DOUG'S DESK

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CONSTRUCTION PROJECTS, TECHNIQUES, AND THEORY

Some Antenna Tuner Tips

Antenna matching networks are known by names such as Transmatch, ATU (antenna tuning unit), antenna matcher, and antenna tuner. Technically speaking, all of these names, other than Transmatch, are misnomers. This is because they do not provide a match between the feeder and the antenna. Rather, they create a match between the transmitter and the station end of the feed line. Nearly all amateur radio operators have these corrective devices connected between the transceiver and the antenna feed line.

The SWR protection circuits in modern transceivers require an SWR of 2:1 or less if they are to deliver the full rated power of the transmitter section. Most HF-band antennas designed for use below 14 MHz exhibit an SWR greater than 2:1 near the edges of the band, and the problem becomes worse as the operating frequency is lowered to 3.5 and 1.8 MHz, in particular. An ATU makes it possible for the transmitter to look into a 50 ohm load with almost any antenna, thereby ensuring the sought-after SWR of 1, even though a mismatch exists at the antenna feed point. Ideally, the tuner would be located at the feed point and operated remotely. This would ensure maximum power transfer to the antenna, since this condition prevails only when unlike impedances are matched. Some amateurs do not realize that matching the transmitter to the feed line fails to remedy the mismatch that exists at the antenna. Other misconceptions about tuners are common among amateurs who lack technical knowledge. This article explains the functions and ills of tuners, along with some guidelines for building an ATU.

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Do Tuners Require Shielding?

Contrary to common belief, an antenna tuner does not need to be enclosed in a metal cabinet to prevent TVI. Television interference is caused by (1) fundamental overloading of the TV receiver front end or (2) harmonic energy from the transmitter. A tuning network cannot create harmonic energy unless it has a bad electrical joint that may act as a diode rectifier, in which case strong harmonic currents can be generated. Likewise for poor antenna joints. Since harmonic suppression is taken care of in the transmitter or through a combination of transmitter filtering and an external low-pass filter, tuner shielding is not necessary. In fact, a tuner (depending upon the network used) can attenuate harmonics. It should, however, have an earth ground connected to it for best harmonic rejection.

Power Ratings for Tuners

This part of our discussion is centered around the circuit in fig. 1, which essentially represents the basis for most homemade and commercial ATUs. This T network has spin-offs that include the Ultimate Transmatch by W1ICP (split-stator capacitor at the input) and the SPC Transmatch by W1FB (split stator capacitor at the output). However, the basic T network performs the same functions as the others, and it can suffer from the same power-related problems.

This question arises frequently: "Why does my tuner arc and burn on some bands, but not on others?" For the most part, arcing results from too much RF power (peak voltage) for the plate spacing of the variable capacitors, or switches that have marginal current ratings and inadequate insulation. The same rule applies to tapped coils or rotary inductors that overheat above certain RF power levels. This would not happen if the tuner contained components with proper safety factors.

With regard to tuners that arc on some bands, or frequencies within a given band, the problem is usually caused by a load that presents a very low impedance. For example, a particular multiband antenna that is fed with balanced ladder-line or open-wire feeders, through a balun transformer inside the tuner, may reflect acceptable impedances (say, 50 to 500 ohms) on several HF bands, but at some other frequency the impedance at the station end of the feed line might be a mere 15 ohms. When this happens the peak RF voltage differential across the output capacitor (C2 in fig. 1) may be several thousands of volts, and arcing will occur. The developed RF voltage at the top of L1 in fig. 1 might be, for example, 5000. Concurrently, the voltage across the 15 ohm load could be as low as 75. The same power level might produce 5000 volts across L1, but

