TECH TIME

Helpful tips for the Avionics Technician

BY AL INGLE

This month we continue our series on wire that was suspended in January of 2002. Previously discussed were stranded wire's composition and three characteristics of importance- mechanical strength, voltage drop and current carrying requirements. Additionally, circuit protection devices were explored. 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 purpose of this article is to educate and reinforce the procedures in AC 43.13-1B. It is important to refer to the complete document when servicing aircraft.

Shielded wire is discussed in paragraph 11-89. For detailed information on the types and construction of shielded wire for aircraft, refer to MIL-DTL-27500, Cable, Power, Electrical and Cable Special Purpose, Electrical Shielded and Unshielded General Specifications.

A wire is shielded for two different reasons. One is to prevent signals on one conductor from coupling to another. A second application of a shield is for the efficient transmission of high frequency signals. We will explore signal coupling here, but we must first examine the fundamental nature of an electromagnetic wave. There are two distinct fields in such a wave - an electric field or "E" field, and a magnetic field or "H" field. They are best visualized as two orthogonal waves in space as shown in Figure 1.

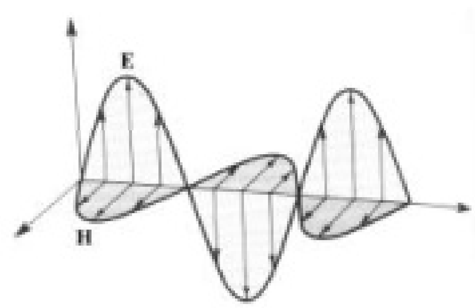

Figure 1 The **E** and **H** vectors in a plane electromagnetic wave, traveling along the positive *x* axis. The field vectors are mutually perpendicular and are in phase.

An "E" field is energy in the form of an electric charge (free electrons) stored in the dielectric between two plates i.e. a capacitor. You can also think of two parallel wires acting as two plates of a capacitor. See Figure 2 below.

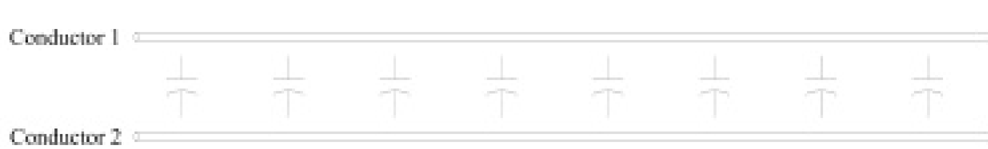

Figure 2 Two parallel wires acting as plates of a capacitor.

When this electric field is allowed to remain constant, then energy within it remains *potential*. It is only when the voltage across the capacitor is changing that energy is either being stored in or being released from this capacitive reservoir. This in turn interferes with the signals on these conductors. The energy transfer is a function of the impedance between these wires or their capacitive reactance, X_C. X_C will depend upon the capacitance, C, between the conductors and the frequency of the changing potential, F, in the following relationship:

$$X_C = \frac{1}{2\pi FC}$$

Refer to Figure 3. By adding a shield to a conductor, this electric field is broken (with the free electrons bled to ground) and capacitive coupling is significantly reduced. Good installation practices will therefore have you minimizing long runs of closely spaced wires where sensitive signals are involved.

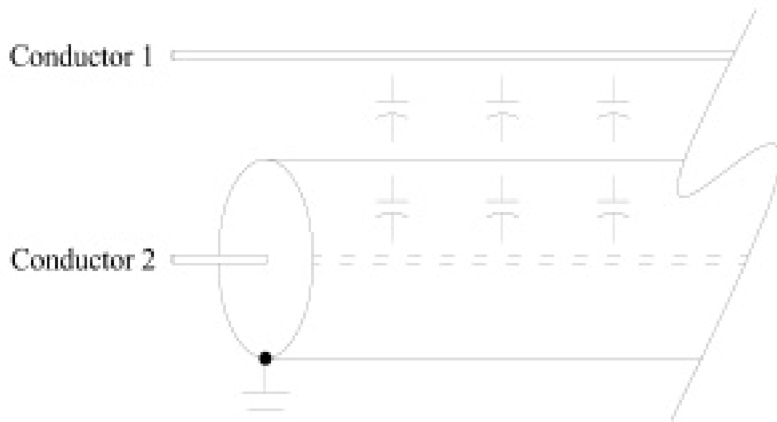

Figure 3 Adding a shield significantly reduces capacitive coupling.

