Do You Need an Antenna Tuner?

Maybe yes, maybe no. It all depends on the type of antenna and feed line you're using.

By Steve Ford, WB8IMY
Assistant Technical Editor

There is a great cloud of mythology surrounding antenna tuners, particularly when the conversation turns to what they can and cannot do. Make no mistake, they are useful devices in the right applications. The trick is deciding whether you need one!

When Rigs and Antenna Systems Disagree

Every antenna has an *impedance* expressed in *ohms*. The same is true of the feed line you use to connect your transceiver to the antenna. Impedance sounds like a complicated beast and, to a certain extent, it is. In simplest terms, it is a combination of *inductive reactance*, *capacitive reactance* and garden-variety *resistance*.

It's probably best to avoid a long discussion about the meaning of reactance. This is "New Ham Companion," not the *Proceedings of the IEEE*. If I had several more pages to devote to this article, I'd be more than happy to bore you to tears with reactance theory. For our purposes, think of reactance as opposition to the flow of an ac signal in a circuit. In this case, the ac is the RF generated by your transceiver and the circuit is your antenna system. File this idea away for the moment. We'll come back to it later.

Meanwhile, back at the radio ranch....

The impedance of the antenna depends on a number of factors, including the length, operating frequency, height above ground, proximity of metal objects and even weather conditions (such as ice on the antenna). The impedance of the feed line depends on how the cable is constructed.

Your feed line does more than simply connect your radio to your antenna. It acts as an impedance *transformer*. That is, the impedance of your antenna is transformed by the feed line into the value your radio "sees" when you connect it to the cable. This *system impedance* acts as a *load* for the energy created by your radio—just like a light bulb is a load for the energy supplied by a battery.

Most amateur transceivers are designed to work with a load impedance of 50 ohms. When your radio sees an impedance of 50 ohms, or something close to it, you're on easy street. You press the mike switch, close the CW key or type on your keyboard and all is right with the world.

But what happens when the impedance *isn't* 50 ohms? Now you have a situation known as a *mismatch*.

When a mismatch exists, a certain portion of the power generated by your radio is *reflected*—like light is reflected by a mirror. This reflected power comes shooting back down the cable to your radio. When it reaches the radio, it is reflected back toward the antenna. The reflected power combines with the *forward* power being generated at the radio to create *standing waves* in the feed line.

By using a *standing-wave-ratio* (SWR) meter, you can measure both the forward and reflected power. A 1:1 SWR reading indicates that no power is being reflected back to your radio. This is good. On the other hand, an SWR of 3:1 or more means that a substantial amount of power is being reflected. This is usually bad. (Don't you love these simple concepts?)

A high SWR can cause considerable RF voltages to develop in the feed line and in the output circuits of your radio. This is a dangerous condition for your rig—especially if it is a modern solid-state transceiver. To prevent this, many radios manufactured within the past 10 years include SWR protection circuits. When the SWR gets too high, these circuits automatically reduce the output power or, in some cases, shut down the transceiver altogether (see Fig 1). Older tube radios are much more forgiving, but even they can be damaged when operated under high SWR conditions.

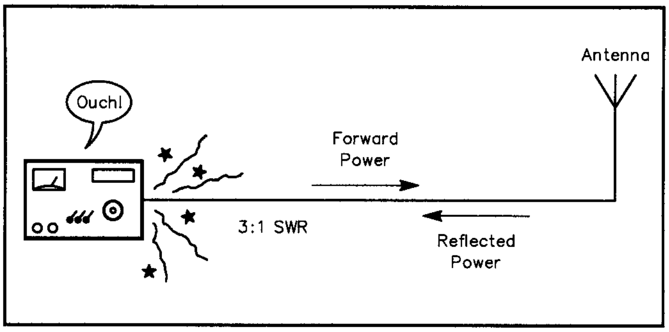

Fig 1—Most transceivers are designed to expect an antenna system impedance of 50 ohms. When the antenna impedance is something other than 50 ohms, a transmission line mismatch occurs and a portion of the RF power is reflected back to the radio. *Standing waves* are created in the feed line and high RF voltages can develop. When the *standing-wave ratio* becomes higher than 3:1, your transceiver may be damaged.

If your antenna system presents a serious mismatch to your radio, what can you do? If you connect your transceiver directly, the protection circuitry will drop your output like a rock. Worse yet, you may find yourself on the receiving end of an expensive repair bill. You need to provide a 50-ohm load for your transceiver—regardless of what is really present. One way to accomplish this is by using an antenna tuner.

