ANTENNA MATCHING UNIT ROUND-UP

E.J. Van Loggerenberg *ZS2LR*

Part 1.

The need

The modern HF transceiver usually has a broad banded solid state final amplifier designed to work into a resistive load of approximately 52 ohm. Since most antenna systems either present a slightly reactive load or are not that exact impedance, such an output system seems to me to be more wishful thinking than any thing else. Apparently, manufacturers have also had their thoughts along those lines since the latest idea seems to be to include a matching unit inside the rig itself together with an S.W.R. indicator. Another consideration is the harmonic suppression level of the average rig. The harmonics are required to be 40 db down by regulation and this is the average specification seen for most commercially available rigs. As I have commented previously, harmonics at -40 db still present a problem to receivers in close proximity to the transmitter. A suitable matching unit also serves the purpose of reducing those offending signals. No station can be considered complete today if it does not employ a good low pass filter, a good S.W.R. monitor and an antenna matching unit. The matching unit should be chosen so that it has a low pass characteristic. Bear these facts in mind when you are experiencing TVI and BCI problems.

The Ideal Matching Unit

The ideal matching unit would have the following characteristics:-

(a) Able to transform from a high impedance to a low impedance and visa versa.

(b Able to tune out any reactance present and present a purely resistive load to the transmitter. It is probably because of this "tuning" ability that the device is commonly known as an "Antenna Tuning Unit".

(c) Able to match both balanced as well as unbalanced lines to the rig.

(d) Includes an impedance noise bridge as an aid to setting up while off the air.

(e) Includes an S.W.R. indicator as a monitor while on the air.

(f) Constructed of components to present little loss and rates in excess of the transmitter output power.

(g) Includes an antenna switch which earths unused antennas and has a position to disconnect and earth all connected antenna systems.

(h) Includes a dummy load to facilitate tuning and loading of the rig off the air for test purposes.

Choice of Circuit

If you intend "rolling your own" as hopefully you do, a careful consideration of the circuit to use should be made. Decide whether you would like to have all the facilities of an ideal unit or if you only require those that fulfill your particular purpose and combine those into one unit. A single purpose unit will not be of much use if you are going to play about with different antenna systems. On the other hand, if you intend using only one antenna for the next twenty years, a single purpose unit should suffice.

Circuits to choose from

There are many circuits to choose from and these will be found in the Radio Amateurs Handbook as well as in the various antenna handbooks. No originality is claimed by the following anthology of circuits since they are common knowledge by now. All of them were taken from available handbooks. Each one has a different characteristic worth studying. All the circuits shown and discussed have been tried by the writer.

Figure 1 shows a simple series circuit consisting of a variable

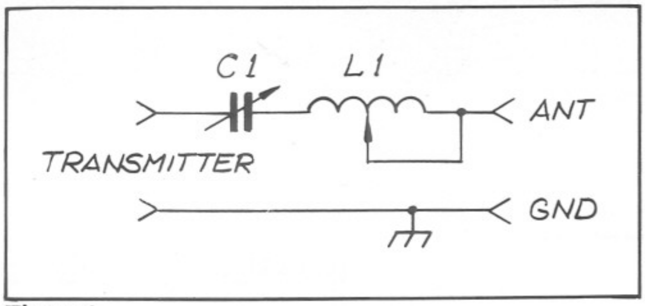

Figure 1

capacitor connected in series with a variable or tapped inductor. It is important to note that the unwanted portion of inductance must be shorted out and not simply left open circuit in this application. The circuit may be used to match an antenna of unknown impedance When the circuit is tuned to resonance the reactances in the circuit cancel each other and the load is applied to the transmitter untransformed. Either side of resonance the circuit is intended for matching an unbalanced antenna such as a random length of wire. Its filtering characteristics can be either high or low pass depending whether the final adjustment results in a capacitive or an inductive reactance respectively. It is not recommended as a harmonic killer.

