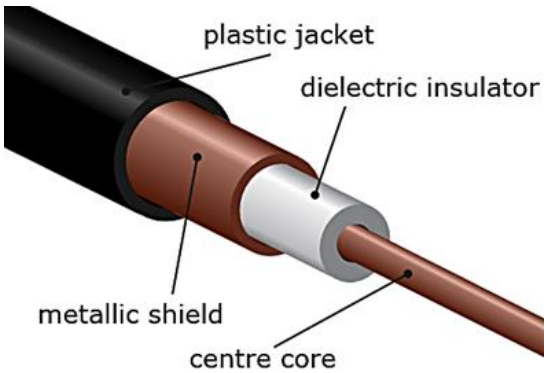
Cables and Cable Assemblies

Coaxial cables are too often taken for granted and RF and microwave systems. As a result, they are often treated like a spool of bell wire, twisted, band, crimped, stepped on, and subject to assorted other abuses. However, the more you know about coaxial cable the more likely you are to treat it with respect, as its integrity, lifetime, and overall performance are at stake.

To get a better understanding of coaxial cables in general, Anatech Electronics has prepared a series of guides that provide information about RF and microwave coaxial cables ranging from the basics contained in this application note to more detailed information about characteristics, applications, specific cable types, and other topics.

THE BASICS

Coaxial cables are "coaxial" because all of their components are on the same geometric axis. They include one main conductor that carries the signal, a dielectric insulating material that surrounds it (which can even be air or gas), a shield that surrounds that (typically grounded) that prevents the signal from exiting the cable and vice versa, and a protective layer or jacket made from one of a variety of types of material depending on the application of the cable. They were invented by Oliver Heaviside, a English engineer and mathematician, who patented the design in 1880. Other patents followed, the most relevant to modern types by AT&T in 1929.



1. Construction of a typical coaxial cable

The benefit of a coaxial cable over other types such as “twinax” is that the electric and magnetic fields it carries are maintained throughout the length of the cable and not leaked into the environment thanks to the outer conductor (shield). The opposite is also true as electric and magnetic fields from outside the cable are kept to a large degree from reaching the center conductor and interfering with the signals it carries. Generally speaking, the greater the amount of shielding, the less the leakage, but as cable diameter increases so does his weight and cost.

Coaxial cables have a characteristic impedance (Z_O) that is almost always 50 ohms except in some data communication systems and virtually all cable (CATV) systems, where it is 75 ohms. Maintaining this impedance throughout the length of the cable is essential in order to ensure minimum reflected power (that is, low VSWR).

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An obvious question might be why only two characteristic impedances, 50 and 75 ohms, are used in the vast majority of cable types. The existence of a 50-ohm impedance originates from early work at Bell Laboratories in the 1920s to determine the impedance best suited for both transmission of high-power signals and reception of weak ones. As it turned out, a value of 30 ohms was best for transmitting signals but not for receiving them, for which 77 ohms provided the lowest loss (for a cable with an air dielectric).

A value of 50 ohms was considered a reasonable compromise and has since been used for almost all RF and microwave systems – except for the cable industry, where a 75-ohm impedance is the norm. The 75-ohm impedance came about because 300-ohm folded-dipole antennas were used for reception of over-the-air signals fed by “twin-lead” cable and a reduction to 75 ohms could be achieved using a 4:1 balun transformer, allowing use of the more advantageous coaxial cable.

TYPES OF COAXIAL CABLES

There are five basic types of coaxial cable (semi-rigid, conformable, flexible, hard line, and rigid). Within each type there are a wide variety of variations. In addition, cables are available for specific applications, such as flight line testing where they are subjected to hostile conditions such as jet fuel, being run over by trucks, and pulling along the portable rack of equipment, among other things.

Other types use specific kinds of chemical-resistant jacking material, as well as heavy armoring for protection. Coaxial cable families include:

Semi-rigid cable

As its name implies, this type of cable can be formed into a shape but is not flexible in the sense that it is “limp” and once been to a specific shape is not designed to be changed. It also requires the bending equipment to form it. Construction is similar to other types of cables, generally employing a silver-plated copper center conductor, but the outer jacket is an aluminum or copper tube.

2. Semi-rigid cables

Its major benefits are very low loss at higher frequencies, consistent dielectric constant, and very high shielding effectiveness. It is available in diameters of 0.034, 0.047, 0.086, or 0.141 in. Semi-rigid cable can be used at very high frequencies, even up to 110 GHz, but its RF power handling ability decreases with frequency.

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Conformable

This type of cable is flexible and unlike semi-rigid cable can be shaped by hand, making it a good alternative to the latter, with which its shares most performance characteristics. It can also be stripped and formed to a desired shape by hand (that is, without tools).

3. Conformable cables

However, although it is formable, it is not flexible in that once bent it will retain its shape but is not intended to be repeatedly flexed. In the tight quarters of many microwave subsystems, the ability to form it by hand is a significant benefit.

