Newcomers and Elmers Net: Transmission Lines/Feedlines
Robert AK3Q 09.03.17

Antenna systems are like chain links—they are only as strong as their weakest length.
-- While I have talked before about feedlines in general, I want to spend our time week going a bit deeper so as to understand not only what role they play in the system, but also to understand how their properties impact their use.
-- I also want to dispel some myths concerning them while hopefully promoting a good healthy perspective toward this important subject.

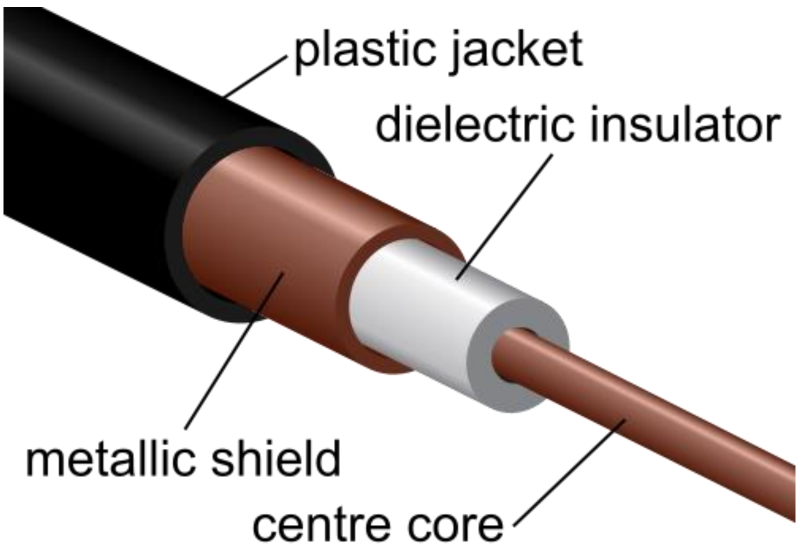
A feedline, or transmission line, is the link between your radio and whatever is being used to radiate the RF energy produced by the radio
-- (I am only looking at feedlines for transmission here because a feedline that works well for transmission on a given band will work well for reception on the same band).
-- Our goal is to take the same amount of energy produced by the radio and make sure all of it gets to the antenna so it can do its job radiating energy out to the world.

In the old days feedlines were commonly made from ladder line and this was a great conducting material for feedlines except for some restrictions.
-- ladder lines are susceptible to problems if they came into contact with other metal surfaces, or if they needed to change direction abruptly.
-- Either condition could cause a signal to terminate or become severely weakened.
-- This type of feedline is also susceptible to wear and tear from the elements, particularly when passing along tree limbs or other rough surfaces.
-- It should also be supported well where it connects to the antenna wires with Plexiglas or a similar non-conductive material.
-- The main advantages to ladder line is cost and signal efficiency—nothing else will give you the most energy transference efficiency as ladder line.
-- Signal loss is negligible out to great distances, particularly when working HF, and its light weight can come in real handy in terms of lowering your support needs.

Coax

Coaxial feedlines came into vogue after WWII because there was such a surplus available after the war which made it relatively inexpensive.

-- The military favored coax because it allowed them to run cables along the ground, around sharp bends, and they didn't have to worry about the cable contacting other metal surfaces.
-- Coax by design has inner and outer insulation (see illustration below), and other than internal breaks/shorts, or RF traveling down the cable into the shack, there is little to go wrong with it.



By the very nature of its design coax does present more resistance to the RF signal which must be accounted for, and its weight can be a major consideration when supporting the antenna.
-- Today coax is rather costly, especially for the higher quality cables, and so one should consider running ladder line wherever it is feasible just for the cost benefit alone.

Feedline Theory (Simplified)
Feedlines consist of two wires which provide paths for alternating current (AC) to flow back and forth along the feedline.
-- Ideally the current flow should be at 180° opposite phase angle and at equal amplitude so that the radiation field generated by the two lines cancel each other out.
-- Remember, this is a feedline—we are not looking for this wire to radiate!
-- The spacing between the two wires of a ladder line is designed to offer enough separation that the two wires do not inhibit the flow of current or generate magnetic fields that interfere with one another.

-- With coax line, there is both insulation and a dielectric material (usually the white plastic material you see surrounding the center wire) which keeps the currents from interfering with each other.

If the currents are unequal or the phase angle is not 180°, the line will radiate energy which will in turn drop the amount of energy getting to the radiating element of the antenna.
-- This is both a simple and yet extremely important element of a feedline, and it is one most often overlooked when putting up an antenna.
-- For example, using ladder line incorrectly, or using the wrong kind of coax for a particular application can lead to significant losses in signal strength (I'll discuss coax more in a moment).