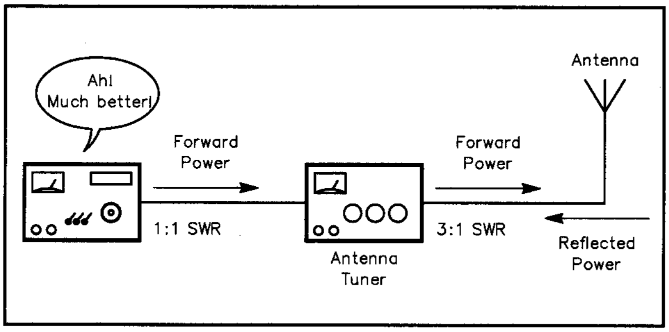

Fig 2—By using an antenna tuner, you can adjust the impedance your transceiver "sees" to a hospitable 50 ohms. The antenna mismatch to the line still exists, but the tuner protects your radio from the RF voltages while allowing it to develop its maximum output.

How Does an Antenna Tuner Work?

In its most basic form, an antenna tuner is simply a network of variable inductors (coils) and capacitors. By adjusting the coils and capacitors, you counterbalance and cancel the effects of the inductive and capacitive reactance at the *transceiver* end of the feed line. (*Now* you know why I bothered bringing up the subject of reactance in the first place!) As the reactances are canceled, the impedance at the transceiver is transformed to 50 ohms (see Fig 2).

As far as your transceiver is concerned, the load impedance is matched and it's free to dump all of its power into the antenna system.

I bet a number of you are saying to yourselves, "*Wait a minute!* The impedance at the transceiver side of the tuner is 50 ohms, but it's still some other value at the antenna side. All you've done is shift the mismatch problem from the transceiver to the tuner!"

You're right. The mismatch still exists, but now it's at the output of the antenna tuner instead of the transceiver. By using the tuner, we're protecting the radio while still allowing it to develop maximum output. If the tuner is well designed, it should be able to handle the RF voltages and currents caused by the high SWR.

Of course, the reflected power is still bouncing back and forth between the antenna tuner and the antenna. Some of this power is lost in the feed line. If you're using low-loss feed line, however, most of it is radiated at your antenna. In the meantime, your transceiver is happy and you're happy. Who could ask for more?

Use an Antenna Tuner if...

...you want to feed your antenna with open-wire line.

Open-wire line (or *ladder line*) offers extremely low loss at HF frequencies (much better than coaxial cable). One problem is that open-wire line is *balanced* while your transceiver output is *unbalanced*. You need to use an antenna tuner with a built-in *balun* to form a bridge between the balanced line and the unbalanced output of your radio. A balun is a type of transformer that converts balanced feed lines to unbalanced, or vice versa. (***BAL***anced to ***UN***balanced. Get it?) Most antenna tuners use 4:1 baluns that also convert the impedance of open-wire feed lines to a value that the tuner can handle.

...you want to operate your antenna on bands other than those it was designed for.

When you attempt to use, say, a 40-meter dipole on 10 meters, a big mismatch will develop, along with a high SWR. By using an antenna tuner, you may be able to create a 1:1 SWR at your transceiver. (I say "may" because the mismatch can sometimes be so great that it is beyond the capability of your tuner to handle.) The high SWR may cause substantial loss in a coaxial feed line, but at least you'll radiate *some* power at the antenna.

...your antenna has a narrow *SWR bandwidth* on some bands.

Some types of multiband antennas do not offer low SWRs from one end of each band to the other. There is usually a range—expressed in kilohertz—where an SWR below 2:1 can be achieved. For example, a multiband trap dipole may offer an SWR of 2:1 or less from 3600 to 3800 kHz. That's an SWR bandwidth of 200 kHz. If you try to operate above 3800 kHz or below 3600 kHz, you'll encounter an SWR higher than 2:1 and your radio may become displeased. With an antenna tuner, you can operate outside the SWR bandwidth and still load the full output of your radio into the antenna system.

Don't Bother with an Antenna Tuner if...

...your SWR is 1.5:1 or less at the frequencies you operate most often.

An SWR of 1.5:1 or less is not serious and does not require the assistance of an antenna tuner. Most modern rigs will tolerate a 1.5:1 SWR just fine. In fact, many will be happy at an SWR of 2:1. If you are using a good-quality feed line, the loss caused by an SWR of 1.5:1 or even 2:1 isn't enough to worry about at HF frequencies. Many hams are obsessed with providing an absolute 1:1 SWR for their radios at all times. Apparently they also have money to burn!

...you have a high SWR at VHF or UHF frequencies.

VHF/UHF antenna tuners are available, but my advice is to save your money. Remember that an antenna tuner massages the antenna system impedance *at the transceiver*. The mismatch still exists and the SWR is still high at the antenna side of the tuner. Even the best coaxial cables have significant losses at VHF and UHF when the SWR is high. A VHF/UHF antenna tuner will make your radio happy, but most of its power will never make it to the antenna. The best approach is to correct the mismatch at the antenna by adjusting whatever tuning mechanism it provides. If the antenna cannot be tuned, check the cable for defects and make sure you've installed the antenna properly.

