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Antenna Matching Unit

Introduction

This kit contains a resistive matching bridge, an optional balun, and the T configuration antenna matching parts. It is suitable for all antennas likely to be encountered in normal use between 10 and 160m but the maximum power is limited to around 20 Watts. This arises from having to use plastic Polyvaricor variable capacitors – nice air spaced ones are prohibitively expensive! The antenna can be fed with un-balanced or balanced feeders. The resistive matching bridge will ensure a safe load to the TX during tuning and also reduces the radiated signal; it uses a LED for the indication but can also work with a conventional meter or with the S meter of the Meter kit. The AMU is supplied with parts for 'open' construction like the smaller Somerset Range rigs. It uses a single sided main base PCB and rear etched single sided PCB front panel to minimise stray capacitance. If you intend to put it in a case, this should really be somewhat larger to make certain the metalwork is further from the coil (which is made from a multi-way PCB strap) and the adjustable matching capacitors. Please read right through these notes and make certain you understand how the various PCB sections are fitted together first.

Technical Aspects

The block diagram is shown in Fig. 1 with the full circuit in Fig. 3.

Supplies None required!

Matching Bridge During adjustment of the matching section, the bridge is brought into action by switching S1 to the REF (reflected) position so that a bridge is formed. One side is the chain between R1/2 and the unknown load from the balun L1 & matching circuits; the other side is the fixed divider formed by R3/4 and R5/6. When the AC voltage between point N and the junction of R3/4/5/6 is zero, the bridge is balanced and the unknown load impedance (across point N to E) is 50 Ohms. This is detected by the RF voltmeter C1/D1 which drives the high intensity LED D3; thus the bridge is balanced when the LED goes out. With S1 in the REF position, the load on the TX has to be between 33 and 100 Ohms irrespective of the matching unit settings – thus always presenting a safe load to the TX.

When S1 is in the FWD (forward) position, the bridge circuit is bypassed by shorting out R1/2. Under these conditions, the RF voltmeter reads only the output RF voltage since there is no RF voltage present in the R3/4/5/6 chain. The preset RT1 sets the maximum current through the LED; however if a meter is fitted, of say 100 micro-amps FSD, this is connected instead of D3. Given that you have just adjusted the load impedance to 50R, an actual meter will indicate the RF voltage with a linear scale and RF output power with a square law scale. If the meter is also acting as a receiver S meter, then the output to the meter is taken from point Q so that D2 prevents any interference to the S meter circuits. (The S meter driver should also have an isolating diode such as is incorporated in the Meter kit.)

Balun The RF transformer L1 is used when the matching section is to drive a balanced feeder/antenna, with neither side connected to any form of RF earth. Examples of balanced systems would include 'ladder' line and slotted ribbon feeder, with either feeder type connected to equal length antenna arms. The fact that the matching circuit is not fully symmetrical is unlikely to distort the radiation pattern of a balanced system significantly. The absence of any specific connection (often by a centre tapped coil or capacitor) to real RF earth allows the matching components to float in an RF sense so that it can be used to drive either balanced or unbalanced systems. When fitted, the balun is placed between TX and matching circuits to ensure that it is always working at 50 Ohm point. (If placed at the AMU output, it might have to handle very high or low impedances and reactive loads - this is not recommended.) If the feeder or antenna is unbalanced, an alternative is to omit the balun and connect point N to G, with O2 connected to E and the rig's main chassis and 0 volt system. The latter should then be isolated from mains earth. You might then need a 'choke balun' at the antenna. Consult antenna 'handbooks' for advice. If in any doubt, use the AMU balun L1, especially if your mains earthing depends on PME (Protective Multiple Earthing).

Matching section This is a T match circuit with two variable capacitors CV1/2 and a tapped inductor L2. The T arrangement can cater for a very wide range of loads – from around 10 to 2000 Ohms, with or without reactance from the feed line. Both sections of CV1 and CV2 are connected to give a maximum capacitance of 225 pF for each. The inductor L2 comprises a 4 inch long flexible 30 way ready made PCB 'strap' (formed into a U shape), with linking tracks on the base PCB completing the turns of the coil. To cater for the larger values that might be needed on 160m, S2 can add an extra 220 pF to CV1 (or CV2) and S3 can add an extra 10 μH L3 to the nominal 18 μH tapped inductor L2. Note that the role of the T circuit is to match the actual impedance at the shack end of the feed line to the 50 Ohms wanted by most transmitters; it does not alter the match between the antenna arms and the feed line so that the line may still have a high SWR – the AMU just conceals this mismatch from the transmitter! The SWR on the feed line will only be 1:1 when the impedance of the line is the same as that of the antenna terminals. If the SWR is high there may be significant line losses depending on the type of line. Generally open wire twin feeders have least loss.