The circuit of **figure 2** is that of an L-network which is

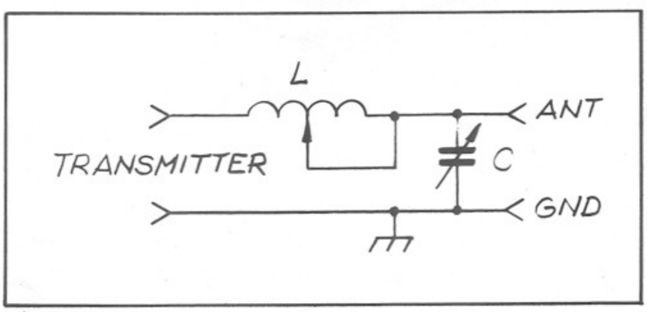

Figure 2

sed to match an unbalanced high impedance antenna to a low impedance rig. Since it consists of a series of inductor and parallel capacitor, the circuit has good low pass characteristics. It is very suited to matching resonant end fed long wire antennas. Circuit values may be calculated from:-

where Rin = input impedance and Ra = antenna impedance..

Inductive reactance $XL = \sqrt{Ra \times Rin - Ra^2}$

Capacitive reactance $Xc = \dfrac{Ra \times Rin}{XL}$

The circuit of **figure** 3 is that of an L-network which is

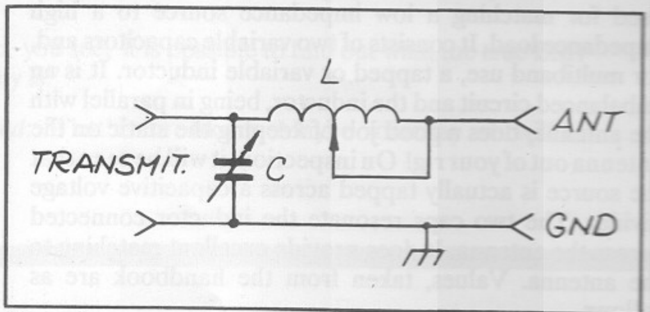

Figure 3

used to match an unbalanced antenna which has a lower impedance than the output of the transmitter. It has good low pass characteristics for the same reasons as given for figure 2. It is suited for matching loads as a quarter wave antenna. Circuit values may be calculated from:-

Capacitive reactance $= Ra \times \sqrt{\dfrac{Rin}{Ra - Rin}}$

Inductive reactance $= \dfrac{Ra \times Rin}{Xc}$

The question that may arise at this point is, "Where do you get a value for Ra, the antenna impedance?" Simply, measure it by means of a bridge. On the other hand, it may be estimated bearing the length of the radiator in mind and drawing current and voltage nodes beginning at the far end of the antenna.

The circuit of figure 4 is that of a Pi-section network which is mostly used to match a high impedance source to a low impedance load. It has very good low pass characteristics. On inspection, it will be seen that it is a combination of the previous two circuits and may be used as such. By setting either capacitor to zero capacitance, the circuit may be used as a simple L-network for matching to either a low or high impedance. It is therefore a very versatile circuit when working with may types of antennas where the impedance may not be known. There is, however, one problem that must be

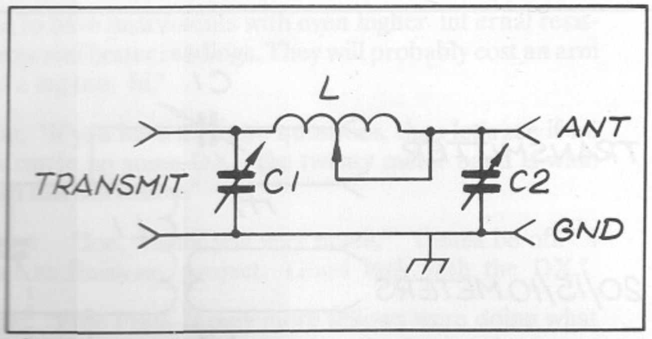

Figure 4

borne in mind. If this circuit is used with a final amplifier which also uses a pi-section output tank circuit and an S.W.R. indicator is placed between the rig and the matching unit, false indications will result on the S.W.R. indicator. You will be loading the input cap of the matching unit, so to speak. The circuit is of course meant for an unbalanced load. If the componets are properly chosen and it is required to match a load which impedance is lower than the source, it is better to do the matching adjustment with the aid of an impedance bridge. After adjustment, ignore the S.W.R. indicator should the rig have a pi-section tank circuit. It will not indicate the true situation. To calculate the values of the components, consult your Radio Amateurs Handbook which gives you full details. It is not as complex as you may at first think.

