

Assembly Manual for the

VHF Gasfet Preamp

K-6311

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HIT



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Here's a 'sister' unit to the UHF GaAsFET preamp, designed to lift receiver front-end performance, particularly if you find it necessary to run a long length of feedline between your antenna and your rig.

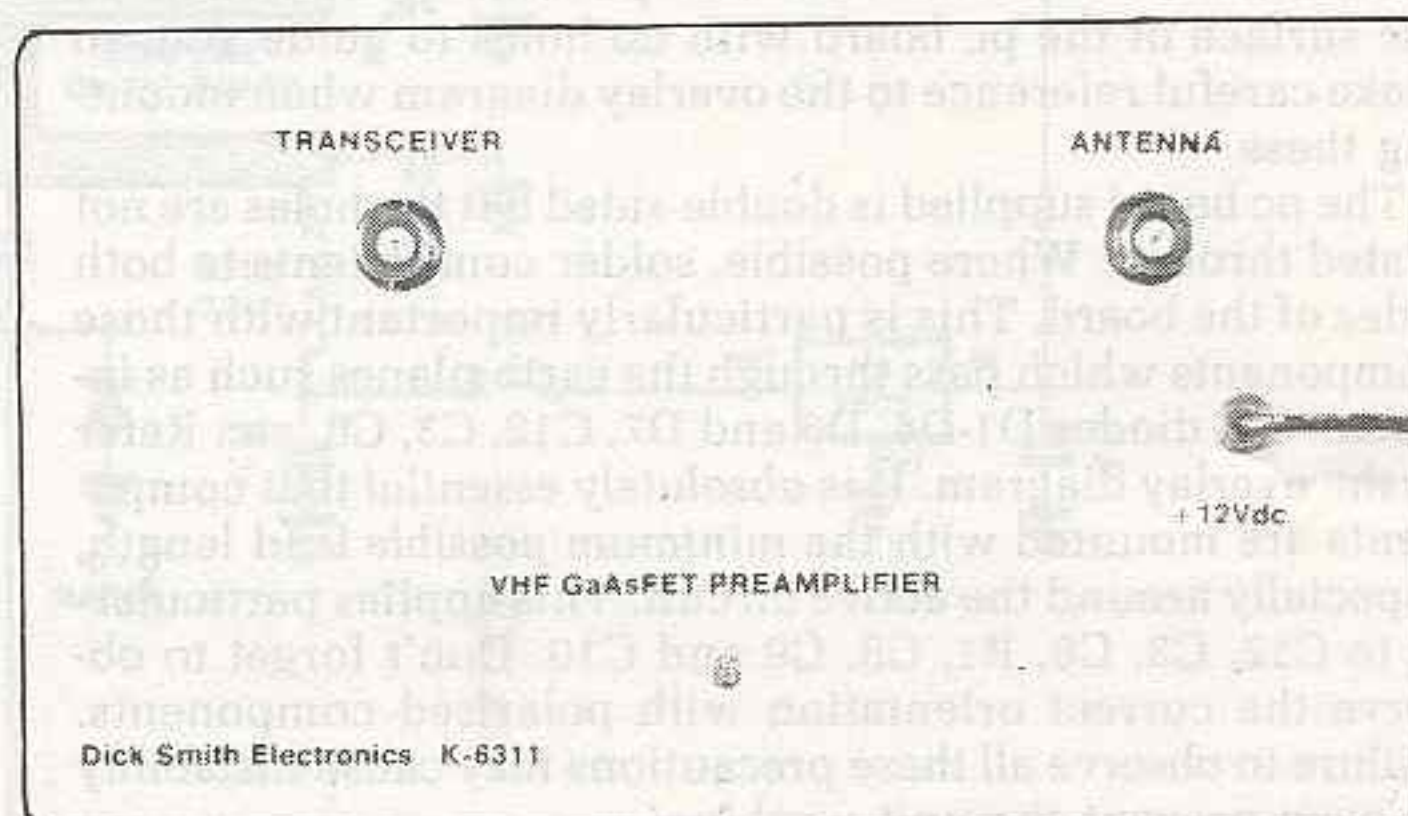
RECEIVER FRONT END noise figure is a major factor in any VHF station 'system performance'. Two things, primarily, determine front end noise figure: feedline loss between the antenna feedpoint and the receiver input, and the noise factor (or noise figure) of the device employed in the first RF stage. Feedline loss between the antenna and the receiver input can be minimised by mounting the first RF stage as close as possible to the antenna feedpoint. Employing a low noise device for the RF stage is the next step. Unless your transceiver or receiver has a demountable front end, you've got a problem. The solution is to employ an 'outboard' RF stage, or preamp.

Two decades ago, the 'vogue' low noise RF amp devices employed for low noise applications on two metres were either a 416B 'lighthouse' tube (valve or 'bottle'), so-called because of its shape, or a 6CW4 'nuvistor' — also a vacuum tube of special construction. They could achieve noise figures of around 2-3 dB when run-of-the-mill front end noise figures were twice that.

These days, noise figures around 1 dB, or less, are regarded as pretty well state-of-the-art on the 144-148 MHz band. But station system performance below 200 MHz, for terrestrial working, is ultimately limited predominantly by atmospheric and man-made noise and this sort of noise figure will pretty well ensure your performance exceeds that. However, for satellite and other space applications, a 1 dB or better noise figure is a distinct advantage and the 3SK121 GaAsFET, with a typical noise figure of 1.5 dB at 800 MHz, falling to under 1 dB at lower frequencies, readily achieves the required performance — and at modest cost.

Design consideration

As pointed out at the head of the article, there are good reasons to mount a low noise preamp as close as possible to the



The preamp is housed in a diecast aluminium box which is mounted as close as possible to your antenna. Note the dc supply lead entering the box at right.

antenna. Firstly, why have a preamp at all? Many operators would be surprised at the noise figure offered by some commercial transceivers — especially the older models. It is the first stage of a receiver which largely determines the overall noise figure. If you added a preamp having a 1 dB noise figure ahead of a receiver with a 4 or 5 dB noise figure (not uncommon!), the resulting noise figure is only slightly higher than the noise figure of the preamp itself. Thus, you can gain quite a worthwhile increase in the signal-to-noise ratio (S/N) of received signals, particularly with FM reception where a 2 dB increase in S/N can mean the difference between a 'scratchy' signal and full quieting!

It is a popular misconception that a preamplifier fitted inside a transceiver will achieve a similar performance. This is borne out by the number of operators who use the recent breed of RF power amplifiers with in-built GaAsFET receive preamps. These can be considered a singularly useless device when trying to achieve low noise figures, unless mounted at your antenna, the reason being that feeder loss is ignored.

If you had a 15 metre (about 50 feet) run of RG58 coax between your preamp/power amp and your antenna, this would introduce a loss ahead of the preamp of around 2.9 dB as RG58 has a loss of about 5.8 dB/30 metres. This loss just adds to the noise figure of the in-built preamp which have typically quoted noise figures of under 1 dB. You would thus end up with a noise figure in excess of 3 dB. Solution — put the preamp up the pole! Better yet, use better quality coax!