Mechanical Assembly

Since this kit uses a single sided PCB it is best to build the main structure first and then fit the parts. The arrangement is shown diagrammatically in Fig. 2. The parts layout is shown in Fig. 4 where the front panel section has been folded down for clarity. The photo later shows a close up view of the left side. Start by examining the front panel and main base PCBs, noting where the copper areas are located and which are soldered to each other to form a rigid structure. The main base PCB sits on four rubber feet with the copper side downwards. The front panel should have the copper on its rear. They are fitted together so that the bottom of the front panel can be soldered to the underside at the front of the main base PCB. Hence the front edge of the base PCB is concealed behind the bottom of the front panel. The two side braces will be soldered at the ends of this joint. There are copper strips up the back of the front panel for soldering to the side braces: but without copper on the topside of the main PCB, it is necessary to install two lengths of wire through the holes provided at the edges of the base PCB. These are soldered underside of the main base PCB and topside to the rear edge of each side bracing piece of PCB material. This will make structure rigid.

Start the actual assembly by lightly tack soldering the front panel to the main base PCB (place main base PCB upside down on bench and hold front panel vertical), then solder a side brace (copper inwards) to the outside edge of the front panel. Fit a short length of the multi-strand wire through the big hole and solder above (to the side brace) and below the main base PCB ground tracks. Check that everything is square. If satisfactory, add extra multiple solder points between the sections and fit the second side brace and wire. Finally fit two rubber feet in the underside rear corners, and the two front ones inset slightly to miss the wires holding the side brace.

Now install the electronic parts.

Electrical Assembly

Start by fitting the front panel controls and wiring. Fit the toggle switch S1 with its body horizontal. Connect the left REF tag of S1 to the point M connection at the rear right of the PCB. Connect the central tag of S1 to point I at the rear left of the PCB. Route both these wires round the left side of the base PCB (outside where the coil strap will be fitted). Connect the third FWD tag to the point N near the front of the base PCB. The LED D3 is installed by first pushing the sloping 'ears' of the mounting bush into the hole from the front of the front panel. The LED body is then pushed into this bush from behind the front panel till it won't go any further; then the plastic ring is slid over the leads and firmly pushed over the 'ears' of the mounting bush till it locks the bush solidly against the front panel. The cathode lead (shorter) is bent back and connected to the 0 volt or earthy track up the side of the front panel, the anode is bent over and soldered to the length of isolated track on the other side to as an anchor point. Fit a wire from this anchor point/ LED anode to the point P at the front right.

Polyvaricons

Before installing the two variable capacitors CV1 and 2, set both trimmers on each to minimum capacity with the trimmer plates not overlapping. Install the shaft extension for each capacitor, this should be fitted 'back to front' with its two 'ends' projecting forwards for maximum length, and is held in place with the longer M2.5 pan head bolt. Grip the flats of the main shaft and its extension with pliers while doing up this nut. Offer each capacitor up to the front panel and check that the two small mounting holes do not need easing with a rat tail file – any sideways stress makes the shaft bearings stiffer! Each capacitor is mounted on the front panel by two short countersunk M2.5 bolts, each with a washer on the front to prevent the tip of the bolt hitting the capacitor vanes. (The PCB has two unused copper strips for an earlier method of securing the capacitors.) The two knobs are fitted so the pointer is horizontal at the extreme rotations – if correct, the grub screws will bear on the rounded part of the shaft.

Front Panel wiring

Now fit the two toggle switches S2 and 3 with their bodies vertical. Cut the anti-rotation lug off the rotary switch S4 and remove the metal ring on the mounting bush so that it can be rotated to all 12 positions! Cut its shaft to a suitable length. Mount in the front panel with tag number 1 is roughly the position shown to ease the wiring. (Common tag to left from on top.) Fit its knob. Make the single connection from the common tag of S4 to the lower tag of the right toggle S3. Now carefully make all 12 connections between the outside tags of S4 and the tapping points of the inductor strap. Keep the wires pretty short and tidy! Start with the first three wires - from the extreme anticlockwise tag number 1 on the switch to turn number 1 of the strap, followed with tag 2 to turn 2, and tag 3 to turn 3. Then do the lower ones – tag 12 to turn 30, tag 11 to turn 26, tag 10 to turn 22 etc until you have completed all 12. Check this twice as I know its easy to go wrong!

Next join the central tag of CV1 to the central common tag of S2 and on to the central common tag of S3 and on to the central tag of the second variable CV2. The 65 pF and 150 pF sections of both capacitors are wired in parallel requiring you to link together the two outer tags of the capacitors. Install a wire from the two joined tags of CV1 to the point G linking to the balun L1. Fit the 220 pF C3 beside CV1 from its two joined tags to the upper normally off tag of the extra capacitance switch S2. The two joined tags of CV2 are then connected with a wire to the point O1 at the front right of the base PCB.

Now wind L3. This is a single winding on the red T68-2 toroid using 22 gauge wire. Each time the wire goes through the central hole of the core it counts as one turn. It needs 42 turns which will not go on as a single layer, requiring about 10 turns to be wound on top of other turns in the middle. Cut off about 1.5 m (60 ins) of the enamelled wire and thread it through the middle of the core – this is the first turn! Slide the core to near the middle of the wire and, with the shorter end, put on 16 turns tightly and close up against each other. Then put on the remaining 25 turns with the other end, starting with about 10 bunched up together and finishing off the rest as a single layer. Tidy up the individual turns around the core and cut the surplus ends off leaving about 15 mm (3/4 inch) for connecting to the two lower tags

of S3 which do already have connections. It will fit comfortably beside the body of S4. The enamel is best burnt off with a very hot iron (don't breath the fumes) or can be carefully scraped off. That completes the front panel wiring.

