

## Tuners And SWR

In the first chapter we learned some terms used in discussing antennas and feed lines. We also dispelled the myth that a high VSWR measurement, indicates RF reflected back to your finals and can cause damage due to RF entering the final circuit of your radio. If that is what you still think, reread the first chapter and think about it some more!

### What does a tuner do?

This would be a good time to discuss the nature and purpose of antenna tuners, originally and more accurately called a matchbox. This device is quite simple in application even though much engineering often goes into the design.

Let's look at a common hookup for the tuner. The coax from the rig goes to the "transmitter" terminal(s) on the matchbox. The antenna coax goes to the "antenna" terminal(s) on the tuner (some tuners accommodate more than one antenna or antenna type).

Adjusting the "Antenna", "Transmitter" and "Inductor" controls on the front panel of a manual tuner in various combinations (or pressing the "tune" button of an automatic tuner) may seem to indicate that you can lower the SWR of an antenna. Sorry to burst your bubble again, **but this too is a myth.**

Myth #2 comes from the false assumption that the SWR meters indicate that you have "tuned" your antenna when using a matchbox. What has actually happened is that the tuner has compensated for the mismatched impedances between your rig and the coax (the lone exception being the exact  $\frac{1}{2}$  wavelength coax at a single frequency). You have, in effect, "tuned" your coax to the rig. The impedance seen by the tuner antenna terminals is a result of the entire antenna system - from antenna feed point, to feedline connector at the matchbox. Adjusting the tuner (manual or automatic - internal or external) supplies reactive and resistive characteristics to the radio that it expects. On the "antenna" terminals, the tuner has adjusted the impedance and reactance presented to the line so as to direct the reflected power back toward the antenna in-phase (see the definitions in part 1) with the incident wave. This in-phase condition is additive and compensates somewhat for the loss in the transmission line due to SWR. This does little for the other end of the coax in terms of "tuning" the antenna. Impedances at the load (antenna) do change some when using a tuner, but the extent of that change depends on a number of highly variable factors. The low SWR readings make your rig happy, because it is operating with good output efficiency. The final tubes or transistors will be able to generate RF without having to work very hard (heat up) and maximum RF power is delivered to the tuner.

Part of the design requirements of most commercial tuners is a very low insertion loss (the loss of power between input and output). This means very little power is wasted in the tuner by passive components and virtually all power is transferred to the coax and antenna. The important point to remember here is that we have not changed the antenna nor the coax, we have merely compensated for the conjugate differences between the antenna coax at the shack and what our rig is expecting as a load.

What if we move the tuner to the other end of the coax? Granted, not every situation would make this a practical situation, but for our purposes – let's say we could do it (some automatic tuners are made to be mounted at the antenna as they come or could be mounted in a suitable weather proof box for outdoor protection). What happens then?

We have the usual coax connected at our rig going to the antenna. The "Transmitter" port of the tuner is connected to the coax from the rig in the shack to the antenna. We must insert the tuner in the feed line before it reaches the antenna feed point terminals. The "Antenna" port of the tuner connects, either directly or with a short piece of appropriate feedline, to the antenna feed point (some antennas, like HF verticals, inverted "L", etc. need only a single wire from the tuner to the antenna and one from the tuner to ground). Tuning the controls (or pressing the "tune" button on an automatic tuner) will now match the antenna to the feedline at the frequency used to tune it to the lowest SWR.

Ultimately, this is the best of all matchbox situations when available. The question then becomes - Why?

### **What the tuner is NOT**

We discovered earlier in our "tuner in the shack" scenario, that a tuner in the shack will not change the SWR presented to the feedline by the antenna. That will remain the same. In that scenario, the tuner only matches the shack end of the coax to the rig. The tuner also changes the impedance and phase of the matching network to redirect the returning reflected wave back toward the antenna in-phase with the forward incident wave in an additive fashion. It does not "tune" the antenna.

So, if we cannot put the tuner at the antenna, how do we avoid the antenna system SWR problem and should we?

### **The role of antenna impedances in SWR**

The common goal of most barely knowledgeable hams is that the antenna would exhibit exactly (or almost nearly) the same characteristic impedance as the feedline at any frequency we wish to transmit on. Practically, however, this is rarely (if ever) achievable. The closest we could practically come is to use a multi-band log periodic antenna that covers all the frequencies we normally transmit on. Even then, the impedance characteristics are not perfect on every band within its operating range. SWR on log periodic dipole arrays (LPDA) often have a range of 1.2 - 1.9 over the design frequencies. Additionally, LPDA's are notoriously large in physical size for HF bands below 20 meters.

The best situation for most hams is to construct the more practical. Multiple antennas of single, two, or three band design, that have a manageable SWR over the normal operating range. The same principal applies to multi-band dipole and multi-band beam antennae.

This is a compromise for most situations, but one most hams will find to be operationally convenient. When possible, placing the tuner remotely at the antenna will always provide the highest available matching possibilities and most beneficial results for broad frequency / band coverage. For operating conditions that do not allow this, use the practical guidelines listed below to avoid the undesirable effects mentioned earlier.