Another misconception with preamplifiers is "the more gain they have the better". This is not necessarily true. As can be seen from the above, decreasing the noise figure will

give an increase in the signal-to-noise ratio. There is not much point in simply amplifying a signal if you are also amplifying the noise as well, you just get a louder signal and louder noise — no change in the ration of signal-to-noise. Too much gain can also introduce instability in an otherwise stable receiver.

The amplifier described here has a gain of around 15 dB at 146 MHz, which should be more than adequate for most applications.

Construction

As with the UHF unit, this preamp employs a double-sided printed circuit board with fibreglass substrate and a solder mask for ease of construction. The GaAsFET output matching circuit is a stripline etched on the pc board, as can be seen in the accompanying overlay and photograph. In addition, the input and output coupling lines running to the relays RLA and RLB are 50 ohm striplines. Thus, the pc board is an integral part of the design. The artwork is reproduced elsewhere in the article for reference. Note that it is copyright to Dick Smith Electronics.

The construction of the board is quite straightforward. First, make a visual check that all the required holes are drilled and of the right size. Components may be mounted in any order but it is preferable to leave Q3, the 3SK121 GaAsFET, till last. Note that some components are mounted on the surface of the pc board with no holes to guide you, so make careful reference to the overlay diagram when mounting these.

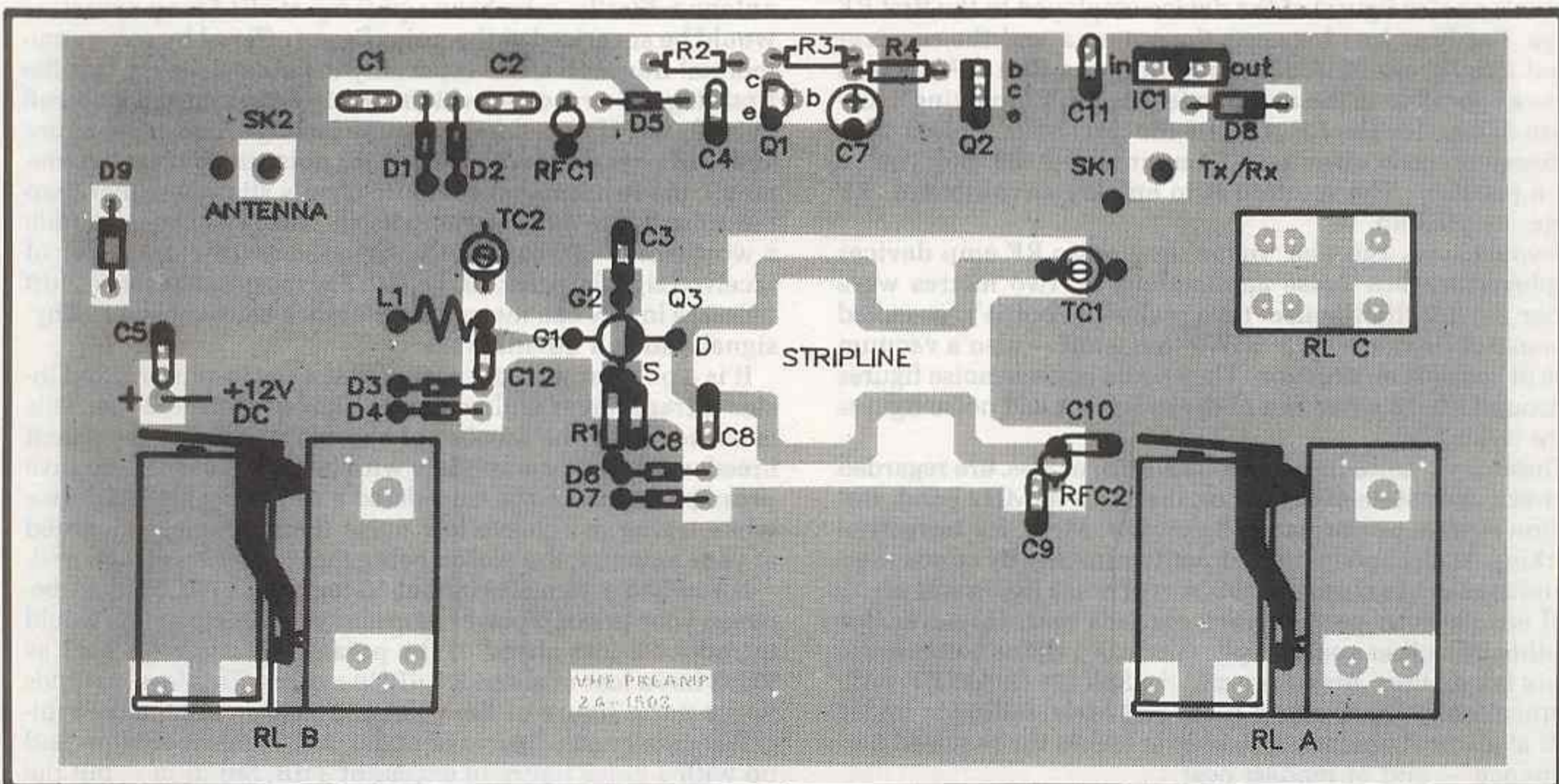
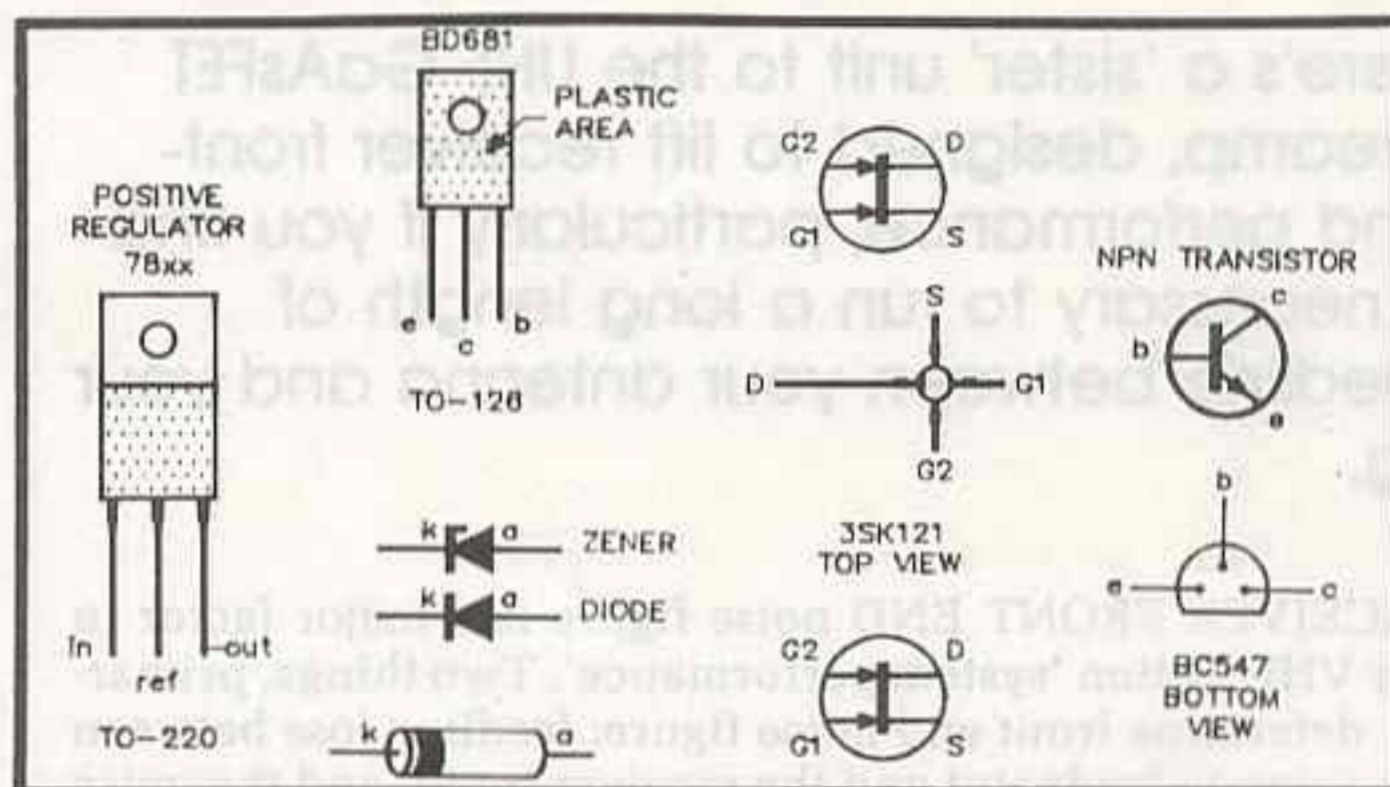
The pc board supplied is double-sided but the holes are not plated through. Where possible, solder components to both sides of the board. This is particularly important with those components which pass through the earth planes such as inductor L1, diodes D1-D4, D6 and D7, C12, C3, C6, etc. Refer to the overlay diagram. It is *absolutely essential* that components are mounted with the *minimum possible lead length*, especially around the active circuit. This applies particularly to C12, C3, C6, R1, C8, C9 and C10. Don't forget to observe the correct orientation with polarised components. Failure to observe all these precautions may cause instability or even prevent the unit working!