Flexible cables

As true flexibility, that is, the ability to be not only shaped but flexed repeatedly without significant degradation makes flexible cable highly desirable in a wide array of applications. Its only major disadvantage is that it does not have the same level of performance as semi-rigid cables..

4. Flexible microwave cable

That said, it's often not used in the same situations as semi-rigid or conformable cable and its flexibility broadens the number of applications in which it is an excellent choice.

If all types of coaxial cable are taken into consideration, the flexible type is by far the most common, ranging from types used from very low frequencies up to about 1 GHz. It is used in a broad array of applications ranging from amateur radio to cable systems and varies widely in quality. That is, the price of flexible coaxial cable used for general-purpose applications can be extremely inexpensive but its performance matches its price.

However, flexible coaxial cable is very different in that in order to deliver high performance it is invariably of vastly higher quality and thus more expensive. Rather than using only a solid center conductor, flexible microwave coaxial cables may also use a stranded center conductor.

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Dielectric materials vary from polyethylene to PTFE and solid high-density polyethylene foam. The outer jacket is typically made from polyurethane or fluorinated ethylene propylene (FEP) although other plastics are also used depending on the environment in which the cable will be used.

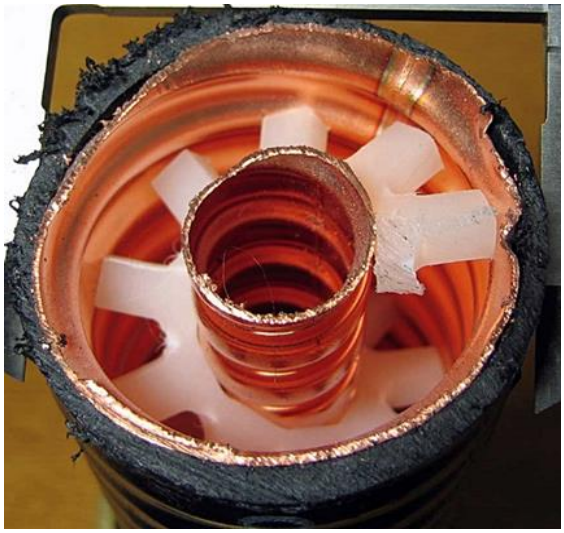
Significant advances in flexible microwave coaxial cable have been made over the years, and various manufacturers have developed proprietary manufacturing techniques, materials, and other technologies to improve its performance.

As a result, the overall capability of flexible microwave cable has dramatically improved over the years.

Hard Line

This type of cable, as its name implies, is not flexible except in its smallest diameters, and its construction varies considerably from other types. It has the ability to handle very high power levels with low loss, which makes it well-suited for long cable runs, up to the top of a broadcast tower for example.

It has a center conductor made from solid copper or corrugated copper tubing or in some cases copper-plated aluminum. It is large in diameter, ranging upwards from 0.5 inches to about 8 inches.



5. "Hard" transmission line

The material used as a dielectric can be polyethylene foam, air, or a pressurized gas such as nitrogen or "dried" air. When plastics such as nylon are used as the dielectric they are typically held in place by a spacer such as a spiral or a variety of other approaches, to provide a rugged separator between the center conductor and the outer conductor.

The use of gas or air as an insulator ensures that dielectric constant remains stable along the cable length and eliminates arcing that could result from the high current levels that are present in the high RF power applications in which this type of transmission line is used.

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Rigid line

Coaxial cable of this type looks more like plumbing than an RF component, and is designed to handle extremely high RF power levels. It consists of two copper tubes, one for the center conductor and one for the outer conductor separated by PTFE supports at periodic intervals. As it cannot be bent at all and changes in direction are accommodated (like pipe) by using elbows.

Connections to the transmitter and antenna are made using RF connectors that accommodate the specific diameter of the transmission line, and rigid transmission line can be made to suit both 50-and 75-ohm impedances. It's most commonly used indoors but can be weatherized as well, as one of its most common uses is in the broadcast industry.

6. Rigid cable installed in a broadcast tower

SUMMARY

This application note covers the basic types of cables used in systems ranging from the least demanding such as amateur radio, to those required to handle extremely high RF power levels encountered in broadcast systems, as well as those designed for use in systems operating at high microwave or millimeter-wave frequencies.

However, within each of these categories there are an enormous variations, as manufacturers use proprietary techniques to differentiate their products. As a result, more detailed information is required to make informed decisions about which cable type to use in a specific application, and this and other topics will be covered in subsequent application notes in this series.

QUESTIONS? WE'RE HERE TO HELP

Anatech Electronics makes it easy to specify microwave cable assemblies, and we can answer any questions you might have. We offer RG-type and LMR-type coaxial cables as well as semi-rigid cables, and can mate them with the connector types best suited for their application.

So please call us at (973) 772-4242, visit our Web site, or send an email to sales at anatechelelctronics.com.