Next install the 30 turn coil made from the 30 conductor strap. First carefully insert all the wire ends of one side into the row of holes nearest the front panel. Check that all ends are properly through the PCB before soldering any of them! Solder the two outside ones first, check all is right and then do the other 28. Bend the other side of the strap over and carefully insert all 30 wire ends into their holes. Do two and check all the rest before soldering them! Finally check the continuity with your Ohm-meter from end to end of the coil. It should be a short circuit.

With a suitable marker pen, you might consider adding the front panel lettering shown in diagram 1.

Matching Bridge

These parts are mounted on top of the rear of the main base PCB:-

R1	100R 2W		C1	10 nF disc	Marked 103
R2	100R 2W		C2	10 nF disc	Marked 103
R3	100R 2W		R7	10K	BN,BK,OR
R4	100R 2W		RT1	100K preset	
R5	100R 2W		D1	1N4148	
R6	100R 2W		D2	1N4148	

Fit the two 2 terminal connector blocks with the wire holes facing to the rear. The only remaining component is the balun L1. If you are in any doubt about the necessity to fit and use the balun, then fit it - that is the safest approach. If you have decided that it is not necessary, link the point O2 to E. Prepare a link for N to G but install only the G end.

If the balun L1 is to be fitted, then it is wound as two interleaved windings on the large violet toroid, with each turn of the primary beside a matching turn of the secondary. See Fig. 5. Start with the primary, this consists of 10 turns of 22 gauge enamelled wire. Cut off 300 mm (12 inches), thread the wire through the toroid and slide it to the middle of the wire. This is the first turn. With one end put on 4 more turns tightly but this time leave a small gap between each turn for the secondary wires. Then put on the remaining 5 turns with the other free end. Trim the free ends to about 25 mm (1 inch) and mark them in some manner to distinguish them from the secondary ones. (Try bending the very tip over.) The 10 turn secondary is best wound from the middle. As before slide the toroid to the middle of the wire. Carefully press or lay the wire against the inside of the toroid between the two middle turns, then thread one end around and through the middle in between the next two turns of the primary. Make certain the secondary wire does not cross over the primary – if it does lift the end just inserted and put it to the other side of the first inside pass of the secondary wire. Repeat this method of adding the secondary turns until the free end is just *outside* the end turn of the primary. Then put on the remaining secondary turns with the other free secondary end till that end is just *inside* the end turn of the primary. If you now count the total number of wires going through the toroid, it should be 20, 10 each for primary and secondary. Trim the secondary ends to about 25 mm (1 inch). Push all the turns tight up against each other so that they are occupying just a small part of the circumference of the toroid. Burn the enamel off all four ends with a hot iron near the toroid. Insert the two secondary wires (without bent tips) into points G and O2. Then cut off the two bent tips, insert the end for the E hole and solder in place. Leave the other end of the primary, which would go to the point N, unconnected for the present. See the next section!

Setting up and testing

You will need an HF QRP transmitter and your 50 Ohm dummy load, apart from your antenna! Frequency is not too important, but if have a choice use 40 or 80m first. For convenience, start the tests using the LED indicator even if you intend to use a meter later. Set the preset RT1 to mid position. Connect your transmitter to the two input terminals I and E, the rig's 0 volt or ground plane should be connected to the E terminal. Use a piece of coax cable if the distance is more than a say 100 mm (4 inches).

So that you can test just the matching bridge first, temporally connect the dummy load to the point N (or the right tag of S1) and to any earthy point of the E track. (If you are not using the balun, make sure G is not connected to N.) Switch S1 to the REF position (switch toggle to right) so that there is definitely a safe load on the TX. Switch on and generate a few watts of steady carrier into the AMU. The LED should NOT light because the dummy load is properly balancing the bridge. If you now switch S1 to FWD position (toggle to left), there is still a 50R load on the TX but the LED should light. RT1 can be adjusted for a fairly bright indication for your chosen power output level. Turn off the RF. Disconnect the dummy load. If you wish to be daring, switch S1 to REF and re-apply the RF, the LED should now light since the bridge is completely unbalanced with no output load! For interest, try shorting N to E, again the LED should light up with RF. Turn off the RF.

Connect the balun L1 primary to the point N (or connect the link between N and G if balun not being used) and reconnect the dummy load to the AMU output points O1 and O2. Set CV1 and CV2 to mid position. Check that S2 and S3 are both up for no extra C or L (unless 160m is being used). With S1 in the REF position, apply RF – the LED is likely to glow due to a poor match to the 50R dummy load. Rotate S4 till the LED is least bright. For the lower frequency bands, it is likely to require roughly three-quarters of the inductance. For the higher frequency bands, very much less inductance is required. Then see if you can extinguish the LED by adjusting CV1. Finally adjust all three matching components for the least glow from the LED. You should be able to get it to go right out – even at full sensitivity on RT1. This condition can be achieved with a range of settings for all three main matching controls - the best settings to use (with either dummy load or real antenna) are those with a higher value of capacitance for CV1 and so lower inductance from S4 – this gives lower Q and less sharp tuning. Having now adjusted the matching controls for best match (indicated by nothing from the LED), you can now switch to the FWD position of S1 for full output – the LED should now shine brightly indicating all is well! You can adjust RT1 for a comfortable full brightness. For practice, change frequency and repeat the AMU tune up procedure with the dummy load still connected to the output.