Balanced Antennas

The previous circuits may easily be used to match antennas that present a balanced load. Insert a balun of suitable ratio between the antenna and the matching unit. Usually a 4:1 ratio will be sufficient. Baluns are very simple to construct and should present no difficulties to the constructor. Once again, details can be found from the handbook or from one of the excellent articles that appear from time to time. A word of warning. If the antenna being fed is a high impedance voltage fed antenna, high voltages appear at the fed end and the insulation used in the construction of the balun must be suitable. The writer has burnt up quite a few during experimentation.

The previous circuits are favorites with the writer. The circuit (as shown on page 8) is a well tried and useful circuit.

The circuit of **figure 5,** (see page 8), is popularly known as the "Z Match" and is intended for use with a balanced feeder. It consists of two interconnected circuits and has good bandpass characteristics. It is a multiband circuit which requires no inductance adjustment. The writer has used this circuit successfully to match a G5RV and a center fed co-linear array. Both antennas used parallel open wire feeders and no matching stubs, baluns or coaxial cable feeders. Don't be frightened by stories of TVI and BCI. As long as your harmonics and spurii are well suppressed, you should have no problems.

Circuit values are as follows:-

L1 = 3,4 μH : 7,35 turns 16 SWG 52 mm diameter. Length is 32 mm.

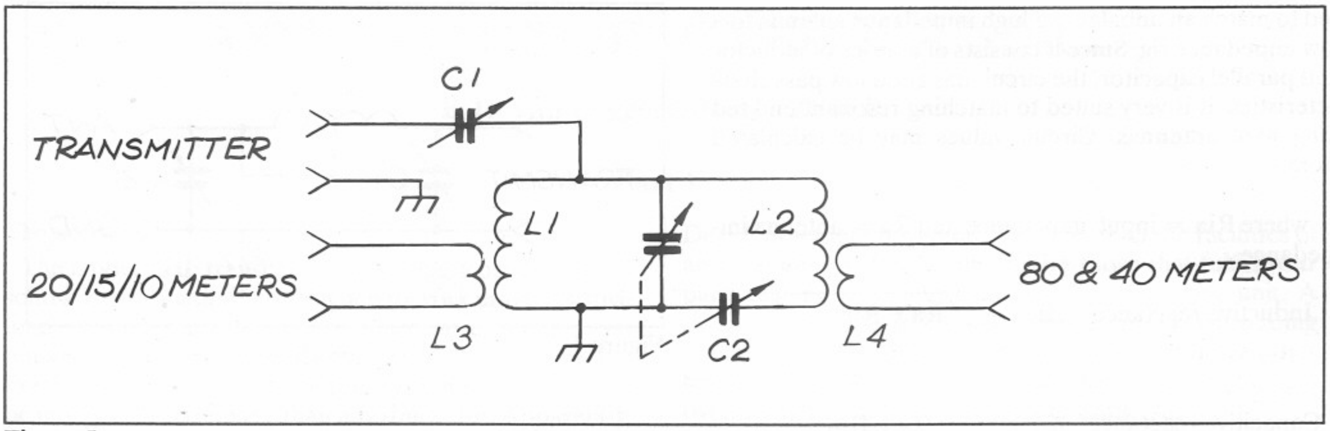

Figure 5

L2 = 1,7 μH : 5,5 turns 16 SWG 52 mm diameter. Length is 41mm.

L3 = 2,35 μH : 6,5 turns 16 SWG 67 mm diameter concentric with L1. Length 13 mm.

L4 = 1,8 μH : 4,75 turns 16 SWG 67 mm diameter concentric with L2. Length 13 mm.

C1 - single gang 340 pf : C2 double gang or split stator 250 pf per section.