The usual electrostatic discharge (ESD) safety precautions should be observed when soldering the GaAsFET, i.e: use an iron with an earthed tip, don't use too much or too little

heat and don't run around on nylon shag pile carpets beforehand. It will probably be necessary to trim the drain lead of the GaAsFET before soldering. Gently tin the device's leads and the tracks on the pc board to which they mount before soldering it in place. To solder it in position, hold it in place with needle-nosed pliers or a pair of tweezers, making sure it's correctly oriented (see the pinout diagram). Then apply the flat of the iron tip to each lead in turn, applying a little pressure, so that the device's leads are sweat-soldered to the tracks.

As you can see from the lead photograph, the unit is housed in a diecast box, which comes pre-drilled. The board mounts to the lid in the same fashion as the UHF preamp. This is the only 'difficult' part of the construction. Before mounting the board, solder a length of medium duty hookup wire, about 150 mm long, to the +12 V pad on the board, adjacent to C5. Tie a knot in it about 20-30 mm from the board to prevent any strain being put on the pc board joint whenever the wire is tensioned. The accompanying diagram shows the overall board mounting arrangement.

The two BNC sockets are mounted to the lid of the box, in the holes provided. Solder lugs are mounted under the securing nut and washer on each. About 20 mm of heavy gauge tinned copper wire should be soldered to each lug which needs to be oriented such that the wire can be soldered to the rear (non-component) side groundplane of the pc board adjacent to the pads for the coax sockets' centre conductor pins. The +12 V supply input wire passes through a small grommeted hole in the diecast box lid adjacent to the ANTENNA socket.



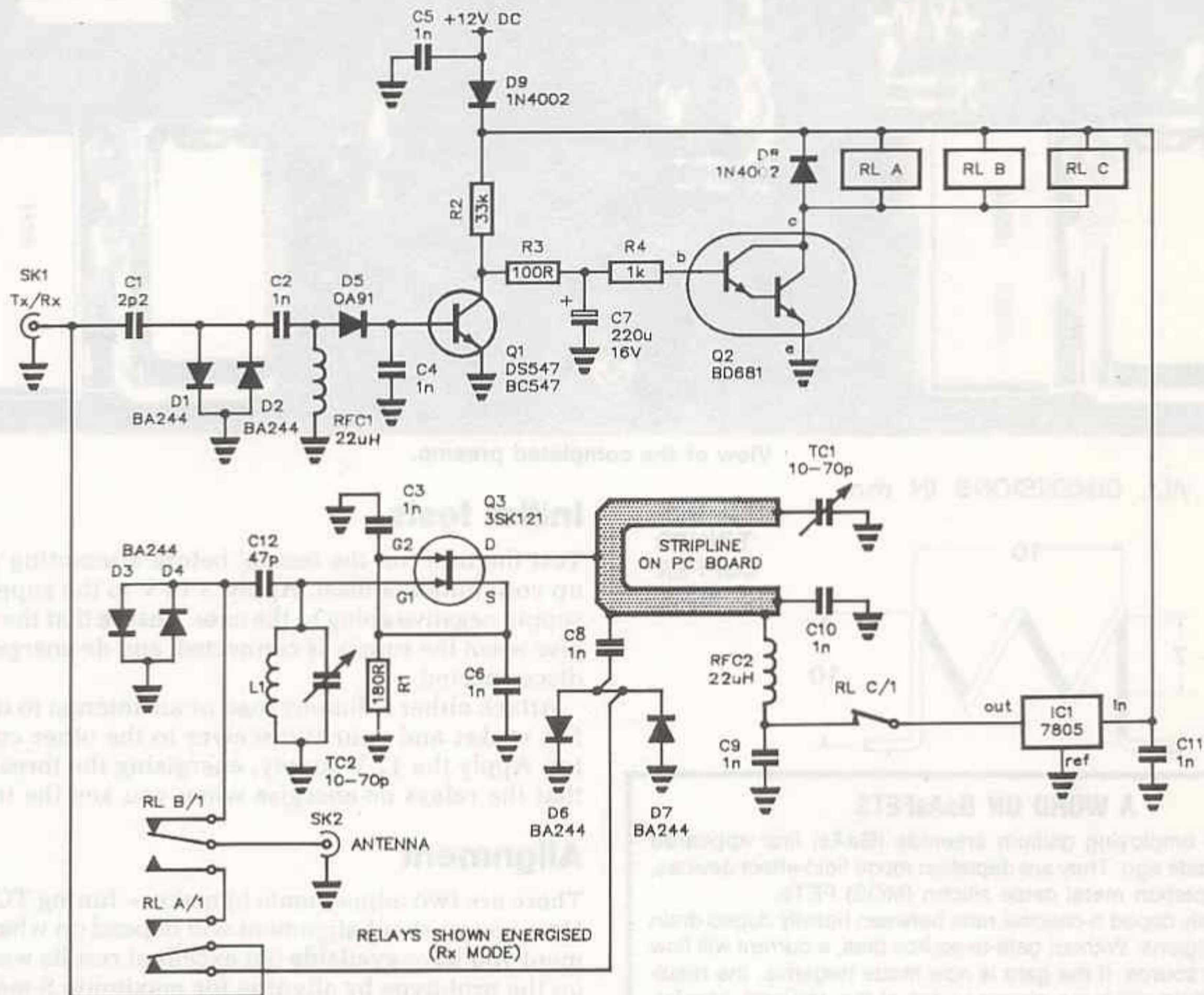
Component overlay. A double-sided pc board is employed, but only the topside copper area is shown here for clarity. Component leads marked with '•' are soldered to the top side of

the board. (Note: some leads are soldered both sides — check the text).

