Application Guide to RF Coaxial Connectors and Cables

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There is a wide variety of coaxial connectors and cables available for use in the RF and Microwave spectrum. While often not much thought is given to these essential components, a misstep here can result in undesirable system degradation. Given that typical RF systems are comprised of any number of items, e.g. RF generators, amplifiers, attenuators, power meters, couplers, antennas, etc., it is not uncommon that a great deal of thought is given to these "high end" devices while mundane items such as connectors and cables are often treated as an "afterthought".

RF coaxial connectors

RF coaxial connectors provide vital RF links in communications, broadcast, EMC testing, commercial and military, as well as test and measurement fields. While there is a vast array of RF connectors available, they are all characterized by just a few key parameters. The most obvious characteristic of a connector is its physical size. Other considerations include power handling and frequency range capabilities. To insure maximum power transfer, the characteristic impedance of the connector should match the source and load. All of these characteristics along with connector durability and cost must be considered in light of the specific application. This application note provides guidance and insight in choosing connectors best suited to accommodate your specific application.

Let's begin by reviewing the most commonly found connector types in RF applications. These ubiquitous "traditional" connectors are available in both male and female configurations, standard and precision grades, high frequency and in some cases high power versions.

BNC

The BNC connector is perhaps one of the most widely used connectors in the test and measurement field. It was developed by Bell Labs in the early 1950's and is most commonly found on oscilloscopes, receivers, analyzers and similar lab test equipment. It is typically used for low power interconnections on RF test equipment such as audio and signal generators, oscilloscopes and amplifiers. The inexpensive BNC utilizes a bayonet retention collar to provide quick mate/de-mate action and also serves to prevent accidental disconnection. The BNC connector is typically designed to provide a characteristic impedance of 50 or 75 ohms, depending on the application. BNC connectors are generally rated for use in the DC-4GHz frequency range; however, they are rarely used above 500MHz. While they are capable of handling 80-100 Watts average power up to 1GHz, they typically do not have a maximum power rating but carry a maximum voltage rating of about 500V.

TNC

The TNC connector is merely a threaded-version of a BNC connector. It provides a more secure connection and thus reduces vibration issues found with the BNC. The TNC will operate at higher frequencies and there are high power TNC versions available.

SMA

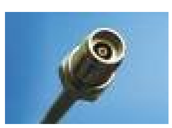
The Sub-miniature Type A connector was developed in the 1960's and has proven to be a very popular choice in low power, high frequency applications. It was originally intended for use on 141 type semi-rigid coaxial cable, where the center conductor served as the center pin. Its use was later expanded to flexible cable with soldered on center pins. It consists of an inner contact ring and a hexagonal clamping nut attached via a snap ring. Special wrenches are used to achieve the correct torque, usually about 5 lb-inches. There are different versions available such as high frequency, self-locking and precision. Commonly used as interconnects on RF boards, microwave filters, and attenuators, the SMA will operate up to 18 GHz. Precision versions extend the upper frequency limit to 26.5GHz. Although the SMA will mate to the 2.92mm, 3.5mm, APC-3.5 and "K" type connectors, it is not recommended as slight dimensional differences may result in connector damage.

3.5mm

The 3.5mm is a precision connector primarily developed at Hewlett Packard (now Agilent Technologies). It is similar in design to the SMA, but employs an air dielectric for higher performance. These connectors perform well to 34GHz, but typically are used to 26.5GHz. A 3.5mm connector can handle power levels comparable to its SMA counterpart. Since the 3.5mm is a precision connector, it is more expensive than similar designs and is thus often found in calibration kits and metrology applications as opposed to most common test and production applications

2.4mm

Developed in the mid 1980's by Hewlett Packard (now Agilent Technologies), this 50GHz connector employs a 4.7mm outer conductor arranged around a 2.4mm center conductor. The 2.4mm is available in three grades; general purpose, instrument and metrology. Since these connectors are not directly compatible with the SMA family, precision adapters are required to mate a 2.4mm connector to an SMA.



2.92mm/K type

This connector was designed and developed by Wiltron (now Anritsu Corporation). Performance is comparable to the 2.4mm, although the maximum frequency is limited to 40GHz. The "K type" designator is derived from its ability to cover all of the K band frequencies.

N Type

This is one of the most common RF connectors in use around the world today. This high performance connector was designed by Bell Labs in the 1940's with a threaded coupling interface and internal gasket to keep out the elements. The N connector is rugged, relatively inexpensive and the standard version is capable of mode-free operation to 11GHz. Precision versions push the upper frequency limit to 18GHz. Commonly found on instruments such as amplifiers, directional couplers, power meters, and coaxial attenuators, this threaded, durable connector provides a very secure connection. There are both 50 and 75 ohm versions available; the latter commonly used in the CATV industry.