Mount the two coil assemblies at the right angles to each other to minimize interaction between the two.

Calculating the number of turns

My apologies for not knowing the metric equivalent, but the number of turns for a special inductor may be calculated from:-

$$N = \sqrt{\frac{L \times (9r + 10l)}{r^2}}$$

where:- N is the number of turns; L is the inductance in microhenry; r is the radius of the coil former; l is the length of coil in inches.

Mount the coils at least the coil diameter away from any metal work. Keep all connecting leads as short as possible.

The circuit of **figure 6** (below), is popularly known as a "Transmatch". The writer found that the pi-section circuit had better low pass characteristics. The circuit is usually used for matching a low impedance source to a high impedance load. It consists of two variable capacitors and, for multiband use, a tapped or variable inductor. It is an unbalanced circuit and the inductor, being in parallel with the antenna, does a good job of keeping the static on the antenna out of your rig! On inspection, it will be seen that the source is actually tapped across a capacitive voltage divider. The two caps resonate the inductor connected across the antenna. It does provide excellent matching to the antenna. Values, taken from the handbook are as follows.

C1 = split stator 200 pf per section.

C2 = single gang 350 pf

The inductor is a variable type having a maximum value of 28 mH. Adding a 4:1 balun at the output makes this a very versatile matching unit. It also suffers from the same problem as other units having an input capacitor across the input terminals when used with a pi-section output tank circuit in the transmitter

The circuit of **figure 7** (see page 9) is that of a tee section matching unit. As will be seen, it consists of two variable capacitors in series with the load and a of the two capacitors. This configuration represents a high pass characteristic. It can be used for matching to both high and low antenna impedances. It does not suffer from the

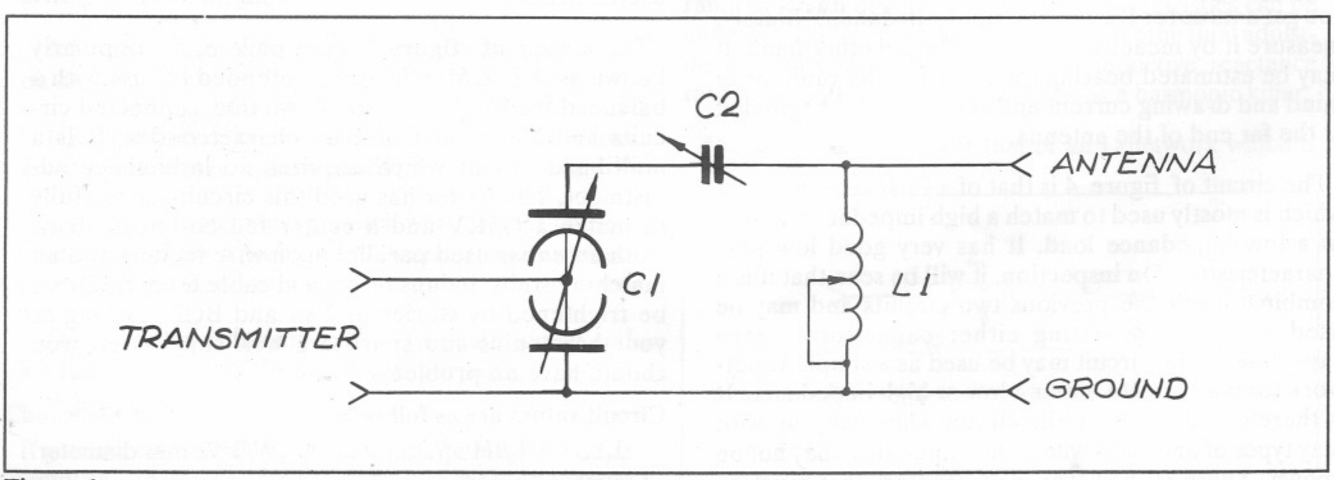

Figure 6

13,3 vol t s (recurring), a meter internal resistance of 0,5 Megohm and a source resistance of 0,25 Megohm-

Since $Vm = Im \times Rm$ and since $Im = \dfrac{E}{Rs + Rm}$

$$Vm = \frac{E \times Rm}{Rs + Rm}$$

therefore:-

$$E = \frac{Vm\,(Rs + Rm)}{Rm}$$

Substituting the values given above:-

$$E = \frac{13{,}3 \times 0{,}75 \times 10^6}{0{,}5 \times 10^6} = 20 \text{ volts}$$

So, you see, it is possible to find out what the true EMF really is."

