About this Article

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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.

JOHNSON COMPONENTS, INC

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.

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

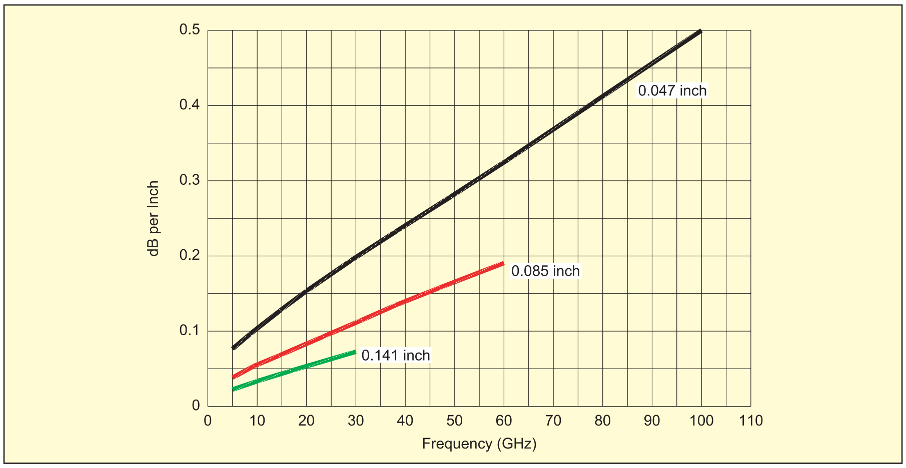

Figure 1—The small loss in small hardline is tolerable in most situations where only a few inches of coax are used to connect microwave components. Smaller diameter coax has greater loss but can operate at higher frequencies than larger coax.

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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.

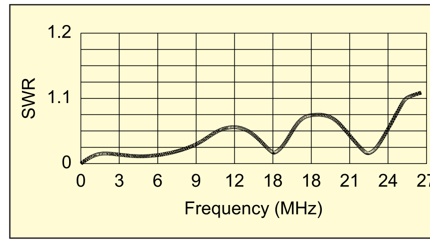

Figure 6—The SWR of a high quality SMA connector.

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.

has been successfully tested at over 10,000 (careful) interconnect cycles with negligible change in performance.

Beyond SMA Compatibility

The 2.4 and 1.85 mm geometries were designed to go beyond the SMA interface constraints, and as a result are *not* SMA compatible. These designs were meant to achieve the highest possible frequency along with repeatable measurements after hundreds or even thousands of interconnects. The male hex head is the same outer size as an SMA, 0.312 inch, tightened with a 5/16 inch wrench. The threads, however, are metric, at M7 × 0.76-6G.

RF COAX, INC

Figure 8—Here are a male 2.9 mm SMA compatible connector on left, and male 2.4 mm (*not* SMA compatible) connector on the right.

It can be difficult to distinguish between a 2.9 mm SMA compatible and a 2.4 mm (non-compatible) unless they are next to each other (see Figure 8). Because they are not mechanically compatible, if you have a male and a female SMA of professional manufacture (carry one of each with you to flea markets), you can put them next to the connector under question and decide whether it is an SMA compatible or a 2.4/1.85.

1.85 mm

The 1.85 mm connector was developed in the mid-1980s by HP for mode-free performance to 65 GHz (see Figure 9). Hewlett-Packard offered their design as public domain in 1988 to encourage standardization of connector types; a few devices are available from various manufacturers for research work. The inside of the outer conductor is 1.85 mm in diameter.

SPECTRUM ELEKTROTECHNIK GMBH

Figure 9—A close-up photo of the 1.85 mm male connector. Anritsu calls this the "V" connector.

1.0 mm

Perhaps the ultimate in coaxial connectors, HP (now Agilent) developed the 1.0 mm connector that supports transmission and repeatable interconnections from dc to 110 GHz. Laboratory instrumentation technicians and engineers are beginning to use the 1.0 mm for millimeter-wave analysis. This connector (shown in Figure 10) is also often used on semiconductor probe stations for the evaluation of millimeter-wave RF MMICs. The use of coaxial connections greatly simplifies what would otherwise require several sets of waveguide-based measurements to a single step. Anritsu has also developed similar connector.