...you're interfering with TVs, telephones and other appliances in your neighborhood.

Despite what you may have heard, an antenna tuner will not necessarily cure your interference problems. It's true that most antenna tuners will reduce the level of *harmonic radiation* (signals your radio generates in addition to the ones you want), and if the interference is being caused by harmonics, a tuner may help. Most interference, however, is caused by RF energy that's picked up indirectly by cables or wires, or directly by the device itself. By using an antenna tuner, you'll probably radiate more energy at the antenna than you did before. That may make your interference problem worse!

Looking for Mr Goodtuner

So, you've decided that you need an antenna tuner after all. Antenna tuners come in all shapes and sizes. What features should you consider?

❑ **A built-in SWR meter**—An SWR meter of some type is a must if you want to use an antenna tuner. When adjusting your tuner, you need to keep your eye on the *reflected power* indicator. Your goal is to reduce the reflected power to zero—or at least as close as you can get. When the reflected power is zero, the SWR is 1:1 at your transceiver.

Many tuners feature built-in meters. If not, you can purchase one separately. Your radio may even have its own SWR meter.

❑ **A roller or tapped inductor**—More expensive tuners feature a variable coil called a *roller inductor*. As you turn the front-panel inductor knob, the coil inside the tuner rotates. A metal wheel rolls along the coil like a train on a railroad track. As the wheel moves along the coil, the inductance increases or decreases.

Less expensive tuners do not use roller inductors. Instead, there is a coil with wires attached at various points. On the front panel, a rotary switch selects the wires. According to how the inductor is wired in the circuit, selecting one *tap* or another

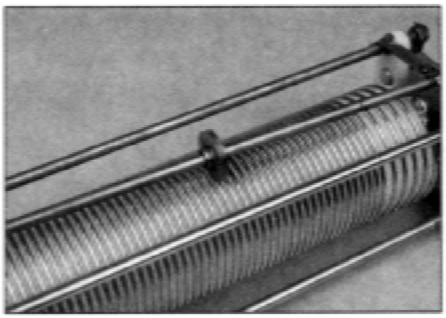

Fig 3—This is a typical roller inductor. Notice the wheel that rolls along the coil windings. As the wheel moves, the inductance changes.

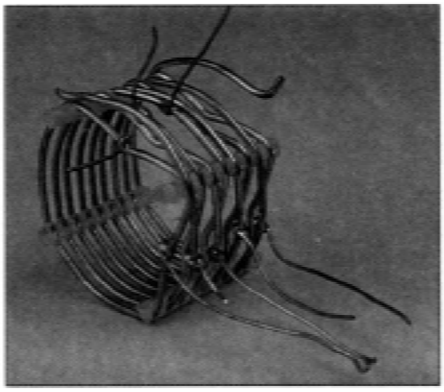

Fig 4—Tapped inductors have wires attached at various points. By selecting a particular wire, you get a fixed amount of inductance.

varies the inductance. This is known as a *tapped inductor.*

There are advantages and disadvantages to both approaches. Roller inductors offer the best tuning performance, but they are subject to the woes of mechanical wear and tear. For example, if corrosion builds up on the wheel or the coil windings, the electrical quality of the connection will deteriorate. Roller inductors are also cumbersome to use. You may have to twist the control many times when moving from one band to another.

Tapped inductors are easy to use and free of mechanical problems (unless the switches get dirty). However, you may find that they restrict the operating range of your tuner. When you turn the switch, you select a *fixed* amount of inductance. You can't easily change it to tune a particularly difficult mismatch situation.

❑ **A built-in balun**—If you intend to use an open-wire feed line, buy a tuner with a built-in 4:1 balun. These baluns often dissipate quite a bit of heat, so always choose a large balun over a small one.

❑ **Multiple antenna capability and dummy loads**—Some tuners offer the ability to connect more than one antenna. This is handy in all sorts of applications. Let's say you have a vertical antenna for 40-10 meters and a wire dipole for 80 meters. You can connect both feed lines to your tuner and easily switch between them.

Built-in dummy loads are convenient, but not necessary. A dummy load is a resistor (or group of resistors) that absorbs the output of your transceiver while allowing very little energy to radiate. It's used for making transmitter adjustments and other tests. If your tuner lacks a dummy load, you can purchase one separately.

❑ **Automatic operation**—Most transceiver manufacturers offer *automatic* antenna tuners. These tuners are usually built in the radio itself, or they're offered separately. Automatic tuners are convenient when you need to change bands or frequencies quickly. You simply push a button and your tuner adjusts its coils and capacitors to achieve the lowest SWR. Some automatic tuners sense when you've changed frequency and will readjust immediately! (You don't have to lift a finger.)