Fred: "That's more like it. Maybe someday we will be able to have instruments with even higher int ernal resistances and better readings. They will probably cost an arm and a leg too. hi."

Joe: "If you have no more questions, then let's see if we can rustle up some DX - the twenty meter band is wide open this afternoon."

Fred: "Joe, thank you very much, I must be off. I want to finish my project. Good luck with the DX."

Joe: "Fine Fred. If only more fellows were doing what you are doing - some construction, the future of amateur radio would be more secure. When you have that project working, how about swotting up old Ohm's Law again; a little of Kirchoff will do no harm as well, but, leave the terrible twins, Norton and Thevenin alone, they are bound to confuse you. hi. hi. Cheers, see you later Fred my mate."

Fred: "Cheers Joe, thanks again."

The two metre rig on Joe's desk remained silent all this time. A great pity.

ZS

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CONCLUSION

The circuit of **figure 7** is that of a tee section unit. As will be seen, it consists of two variable capacitors in series with the load and a variable inductor connected in parallel at the junction of the two capacitors. This configuration represents a high pass characteristic. It does not suffer from the problem that other units have when feeding from a pi-section output tank. The writer found it to be a very effective no-nonsense matching unit. For multiband use, the writer used two capacitors of 350 pF each and a tapped inductor of 28μH. As such, it is intended for use with an unbalanced feeder. Once again, a 4:1 balun added at the output of the unit enables it to be used with balanced feeders.

There are many other specialised antenna matching units which will be found in the handbooks. Most of them are single purpose units using components suited ,mostly to only single band, requiring changing of coils and adjustment of tappings. This makes hopping from one band to another a laborious task and takes the fun out of chasing that elusive rare DX station. All the tuners considered here can be constructed as multi-band units using variable roller type inductors or multi-tap inductors and twelve position switches to change the value of inductance.

