Antenna Tuning Unit (ATU) using the T-Network approach

By Chris Arthur VK3CAE

Some years ago now I decided to build myself an ATU similar to the Ultimate Match as described in the ARRL Antenna Handbook. I had been using a Z-Match unit as found in RSGB publications, however the Z-match does have some limitations and I needed a more versatile unit, the Ultimate Match looked like the answer. At the time I had a nice roller inductor and some Johnson make high voltage variable capacitors, the ceramic insulator type. The problem was that both of these capacitors were of mono stator construction and a split stator was required for the input capacitor of the original ultimate match and the output capacitors of the later SPC match, both shown in fig 1.

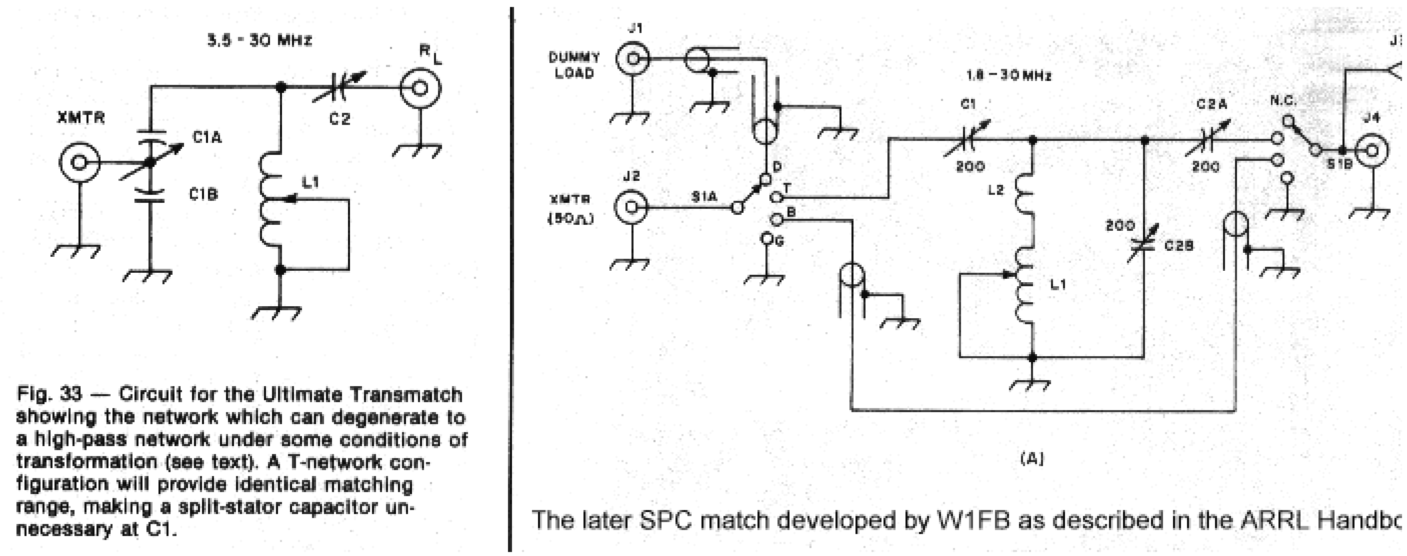


Fig. 33 — Circuit for the Ultimate Transmatch showing the network which can degenerate to a high-pass network under some conditions of transformation (see text). A T-network configuration will provide identical matching range, making a split-stator capacitor unnecessary at C1.

The later SPC match developed by W1FB as described in the ARRL Handbo

fig 1 From the Station Accessories section of the ARRL Handbook

The later Series Parallel Network or SPC was developed by W1FB to correct for poor harmonic attenuation of the original circuit when used under extreme mismatch conditions. After talking to one of the MDRC old timers (Bill VK3ATW Silent Key) I decided that this would not be a problem at power levels of 100 Watts or less and opted for the simple T-Network approach. A T-Network will have an identical matching range to that of the Ultimate match making a split stator variable capacitor un-necessary.

ATU Component Considerations

Prior to souring our ATU bits we should consider a few things like, what power will I be using? Will my ATU be used under severe mismatch conditions and do I need a balun for open wire feeders? These are all important factors as the unit may be exposed to quite high RF voltages and currents, the last thing you want your ATU doing is suffering from flash over or heating problems.