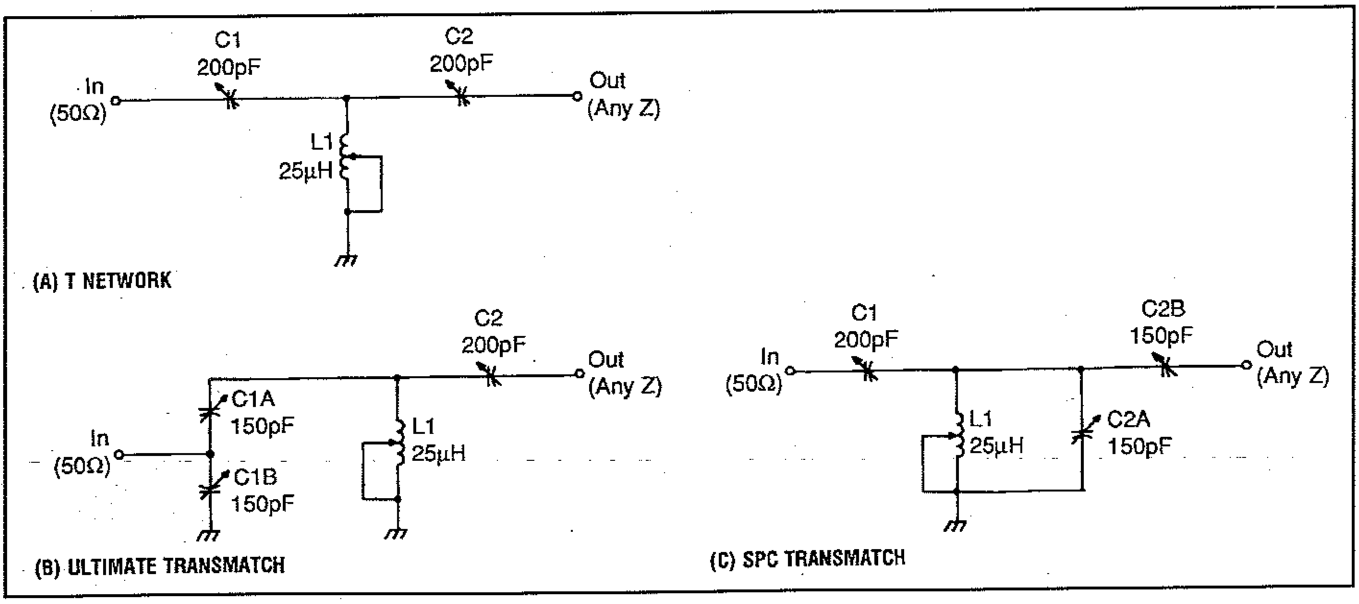


Fig. 1– Schematic diagram of the basic T network around which most antenna tuners are designed. C1 and C2 should have a maximum capacitance of at least 200 pF for operation from 1.8 to 29.7 MHz. L1 requires a maximum inductance of 25 µH or greater for coverage at the low end of the frequency range.

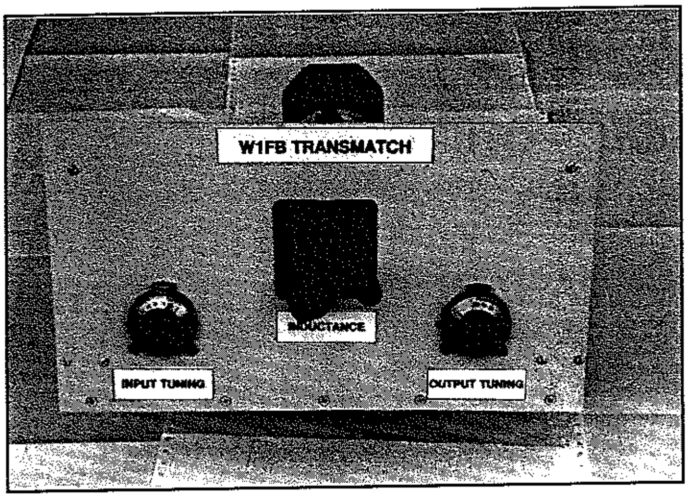
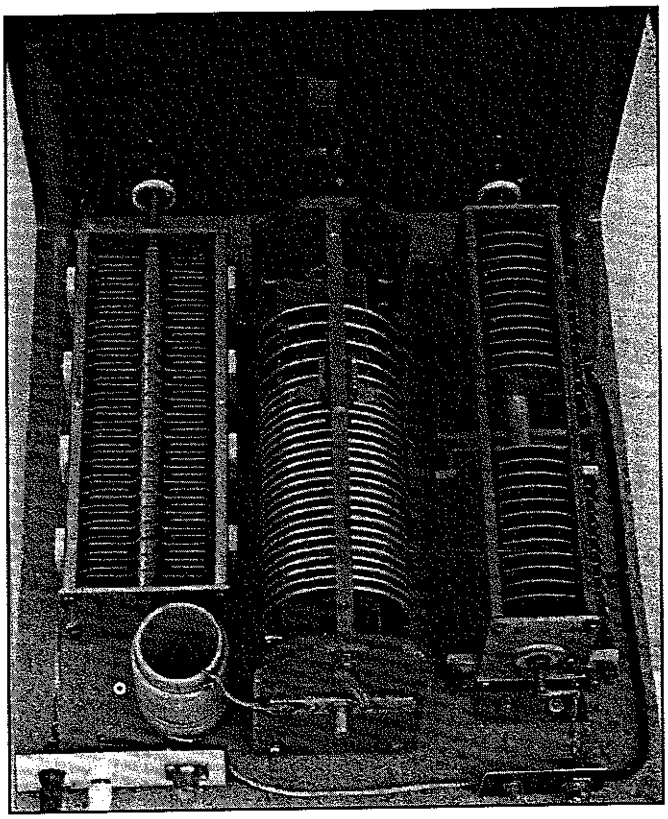