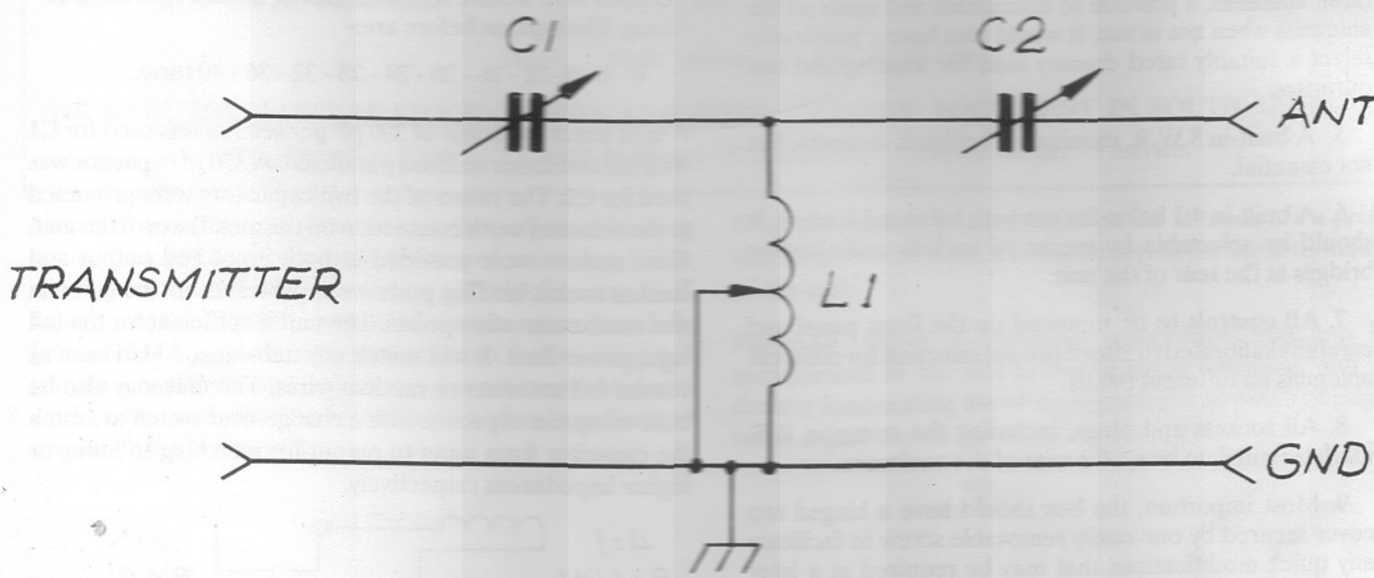

Figure 7

Construction

The first consideration when constructing any piece of equipment is of course the aquisition of components. The biggest problem facing the constructor today is the availability of transmitting type tuning capacitors. They are obtainable - but at a steep price for what you get. There must be a great deal of these components stored away in junk boxes all over the world. The most likely source of supplies of second hand capacitors is from the old timers who used to roll their own in years gone by. Flea markets and swop shops provide another source of supply. Roller inductors are worth their weight in gold today! The writer has not been able to lay his hands on one yet!

The matching unit may simply be constructed on a wooden board (the original breadboard), but to make full sense of the harmonic suppressing capability of the unit, it should be enclosed in a metal box with the case connected to the common R.F. earth. The writers choice of a multiband matching unit would consist of the following:-

1. P-section circuit using a roller inductor. Capacitors suitable for use at the maximum legal power limit with the output capacitor plate spacing suitable for working into fairly high impedances. The input capacitor need not have a large spacing since the impedance is low.

2. The inductor would be a roller inductor of about 28 μH. In the absence of such a unit, an inductor tapped and selected by multi position rotary switches. A large capacity series variable capacitor could be used for fine adjustment of the inductor.

