sensitivity if necessary. Tighten the screw securing the transmitter baseboard. Check that you can get a good null with the receiver baseboard adjusting screw; the receiver sensitivity should be advanced at least 3/4 at the point of minimum signal. If so, glue a small block of wood in place, as per Figure 2, on the underside of the bar where it meets the transmitter baseboard.

That's it. Happy hunting!

Experimentation

The following details are suggestions for the dyed-in-the-wool experimenter. The instrument can be constructed to improve sensitivity to small objects by decreasing the 'loop separation distance' (see Figure 1). We tried a bar only 600 mm long and found the unit would detect a small bunch of keys at about 300 - 400 mm. However, the alignment of the receiver antenna is much more critical.

Smaller antenna loops will improve sensitivity to small objects, at the expense of penetration, as discussed earlier. This, combined with closer spacing, should provide a good starting point for further experimentation. Indeed, a number of units could quite easily be constructed, sharing a common bar perhaps, with different antenna loop dimensions. Incidentally, the loops need not be square or rectangular, but could be circular.

With close-spaced loops, the receiver ▶

Lab Notes

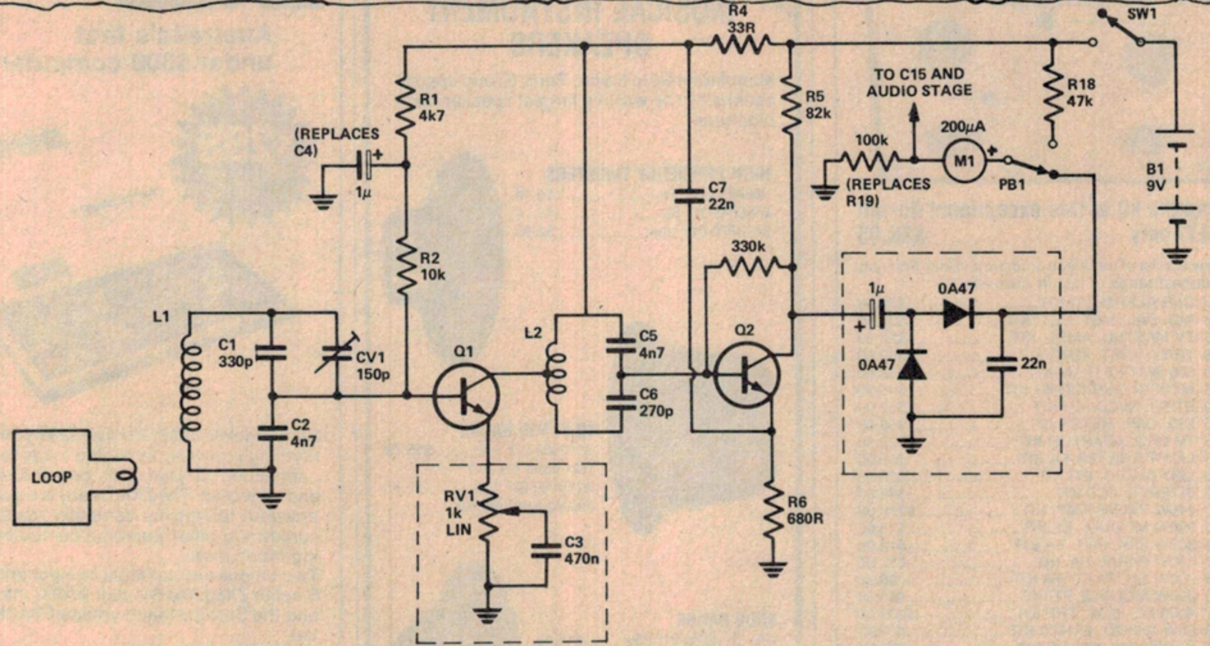


Figure 5. **Suggested alternative for a simpler, lower gain receiver. This may prove a better proposition where small, close-spaced antenna loops are used. The original pc board may be used, the unnecessary components being removed. Major changes are shown inside the dashed squares. A voltage doubler diode detector is coupled directly from the collector of Q2, its output being taken to the pushbutton PB1. R19 is replaced with a 100k resistor; the original audio stage is retained. If you only want to use headphones, the audio stage could be removed also and the phones (Hi-Z) capacitively coupled to the 100k resistor. The construction should be arranged so that there is only a short lead between the gain pot (RV1) and the emitter of Q1. Mount C3 on the pot. Note that C4 is replaced with a 1uF tantalum capacitor.**

may be over sensitive. A modified circuit is suggested in Figure 5. The original pc board may be used but only the first two stages involving Q1 and Q2 are necessary, along with some of the original components. Major changes are shown in the dotted lines. The gain control is shifted to the emitter of Q1 and provides various amounts of degeneration as the bypass capacitor, C3, is connected across a greater or lesser part of the emitter resistance of Q1, formed by RV1. Greatest gain is provided when C3 is connected across the whole of RV1.

A simple half-wave voltage doubler diode detector is coupled from the collector of Q2. A 330k bias resistor is connected between base and collector in this circuit as Q2 in the original circuit had the base bootstrapped to the emitter circuit of Q3 (now removed).

This circuit should provide a stable receiver of adequate sensitivity for close-spaced antenna loops.

As suggested in the original article, lowering the unit closer to the ground from the natural carrying position at arm's length improves penetration. However, it upsets the alignment of the receiver antenna a little and you have to stoop down and re-adjust it. Carrying the instrument in this position is a pain in the . . . whatever . . . so if you can devise some method of carrying it such that the antennas are placed closer to the ground, results can be improved. A strap for this purpose was shown with the original unit and is certainly effective, though it's "fiddly" to adjust the receiver antenna alignment. An extra attachment could be fashioned to perform the same task. We'll leave that to your ingenuity, once again — *but it must not be metal.*

When using the unit close to the ground, it is generally most effective if the bar is not horizontal, but tilted forward slightly so that the receiver antenna is angled towards the ground.

From here on in, it's up to you. Good luck! ●

CONDENSED INSTRUCTIONS

1) Set receiver angle adjustment fully clockwise so that the front of the receiver is close to the bar. Keep away from cars, fences and metal objects when setting up the instrument.

2) Turn on receiver and set the gain to about 3/4 range.

3) Turn on transmitter. A loud tone should be heard in the receiver.

4) To adjust the instrument, hold it level at normal arm length beside your body. Adjust the receiver angle until no tone is heard and/or no meter reading is obtained. Continue adjusting the receiver angle in the right direction until a slight indication is obtained. The instrument is now ready for use.

5) If a correct 'null' cannot be obtained, check you aren't near a metal object and then reduce the sensitivity control.

6) To locate metal objects, proceed along a series of parallel lines until an indication is received. To accurately locate the object, cross this indication point from each direction along your line and mark, each time, with your heel where the indication is strongest. The object will be midway beneath the two marks.