Bob's TechTalk #25
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Impedance (Part X of X)
Coax Cable Measurements

I had hoped a few club members would suggest new topics for the ***Tech Talk*** column, but (sigh) nary a peep was heard. However, it's still not too late for next month; **your inputs please!**

Hey, I was cleaning up in the garage and found a big hunk of RG-8 (50Ω) coaxial cable. It looked in pretty good shape and had PL-259 connectors on each end. I thought about getting out my tape measure, laying the cable on the sidewalk and measuring how long it was. But, it was supposed to start raining at any moment, and besides I was feeling lazy, so I decided to measure the length another way!

I dragged the roll of coax into the ham shack and connected a half-watt 150Ω carbon resistor across one end of the cable using very short leads. (I measured the resistor so I knew the resistance accurately!) The other end of the cable to be measured was connected to my noise bridge, and the impedance was measured at four frequencies that I picked pretty much at random. I chose: 7, 12, 17 and 22 MHz. – avoiding frequencies that were harmonics of each other.

Table One shows the impedance I measured at each frequency and its normalized value for plotting on a Smith Chart. Normalizing was explained last month, but basically each R and jX value was divided by the nominal impedance of the coax (50Ω) to get the normalized values for plotting. I also normalized the impedance of our 150Ω load in the same table. Now all the hard work was done!

Figure One (on page 6) shows a Smith Chart. The first point plotted on the chart was the 150 + j0Ω load impedance (in red); since it is purely resistive, it lies on the horizontal "*axis of reals*". With a compass, a *circle of constant SWR* (solid red circle) was then drawn so that it passes through the load impedance point and has its center at the *prime center* of the Smith Chart. This circle represents all the impedances that would be seen along the coax cable due to the 3.0:1 SWR presented by the 150Ω load, assuming there was no loss along the cable. A (red) line was also drawn from the *prime center* through the load impedance point to the outer wavelength scale.

Next, the four measured impedance points were plotted. Notice that they all fall inside the circle. This is due to loss in the coax; if there was no loss, these points would fall on the SWR circle. Finally, lines (blue) were drawn from the *prime center,* through each of the four impedance points and out to the outer wavelength scale.

How does this let you find the length? Look at the red line where it crosses the outer wavelength scale. Note that there are really two scales marked *wavelengths towards load* and *wavelengths towards generator*. Since we're going to start at the load we'll be using the scale marked *wavelengths towards generator*. Notice that the load (red) line crosses the scale at 0.25 wavelengths. Now look at the line passing through the 7 MHz impedance point; it crosses the scale at 0.43 wavelengths. The difference is 0.18 wavelengths. Since a full circle around the smith chart is 0.5 wavelengths, we know the the length of the cable must be 0.18 wavelengths plus an integral number of half wavelengths. In other words the cable is either 0.18, 0.68, 1.18, 1.68... wavelengths long at 7 MHz. Using the formula for wavelength (feet) vs. frequency (MHz):

$$\lambda_{feet} = \frac{984}{f_{MHz}}$$

we find those cable wavelengths correspond to lengths of 24.8, 95.1, 165.3, 235.6... feet. But wait - that is the electrical length of the coaxial cable. RF moves slower in coax than in free air, so the cable is shorter than those numbers by the velocity factor of the cable, which for standard RG-8 is 0.88. Therefore the length of the cable is either 21'10", 83'8", 145'6" or 207'4". A good guess from looking at the cable is that the cable is 145'6"; but other frequencies can be used for confirmation. Since harmonics give similar results we've avoided them. Lets look at the impedance we see at 17 MHz. The solid blue line passing through the 17 MHz measured impedance reads 0.10 wavelengths on the *wavelengths towards generator* scale. But, watch out; we start at 0.25 wavelengths at the load (red) line and pass the 0.50 wavelength point at the far left of the scale and then continue to the 0.10 wavelength point. Thus the total length is 0.35 wavelengths (0.50 - 0.25 + 0.10 = 0.35). Repeating the procedure above, we see that for 2.85 wavelengths (5 half-wavelengths plus the 0.35 wavelength) we get a length of 165.23 feet electrical, or 145'5" actual length. Table Two shows these results and the results of the other two frequencies.

Notice that the impedance points are inside the SWR circle. Below the Smith Chart are some peripheral scales. These can tell you a lot. Set your compass to the radius of the SWR circle and then place the compass point at the center point of the top scale marked "ATTEN dB" and scribe an arc on the scale. Now set your compass to the distance between the *prime center* and the 22 MHz impedance point (marked 25.5-j12.0Ω). Again place the compass point at the center point of the "ATTEN dB" scale and scribe another arc on the scale (these are shown as purple lines in Figure One). The distance between the lines gives the attenuation of this length of coaxial cable at 22 MHz. I read it as 1.6 dB or about 1.1 dB per 100 feet. Is this good for RG-8? Would you buy this cable from me? Use the tables in the ARRL Handbook to see if this is reasonable for RG-8.

Freq. MHz	Measured Impedance	Normalized Impedance
7.00	23.3 - j18.5	0.466 - j0.37
12.00	108.5 - j24.0	2.170 - j0.48
17.00	31.0 + j27.0	0.620 + j0.54
22.00	25.5 - j12.0	0.510 - j0.24
Load Resistor:	150.0 + j0.0	3.00 + j0.00

Table One - Measured and Normalized Values

73, from AF6C

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Length in Feet for WL + N half wavelengths

	WL	N=0	N=1	N=2	N=3	N=4	N=5	N=6	N=7	N=8
7.0 MHz	0.18	24.77	95.06	165.34	235.63	305.91	376.20	446.48	516.77	587.06
12.0 MHz	0.02	1.45	42.45	83.45	124.45	165.45	206.45	247.45	288.45	329.45
17.0 MHz	0.35	20.52	49.46	78.40	107.34	136.29	165.23	194.17	223.11	252.05
22.0 MHz	0.2	8.83	31.19	53.56	75.92	98.28	120.65	143.01	165.38	187.74

Table 2 - Possible Cable Lengths (electrical) for Measured Cable

Figure 1 - Smith Chart showing plots of 150Ω load resistor at frequencies of 7, 12, 17 & 22 MHz for measuring the length of a roll of coaxial cable