To repeat briefly, procedure is switch to REF, centre CV1 and CV2, apply RF, find least glow with S4 and then trim all three controls till LED extinguished, then finally switch to FWD. The capacitors should be set to the middle of the range over which the LED is extinguished if the exact position is not obviously as you adjust them.

Now connect your feeders and antenna instead of the dummy load. If you have any option, practice first with a balanced and least complex antenna! Choose a band where you think the arms should be resonant, preferably as a half wave dipole. Go through the matching process and check all is well! If there is some reactance, then the proper adjustment of CV2 to minimise the LED output will cancel out the reactance. For 160m, there might not be enough inductance on L2 or enough capacity on either CV1 or CV2. Put either or both S2 and S3 down as required. The extra capacitor C3 220 pF is more likely to be required across CV1, but can alternatively be connected across CV2 (see Fig. 3) if required with some antennas.

If you find the LED indication a little insensitive, you can reduce R7 down to around 1K but it will then tend to dissipate more of your expensive RF!

If you intend to use a meter instead of the LED indicator, disconnect the wire from point P leading to the LED. Connect the positive side of the meter through a suitable meter scaling resistance (to achieve about 10v FSD) to the point P, with the meter negative side to any 0v/E point. Alternatively, use the point Q output where D2 isolates the AMU bridge from any receiver S meter circuits. The drive from the S meter should also have a diode in series. If the Walford Electronics Meter kit is being used, connect the AMU point Q to the Meter kit

point D. The Meter kit matching bridge section is not used and maybe separated from the AGC/S meter section (or at least Meter kit D8 should be disconnected). When used with any meter instead of the LED, RT1 is adjusted for full scale deflection of the meter, when the rig is giving full output into a 50R dummy load. (Due to the potential wide range of resistive loads on RT1, it's settings maybe a bit tender!)

If you plan to install it in a *metal* case, ideally this should be a somewhat larger than the front panel to keep the metalwork well separated from RF parts. If it has to go in a small case, you may find that squashing the coil strap down will decrease its height (so increase the distance to the top of the case) without appreciably affecting its inductance.

