From September 2010 *High Frequency Electronics*

Notes on the Selection Criteria for Coaxial Cable

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Here is an overview of the key considerations that engineers must examine when selecting coaxial cable for their "next" RF/microwave application

There are many factors to consider when selecting the right coaxial cable for your particular application. For example, test cables need to maintain performance over time, with lots of flexing and mating/unmating of connectors. Internal interconnecting cables must be small, well-shielded and generally inexpensive. High power transmission cables must survive weather, pollution and other environmental conditions. They also need connectors that can be easily field-installed and still perform as specified.

These are only a few examples. The remainder of this tutorial article offers a summary of cable construction and electrical performance options. After reading this article, our advice is to study catalogs, application notes and product-specific data from cable suppliers. The cable industry is well-known for extensive technical support resources.

1. Center Conductor

All high-performance small coaxial cables have solid copper center conductors. Silver plating may be added to improve conductivity in microwave cables, where the plating is a significant fraction of the skin effect depth. Silver plating also improves solderability, which is important for reducing heat requirements when soldering to a connector. Stranded copper may be used when maximum flexibility is required, although there is a potential for noise in very sensitive systems, and a slight degradation of VSWR performance compared to solid conductors.

In less-rigorous applications, tin-plated copper conductors might be used for reduced oxidation and better solderability. Very low cost systems may use copper-clad steel conductors (e.g., RG-6 type CATV drop cables).

High power cables will use either hollow copper tubing or a solid center conductor made with a thick layer of copper bonded to a core of aluminum. Tubing conductors may be spiral or corrugated design, usually to match the same design of the outer conductor.

2. Dielectric Material

The purposes of the dielectric in coaxial cables include: supporting the center conductor and keeping it centered relative to the shield; controlling the velocity factor of signal transmission; establishing the breakdown voltage; and doing all these things over the specified temperature range.

The majority of smaller cables have either solid or foamed dielectrics. High power cables will have either foam dielectric or some type of spacer system that supports the center conductor while allowing the average dielectric constant to approach that of air. This is possible because larger cables have more rigid conductors that do not require constant support along their length.

As an example, Semflex [1] offers four dielectric choices:

Polyethylene—Operates over –40 to +85ºC with velocity of propagation of 66% to 85% for solid and foam materials.

Solid PTFE—Operates over –65 to +125ºC with velocity of propagation of 70%.

Low Density PTFE—Operates over –65 to +200ºC with velocity of propagation of 74-78%.

Ultra Low Density PTFE—Operates over –65 to +200ºC with velocity of propagation of 82-85%.

Other cable manufacturers offer different variations in the parameters of these materials, and may also have specialized dielectrics such as:

Silicon Dioxide—Silicon dioxide (the same material as high purity glass or quartz) offers extremely high temperature operation and low loss, as well as low coefficient of expansion. The tradeoff is high cost, which is why this type cable is limited to military, aerospace and harsh environment applications. Meggitt Safety Systems identifies one of its products as having an operating temperature range of –270 to +950ºC with velocity of propagation of 80%.

3. Shield/Outer Conductor

There are many options for applying the shield conductor to coaxial cables. The simplest is solid metal, which is how most large size/high power cables are made. Solid copper (smooth or spiral/corrugated) and solid aluminum may be used.

Mid-size and small cables typically use a braided outer conductor, sometimes combined with an aluminum, aluminized polyester, or aluminized polyimide foil [1, 3, 4].

Copper wire braid provides good mechanical strength, flexibility and reliability. However, the small gaps between the wires prevents 100% shield coverage. Two layers of braid with different patterns achieves near-perfect shielding (90-100 dB), but at a higher cost. Flattening the copper wires in the braid reduces the space between individual strands, also improving shielding, with increased materials and manufacturing cost. Like the center conductor, copper braid may be bare metal, silver plated or tin plated. Some specialized cables use solder-coated braid to achieve a solid conductor.

The combination of foil and braid has proven to be the best cost/performance tradeoff. Polyimide foil has high strength, with high temperature performance and good chemical resistance. This material is usually applied as a wrap, with the need to precisely control overlap. Polyester foils are applied continuously along the length of the cable, with the edges folded to create essentially continuous coverage. When combined with the physical strength and additional shielding of copper braid, these cables provide very high mechanical and electrical performance.

The choice of shield for a specific application will depend mainly on the minimum accaptable electrical performance parameters, requirements for flexing, and ease of installation of connectors.

4. Jacket

Because the outer covering of a coaxial cable is exposed to the environment, there is a wide range of choices for jacket materials. The most common materials to choose from include:

PVC—Lowest cost option, with good flexibility but modest environmental and temperature performance. PVC allows the introduction of fire retardant chemicals, and can be supplied with acceptable UV resistance.

Polyethylene—Low temperature, but UV-resistant and cost-effective. The carbon black content affects the UV resistance and it may be necessary to specify a minimum level. Has a much longer lifetime than PVC.

Polyurethane—This material also has a low temperature rating. Its primary advantage is high abrasion and cut-through resistance. It has good resistance to many chemicals.

