TECH TIME

Helpful tips for the Avionics Technician

BY AL INGLE

This month we continue our series on wire. Having previously discussed shielded wire in general, capacitive and inductive coupling and the pitfalls of grounding shields at both ends, we will now study the conditions where such grounding practices are beneficial. The reference for this series of articles is the FAA's Advisory Circular AC 43.13-1B *Acceptable Methods, Techniques and Practices for Aircraft Inspection and Repair.* The document is readily available at www.faa.gov/avr/afs/300/pdf/1a-cover.pdf.

The Advisory Circular (chapter 11) advises the installer to limit the bend of a cable on a radius to not less than six (6) times the diameter of the cable. It also warns of coaxial cables' inherent vulnerability to damage, both seen and unseen. Precautions listed include:

Never kink coaxial cable.
Never drop anything on coaxial cable.
Never step on coaxial cable.
Never bend coaxial cable sharply.
Never loop coaxial cable tighter than the allowable bend radius.
Never pull on coaxial cable except in a straight line.
Never use coaxial cable for a handle, lean on it, or hang things on it (or any other wire).

What happens to the wire when it is damaged by any of the actions described above? Why is this detrimental? There is a popular bit of wisdom in our industry that goes something like this: *If you want to keep external signals off of a wire, you ground the shield on one end. If you want to keep the signals in the wire, then you ground the shield at both ends.* From previous discussion, we know that the single-ended shield is acting as an electrostatic shield and preventing capacitive coupling (but doing nothing for inductive coupling). It has also been previously shown that grounding a shield at both ends can actually induce unwanted signals into conductors through ground loops. So why do you ground at both ends? Because with high frequency signals, the maximum power that it is possible to draw from a source will be obtained when the load impedance matches the source impedance. To keep the impedance the same throughout the cable, you must carefully match the cable characteristics at each end - either with coaxial connectors or short lengths of wire. What is unusual about high frequency signals is that they do not act like their low frequency counterparts. For example, if you take a typical communications transceiver installation (with RF connectors and suitable coaxial cable) and connect an additional wire from each coaxial connector body to the airframe as shown in Figure 1 below, there will be no effect on reception or transmission quality because *no radio frequency (RF) current will flow through the grounded wires*. This is due to the phenomenon known as *skin effect*. By contrast, at lower frequencies, current would flow through the shield and ground wires as dictated by simple resistances of the return path.

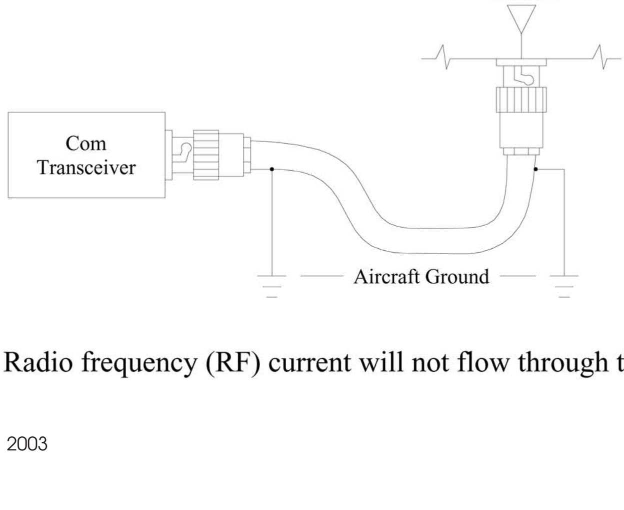

Figure 1 Radio frequency (RF) current will not flow through the grounded wires.

For now what is important to remember is that RF current wants to travel on the surfaces of conductors and shields and will ignore other seemingly obvious routes. Many broadcast transmission lines use a conductive tube for the center conductor for this reason. So why is this important to us? Reviewing the cautions listed in the Advisory Circular (and shown on the previous page), we see that if the coaxial cable is damaged by any of these actions, the flow of RF current will be changed due to the skin effect. In low frequency and DC circuits, a stretched, bent or twisted conductor still has the entire conductor for current flow. But high frequency current only has the outer surface for *optimum* energy transfer and is affected to a greater degree. You are going to pay for discontinuities in coaxial cables. See Figure 2 below:

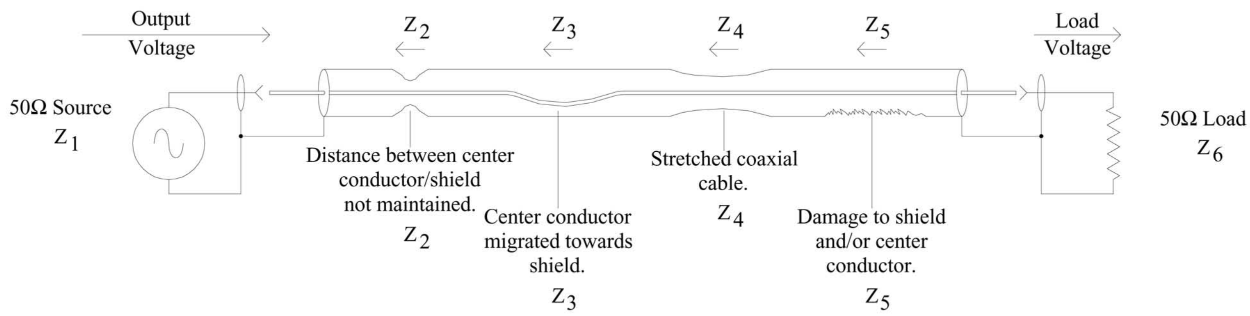

Figure 2 Damage to the coaxial cable causes reflected power.

In the DC world, Ohm's Law is R = E / I where R is the resistance, E is the voltage and I is the current. In the AC world (simplified) we call resistance "impedance" and label it Z. With a 50 ohm source and 50 ohm load, our goal is to maintain the coaxial cable's characteristic impedance at 50 ohms. If we do, maximum power will be transferred. As you can see in Figure 2, the voltage developed at the source travels down the coaxial cable and upon reaching the first damage (from perhaps a tie wrap too tight), the impedance is no longer 50 ohms - it is higher than 50 ohms. The voltage is now too high for the impedance to maintain conservation of energy. Something has to give and the result is a reflected wave back to the source equivalent to the mismatch. As the voltage travels to the load, every deviation in the coaxial cable's characteristic 50 ohm impedance causes a reflected wave to balance the power. The remaining voltage reaches the load and is dissipated. It is these reflected waves that create interference, can potentially damage the source and cause numerous problems in aircraft. Of course, nothing is perfect so we spend our time and resources attempting to minimize these variances. (For a more detailed explanation of this phenomenon, see Reference below).

While using the example of a transmitter above, it is important to remember that these rules must be followed for any RF signal. And do not forget that serial busses should be considered RF even if they do not use coaxial connectors or cable. This is because the clock and data pulses have very fast rise times. From the relationship Frequency = 1 / Period we discover that a square wave with a rise time of 1 µS has a 1 Mhz signal component! Keep those ground leads short and terminated as close to the signal carrying conductor as possible.

Reference

1. Dr. Bogatin, Eric, "What Causes Reflections?", August 2003, Printed Circuit Design and Manufacture.

Next Month: Skin Effect