Feedline loss didn't become an issue for me until I started putting together my own antennas and I started reading about feedline loss and impedance characteristics of different types of coax.
-- I got a rude awakening when I saw how much loss was inherent in RG-58U coax, especially at 440 MHz!
-- I couldn't get better coax on that line fast enough (more on line-loss later)! Since that time I have been much more aware of the effects of feedline choice, so I hope this discussion helps you avoid some of my mistakes.

Back to our theory. When using coax, the process of how the fields are cancelled is a bit different, but the results need to be the same.
-- With coax there is an inner conductor and an outer conductor, all housed within the coax coble. The outer conductor shields or traps the RF energy being transmitted along the inner conductor, and this keeps the line from radiating energy.
-- Breaks in the outer conductor can interfere with this process, as can electrical interference coming in from outside the cable through the skin of the coax.
-- This is why most cable has at least one layer of insulation around the outer conductor, and sometimes two.
-- This "built-in" current separation and field cancellation makes coax a popular choice in most situations since one can be fairly certain the signal will get through properly assuming no malfunctions in the cable itself.

Not All Coax Is The Same
Now before you tune me out from more technical talk, allow me to explain why not all coax is the same. Understanding why you need certain types of coax for certain situations is a big step forward in

understanding the antenna system as a whole, and it will allow you to make the most of each opportunity when setting up a new antenna.

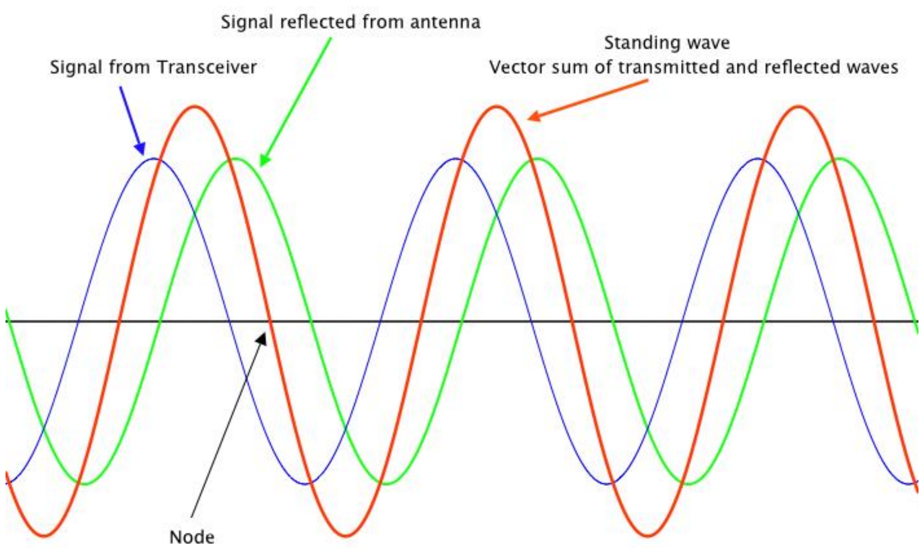
There is a physical property of AC electrical conduction which is called the "skin effect", and it has a direct bearing on feedline design for various frequencies.
-- Skin effect is where RF (electrical) energy travels down the outside (or "skin") of a wire, rather than through the wire itself.
--Smaller wavelengths (higher frequencies) require higher impedance between wires in order to properly cancel the fields created by the conducting wires.

Here's where things get a bit tricky. Because of the skin effect mentioned earlier, current travels on the outside skin of the inner wire, while the current which travels along the outer wire travels along the inner skin of the braided wire.
-- In other words, because of how the skin effect affects both conductors, both the dielectric material and the conductors need a larger dielectric surface area to function properly.
-- Higher frequencies need better dielectric material to keep things flowing smoothly (less leakage into the dielectric material), and a thicker center conductor wire gives more surface area contact for the RF energy to travel down the wire (greater skin effect).
-- This is why higher grade coax costs more than lower grade coax—there's a lot more material involved. Cheaper coax may have an outside diameter of an 1/8" or so, while higher quality coax may be ½" or more in diameter.

Just A Little More Theory . . .
Under the most ideal conditions there is a certain amount of line loss due to the materials used and their size.
-- Let's assume a 100 watt load from the radio is transmitted down a coax matched in impedance to the resistance at 50 Ohms, just as the radio requires.
-- Even with a coax line cut to the proper length for the given frequency, there is a certain amount of signal loss called *matched-line* loss.
-- The conducting wire presents a certain amount of resistance, as does the dielectric material surrounding the conductor.
-- Short runs of coax, say 50' or less, have minimal loss from this effect, but runs over 100' start to become noticeable, and over 200' there can be quite a significant reduction in signal strength.

-- This effect is also increased as frequency increases, so again we come back to the point that good quality coax becomes a real issue for VHF and above transmissions.

What happens when the line is mismatched?
-- forward power is met by reflected power. This mismatch produces a condition where some of the energy creates standing wave ratio, or SWR that is higher than we want. This can cause our radio to reduce power output as a safety measure.