Fluoropolymers—The acronyms FEP, PFA, PTFE and EPTFE are the various fluoropolymers used in coaxial cables. Variations among them include the level of outgassing, specific operating temperature range and mechanical properties. In general, all fluoropolymers have high breakdown voltage, low dielectric constant, good flexiblity and high chemical resistance. The low coefficient of friction can be an advantage for installation in conduit or enclosures. The primary disadvantages are higher cost than other options, and relatively poor abrasion and cut-through resistance.

Armored and metal-jacket cables are also available for cables that will be installed in locations requiring a high level of physical protection. Another use of metal jacketing is in test cables. For example, the Aeroflex/Inmet "caliber" line has stainless steel spiral casing. For test cables, the mechanical protection involves both protection during handling, and dimensional rigidity to maintain cable electrical performance with repeated flexing.

In the past, jacket options included braided fabric for minimum additional thickness. It is uncertain whether there are current sources for replacement of this vintage style.

And of course, unjacketed cable is available where environmental protection and electrical insulation is unnecessary. Also, there are some situations where continuous contact of the shield with other cables in a bundle or with the metal surface of an enclosure is an advantage, lowering the impedance of the "ground" to reduce crosstalk and radiation.

5. Electrical Performance

Having examined the construction of coaxial cables, we can proceed to overall RF performance. Standard parameters that are generally understood and need no further explanation include:

- Characteristic impedance
- Velocity of propagation
- Loss per unit length over the desired frequency range
- Power handling capability
- Maximum operating voltage
- Maximum VSWR (accuracy of characteristic impedance) over the desired frequency range

There are some other electrical characteristics and behaviors that require review for each specifc application:

Shielding Effectiveness—Signal leakage from a cable can be an important parameter for interference reduction, or for accurate measurements using precision instrumentation. Since electromagnetic radiation properties are reciprocal, shielding also keeps unwanted signals away from the desired signals. In a high-RF environment, or when cables are routed in proximity to others, maximum shielding performance may be a key specification.

Phase Stability—When a system uses multiple cables for signal distribution, the phase relationships may be critical. Antenna arrays are an obvious application, but instrumentation cables and sensor systems may have the same need for stable, repeatable phase performance.

Cables designed for phase stable applications use materials and manufacturing processes that minimize variation from one lot to another, even from one end of a reel to the other.

Cutoff Frequency—The physical dimensions of a coaxial cable result in a frequency above which signals no longer propagate via the tranverse electromagnetic (TEM) mode. In short, above the cutoff frequency, discontinuities will create higher mode propagation and multiple "images" of the signal will arrive at the far end. Although a continuous cable can operate properly somewhat above cutoff frequency, the potential for "moding" makes this unwise. Typically, issue of moding arises when engineers are tempted to use a larger cable to handle higher power at microwave frequencies.

Passive IMD—Wireless base stations have high power transmitters adjacent to sensitive receivers. Very small distortion products can create sufficient signal strength to cause interference and reduce the range and reliability of the system. Cables alone rarely are a concern, but the quality of the connectors, their installation, and damage to the cable during installation are possible sources of low-level distortion products. While a discussion of passive IMD is outside the scope of this article, designers should be aware of this parameter in cable specifications.

Self-Generated Noise—Cables can create significant noise when flexed. The movement of dielectrics, conductors and shield layers within a cable can result in electrostatically-generated electrical signals at low frequencies and RF. Minimizing this noise requires a mechanical design that prevents the motions, by arranging the shielding and jacketing materials properly. Although quality cables have very low noise, some manufacturers offer special low-noise cables that are constructed to further reduce the noise for applications with critical requirements.

6. Environmental Considerations

Several environmental characteristics have already been noted, especially for jacketing materials. The main additional comment is that some performance characateristics are mandated. In-building cables will have fire ratings, military applications have specific requirements. Outdoor installations have required UV performance, or may require proper perforance for direct burial.

7. Connectors

The final area to consider when selecting a cable is its connection to the rest of the system. Many cable purchases are assemblies with connectors attached by the supplier. Providing the proper specifications for connector type, attachment method, electrical performance, etc., will result in better system performance and reliability.

Some companies offer enhanced connector designs for special applications or to address particular problem areas. For example, the recently-introduced eSMA from San-tron has an extended ferrule (cable end of the body) that provides extra protection against kinking when used with hand-formable cable. In addition, this connector was specifically designed for use with Times Microwave TFlex cables. Similar cooperative development has been done by other companies to solve different problems.

Field-installed and lab-installed connectors have special requirements as well. They must be designed for easy assembly whenever possible. However, some connectors require detailed assembly techniques to achieve best performance, and assembly instructions may be quite detailed (including online video). Manufacturers often have specialized installation tools to help achieve the best results.

References

1. "Technical Overview for Coaxial Cable," Semflex div. of Emerson Network Power Connectivity Solutions, www.semflex.com

2. Meggitt Safety Systems product information: www. stablecable.com

3. "Wire, Cable, and Fiber Optics," workshop notes, Belden Inc., www. belden.com

4. "A guide to the selection of RF coaxial cable," Times Microwave Systems, www.timesmicrowave.com

5. "Selecting the Right Cable System for your Environment," W.L. Gore, www.gore.com

Additional useful reference information is available on most cable manufacturers' web sites. With their close collaboration, connector companies also provide good information.