ELMER's NOTEBOOK

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antenna tuner

In last month's Notebook I discussed transmission lines and their construction and impedance. The May 1988 *ham radio* is the annual antenna issue, so next month's column will focus on that subject. In this issue, let's look at another part of a transmitting/receiving system — the "antenna tuner".

Most everyone calls the device used by Amateurs between their station and the antenna an "antenna tuner", even though this isn't really what it is. The proper term is *impedance-matching circuit*, but that just doesn't turn people on the way "antenna tuner" does. In earlier days, the circuitry used to get an antenna to "load" was an antenna tuner of sorts; the end of the antenna was brought right into the shack and tapped on the tuned circuit. Adjustments were made by changing the coupling link from the transmitter and moving the antenna tap on the coil, **fig.1**.

This system worked, and still does, but it has faults. For one, it brings a lot of rf right into the shack. This was okay in the days of vacuum tubes that were not too sensitive to the presence of rf, but stray rf certainly creates big problems with today's semiconductors, not to mention nearby TV and hi-fi sets.

Getting the antenna out of the shack and up in the air had two desirable results: it reduced the rf problem and improved radiation by being in the clear, away from nearby objects. This created the need for a transmission line to conduct power between the transmitter and the antenna, but did not eliminate the need for some type of matching device at the transmitter output. No two antennas are alike in installation, environment, construction,

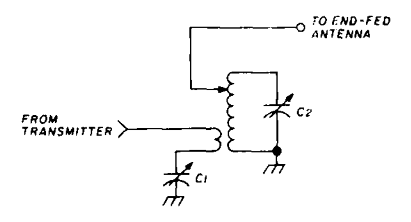

fig. 1. Matching circuit for an end-fed wire antenna. The tap is moved along the coil until the transmitter is properly loaded.

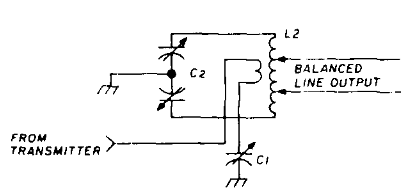

fig. 2. A simple circuit for providing a match between 50- or 75-ohm coaxial cable and parallel-wire transmission line of any impedance.

or impedance and method of feed, and what works well on one band is not necessarily the optimum choice for another. Operation over a wide portion of any band creates another problem. You can make the length of an antenna correct for one part of a band but it is not resonant in another part, so if you move your operating frequency very far you'll see the VSWR start to climb. Some rigs will put up with this, but many will not.

Enter the impedance-matching circuit, sometimes called a "Transmatch" or "antenna Coupler" or "antenna Tuner."

A basic circuit is shown in **fig. 2**. The simple tuned circuit has a link to couple energy from the transmitter to it, and taps on the coil for matching to twin-lead transmission line. This type is ideal when you have a center-fed dipole with a feedline of TV ribbon or open-wire "ladder line." The capacitor (C_1) in series with the link "tunes" it for maximum coupling of energy from the transmitter. C_2 and L_2 form a resonant tank at the operating frequency. The taps are simply moved equal distances from the center of the coil until the transmitter shows proper loading.

A "Transmatch" or "Ultimate Transmatch" is another all-purpose tuner. It one of the most useful, wide-range matching circuits in Amateur radio, and has several variations. The basic circuit is shown in **fig. 3**. The transmitter input is coupled to the circuit by C_1, and the combination of variable capacitance of C_1, inductance L_1, and the output capacitor C_2 provide matching for a load that can be anything from 50-ohm coaxial cable to open-wire line or a single-wire end-fed antenna (if you still want to bring rf back into the shack).

The inductance (L_1) for this kind of circuit is usually variable, consisting of

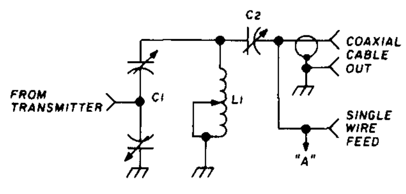

fig. 3. A versatile Transmatch type of matching circuit. The variable capacitors and inductor allows it to perform over a wide range of frequencies and impedances. As shown here, the output will accept either coaxial cable or single-wire feed (as for an end-fed antenna).

turns of wire on a ceramic cylinder that can be rotated by a knob on a panel. The tap is a roller that contacts the turns of the wire as the inductor is rotated providing a continuously variable inductance which (along with C_2) matches a wide range of impedances. A variation of this circuit uses a tapped inductor and a well-insulated switch to select the proper value, eliminating the hard-to-find roller inductor.

A balun transformer allowing connection to a balanced line is a useful addition to this Transmatch circuit; one is shown in **fig. 4**. It can be built into the same enclosure as the Transmatch, or as a separate unit and attached to the coaxial connector. If you build it into the Transmatch circuit enclosure, connect the points shown as "A" in **figs. 3** and **4**. The transformer is wound on a ferrite core.

Commercial Transmatches are available but they are not difficult to construct in the home workshop. Looking for the roller inductors and variable capacitors to build a Transmatch is a favorite pastime of Amateurs at hamfests and flea markets. It is a popular project.

