Bob's TechTalk #18
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Impedance (Part III of X)

Feedline Impedance:

Last month we took a break to discuss Anderson Powerpole® connectors, how the are used and why they have become the standard for 12V radio equipment. This month we're back on our trip down the coax from the antenna to the transmitter! We left off after discussing the impedance of the dipole antenna and how it varied as the length (or frequency) changed from resonance. This month we'll begin discussing the feedline and how impedance varies along a feedline down to the transmitter.

Coaxial Cable:

Let's talk a little about coaxial cable (coax) before we start. Coaxial cable became popular during the second world war. Prior to that, open feedline was commonly used. The advantages of coaxial cable are good shielding (unaffected by near by objects), low impedance and easy routing (through holes, around sharp bends, beside a metal structures [fuselage], next to other feedlines, etc). These make up for the disadvantages which are higher cost, higher losses and lower SWR handling capability. The additional loss in coax is due mostly to the dielectric material. The dielectric material has another effect; radio waves travel slower in coaxial cable than in free space; the ratio between these speeds is the velocity factor of the cable. Velocity factor (Vf) is determined principally by the dielectric used in the cable and values between 0.82 and 0.66 are common. When we talk of cable length in wavelengths the velocity factor must taken into consideration. A one-quarter wavelength at 10 MHz in free space is 7.5 meters (24.6 feet) while a quarter-wavelength in standard RG-8 with a polyethylene dielectric (Vf = 0.66) is 5 meters (16.2 feet).

Lossless Feedline:

Let's start with an ideal resonant dipole with an impedance of 72+j0Ω at your frequency of choice; this is measured right at the antenna terminals. If we feed this antenna with **lossless** 72Ω coaxial cable, then the impedance at the far end of the cable will also be 72+j0Ω independent of the length of the cable. This is the ideal case, but not one usually found in the real world, especially if you like moving away from your frequency of choice.

Distance in Wavelengths from Antenna	Impedance at this Point for loss less 72Ω coaxial cable
0	57.6 - j43.2
1/8	36.0 + j0.0
1/4	57.6 + j43.2
3/8	144 + j0.0
1/2	57.6 - j43.2
5/8	36.0 + j0.0
3/4	57.6 + j43.2
7/8	144 + j0.0
1	57.6 - j43.2
1-1/8	36.0 + j0.0
1-1/4	57.6 + j43.2

Table 1

Instead, take a more practical dipole that is somewhat off resonance with a terminal resistance that measures 57.6 - j43.2 Ω, at your frequency of choice, and feed it with 72 Ω lossless coaxial cable. We haven't talked much about SWR so trust me when I tell you that this represents an SWR of 2.0:1. If we move down the feedline one-eight wavelength and measure the antenna impedance from this point it will measure 36 + j0Ω. Moving another one-eight wavelength, one quarter wavelength total, the antenna measures 57.6 + j43.2 Ω. If we continue moving from the antenna in one-eight wavelength intervals taking measurements we get the results shown in table one.

While the values in this table are only for the specific antenna given above, a lot of information can be obtained from the data. Notice that at every half-wavelength from the antenna the impedance is the same as at the antenna. Not only that, but the impedance at any point along the coax is the same as it is one-half wavelength away from that point! Also, notice that every quarter-wavelength the reactance changes between capacitive (– j) and inductive (+ j). In order for this change to occur, the reactance must go through zero, and we know that where that occurs is a point of resonance. What exactly is resonant? Not the antenna, but the antenna and the given length of coax in combination. In the table above, the first two of these resonant points occur at 3/8 and 5/8 wavelength. Notice that at one the resistive component is low (36 ohms) and at the other it is high (144 ohms). Since the nominal impedance of the coaxial cable is 72 ohms both of these resonant points can easily be shown to have an SWR of 2.0:1 (144/72 = 2.0 and 72/36 = 2.0); so do all the other points in the table. The change in impedance that occurs along a section of mismatched coaxial cable is sometimes used to help match an antenna to a transmitter. This is why instructions for an antenna sometimes give specific lengths of coax to use for the feedline. For instance, it might be easier for a transmitter designed to match 50+j0 ohms to match this antenna if it sees an impedance of 36+j0 ohms rather than an impedance of 144+j0 ohms or even an impedance of 57.6 ± j43.2 ohms.

The Smith Chart:

The impedance at all points along a coaxial cable can be easily determined, if you know the frequency and the impedance at any one point, by using a Smith Chart. The Smith Chart is an ingenious tool, easy to use, and it can help solve many types of impedance and matching problems. It is beyond the scope of this series, but was well presented in some older ARRL Antenna Handbooks and again in recent volumes. I suggest you look there for more information.

Lossy Coax Feedline:

Unless you shop in *Diagon Alley*, lossless coax doesn't exist. How does lossy coax affect the chart above? If the coaxial cable is old and has lots of loss, say a bit over 2 dB over its one-and-a half wavelength (extremely bad coax!), table two shows the impedance you would measure at different distances from the antenna.

Distance in Wavelengths from Antenna	Impedance at this Point for lossy 72Ω coaxial cable
0	57.6 - j43.2
1/8	38.2 + j0.0
1/4	59.8 + j40.3
3/8	132 + j0.0
1/2	61.9 - j36.8
5/8	41.8 + j0.0
3/4	63.4 + j33.8
7/8	117 + j0.0
1	65.5 - j30.2
1-1/8	46.8 + j0.0
1-1/4	67.0 + j27.4

Table Two

Notice the differences between table one and table two. The resonance points occur at the same position along the cable and the resistive component still alternates between a high and low impedance; but, in table 2, as you move farther from the antenna, the low and the high resistance component values get closer together. They are actually converging on 72 ohms, the nominal impedance of the coaxial cable. The points that are not resonant are also converging towards 72 + j0 ohms. In our example above, if you calculate the SWR (that is 2.0:1 at the antenna) you will only measure about 1.5:1 at the other 1-1/4 wavelength end.

Lossy long coaxial cable will result in an almost perfect SWR in your shack no matter how badly the mismatch is between the coax and the antenna. The bandwidth of the antenna will also appear very broad; changing frequency won't require much retuning. You will also find yourself not making a lot of contacts. The ideal broadband antenna is called a dummy load. Be happy if you have a full sized antenna and have to retune when you change frequencies. Yours is probably working well!

More than one ham has complained after installing new, lower-loss, coaxial cable that his SWR had increased noticeably. No, the SWR didn't change; it's still the same at the antenna; it's just that your SWR bridge down in the shack is now measuring the SWR more accurately. You're also getting more power to the antenna. Rejoice, don't complain!

Conclusion:

What have we learned? Since lossless coax is unobtainable for mere muggles, the discussion involving Table one may seem useless. On the contrary, at HF frequencies, on good coax the losses are small enough that you can assume lossless coax and still be reasonably accurate at calculating the impedance at any point on the feedline if you know the value at just one point. Here's a tip next time you install a new antenna or feedline. Before you install the coax, measure its length as accurately as you can. Record this as well as the published specifications for the cable (velocity factor and loss). Antenna analyzers are becoming more accurate and less expensive so if you buy or borrow one in the future you can find the impedance right at the antenna from the far end of the coax with the data you acquired when you installed the feedline!

Next Month:

Next month we'll finally reach the antenna tuner and transmitter on our journey down the coax. We'll discuss such questions as "What does the antenna tuner really do?" and other controversial stuff that are usually only found in the most adult of ham magazines behind the "Sterba Kurt'N."

73, from AF6C

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