Fig. 2– Photograph of a T-network ATU that will accommodate power levels up to 3 kW peak. Note the wide plate spacing of the variable capacitors. The input capacitor is a dual-section unit with the sections connected in parallel. The large roller coil has a heavy-duty silver-plated conductor. The output jacks are mounted on a delrin plastic block to prevent arc-over at high levels of power. The output SO-239 coax jack has teflon insulation for the same reason. A wooden base is used as the tuner foundation, but the panel is made from aluminum sheeting. The capacitors are isolated from the panel by means of insulated couplings. A large flexible coupler joins the roller coil shaft to the surplus turns counter.



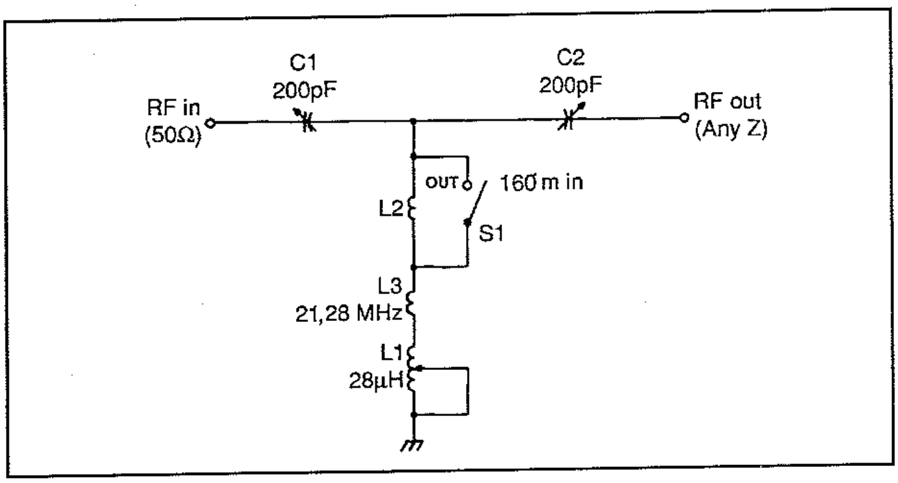


Fig. 3– Schematic diagram that shows how to add a coil (L2) for obtaining additional inductance on 160 meters. L2 consists of 15 turns of solid No. 12 vinyl-covered electrical wire on a 2 inch OD by 5 inch long section of PVC pipe (see text). L3 may be added for improved operation at 10 and 15 meters (see text).

with a 100 ohm load the developed RF voltage would be substantially higher, thereby reducing the voltage differential across C2. The same situation can exist if the load Z is high and the network Z is low. This can be the difference that prevents arcing. Changing the length of the balanced feed line may resolve this problem.

Coil heating may not occur on all of the bands. Again, this will depend upon the RF current that flows through the coil at certain settings of the three controls when feeding a particular multiband antenna. I had an antenna with which my tuner coil (E. F. Johnson roller inductor) ran cool on all bands except 40 meters. After a few weeks of operation the center turns on the coil turned black from excessive heating. Power is wasted when this situation prevails, since heat cannot be generated without dissipating power. The obvious cure for this malady is to use a coil with a much larger conductor size, such as that seen in the fig. 2 tuner.

160 Meter Operation

Some ATUs run out of gas, so to speak, below 3.5 MHz because the capacitors and coil are too low in value to provide a match at 1.8 MHz. A few tuners of commercial origin "almost make it" only at the high end of 160 meters, but that is with the controls set at or near their maximum values. Insufficient inductance is generally the cause of this ailment. Additional inductance (L2) can be inserted at the high-Z end of L1 in fig. 3 to cure the problem. An RF-rated SPST switch can be used to short the additional coil for operation above 2 MHz. If C1 and C2 have a maximum capacitance of 200 pF, they should be adequate for use at 1.8 MHz and above. A fixed-value, high-current, high-voltage capacitor may be shunted across C1 or C2 if those capacitors have values that are too low for 160 meters.

