Antenna Tuners: Making a Match

Antenna tuners are known by many names—matchbox, transmatch, coupler, matching network, antenna tuning unit, ATU, or simply a tuner. They can be built into your transceiver, or they can be a separate, external device. They can be manually operated or automatically controlled with the push of a button. Here's a closer look at the tuners hams use to create an efficient transfer of power between the transceiver and the antenna.

In electronics, a *load* is anything connected to a power source that consumes power. If you connect a light bulb to a battery, the light bulb is the load. By the same turn, an antenna system—its radiating elements and feed line—connected to a transmitter is a load. It sounds like a simple idea, and to a certain extent it is, but when you're working with radio-frequency (RF) energy, there is a bit more to it.

For now, though, let's keep it as simple as possible. For this discussion, just assume that every antenna system has a *load impedance* measured in ohms. The output of your transceiver has an impedance value too, and it is usually 50 ohms. (For more about impedance and resistance, see "Untangling SWR" and "When an Antenna *Isn't* an Antenna: The Dummy Load," both in this issue.)

To efficiently transmit a radio signal, the antenna system impedance must be as close as possible to the transceiver impedance. When this occurs, we say these circuits are *matched*.

Let's try an example. Figure 1 shows an antenna system that is presenting a load impedance of 108 ohms at the frequency at which you want to transmit—but remember that your transceiver expects an impedance of 50 ohms. This is a *mismatch* situation, and it results in an elevated *standing wave ratio* (SWR) within the cable. An elevated SWR will cause a certain amount of the radio's power to be lost as heat in the cable. The radio will also respond to the higher SWR by reducing its output power. Neither of these things are good!

One solution is to adjust the antenna to reduce its impedance to a value closer to 50 ohms. If that isn't possible or practical, the alternative is to use a device known as an *antenna tuner*.

Antenna Tuners for VHF and UHF?

Why do you almost always see antenna tuners designed for HF frequencies, but not for VHF or UHF? In theory, there is nothing preventing the use of an antenna tuner at VHF or UHF frequencies. The problem is that the losses in such devices at these frequencies can be exceedingly high. In addition, allowing a high SWR to exist in a coaxial cable at VHF or UHF will result in even more loss. Taking all this into consideration, you are far better off adjusting your VHF or UHF antenna to deliver a proper impedance match, rather than attempting to use a tuner. In most cases, antenna tuners are only practical to use at frequencies below about 54 MHz.

Tuning It Up

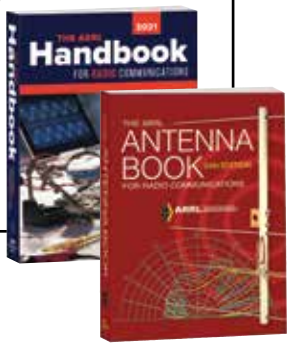
An antenna tuner acts like the transmission in your car, which selects the proper gear ratio for the work being done, such as starting from a standing position, cruising at a steady speed, or climbing a hill. If the transmission does not match the right gears, there won't be an efficient transfer of power. The engine will be stressed, and could be damaged in the process of trying to do work that's unsuited to the gear it's in.

Look at Figure 2. Everything is the same as Figure 1, except that we've added an antenna tuner. The antenna tuner will take the 108-ohm impedance from the antenna system and convert it to 50 ohms for the radio. Now the SWR at the radio is reduced, and the radio will dump all its power into the antenna system.

There is an important thing to notice in Figure 2, however. While the antenna tuner provides the 50-ohm impedance to the radio, the impedance of the antenna system *has not changed*; it is still 108 ohms. This means there is still a mismatch taking place, but now it is occurring between the antenna tuner and the antenna system. So, the elevated SWR and the loss in the cable is still present, but at least now your radio has pumped more power into the system to compensate. ☛

How it Works

An antenna tuner works its magic by adjusting inductors (coils) and capacitors in various combinations. If you're curious to learn more (and don't mind dealing with some mathematics) you can dig much deeper in books such as *The ARRL Antenna Book* or *The ARRL Handbook*.