Variable Capacitors

Most manufacturers of air gap type caps (variable or other) use a de-rated breakdown figure for the safe WVDC level. The actual break down Voltage of dry air is around 10E6 Volts per Metre, or 1000 V / mm. So a variable Capacitor with 1 mm plate spacing could take up to 1000 volts DC or Peak to Peak AC before arcing would occur, this figure would be somewhat less in humid or damp air (< 700 Volts). This break-over voltage is one of the factors that determines the ATU's safe operating power and in-turn limits its impedance matching ratio.

On recalling Ohms Law, we know that for a fixed power level a higher resistance value will cause a higher Voltage. In a 50 Ohm system we would have around 200 Volts Peak to Peak for the nominal 100 Watts output from your average HF transceiver. However, for an impedance of 600 Ohms you would have around 700 V P-P at the same power level. So if you want your tuner to match over a wide range of complex impedance's then you should use around 1 kV rated variable capacitors (at least 1mm spacing between plates) for the 100 Watt level and 3 to 5 kV for the VK legal limit (and higher).

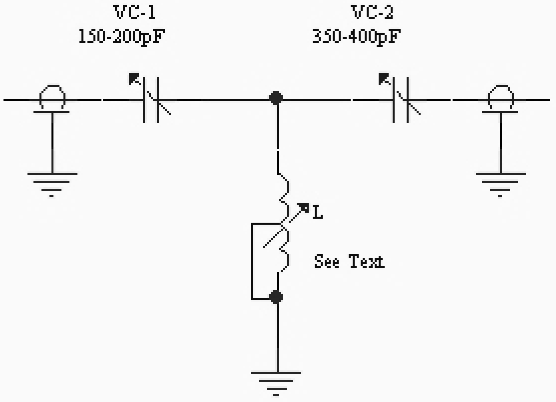
Variable Inductors: Switched & Rotary

Inductors used in ATU applications will under some conditions carry very heavy currents to ground, if the windings use a wire of insufficient diameter there will be high Q losses and considerable heat generated. A good rule of thumb would be "the heavier the inductor wire the better" but then physical size and mechanical constraints may become a problem. For most amateur type ATU applications a wire diameter of 2 mm (No 12 AWG) would be fine, this would be suitable for powers up to the legal limit. For low power to a maximum of 100 Watts you could get away with using wire diameter of 1 mm but in the end one should always go for the heaviest wire possible. Suitable values of inductance for use with the circuits shown in this article would be in the range of 25 to 35uH. Inductors can be of a fixed tapped type or a roller type, I find that roller inductors are much easier to tune when compared to the switched inductors (if you ignore turning time that is).

A roller inductor with 25 or more turns of 1.2 mm dia wire (No 17 AWG) on a 50 mm former would be nice for the 100 Watt level and would easily cover 160m through 10m operation. This is what I used in the T-Network described below but if you can't get your hands on a roller inductor then you can use a tapped and switched inductor as follows:

- 24 turns of 2 mm dia wire spaced at 6 TPI on a 50 mm dia former (air).

- Place taps (from non-earthed end) at 2 turns, 5 turns, 8 turns, 12 turns, 16 turns and 20 turns,
giving a total of six taps for switching to ground.



The Simple but effective T-Network type ATU
Tri-pole, 5 way switching was added for ant A, B or Dummy.

- A High Voltage ceramic insulated single pole multi-way switch is used to short the unused turns to ground.