C Type

The C connector was designed by Amphenol to handle high power applications as well as provide quick mate/de-mate action. It uses a dual-stud bayonet retention collar similar in design to the BNC. The popularity of the C connector has diminished over the years but it is still available from most suppliers. The 7-16 DIN has been used as a replacement in many cases due to its similar frequency and power capabilities. There are 75 ohm versions available as well as an "SC" version which incorporates a threaded collar for a more secure connection.

7-16 DIN

This is a relatively new connector in the U.S.A., compared to the previous connector types mentioned. The 7-16 DIN was developed by the Deutsches Institut fur Normung, aka the German National Standards Organization; hence the "DIN" designation. The numerical part of its name refers to the size of the inner and outer conductors; "7" for the inner conductor and "16" the outer conductor diameters in millimeters. The 7-16 uses an M29 x 1.5 threaded coupling nut. The 7-16 DIN connector was designed with low inter-modulation in mind for communications applications. Other common applications include antennas, base station connections, RF cables, satcom and lightning protection systems. Power and frequency are limited to approximately 1500 Watts average at 7.5GHz with the standard version. There are higher power versions available with FLH dielectrics.

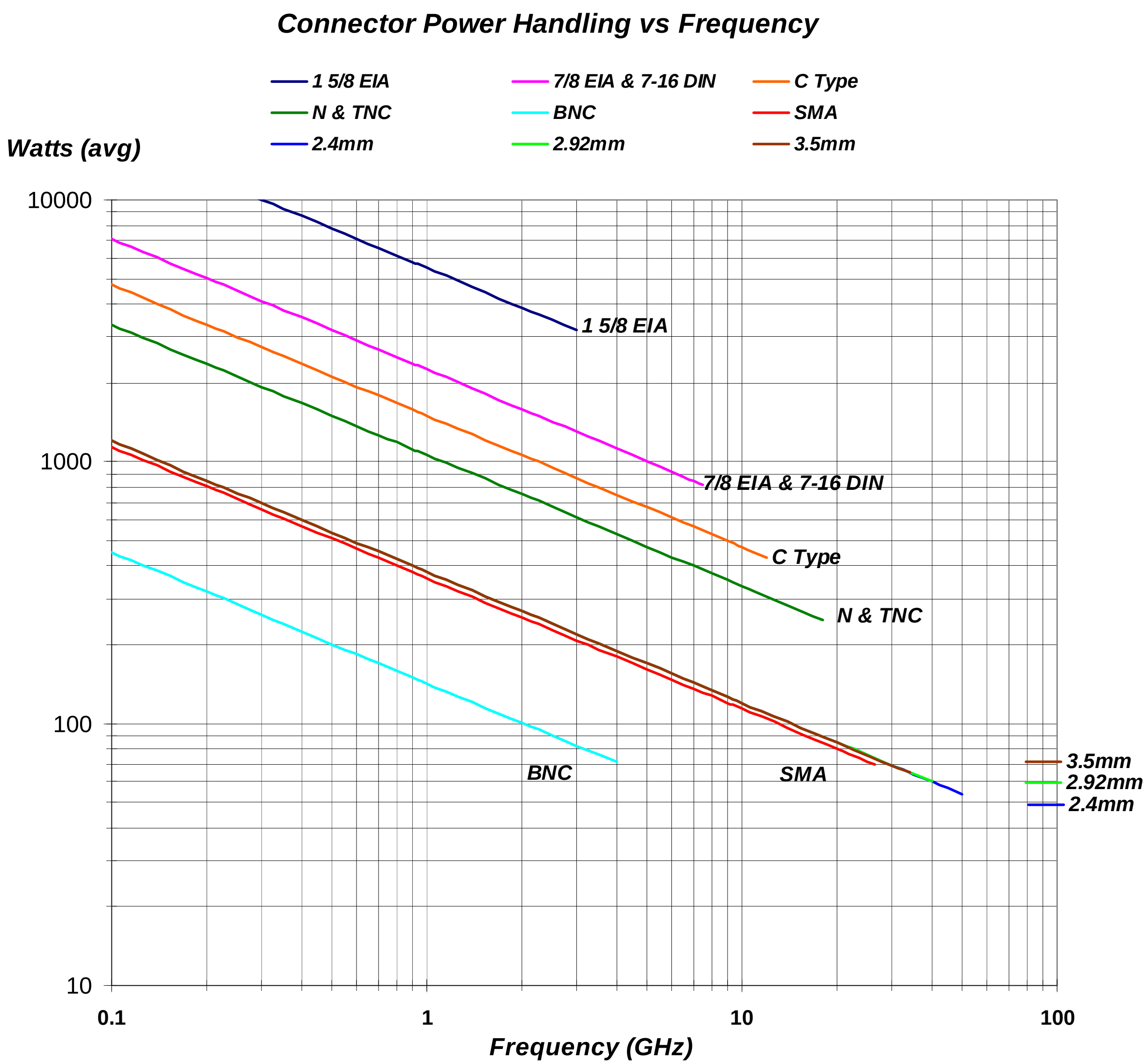
EIA Series

The EIA series of coaxial connectors are available in EIA 7/8", EIA 1 5/8", EIA 3 1/8", EIA 4 1/2" and EIA 6 1/8"versions, all of which are suitable for RF applications. They have been designed to support cables with foam or air-dielectric and consist of a main body, mounting flange with various bolt circles, and typically have interchangeable center conductor "bullets". EIA connectors can be found in high power applications on directional couplers, coaxial cables, power amplifier outputs, and interconnects on communication towers and antennas. The most common sizes found in general test and measurement applications are the 1 5/8 and 7/8 EIA. There are a variety of adapters available to adapt the EIA series to some of the larger RF connectors such as the 7-16 and N type.