There is very little room to solder the centre pins of the coaxial connectors to the underside of the board, and care should be taken to obtain a good electrical and mechanical joints here as the board is, in part, supported by these connectors. The method used in constructing the prototype was to liberally tin the tracks on the underside of the board as well as the centre pin of each connector. The pc board is then placed over the pins and heat from the iron applied from the

upper (component) side of the board to the pins whilst solder is fed to the joint on the underside. It is a bit awkward but can be accomplished, with care. Don't forget to solder the wires from the BNC socket lugs to the board on both sides. It would be advisable to check the joints with a multimeter (on resistance) after soldering.

Finished? Give everything a thorough visual check.



CIRCUIT OPERATION

A Toshiba 3SK121 dual-gate GaAsFET is the 'heart' of the preamp. Input matching and tuning is achieved with a parallel-tuned circuit comprising L1/TC2. Output matching and tuning is accomplished with a stripline in the pc board, resonated by TC1.

In the 'through' mode, the antenna input is connected via the two coaxial relays and 50 ohm stripline to the output socket.

In 'receive' mode the three relays, RLA-RLB-RLC, are energised. This is done to provide 'fail-safe' operation so that if the 12 V supply to the amplifier should fail or be inadvertently turned off, the amplifier will assume the 'through' mode.

Coaxial relays RLA and RLB connect the antenna to the input of the amplifier and the output to the receiver or transceiver. The miniature relay, RLC, connects the supply from the five volt regulator IC1 to the GaAsFET.

The 3SK121 (Q3) is self-biased via R1 in the source circuit. The antenna is coupled to gate 1 via C12, the input tuned circuit being in parallel with gate 1.

The unit employs RF sensing to automatically switch between receive (preamp) and transmit (through mode). Fast-switching diodes D3-D4/D6-D7 are used at the input and output of the amplifier itself to shunt excessive RF whenever the transmitter is activated.

When power is first applied, C7 charges via R2-R3, turning Q2 on after a short delay. Whenever the transmitter is activated, the RF signal is coupled to the sensing circuit via C1 (2p2). Again, fast-switching diodes, D1-D2, prevent excessive RF voltage appearing here. The RF is rectified by a germanium diode, D5, and the resultant dc turns transistor Q1 on. Capacitor C7 (220µ) discharges quickly through R3 and Q1, thus turning the Darlington transistor Q2 off and relays RLA, RLB and RLC de-energise.

When de-energised, the coaxial relays switch the transmitter straight through to the antenna, while relay RLC removes the 5 V supply to the GaAsFET.

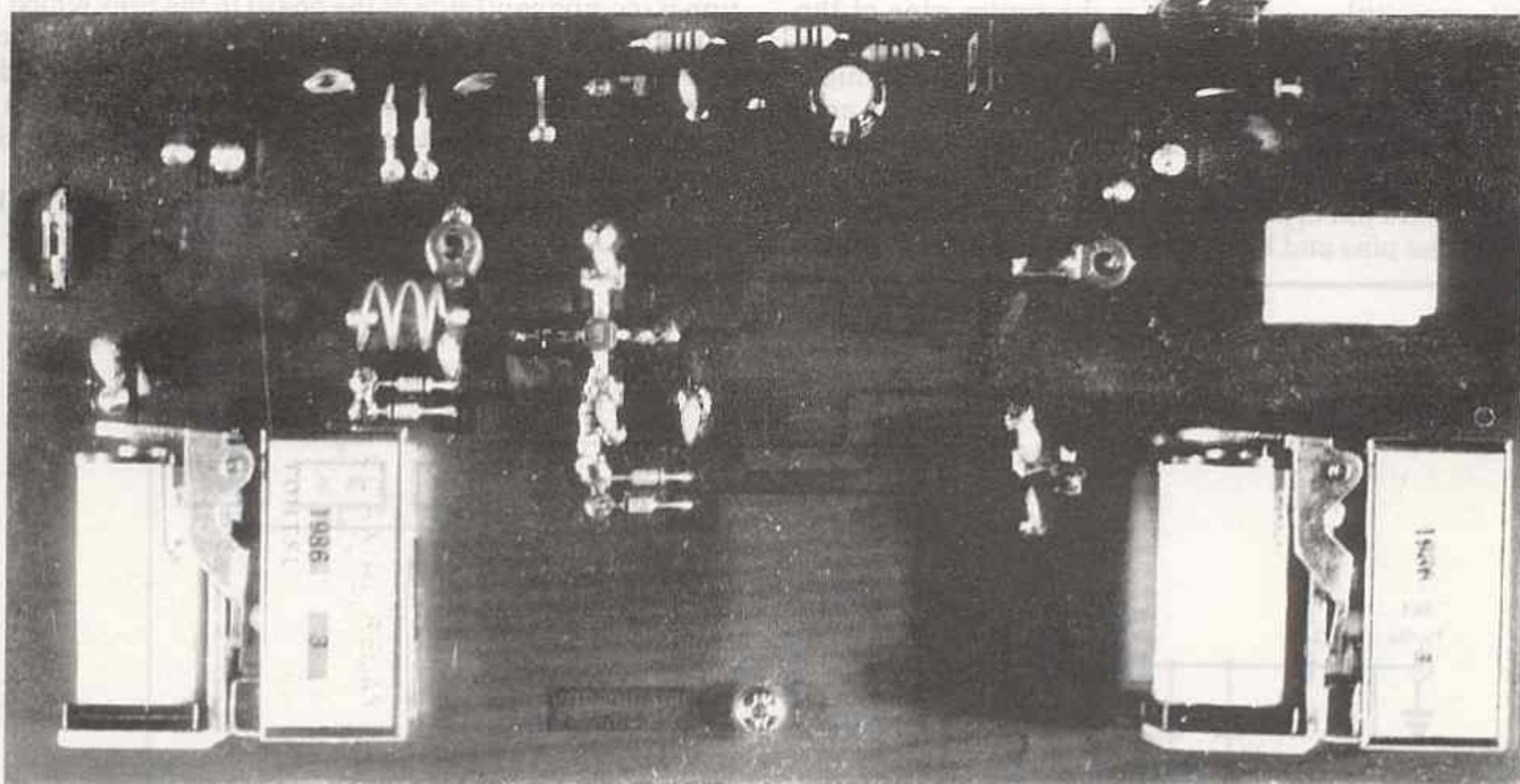
Whenever the transmitter is turned off, transistor Q1 will turn off also, allowing C7 to charge slowly via R2 (33 k) and R3 (100 R). When C7 has charged sufficiently (to about 1.3-1.6 V), the Darlington Q2 will turn on again, receiving bias via R2-R3-R4, thus energising the three relays. The signal is then coupled to the receiver via the preamp (C12-Q3-C3). The delay in turning on is provided to prevent relay chatter when using SSB or CW modes. The delay may be shortened if desired by reducing the value of R3.