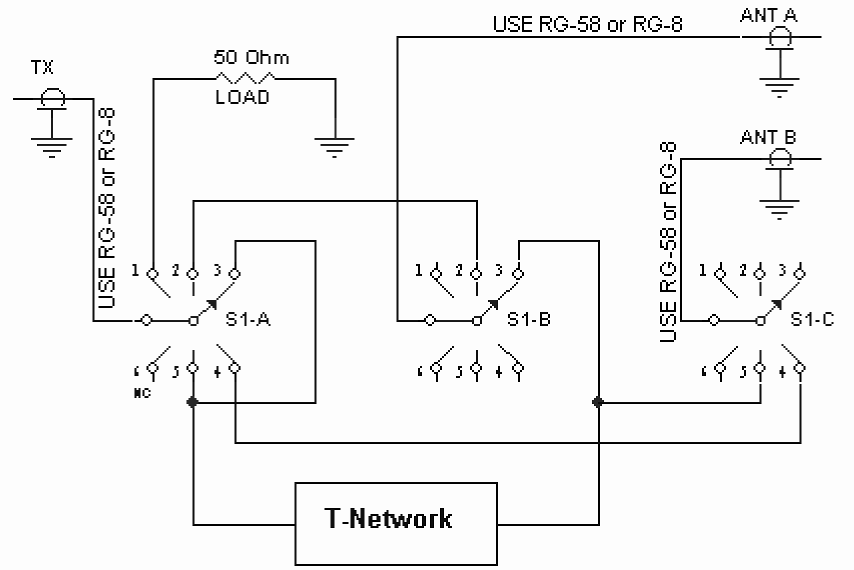
In my test version this configuration gave quite good results but the inter-connects between coil taps and switch block should be kept as short as possible and made with heavy wire there-by reducing additional inductance. I also found that a good match was difficult to obtain under some load conditions when using 150 pF for C1. Use a 200 pF for C1 with a switched type inductor, this should give some over-lap in each switch position.

The Simple T-Network type Antenna Tuning Unit

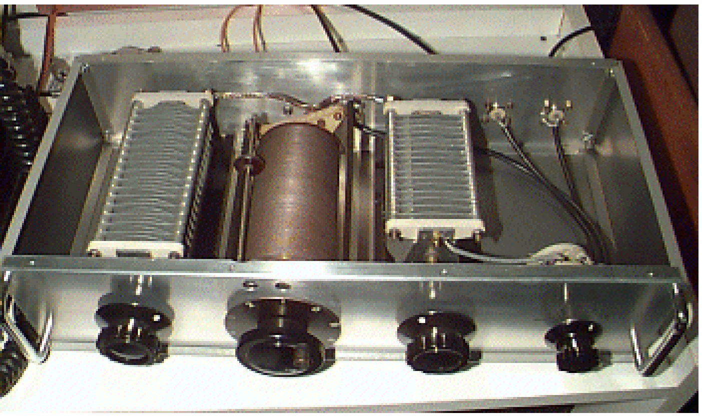
The basic T-Network ATU performs reasonably well under a wide range of impedance mismatches and its adjustment can be quite straight forward if a roller inductor is employed for L. As mentioned previously the only real problem with this T-Network circuit is that the ability to suppress harmonics degrades somewhat under severe mismatch conditions. At powers of up to 100 Watts this is not really a problem but if you're planning on using big power in suburbia with a wire antenna, then one should consider the SPC match with its better harmonic suppression characteristics as an option.

All of the components used in constructing my ATU were reclaimed from surplus type equipment found at amateur radio swap meets and the like. Purchasing the Johnson make Variable Caps new here in VK would set you back around hundred dollars each and then there's the roller inductor, another $150, you can see why a good commercial ATU cost big dollars. When laying out components you should allow a clearance of at least 15 mm in order to minimise coupling effects. Interconnecting wires on caps and inductors should be heavy enough to prevent inductive losses. I used the braid from RG-58 coax, when in place, solder was flowed through it to make a heavy rigid wire.

Switching scheme used in the VK3JEG ATU



To maintain low intro SWR make sure that input/output sockets are connected to S1-x via 50 Coax.



If you wish to add antenna or dummy load switching as I did, then you must run 50 Ohm coax between all sockets and switches. The coaxial braid must be earthed at any sockets and joined at all break points around switch gear, this will minimise the introduction of Standing Waves when switched through (ATU by-passed). A set of three wafers each having five way switching (3 x single pole, 5 way) on a common shaft will allow selection of two separate antennas (A or B) in a bypass or through ATU situation, plus a spare contact for a dummy load or off position.

If you follow the basic guidelines given here, you should be able to build a useful ATU for your station at minimal cost. This picture shows my ATU with the top panel removed, a pair of 50 Ohm dummy load resistors were also removed to show the connector placement (right side behind switch block).

This article is dedicated to Bill VK3ATW Silent Key