Automatic antenna tuners are expensive and their tuning range is limited. If your operating style requires you to jump from band to band rapidly (contesting is one scenario), consider an automatic tuner. Otherwise, conserve your cash and invest in a manual tuner.

A Word About Power Ratings

If your transceiver produces only 50 or 100 watts of power, a 200- or 300-watt tuner should do the trick, right? Well...yes and no. Remember what we said about mismatches causing high RF voltages in the tuner? If you're trying to use your tuner in a high-SWR situation, the RF voltages at the tuner may cause an unpleasant phenomenon known as *arcing*. That's when the RF energy literally jumps the gaps between the capacitor plates or coil windings. When your tuner arcs, you'll usually hear a snapping or buzzing noise. The reflected power meter will fluctuate wildly. Interference to your TV and other devices will increase dramatically. You may even see brilliant flashes of light inside your tuner!

Arcing is obviously bad news for your tuner. It's your tuner's way of saying, "Stop! I can't handle this mismatch!" There are two cures for arcing: reduce your output until it stops, or get a tuner with a higher power rating.

High-power tuners use large capacitors and coils. The gaps between the plates and windings are greater, making it more difficult for an arc to occur. If you can afford it, you're always better off buying a tuner with a 1.5 kW rating or better. (The exception is QRP operating where you're running low power levels.) A hefty tuner costs more, but it will serve you well in the long run.

Buy or Build?

As you comb through the advertising pages of *QST*, you'll see many new antenna tuners for sale. The prices are often reasonable and the quality is usually good. Keep your eyes open for used tuners, too. If an old tuner is in decent condition, it's every bit as usable as a new one.

If you like to build things, however, consider an antenna tuner as your next project. Antenna tuners are relatively easy to construct. You can find capacitors and coils at hamfest flea markets at low prices. Even roller inductors—the most expensive part of a roller-inductor tuner—can be found for less than $40 if you look carefully.

Your chances of success with an antenna tuner project are excellent. You have to try pretty hard to build one poorly! Best of all, you'll have the satisfaction of using a piece of equipment that you've put together yourself. The *ARRL Handbook* offers several tuner designs you can try. Heat up your soldering iron and go to it! QST

Radio Tips:

Log it or Lose it

Back in the old days (not all *that* long ago!), the FCC required every amateur to keep a detailed station log. (In addition to regular QSOs, hams even had to log unfruitful CQ calls.) And although we're not required to keep a log nowadays, an accurate station log is useful not only today, but tomorrow, too.

We all have things we like to keep track of: states and countries worked and confirmed; information for awards; or the names and addresses of our on-the-air friends. A well-kept station log is invaluable in your quest for the Worked All States or the DX Century Club (DXCC) awards. In addition to keeping a running list of states and countries, your logbook is the perfect place to keep detailed information on a wide range of subjects.

Your logbook is also a good place to keep notes on modifications to your equipment. Not only will the information be easy to find for future reference, it will be easier to note the effects of such changes by referencing contacts before and after.

How does your new loop antenna compare with your old trap vertical? Check out the signal reports in your logbook and you'll have a good idea!

DXers often refer to their logs when trying to work into specific parts of the world. When is the best time to work Africa in the winter? A quick check of last year's log entries will probably turn up the required information.

While you're at it, why not keep other changes in your log? When you upgrade, note it in your log. When you get a new rig or put up that long-awaited tribander, write it down. Ten years down the road, your log entries will bring back a flood of memories!

Speaking of memories, poring through your old logbooks can be a lot of fun. You'll come across your first QSO and remember how nervous you were, or you'll come across rare DX stations you've worked, pileups you've busted or the first time you worked someone special. Reliving those events is almost as much fun as it was when it happened!

Computers have become quite popular in ham shacks across the country—especially those belonging to contesters and DXers. If you have a PC in your shack, you might want to consider keeping your station log on your computer. A number of suitable programs are available. Check the ads in *QST*. Logging programs may also be available through your local club or computer user's group. If you're into programming, consider writing your own logging software.

If you do go the computer route, remember to keep regular backups and a hard copy of your log information—otherwise, the benefits of having instant access may be lost if your data disks are lost or damaged.

If computerized logging isn't your thing, *The ARRL Logbook* is just what you've been looking for. Used by thousands (millions?) of hams over the years, the latest version is available from the ARRL for $3.50. It has room for nearly 1000 QSOs and includes useful information such as Q signals, a time-conversion chart, the ITU phonetic alphabet, an RST chart, international call sign prefixes and more.—*NTØZ*