Coaxial RF Connectors for Microwaves

There are two common ways to connect RF components—coax and waveguide. In this issue we will examine the coaxial connectors that are in use for microwave frequencies.

Equipment that microwavers buy new, find surplus, and build needs to be interconnected. Usually, low loss, ability to form repeatable connections and low cost are important issues.

What Makes a Good Coaxial RF Connection?

Coax is a very convenient transmission line for short runs of microwave energy. Although coaxial cables are lossy, except at the very highest frequencies most circuits can tolerate the small loss incurred in a few inches of cable. The benefits of easy interconnections offered by small microwave coax, such as 0.141, 0.085 and 0.047 inch Hardline (see Figure 1), hand formable semi-flex and braided varieties often outweigh the loss.

A good coaxial connector continues the transmission line characteristics through the interface to the other side, which can be another piece of coax or some kind of transition to a stripline circuit or waveguide. Because coax consists of a coaxial set of cylinders, where the internal conductor is surrounded by a dielectric and another "ground" external conductor, a coax connector follows the same geometrical form.

The only difference between coaxial cable and a coaxial connector is the need to break and make the connection. In most common connectors, the center conductor has one end with a pin (male) and the other has a socket (female). Because the female end must be made of sprung fingers in order to make good contact (usually four of them), it will change shape when the connection is made. Precision manufacturing results in perfect cylindrical shape of the internal conductor once the connection is made. Also, if one wants to reuse the connector, the springy female end must have sufficient strength to prevent weakening or breaking of the fingers.


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As the frequency is increased in any coaxial transmission structure, a point is reached where the wavelength approaches about one half the size of the coaxial diameter and the coaxial cable becomes a waveguide. Engineers refer to this as the "excitation of the first circular waveguide mode." At this critical frequency, coaxial cable can produce unpredictable results. The same is true of coaxial connectors. Connectors are often rated by their maximum usable frequency, which is defined by the frequency where a waveguide effect becomes possible.

Connectors in Widespread Use

There are so many RF connectors in use that there is not enough space available in this column to list them, let alone describe them. Fortunately, amateurs generally limit their use to those that are more common because they are installed on new and surplus equipment or are easily available at flea markets and hamfests. Here is a list of some of the many microwave connectors in use that will not be described in this issue: 7/16 DIN, GR874, SMB, SMC, OSSM, SSMA, SSMB, SSMT, OSMT, MCX, OS-50P, BMA/OSP, OSMP, OSSP, GPO, GPPO, SMP, SSMP, Nanohex, MMCX.

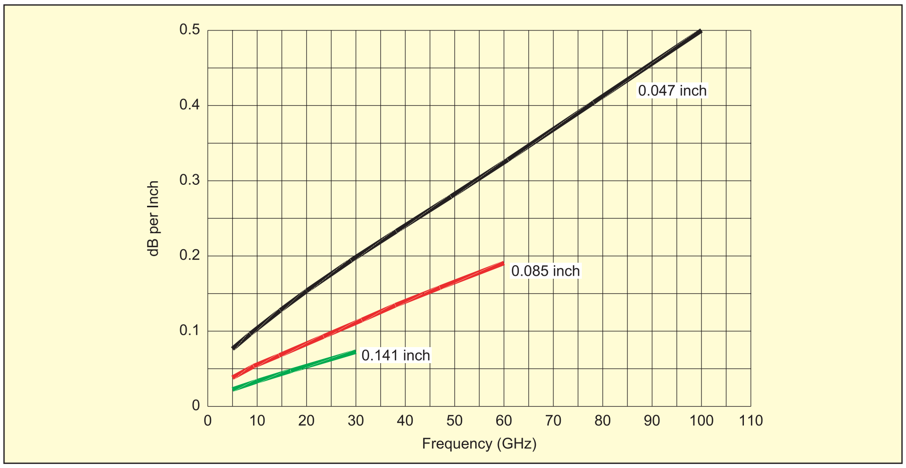

Figure 1—The small loss in small hardline is tolerable in most situations where only a few inches of coax are used to connect microwave components. Smaller diameter coax has greater loss but can operate at higher frequencies than larger coax.

The "UHF" connector does not enter a waveguide mode through the UHF bands, but it is not truly a 50 Ω connector and therefore does not perfectly match standard transmission cables. Various versions have measured from about 25 to 40 Ω impedance. Like other connectors, it is not physically long, so in use it presents the equivalent of placing an insignificant fraction of a wavelength of different impedance coax into your line—at least on bands up through 2 meters. At 430 MHz and above, the impedance "bump" that a UHF connector places into your transmission line starts to become significant. This is why you see very few radios with this connector for bands above 430 MHz. Generally speaking, microwavers who are on 902 MHz and above do not use UHF connectors.