### **Other Factors**

The tuner in the shack scenario could represent an operational problem. Suppose one side of our antenna is near a tree or building. Or one leg of our inverted "V" is, by necessity, lower than the other. This presents unequal loading to one side of the antenna and unequal currents at the antenna terminals.

We will examine the effects of antenna height and proximity to ground in a later chapter.

Unequal RF currents returning from the antenna to the rig, tend to flow on the outside of the coax cable. On open wire twin lead, currents in the two parallel conductors are not equal and opposite. The RF flow on the coax shield or the unequal currents in open wire line can then radiate just like your antenna, although with open-wire line the effect is much less noticeable. Because SWR is an additive component of the reflected wave (reference our discussion from Part 1) the same radiation occurs in open-wire transmission line or flat twin-lead "ladder line", as with coaxial cable. This is because the delicate balance between the two conductors will not be equal. It is an unintended consequence of uncontrolled feedline currents. The phenomenon is often manifested in incidental RF sparking or burns in the ham shack when transmitting. Also, the radiation pattern of your antenna may be altered due to the additional radiation from the feedline - adding a more or less omni directional component rather than the usual directional pattern expected. Sometimes you don't know about it until the neighbors complain you are getting into their television, telephone or stereo.

One unenlightened, but well meaning, ham decided to eliminate the RF on the coax by grounding the coax shield at the shack end of the coax to his vertical antenna in addition to the antenna and coax ground at the antenna (no, it was not me HI HI). When he tried to transmit, he discovered nothing would tune up properly. If you think about it, what he had done was to essentially reduce the feedline impedance by half and made it into a giant tuned circuit (remember coax has both series inductance and parallel capacitive characteristics). Depending on the length of the cable, it could become a very broadband tuned circuit. All sorts of problems could arise from this, including but not limited to radiation on a different frequency than your transmitter is tuned to.

Elimination of what is called "common mode" currents (reflected RF currents on the outside of coax or unequal currents in twin-conductor wire line) is a relatively simple application of some very old techniques. Configurations include broadband baluns, coils of coax, ferrite beads over the outside of the coax, and coaxial sleeve chokes sometimes called a "bazooka choke". All of these methods have usefulness in ham radio antenna systems and the selection of which will work for you depends on your particular installation..

### **Operational Guidelines**

Here are some operational guidelines that will aid you in making choices and provide long and successful operations.

**Rule #1:** Know the characteristic impedance of your antenna at the frequency you will be transmitting. In the past, experimentation and general knowledge of antenna and transmission line characteristics were difficult to obtain. The high cost and low availability of measuring instruments were prohibitive for most hams. Today, several very sophisticated antenna and network analyzing instruments are available for the ham shack in the under \$1000 range. The most notable of these is the MFJ SWR analyzer in various models. This valuable tool (or any one of several others that serve the same purpose) should be one of the first purchases for the serious antenna experimenter (worry about an SWR meter later - when you fully understand SWR). If you like to homebrew, the 1980 ARRL Handbook has a project to build an antenna impedance bridge. This device is not as accurate as the MFJ analyzer, but will go a long way toward presenting appropriate data to the experimenter for only a hundred dollars or less in parts.

**Rule #2:** Use only good quality, low loss transmission line that is the closest match for the antenna. If

the antenna feedpoint impedance at your operating frequency is  $72 + j75$  as measured by an analyzer (common for dipole type antennas), RG-216 or RG-6X is a better choice than even the most expensive RG-8, LMR-400, or RG-214. Let your tuner provide the rig-to-coax matching of impedances. If you plan to operate multiple bands with one wire antenna and one feedline, use ladder line instead of coax, and a balanced line tuner at the shack end, or a coax-to-twin line balun before the 50 ohm coax tuner. The ladder line has considerably less loss at high SWR than coax. It also exhibits the fortunate phenomenon of handling a very wide frequency range with little loss even with high SWR and high power. Know the loss characteristics of your coax and make your coax type choices so that there is an acceptable loss at your antenna operating frequencies. For instance, do not use RG-58/A/AU/AX for any antenna designed for use above 30 Mhz. The characteristic losses are much too high to be acceptable.

**Rule #3:** If your tuner is in the shack or your radio has an internal tuner: don't try to match SWR conditions that exceed 6:1 with your matchbox or radio (or 3.5:1 on some radios and amps). Remember the impedance differences are on the feedline and antenna, and will still be the same no matter how low the tuner is able to indicate the SWR is in the shack.

**Rule #4:** Construct well-designed, low SWR antennas for a broader frequency range than you will operate. In other words; if your antenna will stay under say 6:1 from 14.000 to 14.100, trying to use it in the 14.200-14.300 range of the band may not be recommended even with a tuner unless the tuner is remotely located at the antenna and can handle the very high SWR at the higher frequencies. You may also consider feeding the antenna with open wire or ladder line.