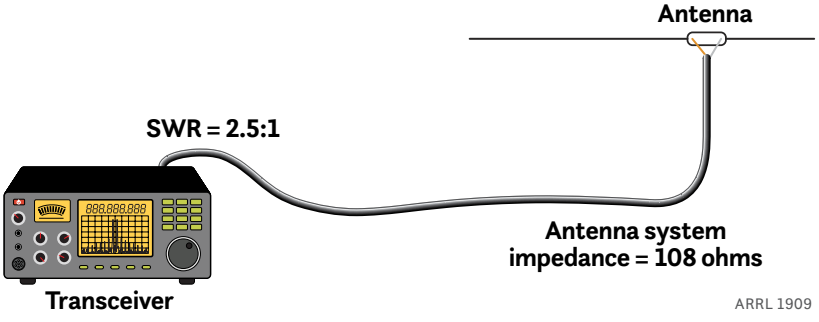


Figure 1 – Here we have a transceiver that expects a 50-ohm impedance, and it is connected to an antenna system with a 108-ohm impedance. This is a mismatch, and it will result in an elevated SWR of about 2.5:1. The transceiver will respond by reducing its output, and the elevated SWR will also cause some power loss in the feed line between the antenna and the radio.

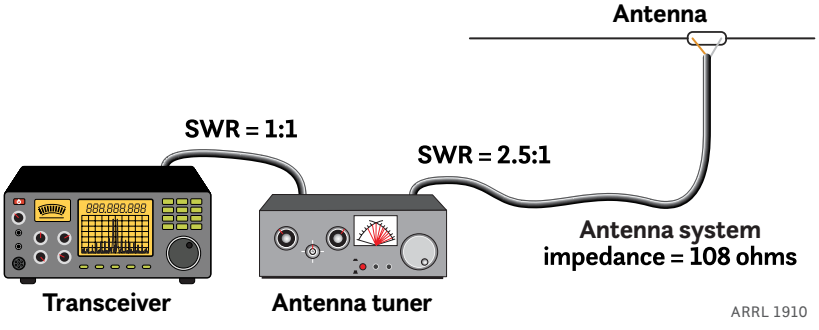


Figure 2 – With an antenna tuner in the line, the radio has a 50-ohm impedance match to the antenna system and it "sees" a 1:1 SWR. Now it can transfer all its power. Note, however, that the mismatch and the higher SWR still exist between the tuner and the antenna.

Remote Tuners

Some automatic antenna tuners are designed to be installed outdoors, as close as possible to the antenna. They are built to withstand the elements, and they usually get their operating voltage through a separate cable, or through the feed line itself. These are known as *remote antenna tuners*.

The advantage to using a remote tuner is that the tuner the creates the match nearer to the antenna, which means that a low SWR exists in the cable that goes back to the transceiver. The result is that you lose less RF energy in the cable, and instead deliver more to the antenna. This can be particularly critical when operating at higher frequencies where power loss due to SWR can be substantial.

This remote antenna tuner is housed in a weatherproof enclosure and installed outdoors, near the antenna.

Manual and Automatic Tuners

Antenna tuners come in two varieties: manual and automatic. Automatic antenna tuners are popular because they use an onboard computer processor to detect the impedance mismatch and then quickly determine the inductors and capacitor choices necessary to make the best conversion. Automatic antenna tuners also have memories that allow them to restore the settings for a particular frequency when you return to it, usually in less than one second.

Some automatic tuners can sense the energy coming from your radio and will begin tuning immediately. Other models require you to start transmitting and then push a button on the tuner to begin the tuning process.

With a manual tuner, it is up to you to make the adjustments. A manual tuner has switches and knobs that you operate while transmitting and watching the SWR on the tuner's meter (or on the meter in your radio). The goal is to reduce the SWR reading to 1:1 (or a value close to this). Once you've achieved the lowest SWR, you can write down the knob and switch settings for later use.

Depending on the tuner's size, features, and quality, prices can range from very inexpensive basic units to pricey full-featured units capable of handling high power levels.

The impedance conversion range depends on the capacitors and inductors used inside the tuner. Tuners designed for low power (QRP) operating are quite compact and lightweight, whereas tuners that are capable of tuning wide ranges at legal limit power levels are large and expensive. In addition to capacitors and inductors, an antenna tuner might include meters to measure RF power and SWR, antenna selector switches that allow the tuner to be used with more than one antenna, and perhaps a lamp to illuminate the meters.

Are Antenna Tuners Always Necessary?

Do you always need an antenna tuner? If your antenna system already provides a good impedance match on all your favorite frequencies, that answer is "no." Not every ham has this luxury, though. For instance, when a single wire antenna will be used on multiple bands, then an antenna tuner may be needed to match the antenna to the radio at each frequency.

Antenna tuners aren't miracle workers; they won't turn a poorly matched antenna system into a perfect one. The mismatch losses will still be there, but thanks to the tuner your transceiver will be able to transfer as much power as possible. More power going into the antenna means more communication for you!