The "N" Connector

A true 50 Ω connector, the N is a sturdy, gasketed connector. It was designed in the 1940s for military systems and follows the standard MIL-D-39012. Several sources

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Figure 2—Male N connectors. On the left is a slotted, and on the right a higher performance slotless connector.

give different attributions to the name "N," the two most popular are Navy and Mr Paul Neil, an RF engineer at Bell Labs. Air is the dielectric between the center pin and the outer conductor inside the connection. Although originally designed to work up to 5 GHz, refinements in the 1960s pushed performance to 12 GHz and later to 18 GHz. Agilent, Kings, Amphenol and others offer some N connectors with slotless outer conductors for improved performance to 18 GHz and beyond. Waveguide modes begin at about 20 GHz. A 75 Ω version is in use by the cable-TV industry. It has a smaller center pin. Figure 2 shows slotted and slotless males and Figure 3 shows a female N connector.

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Figure 3—A female N connector. This one is intended to be chassis mounted.

The BNC Connector

Designed for military use to at least 2 GHz, the BNC uses a slotted outer conductor and some plastic dielectric on each gender. The dielectric causes increasing losses at higher frequencies, but the impedance remains fairly constant. Above 4 GHz the slots may radiate, so the connector is usable but not mechanically stable up to about 10 GHz. 50 and 75 Ω versions are available. The genesis of the name again depends on the source. One calls it the Bayonet Navy Connector, while another the Bayonet Neil-Concelman. My sources indicate that Karl W. Concelman created the "C" connector—another high performance constant impedance connector. Figure 4 shows a male and female BNC.

A threaded version, the TNC helps resolve leakage and mechanical problems, permitting stable operation up to 12 GHz. There are special extended frequency versions of the TNC that adhere to the IEC 169-17 specification for operation to 11 GHz or 16 GHz, and the IEC 169-26 specification that operate mode-free to 18 GHz (but with significant losses).

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Figure 4—A male BNC on the left and a female BNC on the right.

The SMA Connector

Bendix Scintilla Corporation designed the SMA (Subminiature A) connector. Omni-Spectra Corporation called this the OSM connector (see Figure 5). The SMA connector is perhaps the most widely used microwave connector, and is certainly in widespread use by radio amateurs. It takes the cable dielectric directly to the interface without air gaps. A few hundred interconnect cycles are possible if performed carefully. Care should be taken to join connectors straight-on. Prior to making a connection it is wise to inspect the female end to assure that the center socket is in good condition (fingers not bent or missing).

A standard SMA connector is designed for interconnects to 12.4 GHz. Fortunately, a good SMA is useable to 18 GHz in most cables, and if well constructed with greater loss and SWR to 24 GHz. Figure 6 shows the SWR for a very high quality SMA connector. Bumps at 12.4, 18 and above 24 GHz indicate geometric constraints within the connector that lead to limitations at these three frequencies depending on the quality of the connector. Problems in anchoring the dielectric support limit the number of interconnect cycles and general performance.

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Figure 5—A pair of SMA connectors, with male on the left and female on the right. Like many connectors, these are available in nickel, stainless steel or gold finish.

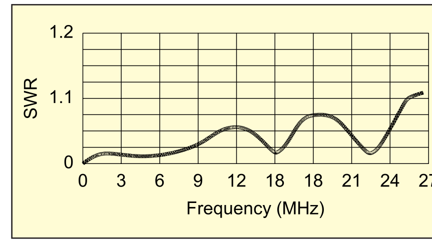

Figure 6—The SWR of a high quality SMA connector.

Precision Connectors

Two precision SMA compatible connectors were developed. One is the 3.5 mm (also called the Wiltron WSMA) and the other is the Wiltron K (or 2.92 mm or SMK). All connectors in this family and the SMA mate to one another.

Although compatible, there is the possibility of damage to the (unsupported) female fingers of the 3.5/2.9 if an SMA male is inserted other than perfectly straight-on, or if the SMA is improperly prepared with a pin that is too long.

The 3.5-mm connector was primarily developed at Hewlett Packard (now Agilent), with early manufacturing at Amphenol. It was designed to be rugged and compatible with popular SMA dimensions, allowing thousands of repeatable connections. It is mode-free to 34 GHz. One obvious difference between the 3.5 and the SMA is that the 3.5 uses an air dielectric throughout the female connector (see Figure 7).

The K connector, trademarked by the Wiltron Corporation (now Anritsu), was developed in 1983. Also known as the 2.9 mm, the K offers mode-free performance to 40 GHz, usable to 46 GHz. Some manufacturers call this the "2.9" and others the "SMK." The K connector

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Figure 7—The 3.5 mm connector, female on left and male on right. A black plastic with air holes is used to support the male pin, while the female fingers are suspended in air.