10 and 15 Meter Operation

Amateurs sometimes encounter matching problems when operating a homemade ATU at the upper end of the HF spectrum. This is because the lead lengths in the high-impedance part of the circuit are excessively long (inductive) and because the coil form factor (diameter to length) is so poor that the Q is extremely low: Only one coil turn, or less, may be required for a match at 10 or 15 meters. This prevents establishing the desired 1:1 or 2:1 form factor.

The usual cures for the malady are to shorten the leads between the variable capacitors and J1, J2, and L1. It is vital also to use wide conductors, such as 3/8 inch wide strips of copper. The wider the strips the lower the unwanted parasitic inductance. Also, C1 and C2 of figs. 1 and 3 must not have too great a value of minimum capacitance for operation at 10 and 15 meters. Mounting the capacitors at least 2 inches above a metal chassis lowers the minimum capacitance that occurs between the capacitor plates and the chassis.

The upper HF range problem can often be

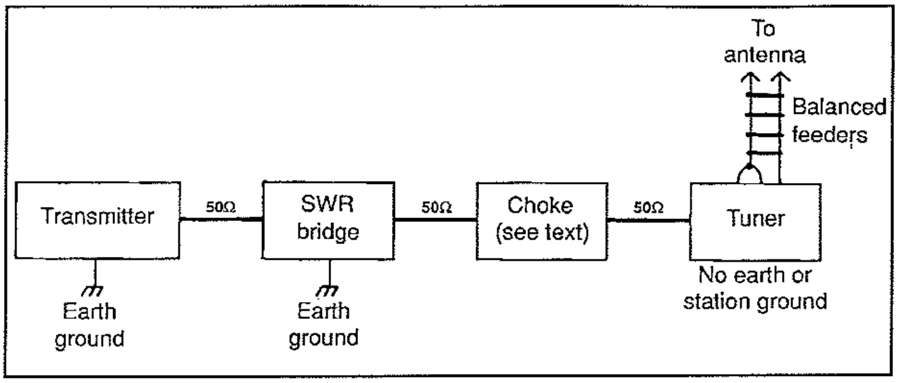


Fig. 4– Pictorial diagram that shows how to float an ATU by means of a 50 ohm RF choke. This technicnique makes it possible to use a single-ended ATU for feeding balanced feeders without employing a balun. An earth or station ground must not be attached to the tuner chassis when this system is used.

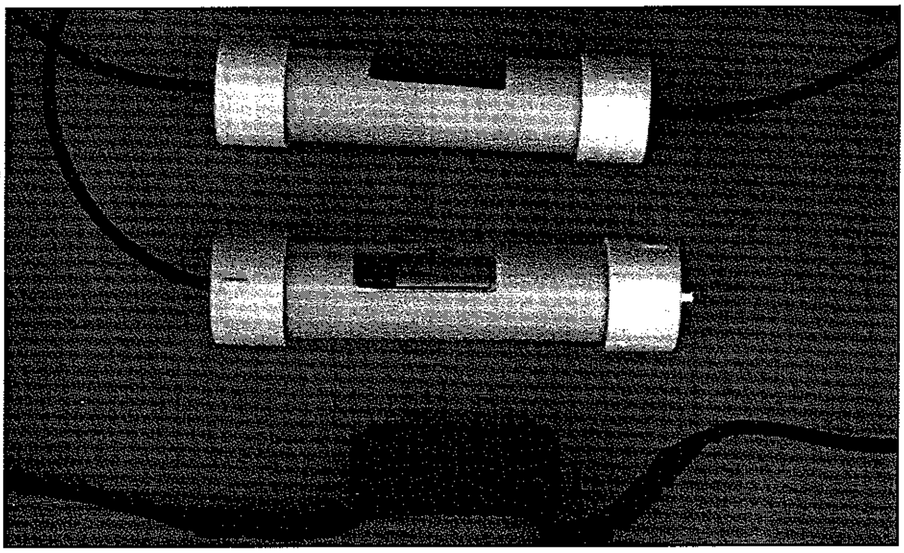


Fig. 5– Photograph of the W1FB homemade RF choke seen in the fig. 4 block diagram. Two commercial line isolators sold by The Radio Works are shown also (see text). The W1FB model consists of RG-8X coaxial cable wound to fully occupy a bundle of seven 3/8 × 6 inch 125 mu ferrite rods taken from scrap AM BC-band radios. The rods are held together by means of epoxy cement. Five Amidon Associates FB-43-5621 ferrite beads are slipped over the RG-8X at each end of the main choke. The choke winding and the beads are held in place with vinyl electrical tape.

resolved by adding a small, large-conductor coil in series with the main coil (L3 of fig. 3) at the high impedance end of L1. I use 5 turns of 1/4 inch copper tubing for this, wound for a 1 1/2 inch ID and a length of 3 inches. No switch is required for shorting this coil.

