Newcomers and Elmers Net: Coax Do's and Don'ts 8-24-14
Robert AK3Q

Transmission Line Refresher

Transmission lines have some things in common which are worthy of calling back to mind. First, all transmission lines have something known as a velocity factor. This is a measurement of how much resistance, and therefore velocity reduction, the insulating dielectric material introduces into the system as compared to free space. This velocity factor, along with the diameter of the conducting wire and the skin effect of the conducting material all impact signal efficiency and the frequency characteristics of a transmission line.

One does not need to test for the dielectric characteristics of transmission lines if using known materials, but attention should be paid to manufacturer's ratings of various materials. In critical applications, however, an antenna analyzer can be used to measure the velocity factor of a piece of coax and thus determine a resonant frequency.

Another aspect worthy of note is the phase cancellation between conductors of a transmission line. When using open line the distance between conducting elements determines whether or not the fields generated on both lines are 180 degrees out of phase and thus cancel each other out (assuming equal amplitude). With coaxial line the inner conductor is surrounded by the dielectric material which insulates it from the outer braid. The fields generated by the current flowing on the outer surface of the inner conductor and on the inner surface of the outer conductor cancel each other out.

While current inside the coax is prevented from radiating along the coax, RF may travel along the outside of the coax, in essence traveling along the outer surface of the outer shield, depending on whether the coax has a single or double shield.

Finally, every transmission line exhibits some loss of power from resistance of the materials and from a certain amount of current being absorbed into the dielectric material. This loss is minimized significantly by using open wire line as compared to coax, but it is still there.

A Circuit

In any antenna system there is a *source* and a *load* and the path between them. In a matched system a line with capacitive reactance is connected to a purely resistive load (antenna) and the current traveling along the system "sees" the antenna as just more transmission line. When the system is unmatched, the current meets more or less resistance than the characteristic impedance of the line, and some of the power is reflected back toward the source. As more power moves from the source to the load, more power is reflected back, leading to a standing wave ratio (SWR) in which the alternating current is fighting itself.

When the line is unmatched, the transmission line begins to act like either a radiator or a resistor. Neither case is desirable in most situations. Ultimately if the coaxial line is presented a matched impedance and RF power is not being converted to heat, eventually all the power ends up going out the antenna.

A transmission line is intended to be just that—a conduit between radio and antenna, but it is an integral part of the system. Hopefully this is already obvious, but I mention it just in case. Like any electrical circuit there must be a clean, unobstructed flow of energy from source to destination if the circuit is going to perform properly. Any obstructions, choke points, shorts or breaks will diminish or completely interrupt the transmission of the intended signal.

Transmission lines, regardless how well made or how optimally designed, will introduce resistance to the electrical circuit. That resistance may indeed be put to good use, but it can also be a destructive source if not managed properly.

Choosing Coax

Choosing the appropriate coax for the signals intended is important. Since most folks choose coax over open line these days, my advice? Always go at least one grade higher than the minimum recommended for your application. If RG-8 is acceptable, go with RG-213. If RG-213 is okay, go with LMR-400. And so on.

If flexibility is needed for rotation or other reasons, make the main run a high grade (thicker) coax and then a short run of slightly lower grade (thinner) coax to rotate or to handle easily in the shack.

2:1 Means Trouble

There once was a time when VSWR meant nothing to amateur radio operators, particularly before the 1950s-1960s. Hams did not have SWR bridges or antenna analyzers or anything like that, and their radios did not cut back power at VSWR ratings of 2:1 or even less. Ah for the good old days!

Antenna performance should not, and indeed, cannot be measured based on VSWR alone. Cutting a dipole to resonance and feeding it with exactly ½ wavelength of coax is not the only way to get a signal out!

A "high" SWR is often considered to be anything above 1:1, but often anything above about 1.5:1; it is assumed too much power is being lost because of reflections down the transmission line. As noted above, reflected power is not lost—it is met by stronger waves coming from the radio back out the transmission line, and is ultimately caused to radiate out the antenna.

If you doubt this, think of the lowly 2-meter antenna on many cars which is built at a non-resonant length of 5/8 wavelength. Most people will say it out performs the (resonant) ¼ wavelength antenna, but since it is non-resonant, how can that be?? The non-resonant antenna does not reflect power back into the radio, nor does it "lose" power heating up the coax. It radiates all the power and produces an excellent signal, better than its "resonant" cousin.

Now let's think about open wire transmission line and how the SWR is even less of an issue. If we feed an 80-meter dipole resonant around 3.800 MHz, even coax line can be tuned across the band with a tuner, no problem. Try going to 40 meters and tuning the same antenna! Impedance will be around 4000 Ohms, or about 80:1 SWR. Switch out to 450 Ohm open wire transmission line and the SWR drops to around 9:1, something a tuner can easily handle.

"Wait! 9:1 SWR? That's ridiculous!" Not if the reflected power does not really diminish radiated power (which it doesn't, remember!) at even 10:1 SWR. A tuner will give the needed 50 Ohm impedance match for the radio, and the laws of physics will take care of the rest.

Here's why. Remember one of the basic tenets of AC theory: when the internal impedance of the generator is equal to that of the load, maximum power will be transferred from the generator to the load. Reflected power does not come back down the line and heat up the radio or the amplifier—only power unable to leave the generator (PA or external amp) can "heat up" the circuits and cause damage (under-loading). A modern rig cuts back power because of an impedance mismatch between radio and feedline, not from reflected power. On old tube rigs the internal matching network is adjusted by dipping the plate voltage—now the amplifier is happy and maximum power goes to the antenna system.

Feedline Misconception
An impedance match refers only to the radio/feedline match. Again this misconception comes about because of our focus on modern rigs and their power reduction circuitry which kicks in to protect the radio. An impedance match at the transmitter end created by a tuner keeps the radio happy, but it has no bearing on the impedance match at the antenna end. The antenna itself must present a reasonable match to the feedline for the signals to get through. If the antenna has an impedance of 30 Ohms but the feedline is 450 Ohms, a mis-match has occurred.

Likewise, a Yagi which presents an impedance of 10 Ohms to a 50 Ohm coax also represents a mismatch. A tuner at the receiver/transmitter cannot fix this mis-match. The antenna design must be matched to the feedline being used, just as the feedline must be matched to the transmitter output. There is nothing magical about 50 Ohms, by the way—it is simply what manufacturers have agreed upon as an output impedance for the radio and an input impedance for the coax.

Again we come back to feedline efficiency and antenna efficiency as the primary concerns for getting power out from the radio into the air. Every feedline has losses, and every antenna represents some amount of resistance to the current being sent through it. VSWR as a measure of these factors is useful—only used as a measure of feedline-to-radio efficiency is not useful.

Real results come from a low-loss feedline and a low reflection coefficient for the antenna—in simple terms a well-matched antenna with a good feedline makes VSWR more or less irrelevant, particularly when VSWR readings are understood properly.

Good Resource for Coax information we used in the net:
http://audiosystemsgroup.com/Coax-Stubs.pdf