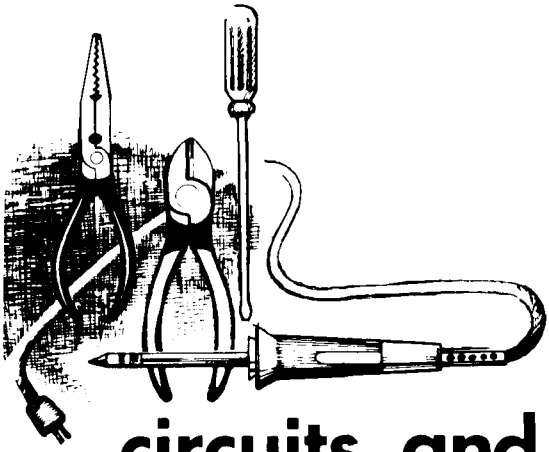

circuits and techniques

ed noll, W3FQJ

antenna tuning units

Antenna tuners come in a variety of different sizes, circuits and tuning arrangements. Most are homemade, but some commercial units are available, including the low-power Ten-Tec AC5, and the higher power Johnson Matchboxes and Drake Matching Networks.

Antenna tuning units are used primarily for transmission-line impedance conversion (high to low or low to high), but they may also be designed for converting from one type of feedline to another (balanced to unbalanced or vice versa).

Three very common applications for antenna tuning units (or ATUs) are shown in **fig. 1.** The impedance at the input end of the coaxial transmission line is matched to the output impedance or the transmitter. This may be an unbalance-to-unbalance match such as shown in **figs. 1A** or **1B,** or an unbalance-to-balance match as illustrated in **fig. 1C.**

The antenna system impedance can be several times higher (or several times lower) than the transmitter impedance, and a good match can still be obtained with a relatively simple circuit such as the L-network, pi-network or T-network shown in **fig. 2.** I personally prefer the T-network.

The L-network in **fig. 1B** is the most common antenna tuner configuration for matching random-length, single-wire antennas. The multiple tapped coil accomodates the random wire length over a wide span of operating frequencies. The variable capacitor sets resonance and influences the impedance ratio needed for satisfactory matching.

The arrangement of **fig. 1C** links a balanced antenna and transmission-line system to the low-impedance and unbalanced output of a transmitter. Resonant tuning is provided by the split-stator variable capacitor, while impedance matching is mainly a function of turns ratio and coupling between the separate coils.

atu circuits

A simplified circuit for the Johnson kilowatt matchbox is shown in **fig. 3.** An untuned link, L1, transfers transmitter

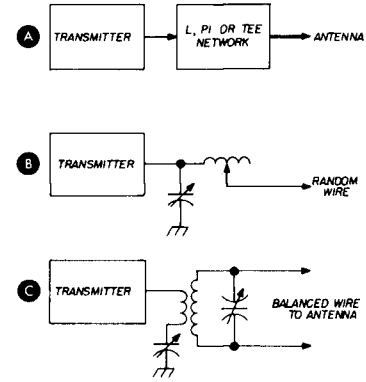

fig. 1. Common applications for antenna tuning units.

output power to a multiturn and band-tapped secondary coil, L2. Resonant tuning is the responsibility of variable capacitor C1. Loading and matching are handled by the dual-differential capacitor C2.

The Johnson Kilowatt Matchbox matches balanced antenna system inputs between 50 and 1200 ohms, and unbalanced, between 50 and 200 ohms. This is not to say that the tuner cannot be used to match low impedance antennas (impedances lower than 50 ohms). If you want to match a very low impedance antenna, such as a beam, without an antenna matching section, you can still obtain proper matching to the transmitter by using a transmission line of a proper overall length. A very low impedance antenna can be made to reflect an impedance higher than the characteristic impedance of the transmission line by using an overall transmission-line length that is some odd multiple of a quarter wavelength, **fig. 4.**

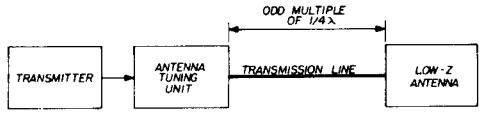

Fig. 4. Tuning a transmission line attached to a low-impedance antenna.

Keep in mind that a mismatch at the antenna can be reflected to the receiving end of the transmission line as an impedance higher or lower than the surge impedance of the line by regulating the overall length of that line.

balance-to-unbalance versatility

If leads are brought out from the various components of an antenna tuner, it can be made to have added versatility as shown in **fig. 5.** This arrangement also includes a tuned primary for further optimizing performance and obtaining an exact impedance match. In this circuit the impedance of the parallel resonant circuit can be made high, medium or low, depending upon how the terminals are interconnected.

A low-C parallel circuit is obtained by connecting series-connected capacitors in parallel with the coil. This can be done by joining 1C and 2A. The transmission line is attached by joining 1A to 1B and 2C to 2B. A high-C matching resonant circuit is obtained when 1C is linked to 2C and 2A to 1A. Output is again provided by connecting 1A to 1B and 2C to 2B.

In low-impedance series tuning, the capacitors must be connected in series with the coil. To do this you need only connect 1B to 1C and 2B to 2A.

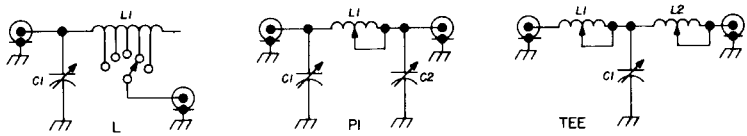

fig. 2. Three basic antenna tuner networks, the L, the Pi and the T.