Putting it all together

Now that we have reviewed the most popular RF coaxial connector types, let's consider the thought process that one must apply to make intelligent connector choices.

First of all, the specific application will determine the frequency range and power handling requirements of the connector. The summary chart below provides guidance in the selection of an appropriate connector type to accommodate system power while operating at the highest frequency required.



The above power chart is a theoretical representation of a matched impedance connection (50 ohms) and VSWR < 1.35:1. Under these circumstances, approximately 97.7% of incident power will be delivered to the load, thus resulting in minimal reflected power. This will reduce the power handling capability of the cable assembly by as much as 50%. Power handling can vary greatly depending on VSWR, environment, connector manufacturer, etc. Actual maximum power levels at lower frequencies would be subject to internal voltage breakdown in the connector. This value is determined by the equation $P=k/\sqrt{F}$, where k is a constant, P is power in watts and F is frequency in MHz. This assumes a maximum accepted power at a given frequency. Example; the N type connector will handle 1000W @ 1GHz.

The table below further defines maximum frequency, power, and coupling torque parameters for the RF connectors covered in this application note.

Maximum frequency, power and coupling torque

Connector Type	**Maximum Frequency (GHz)**	**Maximum CW Power @ Max, Frequency (Watts)**	**Coupling Torque**	
			(N/cm)	**(in/lb)**
2.4mm	50	55	90	8
2.92mm/K	40	60	90	8
3.5mm	34	65	90	8
SMA precision	26.5	70	57	5
BNC	4	70	N/A	N/A
TNC	18	250	N/A	N/A
Type N	11	150	135	12
Type N precision	18	250	135	12
Type C	12	440	N/A	N/A
7-16 DIN	7.5	820	226	20
7/8 EIA	7.5	820	N/A	N/A
1 5/8 EIA	3	3200	N/A	N/A

N/A = not applicable

Having selected RF connectors using the guidelines provided above, the next logical step is the selection of appropriate RF cables. There are a myriad of coaxial cable types to choose from. As with the RF coaxial connectors, coaxial cables are classified by physical characteristics as well as electrical parameters. Both flexible and semi-flexible or rigid armored cables are available. Electrical parameters such as characteristic impedance (50 and 75 ohms are popular), insertion loss, maximum voltage and maximum power capabilities must be considered. The application will determine the proper cable choice. Some applications require low loss cable to maximize power transmission. Other applications require flexible cables, perhaps without restrictive armor, for user friendliness. Coaxial cables contribute to the overall performance of the RF assembly and can become a limiting factor for maximum frequency and power handling capability. Keep in mind that any cable assembly will be limited both in frequency and power handling capability by the lowest power rated and frequency capable RF connector.

To facilitate cable selection, AR/ RF Microwave Instrumentation has developed a line of high quality, built-to-order coaxial cables. These low loss cables are characterized by very low VSWR and are tailored to the end users specific needs. There are four basic series; CCxxxx, CC1, CC2 and CC3. Custom lengths are available in 0.5 meter increments with a variety of matched connectors. An overview of each cable type is provided below. Please see latest specification sheet for full details.

CCxxxx – This cable series provides a wide selection of cables compatible with our A, S, W, and T series broadband amplifiers. Cables are available to cover DC to 18GHz with power capabilities ranging from 70 to 15K Watts.

CC1 Series – These are armored, low loss cables for applications to 18 GHz. They are available with SMA, TNC, N or 7-16 connectors.

CC2 Series – These are armored, low loss cables for applications to 40 GHz. They are available with 2.4mm, 2.92mm, 3.5mm, SMA, TNC or N connectors.

CC3 Series – These are low loss cables compatible with higher power applications to 12.4 GHz. They are available with N or 7-16 connectors.

Summary

RF coaxial connectors and cables are often the "forgotten" components of RF systems. Since so much time is devoted to the selection of key instrumentation in these systems, often system engineers tend to rush through the accessories specification phase. This application note is intended to highlight these items in hopes that their importance has been demonstrated. While they may not command the interest and attention of the more costly system components, improper selection of RF coaxial connectors and/or cables can render a sophisticated system ineffective. We recommend you contact one of our application engineers at 1-800-933-8181 to discuss your specific system application to preclude such an occurrence.