AGILENT, INC

Figure 10—A close-up photo of the Agilent (HP) 1.0 mm male connector. The dielectric diameter is only 1 millimeter.

For more information, see **www.wa1mba.org/rfconn.htm**.

NEW BOOKS

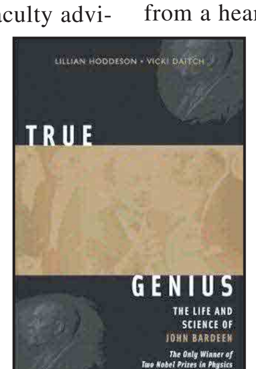
TRUE GENIUS: THE LIFE AND SCIENCE OF JOHN BARDEEN

By Lillian Hoddeson and Vicki Daitch

Published by Joseph Henry Press. 500 Fifth St NW, Washington, DC 20001; **www.jhpress.com**. *First edition, hardcover, 6¼ × 9¼ inches with black and white photographs. ISBN 0-309-08408-3, 482 pp.*

Reviewed by Gil McElroy, VE3PKD

◊ A "Stray" in the January 1965 issue of *QST* reported that ham radio was being used to keep a number of PhD students in Argentina in touch with their faculty advisor in the physics department at the University of Illinois. It was just another instance of a close brush John Bardeen would have with Amateur Radio throughout his life, for the faculty advisor in question, J. C. Wheatley, was part of a group loosely organized around Bardeen as he worked toward developing a theory of superconductivity. His eventual success would lead to his second Nobel Prize for Physics and make John Bardeen the only person to have ever won twice in the same discipline. It is, however, his first Nobel Prize, shared with Walter Brattain and William Shockley, that is of particular interest to hams. Awarded in 1956, it was for the invention that forever changed the face of electronics: the transistor.



True Genius: The Life and Science of John Bardeen biographically documents the life and work of this fascinating and modest man (for years, his long-time golf partners had no idea what he did for a living). Lillian Hoddeson, who coauthored this book with Vicki Daitch, has been this way before as coauthor of *Crystal Fire: The Birth of the Information Age*, which detailed the story behind the transistor and briefly laid out the lives of its inventors. Here, though, her attentions are focused entirely on both the biographical details of Bardeen's life—from his birth in 1908, son of the Dean of the University of Wisconsin School of Medicine, to his sudden death from a heart attack in early 1991—and his singular achievements at Bell Telephone Laboratories where the transistor was invented in 1947, and later at the University of Illinois where he developed the theory of superconductivity for which he received the Nobel Prize in 1972.

Bardeen's very first brush with Amateur Radio? That came in the 1920s when, like so many young men and women of his generation, he fabricated his own crystal radio so as to spend hours listening in to the sounds it pulled from the electromagnetic environment.

With this very readable biography, the authors lay out an excellent case for remembering John Bardeen as a *True Genius.* If only he had been a ham.

STRAYS

ANTARCTICA AWARD

◊ The Mediterraneo DX Club issues the *Antarctica Award* (**www.mdxc.org/antarctica/**) for contacting Amateur Radio stations operating from the various bases in Antarctica. The area encompassing Antarctica is defined as the area south of 60° S latitude, including islands and ice shelves, to which the provisions of the Antarctic Treaty apply.

The *Antarctica Award* is available to either licensed amateurs and SWLs. All contacts must have taken place since January 1, 1961. Contacts may be made on any amateur radio HF band from 10 to 160 meters, on CW, SSB and RTTY (neither single band nor single mode endorsements will be issued).

The Basic Award is issued for confirmed contacts with five different bases located in at least three of the seven sectors into which the Antarctic territory has been divided up for the purposes of this Award.

Full rules can be found at **www.mdxc.org/antarctica/rules.asp**.—*Antonio Cannataro, IZ8CCW, Secretary, Mediterraneo DX Club*