Likewise, an "H" field is energy in the form of a magnetic field stored around an inductor in which current is flowing. A steady direct current flowing through a wire (inductance) will set up a steady, unchanging magnetic field, and in such a field the energy is *potential*. When the current is changing, energy is being added to the field or taken from it; increasing current means more energy being stored, and decreasing current means that energy is being returned to the sourcing circuit. See Figure 4 below:

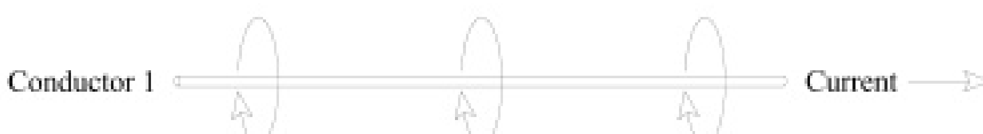

Figure 4 Magnetic field created by current flow.

The *changing* magnetic field can now induce a voltage into surrounding wires in the same manner as a transformer, which in turn interferes with the signals on these conductors. See Figure 5 below:

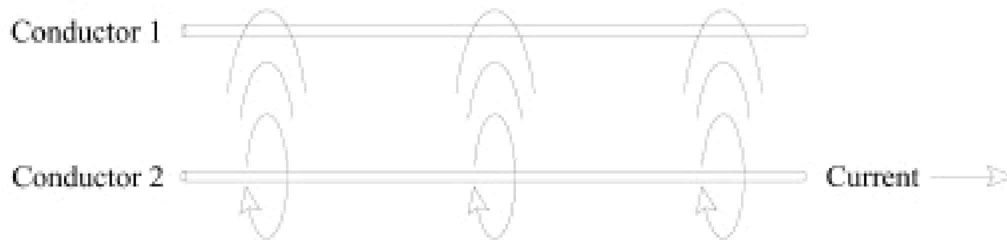

Figure 5 Magnetic interference caused by current flow.

The energy transfer is a function of the amplitude and frequency of the magnetic field and the coefficient of coupling between these wires. This in turn depends upon the permeability of the material between conductors (you may get conduction greater than free air), the distance and angle between them, etc.

While a steady direct current is required for "quiet" conditions in a charged conductor, no *voltage* is needed to maintain the field. In contrast, the electric field is "quiet" when there is a steady voltage but no current. In an ideal world, no electrical power is needed for maintaining a steady field of either type, because if either the voltage or current is zero, the power (current x voltage) is also zero. Our world is not perfect, and there are internal resistive losses to contend with, but the interference from capacitive and inductive coupling is very real and must be dealt with. Technicians installing avionics or troubleshooting interference related problems must understand this phenomenon.

In the case of magnetic, or "H" field coupling, a shield is worthless. Magnetic lines of force, being continuous and closed upon themselves, cannot be defined to a given space. There are no "magnetic charges" to be drained off. For all practical purposes in an aircraft, *the only way to contend with a magnetic field is to stay away from it*. Fortunately, a magnetic field's intensity decreases exponentially with distance so a little gap, even 0.25", goes a long way in reducing its effects. Also, routing sensitive wires at right angles to current carrying wires will minimize coupling.

One technique of segregating current carrying wires from sensitive ones is to use color-coded wire during installation of new equipment. For example, you can use red for power, black for aircraft ground, yellow for dimmer/lighting equipment, and blue for low level audio. Then, when bundling these wires they can be routed so that interference is minimized. This also eases troubleshooting later.

Paying constant vigilance to your wiring layout, with capacitive and inductive coupling in mind, will afford your customer the best performance possible. Quiet, reliable installations are not created by accident.

Next Month: Coaxial cables