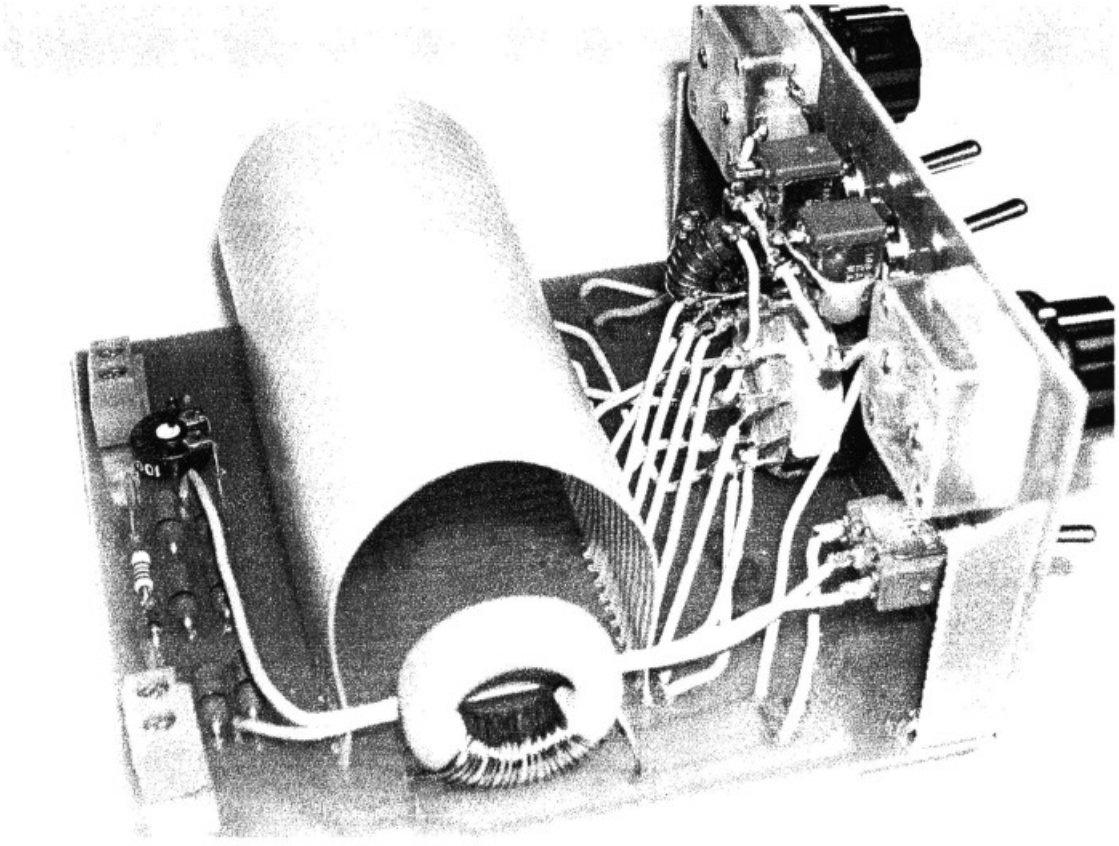
Unbalanced antennas

These often cause more problems with a tendency for RF feedback into the transmitter causing instability. This is especially true of end fed long wire aerials lacking a proper balancing RF earth! They can work very well but care is needed. This AMU will not work unless there is a complete circuit for the return RF currents flowing into and out of the wires to O1 and O2. Hence just attaching a random length wire to O1 alone is no good – you must have a connection to O2 also! If you are using an end fed long wire then some form of RF ground connected to O2 is essential, there are two preferred choices. Firstly a counterpoise consisting a quarter wave length of wire for the band being used – it does not have to be up in the air! The counterpoise is the missing half of the half-wave dipole! For multi-band use, many different quarter wave wires can all be connected to O2. Another alternative is to use a good real RF earth made up of several spaced out stakes driven into the ground and linked by thick cables (least R/L). This must not be directly connected to mains earth for safety reasons.

The other group of 'earthy' alternatives - water pipes, central heating pipes, structural steel, or even mains earth, are not recommended. They may help you to radiate tolerably well but you are much more likely to have problems with inference to other equipment nearby, and or suffer mains induced interference in your own RX! A common suggestion for a low frequency band, is to use the feeders of a higher band dipole strapped together working as a T aerial tuned against some form of 'earth'. This is fine if a good RF 'earth' is available but the quality of that earth is crucial; using mains earth etc. can lead to tender AMU settings – the reason is that your house wiring may actually be resonant for the band being used! These sorts of unpredictable RF 'earths' are best avoided.

That's all! I hope all goes well! Finally I must thank those many customers who have nagged at me for an AMU project and to Andy Howgate in particular for strongly suggesting that it be based on the T configuration! This is the Mk 4 version!

Tim Walford Dec 23rd 2002, Updated Feb 3rd, Mar 12th, June 5th 2003



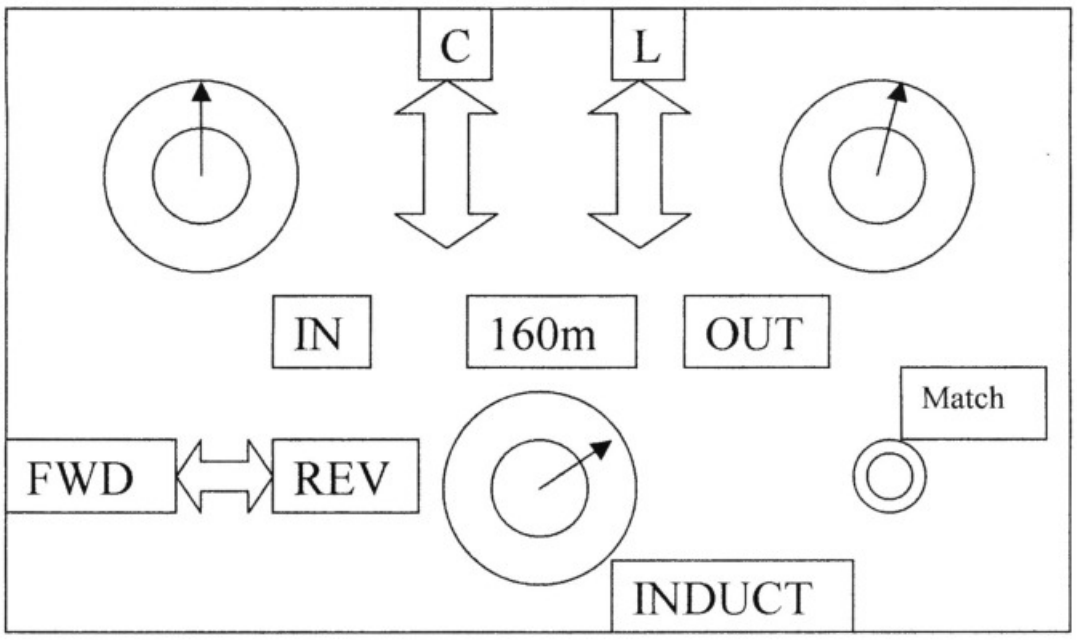


Diagram 1 – Suggested front panel lettering.

