Newcomers and Elmers Net: Transmission Line Myths and Misconceptions Parts 1&2
Feb. 15 & 22, 2015 Robert AK3Q

Transmission lines are the subject of many myths and many misconceptions, particularly when it comes to losses and the effects of radiating transmission lines.
-- Like a number of other antenna fundamentals, transmission lines are the victim of anecdotal experiences, more often than not, as well as some long-held misconceptions.
-- World War II was a time of change for amateur radio operators as transmission lines quickly moved from open/balanced line to due primarily to low cost and ease of use
-- Open line/ladder line is enjoying a bit of a resurgence as operators are once again discovering some of its advantages, including low-loss over greater distances, increased bandwidth, and substantially decreased cost.
-- Where coax was once an inexpensive surplus item, it's rather costly today.

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.

We do 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.

As we discussed with SWR, 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.

Myth #1 – A Feedline is just a Feedline
Beyond the obvious difference between open wire and coaxial transmission lines, many folks begin to believe a feedline is just a feedline.
-- Instead of seeing radio, transmission line, and antenna (and tuner and balun and everything else in-between) as a system, many folks consider radios to be one entity and the antenna as another
-- A transmission line is intended to be just that—a conduit between radio and antenna, but it is an integral part of the system.
-- 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 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.

Myth #2: Avoid ¼ λ Transmission Line Multiples
Every antenna setup is a bit different, particularly when it comes to surrounding area, ground, and placement of an antenna.
-- Somewhere along the way someone must have had some bad experiences with a transmission line and decided it was because it was ¼ wavelength.
-- More likely it was because given his particular situation, the feedline picked up some radiation from the antenna throwing things off a bit.
-- Transmission line length is really only relevant in terms of impedance transformation and in signal/power loss.
-- The shorter the feedline run the better, typically, and beyond that the feedline length factors primarily into the impedance matching.
-- This is not to say that using a feedline as part of the radiation pattern of the antenna is wrong, but only if that is desired.
-- Any other RF radiating from the antenna should be stopped before getting to the feedline.
-- Use the length of transmission line which works best for the antenna/location combination, and do not worry if the length comes out to a ¼ wavelength multiple.

Myth #3: A VSWR > 2:1 Means Trouble
As we touched on when discussion SWR, 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
-- 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 loss 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.
-- 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.
-- 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 transmitter or 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.

There are places where the choice between coax or ladder line is just a personal one, or there may be situations where one is the obvious choice over the other
-- just remember the feedline is an integral part of the antenna system, and care should be taken to consider both one’s immediate needs and one’s future needs as best we can anticipate such things
-- coax has a lot of advantages, but so does ladder line
-- I recommend using ladder line wherever it is practical , both for its advantages and for its reduced cost
-- As an aside, one does not hear much about dummy loads these days, but EVERY shack should have at least one which has a capacity greater than the highest transmit power capability of the shack. A dummy load matches the impedance of the transmitter at 50 Ohms, and therefore allows full power out from the radio. They are designed to absorb the power for a short period of time, which is perfect for testing circuits.

Wrap-up
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 mismatch 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 mismatch. The antenna design must be match 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—when only used as a measure of feedline-to-radio efficiency it 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.