Diodes D3-D4 serve another purpose, apart from preventing excessive RF from the transmitter reaching Q3. They secondarily prevent any static charge which may build up on the antenna from destroying Q3.

Some operators may prefer to use hard switching in lieu of RF switching. This can be accomplished by omitting C1, D1, D2, C2 etc, and connecting the switching voltage (usually 12 V) via a suitable resistor to the base of Q1. It would be wise to retain C4 (1n), and also feed the switching voltage into the enclosure via a suitable feedthrough capacitor.

The unit is powered from an external 12 V dc (nominal) supply and consumes about 200 mA in receive mode. If extremely long runs of cable are used, it would be advisable to check that the supply is not below 12 V at the amplifier or the 12 V coaxial relays may not switch reliably. Diode D9 provides reverse supply polarity protection.

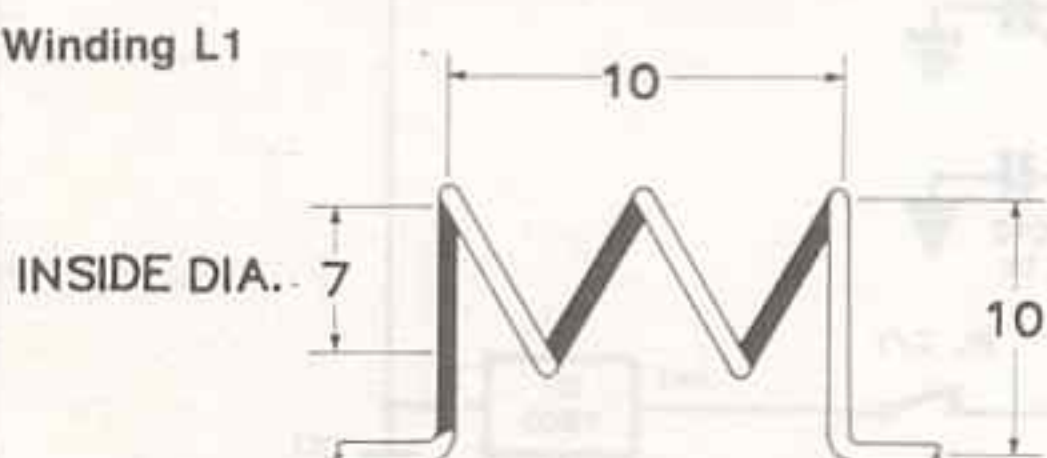
It is important to remember that the dc return (-ve side of supply) is via the outer braid of the coaxial feedline, from the transceiver to the amplifier, and if a separate supply is used to power the amplifier, a connection should be made between the negative side of the supply and the braid of the feedline. If the same supply is used to power both the amplifier and the transceiver this will probably be unnecessary as the coax outer braid connection of the transceiver will usually be common to the negative supply.



View of the completed preamp.

ALL DIMENSIONS IN mm

Winding L1



0.5 DIA.
TINNED
COPPER
WIRE

Initial tests

Test the unit 'on the bench' before attempting to mount it up your antenna mast. Apply +12 V to the supply lead, the supply negative going to the case. Ensure that the relays energise when the supply is connected, and de-energise when it's disconnected.

Attach either a dummy load or an antenna to the ANTENNA socket and your transceiver to the other coax connector. Apply the 12 V supply, energising the three relays. See that the relays de-energise when you key the transmitter.

A WORD ON GaAsFETS

FET devices employing gallium arsenide (GaAs) first appeared around a decade ago. They are depletion mode field-effect devices, similar to depletion metal oxide silicon (MOS) FETs.

A moderately doped n-channel runs between heavily doped drain and source regions. Without gate-to-source bias, a current will flow from drain to source. If the gate is now made negative, the resultant electric field will force electrons out of the channel, 'depleting' the channel of charge carriers, reducing the drain-source current flow. When a positive voltage is applied to the gate, the channel will be 'enhanced', increasing drain-source current flow.

Single gate types are not as linear as enhancement types, but having two gates on the channel overcomes this. Hence, dual-gate types are widespread. Gallium arsenide is an inherently lower noise, higher speed semiconductor, though devices employing it are generally costlier to manufacture than silicon-based semiconductor devices. However, their cost has dropped considerably in recent times.

Typically, they are employed as low noise amplifiers and mixers in UHF circuit applications. For this reason, they are generally housed in a "macro-X" stripline package as illustrated in the 3SK121 pinout.

