The Amateur in You, Part 2

What have you been pondering?

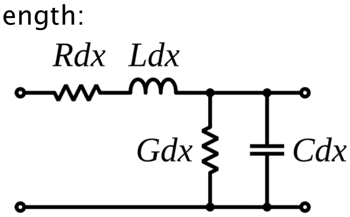
How is coaxial cable 50 ohms?

Some time ago, I read a blog question posted by a young man who recently purchased some coaxial cable. And because he was planning to use it for ham radio, he made sure that it was listed at ***50 ohms***.

But when he received the cable and measured it with an ohmmeter, he found that it read like an open circuit between the center conductor and the shield. He measured the shield from one end to the other, and then the center conductor the same way, and they were dead shorts, nearly zero ohms, as expected. But, when he measured the resistance between the center conductor on one end and the shield on the other end, it still showed infinite resistance, instead of 50 ohms. He was ready to return the coax, but thought he had better ask about it first.

What the young ham discovered was correct, if his coax was in good shape. But if that's the case, then where do we get this notion of ***50 ohms impedance for coaxial cable***?

The following diagram generalizes the appearance of almost any transmission line, such as coax, in which ***Ldx*** is the inductance per unit length and ***Cdx*** is the capacitance per unit length:



The cable does indeed exhibit some resistance, labeled ***Rdx***, but that value tends to be rather small, typically less than a third of an ohm for 100 feet of RG-8X and less than a tenth of an ohm for 100 feet of LMR-400, for example. The conductance, labeled ***Gdx***, is the reciprocal of the huge resistance between the center conductor and shield, so tends to be very small, in the order of micro-siemens per foot. The generalized equation for transmission line impedance is defined as

$$Z = \sqrt{\frac{R + sL}{G + sC}}$$

in which ***s*** is the imaginary unit and frequency, or ***j2πf***. If ***R*** and ***G*** are as small (effectively zero) as we believe, then the frequencies (the two s variables) cancel, and we have ***Z_o***, known as the ***characteristic impedance***:

$$Z_0 = \sqrt{\frac{sL}{sC}} = \sqrt{\frac{L}{C}}$$

For example, given that RG-8X cable exhibits 0.077 μH/ft and 30.8 pF/ft, the Z_0 for RG-8X = √[(0.077 μH/ft)/(30.8 pF/ft)] = **50 ohms.**

But if the frequency values cancel (because the cable resistance and conductance values are so low), it means this characteristic impedance holds, ***regardless of frequency***. In real-life, however, cables do have an upper usable frequency limit. RG-8X can by used to 1.0 GHz and LMR-400 can be used to 6.0 GHz, for example.

Because the coax inductance and capacitance are the result of cable geometry, the characteristic impedance can also be defined by

$$Z_o = \frac{138 \times log_{10}\left(\frac{D}{d}\right)}{\sqrt{\varepsilon_r}}$$

in which ***D*** is the inner diameter of the outer conductor, ***d*** is the diameter of the inner conductor, and ***ε_r*** is the relative permeability of the dielectric material. And now you know how coaxial cable has a characteristic impedance of 50 ohms.

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