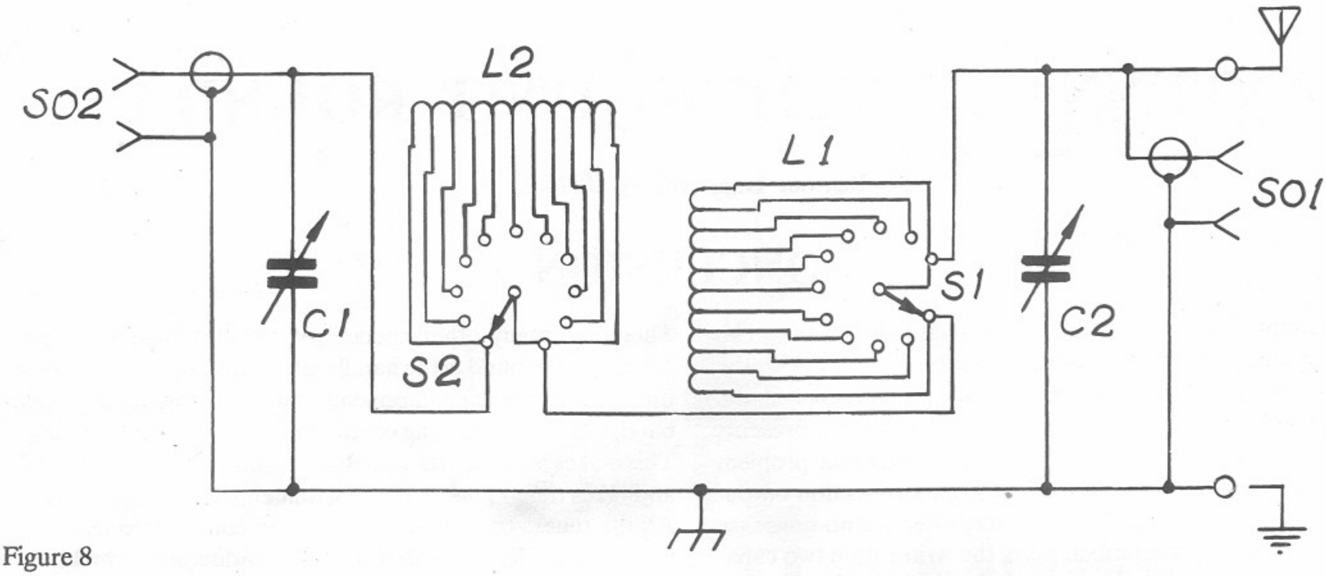

Figure 8

3. A built in noise bridge for matching adjustment off the air, switchable in or out of circuit with an interlock contact on the selection switch to disable the transmitter while the bridge is in use.

4. A built-in antenna switch capable of selecting at least three antennas, a position to disconnect and earth all the antennas when not in use. It would also have a position to select a suitably rated dummy load for loading and test purposes.

5. A built-in S.W.R. monitoring bridge is desirable but not essential.

6. A built-in 4:1 balun for use with balanced feeders. It should be selectable by means of sockets and shorting bridges at the rear of the unit.

7. All controls to be mounted on the front panel and carefully calibrated to afford pre-set selection for different antennas on different bands.

8. All sockets and plugs, including the common R.F. earth terminal, to be on the rear of the enclosure.

9. Most important, the box should have a hinged top cover secured by one easily removable screw to facilitate any quick modifications that may be required at a later stage. Amateurs are experimenters!

If you have bothered to read this far, then you are probably a home-brew type and not a "buy-it-over-the-counter" type. Good luck and have fun. Incidently, 150 watts at 53 ohms represents a peak voltage of about 125 volts; at 300 ohms it is about 300 volts and at 1000 ohms it is 1100 volts. The peak to peak value, which the capacitors should be rated for, are double those voltages.

Getting back to earth, for the benefit of those that may want to hame brew their own matching unit, but lack ideas, figure 8 shows the circuit diagram of one of the writers matching units.

Si and S2 are eleven position single wafer switches arranged to progressively short out L1 and L2. The two inductores L1 and L2 are mounted at ninety degrees to each other to minimise coupling between the two coils.

L1 consists of 16 turns of 1,18 millimeter bare tinned copper wire wound to a diameter of 50 mm and 50 mm long. The taps are made at the following number of turns (including beginning and end).

0 - 2 - 2.5 - 3 - 3.5 - 4 - 4.5 - 5 - 6 - 7 - 16 turns.

L2 Consists of 40 turns of 1,18 millimeter bare tinned copper wire wound to a diameter of 50 mm and 120 mm long. The taps, as before are:-

0 - 4 - 8 -12 - 16 - 20 - 24 - 28 - 32 - 36 - 40 turns.

A split stator capacitor of 200 pF per section was used for C1 with the two stator sections paralleled. A 350 pf capacitor was used for C2. The rotors of the two capacitors were grounded to the common earth connection on the metal case of the unit. Coax sockets were provided at both input and output and banana socket/binding posts were provided for the antenna and earth connection points. The unit is sufficient for the full legal power limit. It will match any unbalanced load such as coaxial fed antennas or random wires. The unit may also be built using one capacitor with a change-over switch to switch the capacitor from input to output for matching to lower or higher impedances respectively.