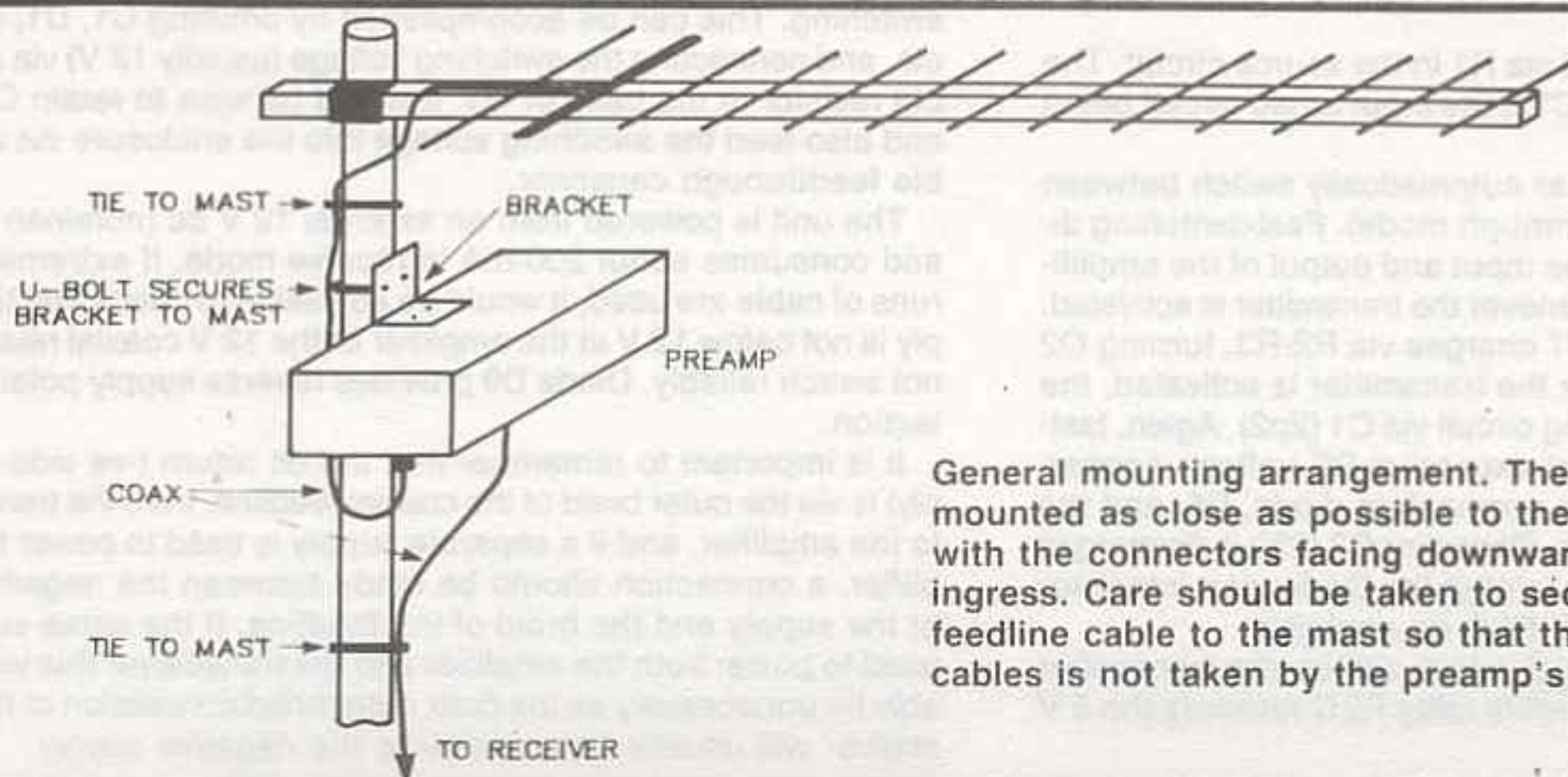
Alignment

There are two adjustments to make — tuning TC1 and TC2. How you go about alignment will depend on what test equipment you have available but excellent results were obtained on the prototype by aligning for maximum S-meter reading on a weak signal. Start with TC2 and adjust till the reading is peaked, then adjust TC1 for a peak. Repeat a few times until the reading on the S-meter is maximised. You can check that this delivers the required signal-to-noise ratio improvement by alternately energising and de-energising the relays.

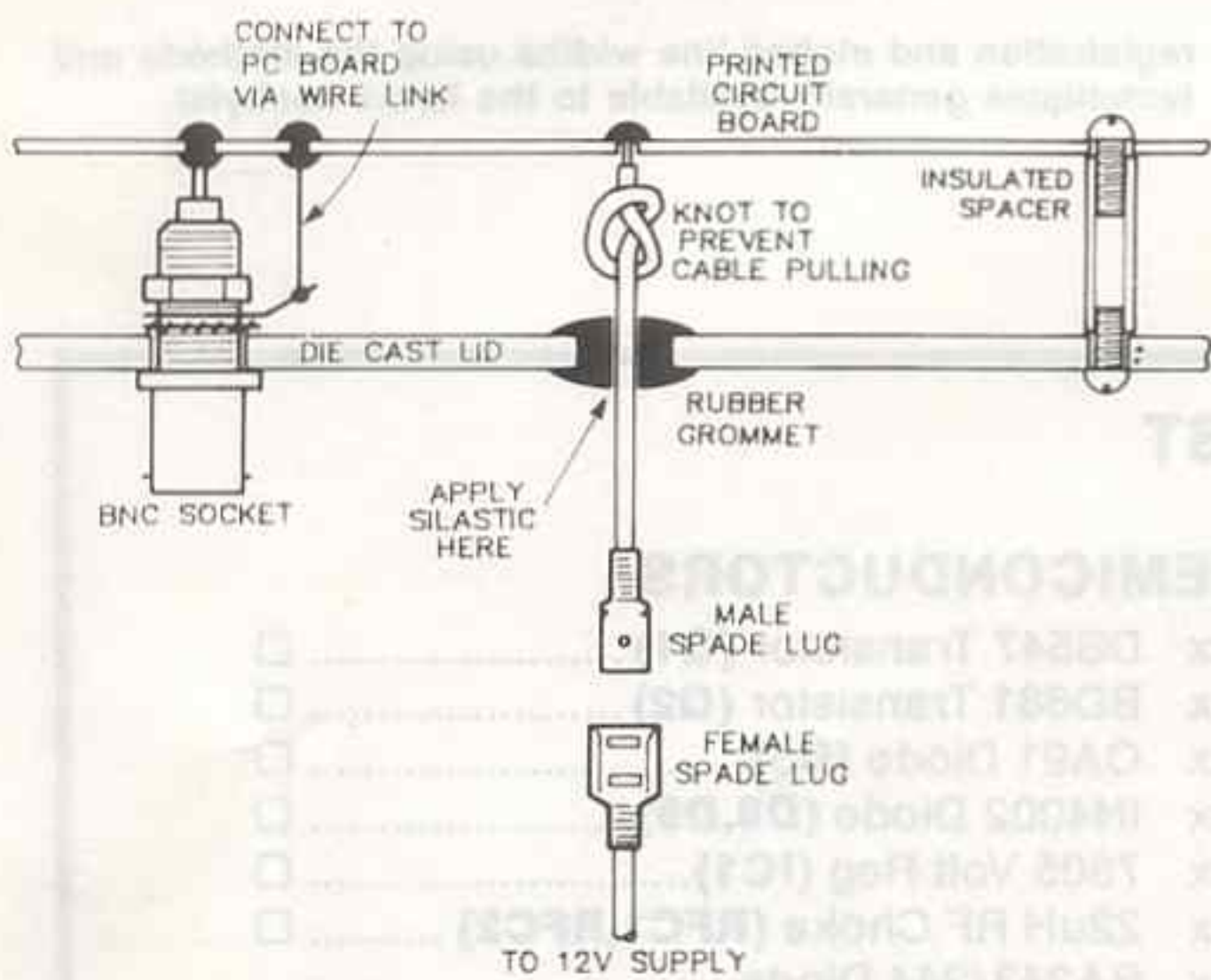
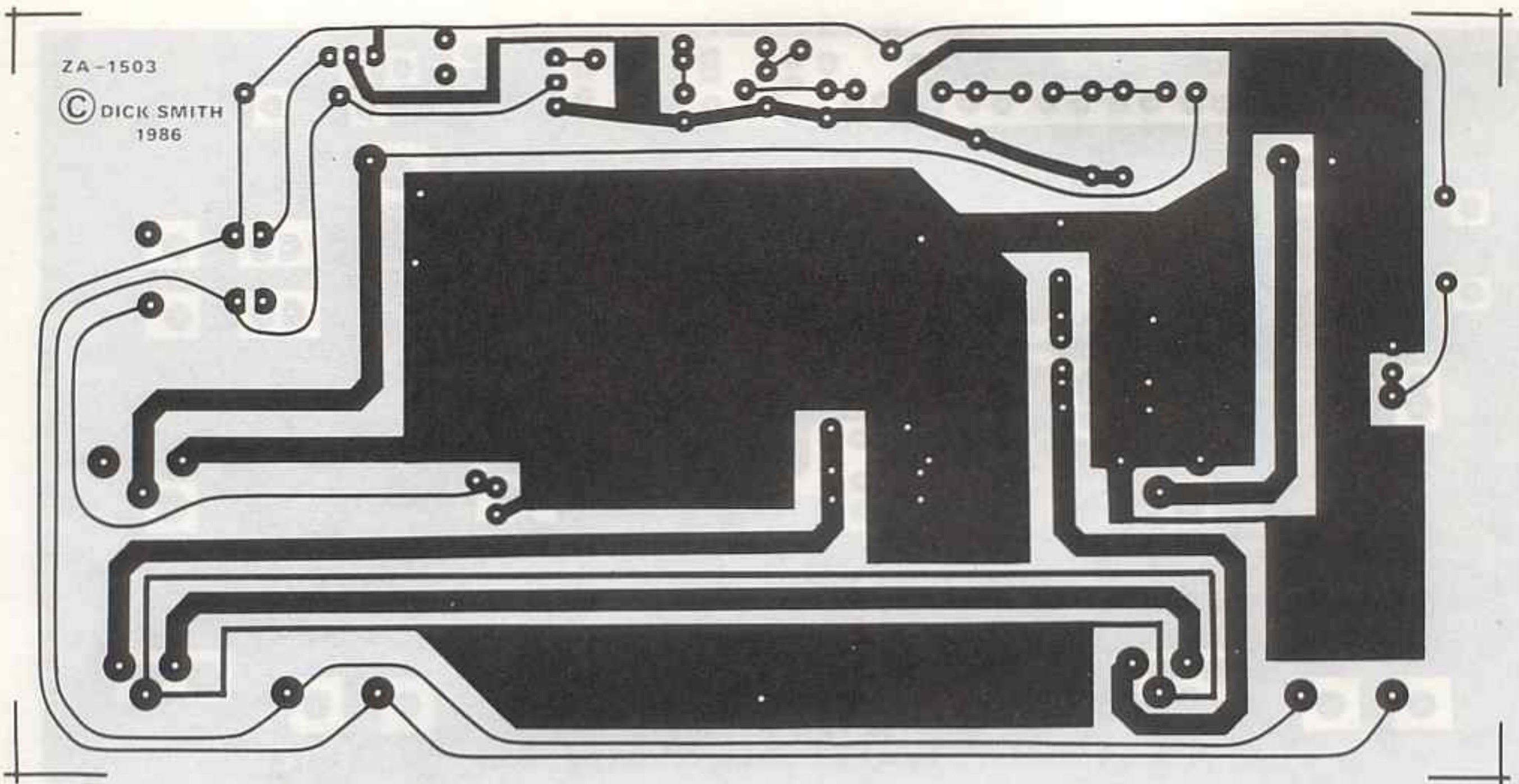
With the alignment completed to your satisfaction, screw the lid in place, putting silicone sealant around the rim to prevent the ingress of moisture.