The voltage at the node is the median voltage compared to ground

Losses by SWR mismatches don’t actually account for much overall line loss, but when coupled with inadequate coax (that is, coax with insufficient matched-line loss ratings), the losses can get quite high.
-- And this assumes coax which is in perfect shape—no tears, shorts, or line RF pick-up along the way.

Since the problem of line loss increases with frequency, it is not unusual for systems to only radiate 10% or less of applied power at VHF frequencies.
-- This happens much more often than you might expect, especially when using coax runs of 100’ or more for the higher frequencies.
-- This is also why you cannot simply trust low SWR readings at the radio—without going into all the math, inadequate coax can actually *reduce* the measured SWR at the load end, fooling you into believing everything is okay. A bit of nasty business there, eh?

-- Beware of low SWR readings across a band, especially at higher frequencies.
-- SWR should and will vary significantly over a given band as most antennas have a fairly narrow bandwidth.
-- Start looking for problems if SWR remains mostly constant over the band unless you know for sure the reasons behind it. The old adage remains, “If it seems to good to be true it probably is.”

So What Should I Use?
The first rule of thumb when it comes to feedlines is to use the least amount possible to get the job done.
-- The second rule of thumb is to use the best feedline for the job, either good quality ladder line or a high-quality coax.
-- Ladder line is best used when you have a basically straight run from the radio to the antenna with no nearby metal surfaces to de-tune the antenna.
-- Ladder line should never lay on the ground, nor should it have any sharp or moderately sharp bends along its path.
-- Keep in mind window frames, metal gutters, downspouts, etc. can all impact the function of ladder line.
-- For long runs it is the best choice whenever possible for HF communications, since it is inherently much more conductive than coax.
-- When matched properly ladder line will not radiate any RF, and it is the perfect choice for many situations.

Unfortunately life gets in the way of perfection, and often times we have to make compromises and use coax.
-- since coax is far less temperamental than ladder line, short runs of coax are usually far more practical and virtually indistinguishable from ladder line at lengths of under 100’ for HF.

Coax is very expensive, especially compared with ladder line, and so while we want to use the best we can there is no reason to waste money.
-- For HF coax runs of 150’ or less, I would recommend a good quality coax such as LMR200.
-- It’s matched-line loss at 30 MHz is only 1.8dB/100’, which means at typical HF frequencies it is almost negligible.
-- To use a better quality coax such as LMR400 would be overkill on HF.
-- Higher power usually requires better quality coax, so research the coax you intend to use for its power limits if you plan on using an amplifier or if you plan to use 200 watts or more.

-- The higher the frequency the lower the power limits of coax as well, so bear this in mind when choosing coax for VHF and above.

When working at VHF frequencies and above, there is no substitute for getting the best coax you can.
-- Don't pinch pennies here because the differences are staggering, especially as you move into the 440 MHz range of frequencies.
-- LMR200 at 445MHz is a whopping 7dB attenuation, and that assumes no other mismatched line loss.
-- RG213 clocks in at about 5.1dB, while LMR400 rates about 2.7dB. The additional money spent on high quality coax at this end of the band is better (and cheaper!) than buying a high powered amplifier!
-- Don't neglect this point—high frequencies require excellent, well-matched coax to keep the feedline from being an expensive dummy load.
-- A lot of people complain about their 440MHz coverage, but I would hazard a guess the problem lies not in the band but rather in their feedlines.
-- We hams tend to be a frugal bunch, but this is where you can be penny wise and pound foolish! Enough said.

Note: Charts abound on the internet for various coax/line loss combinations, as well as being available in books on antennas. Compare data from several charts to ensure the data is reasonably accurate for the coax/length/frequency combinations you intend to use.

SWR Readings
Let me make some final comments about SWR readings. If you have a measured SWR reading of 2:1 or less (real SWR from a properly set up antenna and transmission line) don't sweat over trying to get it down to 1.1:1.
-- Long before modern rigs which require low SWR to operate at max power-out, old timers didn't worry at all about SWR—they focused on having good antennas and quality feedlines and let their tube radios worry about the rest.
-- As a culture hams have recently become obsessed with SWR readings, tweaking perfectly good systems to get the supposedly "magical" 1.1:1 match and accepting nothing less.
-- I assure you, all that time spent tweaking their system could have been spent enjoying themselves on the air. In some cases, the signals

produced by a so-called perfect 1.1:1 are not as good as those at 1.5:1!
-- Don’t obsess over low SWR readings. Get (or build!) a good antenna, put the best feedline you can for your setup, and get on the air and have fun!

Keep in mind one change in S units is roughly equivalent to 6dB, so tweaking an already good system to get perhaps 1dB improvement isn’t going to make a whit of difference to the person on the other end.
-- It may make us feel good or give us bragging rights amongst our cronies, but real world difference won’t matter one bit. There—I said it!