There are other circuits that can be used to match impedances; two of the most common are the "L" network and the "Pi" network in **fig. 5**. The L network is useful for matching a low impedance to a high one. The lower impedance must always be connected to the inductance end of the circuit and the higher impedance must always be across the capacitor. This circuit

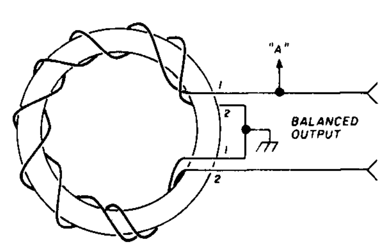

fig. 4. A balun transformer is a useful addition to the Transmatch circuit. The point labeled "A" connects to "A" in *fig. 3*.

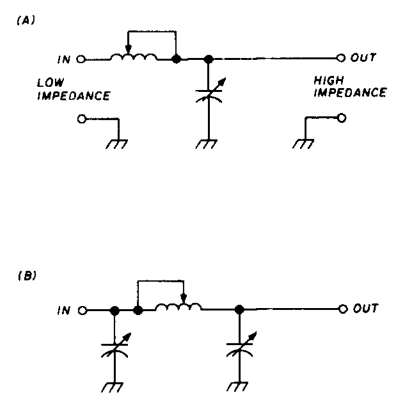

fig. 5. The L network, at A, is useful for matching some types of antennas, particularly a vertical radiator where the circuit is placed at the base. The Pi circuit at B will match a very wide range of input and output impedances. It can accept low or high impedances at either the input or output.

works well as an "antenna tuner", placed at the base of a vertical antenna and adjusted to provide a match between the antenna and the feedline to the transmitter.

The Pi network covers the widest range of any common circuit, and was for years the mainstay of impedance-matching techniques. Many transmitters used this type of circuit at the output of the power amplifier, and it was said that they would "match anything". I can personally attest to one trial to see if this was true.

In Willimantic, Connecticut, three of us decided one evening to see if this circuit really would (as a popular saying of the time claimed) "load a piece of wet string". We soaked some heavy twine in a bucket of salt water and quickly connected it to the network, suspending the far end over the limb of a convenient tree. We made a contact on 20 meters, but the rf power kept drying out the string so we had to re-wet it while our operator was receiving. He then waited for our "ready" yell before transmitting. I don't think the guy at the other end of the contact ever believed us, even when he got the QSL card listing the antenna as "1/2-wave wet string"!

The Pi network is bi-directional; either end can be the high- or low-impedance port.

receiver benefits from matching (circuit)

In addition to the impedance-matching, these circuits also reduce harmonics that might otherwise get to the antenna and be radiated. Also, when the selective circuit is placed between the antenna and the receiver, interference from strong stations outside the Amateur bands is reduced. Receivers, like transmitters, do perform better when their input impedance is properly matched.

It is important to remember that none of these circuits change your antenna impedance or reduce the VSWR on the transmission line feeding your antenna. If your dipole on 15 meters looks like 7-1/2 ohms at the feedpoint, absolutely nothing you do in your shack will change that. Likewise, if the VSWR on the transmission line is 15:1, it is going to stay there no matter what kind of "matcher" you use. The main function of a matching circuit in your shack is to present your transmitter with a proper load. Any VSWR problems on the feedline can be cured only by working on the antenna itself or by placing a matching circuit right at the antenna feedpoint. It's okay if the VSWR is moderate — systems with 3:1 or 4:1 on the line between the antenna and the Transmatch do their job just fine. At values higher than that, you are losing some power in the feedline and perhaps radiating some of it from the line rather than the antenna, so some antenna work is in order.

operating practices

No one likes to hear stations tuning up in the middle of their QSO, but these circuits do require adjustment from time to time. Here are a few tips to make life easier for everyone:

- On most matchers, the variable capacitors and inductors have calibrated knobs, dials, or multiturn indicators. Make a calibration chart or marks on the panel listing the tuning positions for each of your favorite bands and operating frequencies. Then you will need to make only minor adjustments, or perhaps none at all, when you change frequency.
- Initial tuning and calibrating of the Transmatch should be done when a particular band is dead, using the lowest value that your power and SWR meters will accurately indicate. Your VSWR is not going to change if you tune up with 5 watts and then use 200 for QSOs.
- Do your initial tuning of the transmitter only into a dummy load, then switch to the matching network. From then on, make minor adjustments of the matching network to keep the transmitter happy; don't readjust the transmitter tuning. Some Transmatches have a built-in switch to select a dummy load, and a power/SWR meter to aid in tune-up. Both are worthwhile additions if you build your own.

the other side of the coin

On the other hand, Transmatches (and all matching networks, for that matter) lose some of the power on the way through. Circuits constructed with quality components — heavy or silver-plated wire, and inductors and capacitors with steatite or ceramic insulation — have losses small enough to ignore. Poor insulation and small wire can increase losses significantly. Also, some circuits are built using toroidal transformers and if their core material is not meant for use at the frequency of operation, the losses will be large.

ham radio