Installation and use

The completed and aligned unit should be mounted on the antenna mast and the ANTENNA socket linked to the antenna feedpoint with a short piece of good quality coax.



General mounting arrangement. The unit should be mounted as close as possible to the antenna feedpoint with the connectors facing downwards to prevent moisture ingress. Care should be taken to securely strap the coaxial feedline cable to the mast so that the full weight of the cables is not taken by the preamp's coax connectors.



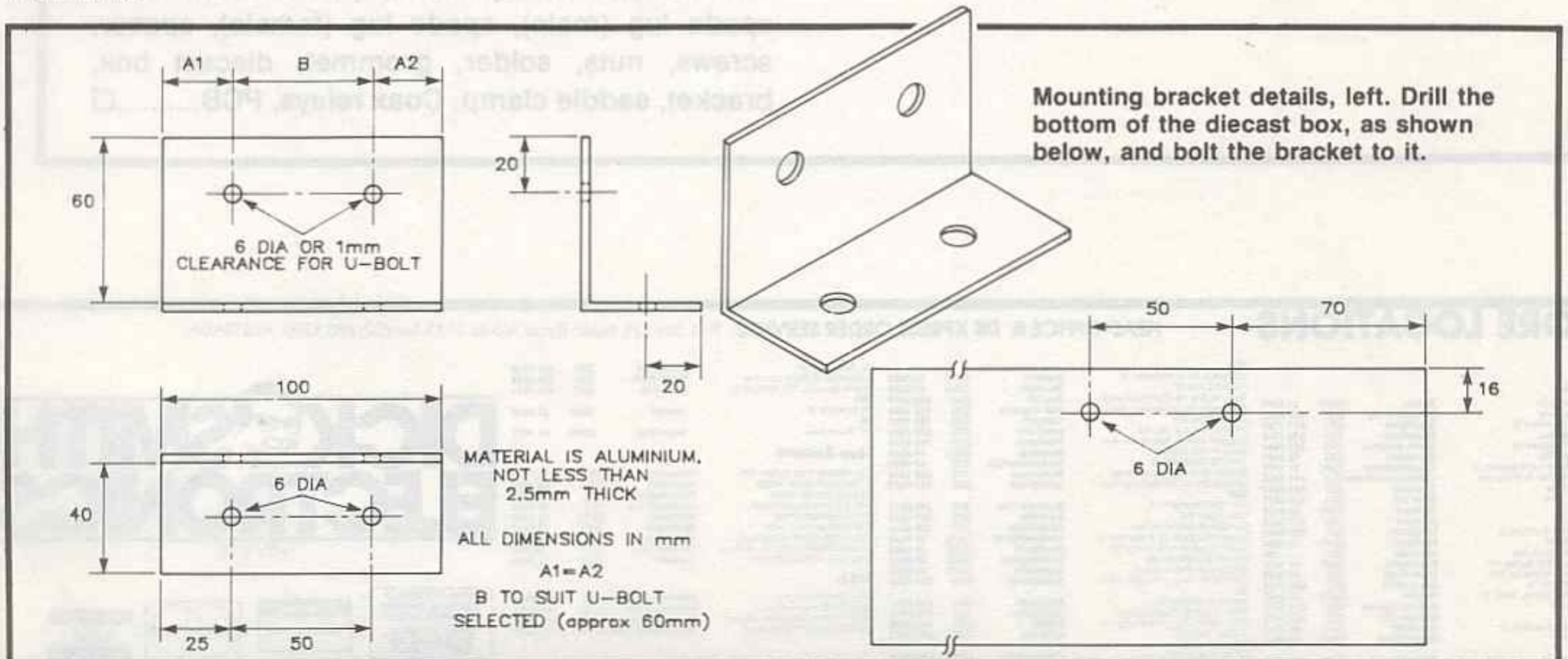
Showing arrangements for the +12 Vdc supply lead. Care should be taken that, when mounting the preamp on your mast, the spade terminals should be prevented from shorting against the case or the metal mast. Slip plastic 'spaghetti' insulation or heatshrink tubing on one lead, then smear petroleum jelly ('Vaseline') on the assembled spade connector before covering it with the spaghetti or heatshrink.