Parts List for the Antenna Matching Unit

Resistors			Capacitors		
6	100R 2 Watt	R1 to 6	2	10 nF disc – 103	C1, 2
1	10K	R7	1	220 pF HV disc - 221	C3
			2	65/150 pF Polyvaricon + shaft	CV1, 2
1	100K preset	RT1	4	M2.5 6mm Counter-sunk bolts	CV1,2
			4	M2.5 washers	CV1,2
			2	M2.5 12mm pan head bolts	CV1,2
Inductors and semi-conductors			Miscellaneous		
1	Large violet toroid	L1	4	Rubber feet	
1	30 way 4 inch PCB strap	L2	2	Two terminal screw blocks	
1	T68-2 Red toroid	L3	3	SPCO toggle switches	S1,2,3
2m	22 Gauge Enam wire	For L3	1	1 pole 12 way rotary switch	
			3	Small knobs	
2	1N4148	D1, 2	1.5m	Single core wire	
1	High Intensity LED plus mounting bush/ring	D3	100mm	Multi-stranded wire	
			2	PCB side braces	
			1	Etched SS front panel	
	TRN Walford G3PCJ	14/12/02	1	Main SS etched PCB, Mk4	Is 1A

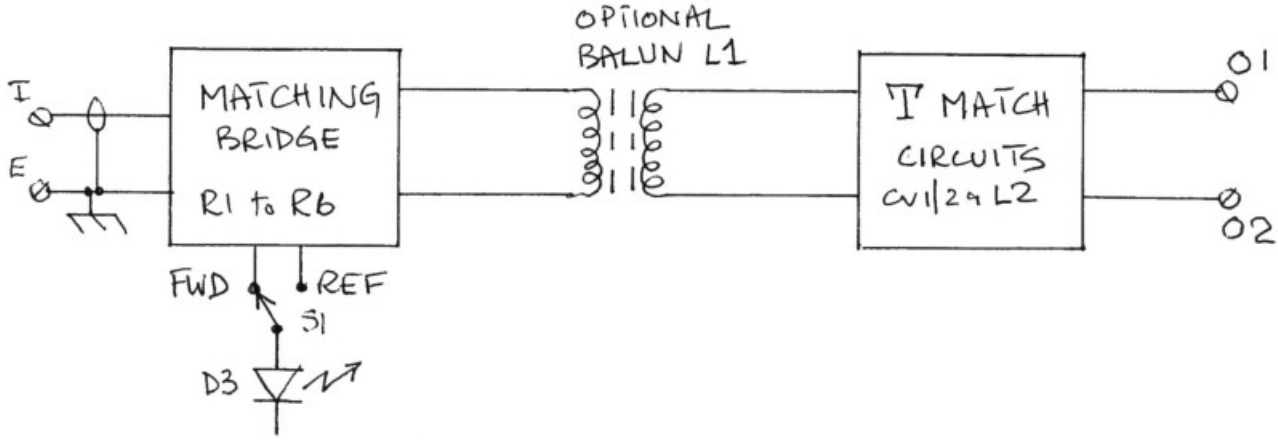


FIG 1: BLOCK DIAGRAM OF AMU

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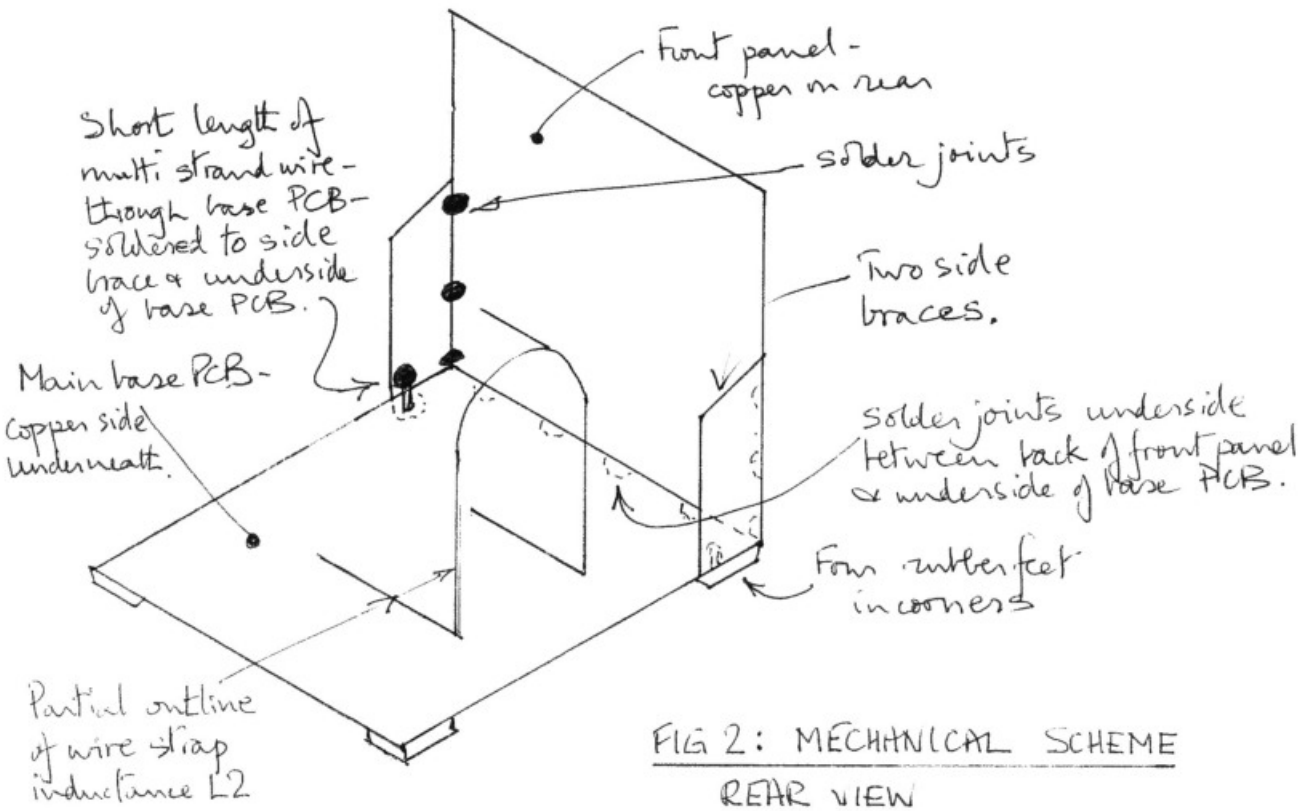