Other Construction Tips

I like to use a wooden chassis for my tuners because I object to paying the high prices being asked for commercially made metal chassis. Since tuners need not be shielded, wood is fine. A secondary benefit of using wood is that standoff insulators are not needed for the variable capacitors. These components can be mounted directly on a wooden base. There is no reason why plywood or masonite can't be used for the tuner cabinet and panel. The tuner in fig. 2 is built on a piece of 3/4 inch particle board. The panel is made from 16-gauge aluminum. Shelf brackets hold the front panel rigid.

Most ATUs tune sharply if the circuit Q is high. It is for this reason that I use vernier drives[1] for both capacitors. Insulated couplers are used between the drive units and the capacitor shafts. The dial numbers allow me to log the control settings for my popular operating frequencies—a great time saver when QSYing, especially during a contest.

Labels for the tuner in fig. 2 were made with my computer using WordPerfect software and a laser printer. I first created a figure box (ALT F9) of the desired size, deleted the wraparound default (8 and N), and printed the control names inside the figure boxes with Helvetica font that was scaled for the desired pitch. The printout was reproduced on white poster board with a copy machine, after which the labels were removed with a paper cutter and pasted on the panel with contact cement. A coating of clear Deft brand spray lacquer or Krylon clear spray may be used to protect the labels. This method is much less frustrating than using press-on decals, which never seem to come in large sizes for big equipment.

Tuned Feeders Minus a Balun

There can be no more hostile an environment for a balun transformer than in a multiband antenna system that has balanced feeders. Very high impedances are reflected to the balun on some frequencies, and core saturation or arcing can occur. Furthermore, there is little or no true balance under these adverse conditions. Certainly, some tuner manufacturers who include built-in baluns fail to recognize this limitation.

In an ideal situation a balanced tuner, such as the E. F. Johnson Matchbox, would be used with a balanced feed system. However, the matching range of those units is limited, and they won't work on 160 meters. I was delighted when I ran across an excellent paper by A. Roehm, W2OBJ, that appeared in *The ARRL Antenna Compendium*, 2nd edition, on page 172. Roehm described a method for "floating" a conventional single-ended ATU (minus balun) for use with balanced feeders. The technique requires RF-isolating the tuner from the rest of the station gear by means of a 50 ohm choke (see fig. 4). There can be no earth ground attached to the tuner. One side of the feeder connects to the "hot" post on the ATU, and the remaining side is attached to the tuner chassis. I measured the currents in each feed line conductor on various bands and found them to be nearly identical, thereby indicating that balanced feed was occurring. The article also describes how to build the RF isolation choke from ferrite materials. Some of my amateur peers and I have used the Roehm system successfully for some time with 160 meter inverted Vs that are fed with 450 ohm ladder line. Fig. 5 shows my homemade isolation choke plus the 4K-L1 and Terminator-3 line isolators that are available from The Radio Works.[2] These chokes operate without discernible heating at maximum amateur RF power from 160 through 10 meters.

Tag Ends

If you use a linear amplifier, I suggest you build an ATU that can handle the onslaught of RF voltage and current under all matching conditions. I find that 1/4 inch or greater plate spacing in the variable capacitors provides more than ample reserve for my Ameritron AL-80A amplifier. The larger roller coils may be available at hamfest fleamarkets. I paid $50 for the surplus military Cardwell unit seen in fig. 2. However, don't overlook the merit of using a large homemade inductor with taps and a switch. These can be made inexpensively from 1/4 inch copper tubing. The taps can be selected experimentally for the antennas you normally use at various frequencies. Once the correct taps are determined they can be affixed permanently (preferably with silver solder).

Footnotes

1. Mouser Electronics, 2401 Hwy. 287 N., Mansfield, TX 76063-4827 (1-800-346-6873). Catalog available.

2. The Radio Works, P.O. Box 6159, Portsmouth, VA 23703 (804-484-0140). Catalog available. ■