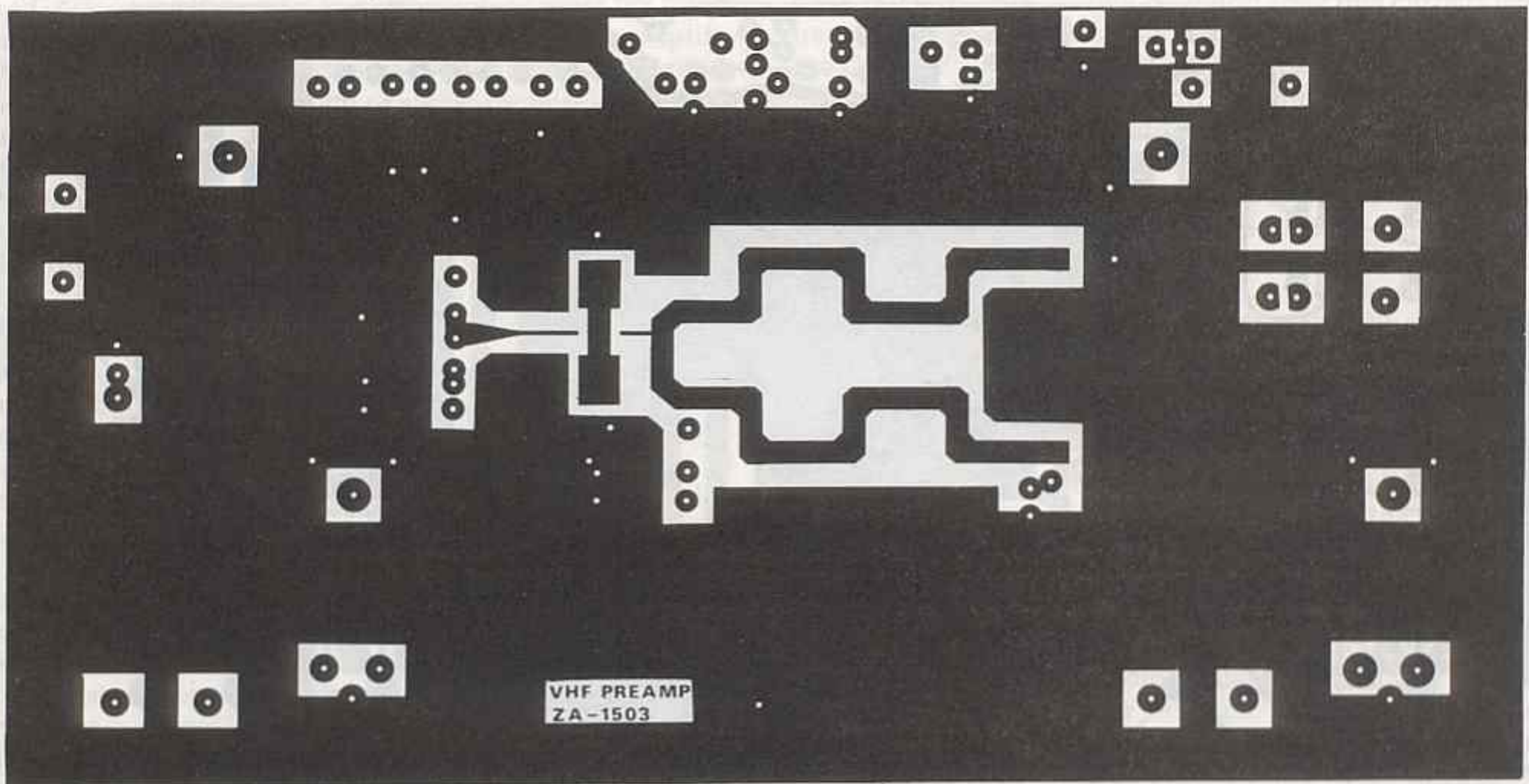
The feedline to the transceiver is then connected to the TRANSCEIVER socket of the unit and a line run from the unit's +12 V lead to the power supply in your shack.

A mounting bracket, as shown in the accompanying drawings, may be needed to secure the completed unit to your antenna mast, unless you have some other arrangement in mind. This can be bent up from a scrap piece of metal, as shown here, and attached to the box with a pair of large, galvanised bolts and nuts. The bracket should be attached before final assembly.

Care should be taken to secure the coaxial feedlines to the mast to prevent undue strain on the connectors. This applies for the 12 volt supply also. Mount the unit with the connectors facing downwards to prevent the ingress of water. If desired, the whole unit, including the coax connectors, can now be painted with a sealant, such as Selley's 'Redskin' or similar, to gain an absolutely watertight installation. Smear all the exposed bolts with petroleum jelly ('Vaseline'), or spray them with WD40, to prevent corrosion.

If you are using very low power, like 2.5-5 watts, it may be necessary to replace the input coupling capacitor, C1, in the sensing circuit with a slightly higher value, e.g: 4p7, to ensure reliable switching. On the other hand, if you are using very high power, e.g: 80-120 watts, C1 should be reduced to 1 pF. **DSE**





Printed circuit artwork. This is given for reference purposes as it is impractical to make a double-sided pc board such as this and obtain the required critical

registration and etched line widths using the methods and techniques generally available to the home hobbyist.

PARTS LIST

RESISTORS

All resistors 1/4 unless specified

- 1 x 100R Resistor (R3)
- 1 x 1k Resistor (R4)
- 1 x 180R Resistor (R1)
- 1 x 33k Resistor (R2)

CAPACITORS

- 1 x 2.2pf Ceramic cap (C1)
- 1 x 47pf Ceramic cap (C12)
- 9 x .001uf Ceramic cap (C2-C6, C8-C11)
- 1 x 220uf Electro 16V RB (C7)

SEMICONDUCTORS

- 1 x DS547 Transistor (Q1)
- 1 x BD681 Transistor (Q2)
- 1 x OA91 Diode (D5)
- 2 x IN4002 Diode (D8, D9)
- 1 x 7805 Volt Reg (IC1)
- 2 x 22uH RF Choke (RFC1, RFC2)
- 6 x BA243/244 Diode (D1, D2, D3, D4, D6, D7)
- 1 x 3SK121 Gasfet (Q3)
- 2 x 10-70pf Trimmer (TC1, TC2)

MISCELLANEOUS

Mini Relay, sockets, tinned copper wire, H/u wire, spade lug (male), spade lug (female), spacer, screws, nuts, solder, grommet, diecast box, bracket, saddle clamp, Coax relays, PCB.....

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