FIG 2: MECHANICAL SCHEME
REAR VIEW

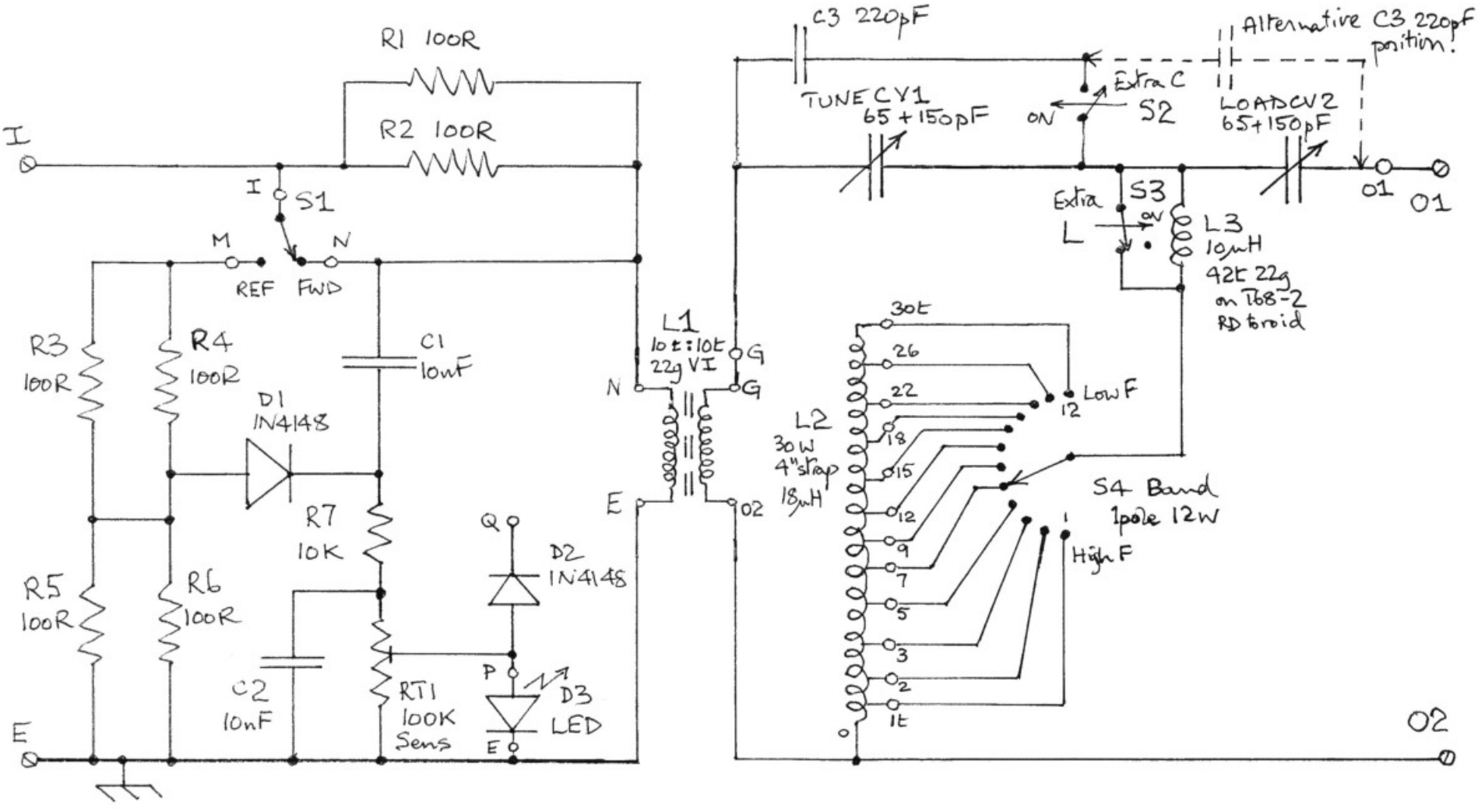


FIG 3 : CIRCUIT OF ANTENNA MATCHING UNIT

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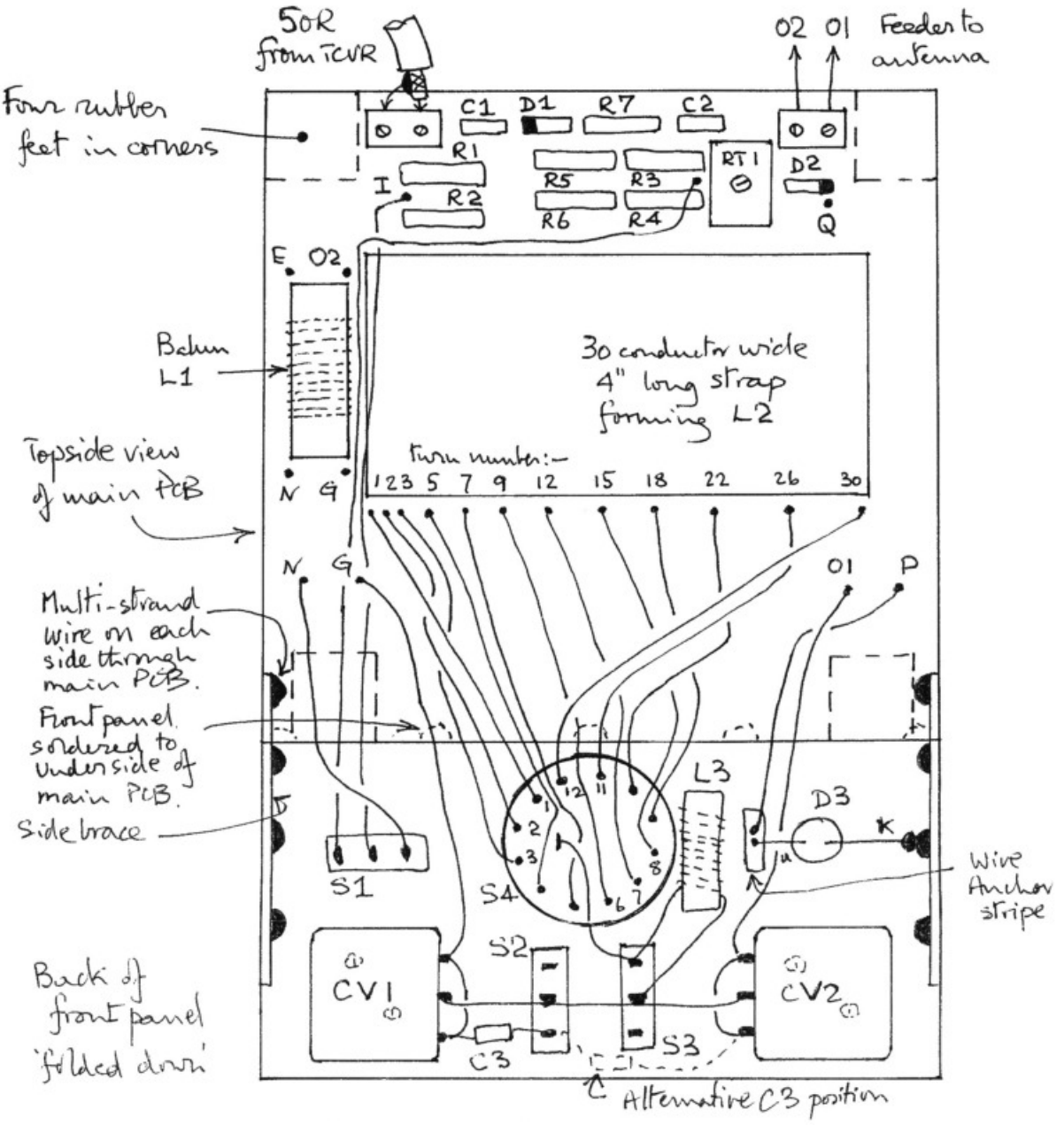


FIG 4: PARTS LAYOUT OF THE AMU

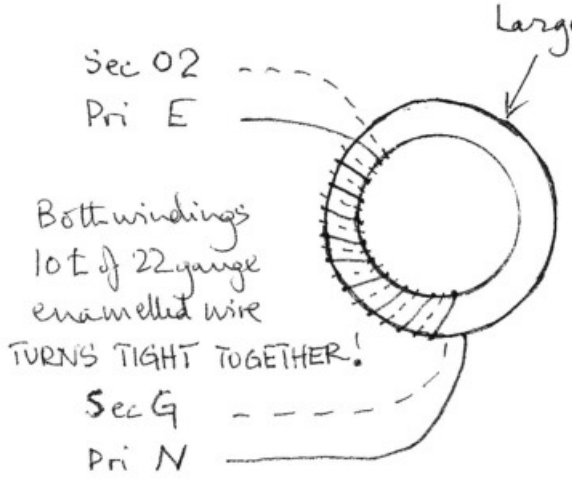


FIG 5: SIDE VIEW OF BALUN RF TRANSFORMER L1.

(Not to scale)

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6/6/03