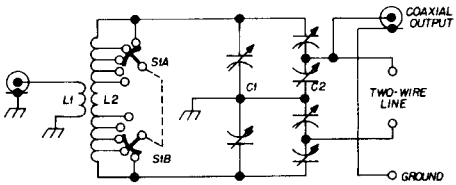

fig. 3. Partial schematic diagram of the Johnson Kilowatt Matchbox.

unbalanced-to-unbalanced T-tuner

The T-network is an excellent tuner for an unbalanced system. It has great range and versatility and can be used to match almost anything connected to the antenna end of a coaxial feed line. It will also function in the same manner when matching a random length of antenna wire as well as a Windom antenna, **fig. 6.**

The T-section antenna tuner is basically a low-pass filter consisting of two

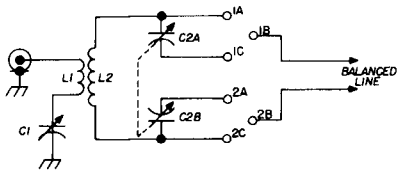

fig. 5. Versatile antenna tuning circuit for balanced transmission lines.

series-connected inductors along with a capacitor connected between their junction and ground as shown in **fig. 2.** Although there is some interaction between the two coil sections, L1 and L2, the value of L1 has a significant influence on the matching between the antenna system and the tuner, while inductor L2 has a greater influence on matching between the tuner and the transmitter. Interaction between the two coil sections can be minimized by mounting them at right angles to one another. Capacitor C1 establishes the proper resonant condition and, if adjustable, acts as a fine tuning adjustment.

For a specific case of matching on a particular frequency, the basic equation of the T-network is:

$$X_{C1} = \sqrt{Z_{IN} R_T}$$

where

Z_{IN} = the input impedance to the line, and

R_T = the output impedance of the transmitter.

Multifrequency and multi-band operation requires the inductors be tapped and the capacitor made variable. Two seven-position switches permit operation on bands 1.8 to 54 MHz. Each coil consists of 30 turns of number 14 wire, 2-5/8-inch length with a diameter of 1-3/4 inches (this is similar to Air Dux 1411 coil stock).

Some experimental work with tap positions will permit optimum performance on each band. In my case ten-position switches were used and taps were placed on the coil so as to decrease distances between taps toward the low inductance end, **fig. 7.** This arrangement permits greater versatility, and I have yet to connect an antenna that could not be made to load the transmitter.

A 50-pF variable is used for 6 through 20 meters. When operating on 40, 80 and 160 meters an additional two-gang 365-pF variable (sections connected in parallel) is switched into the circuit.

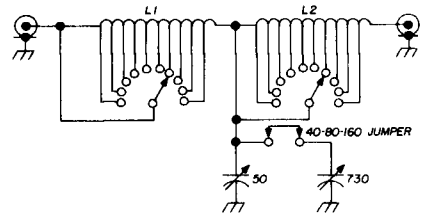

fig. 7. Versatile T-network antenna tuner. L1 and L2 are each 30 turns, tapped at 2, 4, 6, 8, 10, 13, 17, 21, 25 and 30 turns.

When adjusting the tuner you will soon learn the switch positions that favor each band, and, as expected, less and less inductance is needed, the higher the frequency band. However, ideal matching requires some experimentation with each antenna type to find the two most favorable switch positions. Switch positions are found that result in a very low, minimum swr. As the switch positions are selected the variable capacitor is tuned for minimum swr.

You should keep a log for any given antenna so the tuner settings can be quickly changed when you make a band change. If another antenna is used, optimum settings are not likely to be the same. This is a tuner that can be used to load anything, but it does require some initial pre-adjustment to locate the ideal settings for any given antenna. Remember that the tuner can be made to load

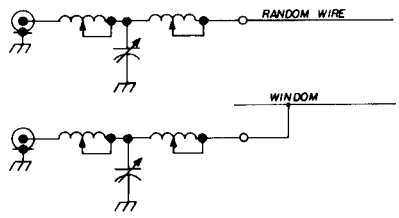

fig. 6. Using T-networks for single-wire fed antennas.

anything but this does not guarantee that the anything you use will function as a good antenna.

T-matching at antenna

In commercial radio services the T-match is popular when the matching is done at the antenna. Three common configurations are shown in **fig. 8**. If the antenna is inductive, the inductance is tuned out by using an input capacitor, C1, which has the same reactance. The T-network must then only match a resistive component to the transmission

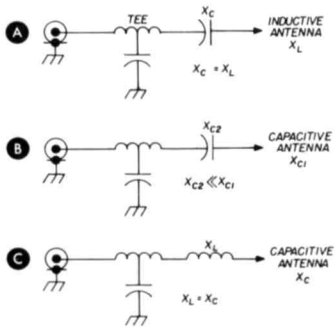

fig. 8. T-networks for impedance matching at the antenna.

line. If the antenna is capacitive, the capacitive reactive component must be tuned out by the input coil of the T-network. An alternative plan, shown in C, uses an input coil, L1, which has the same reactance as the capacitive component of the antenna.

In multifrequency and multi-band operation, as in amateur practice, the components must be variable. The T-network tuner of **fig. 7** is ideal for this type of operation. It performs particularly well when vertical antennas are to be matched at the antenna, and the swr on the transmission line between the tuner and transmitter must be reduced to an insignificant value.

Antenna tuners are a great addition to the amateur station and should be considered essential devices for every ham antenna experimenter.

ham radio