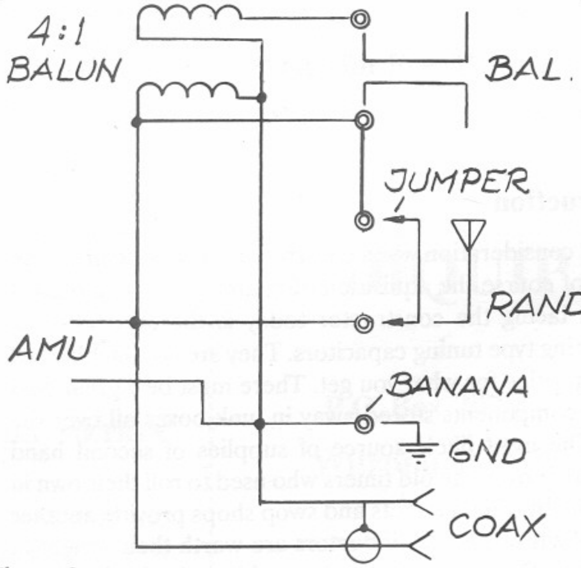

Figure 9

Figure 9 shows a circuit arrangement for connecting a 4:1 balun at the output of the unit so that balanced feeders may be employed. In order to make the connections as short as each end to form a jumper between two adjacent binding posts. The writer's balun is an air wound unit using bifilar windings of 12 turns close wound on a 25mm diameter PVC former. A 42 meter long center fed antenna was successfully fed on all bands from eighty meters to ten meters using this arrangement. If you use such a balun, keep it away from metal work and use sufficient insulation for the high voltage that may appear on the balanced line.

If the presence of static charges on the antenna are a problem, simply connect an R.F. choke across the input terminals of the unit.

Figure 10 shows a switching arrangement that may be incorporated in the unit to switch three antennas and a dummy load making use of a ganged wafer switch. The single wafer switch shown is, of course, better.

ZS

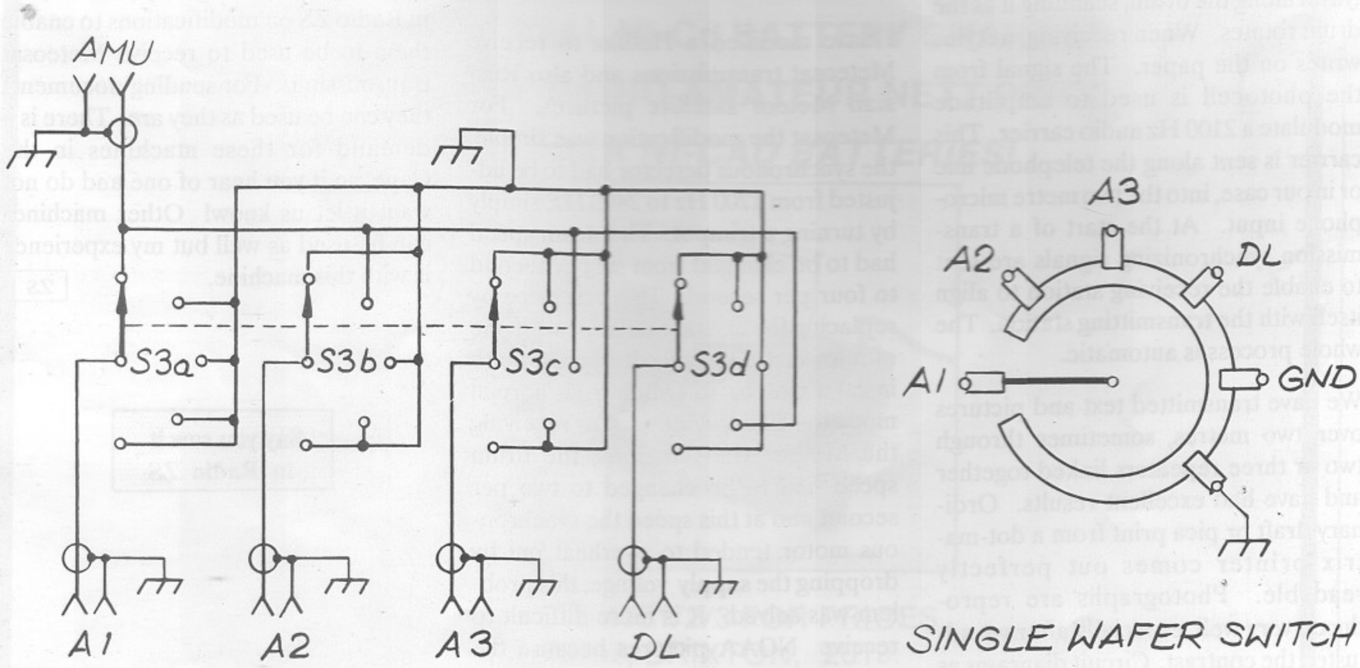

Figure 10