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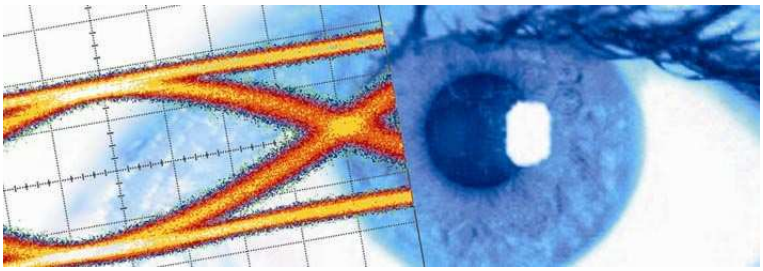
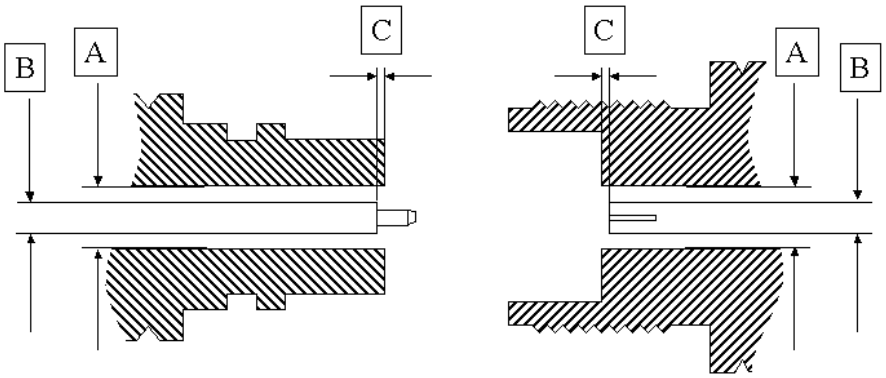


Tutorial Note #2
Microwave Connectors



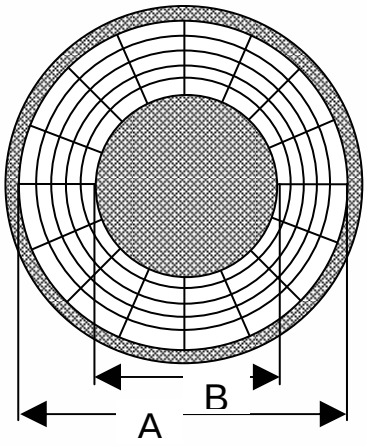
Introduction

In many RF and microwave applications, it is important to have the right choice of connectors, adapters, as well as coaxial cables. Proper selection, application and maintenance can result in prolonged usage cycle and optimum system performance. The purpose of this tutorial note is to provide some background technical information on coaxial cables and connectors in general, to enable customers to make an informed decision in the selection process.

For connecting high frequency devices, SHF offers a wide range of connectors, adapters and cable assemblies (semi rigid & flexible). These products are manufactured by KMCO & Totoku of Japan. Through their use in SHF's test & measurement series these products have been extensively tested and proved to be the best for high frequency, and broad band applications.

Cut Off Frequency

At low frequencies, electrical signals propagate in coaxial lines and connectors in the TEM (Transversal Electro Magnetic) mode. Above the cut off frequency f_c (or first mode frequency) higher order modes such as the H_{11} mode can also propagate. To ensure that only the TEM mode propagates, thus keeping the signal clean, the frequency needs to stay below f_c.



$$f_c \approx \frac{2 \cdot c_0}{\pi \cdot \sqrt{\varepsilon_r} \cdot (A+B)}$$

There is a wide variety of microwave connectors available for general RF and microwave applications. For our instruments and components the following connectors are important: **SMA, 3.5 mm, 2.92 mm, K©, 1.85 mm, V©, 1 mm and W1©**.

Calculating f_c by using the coaxial diameters of above mentioned connector standards shows f_c is higher than the frequency specification, in other words: It is possible to use connectors at higher frequencies if performance degradation is accepted.

Nevertheless, the most significant bandwidth restricting factor is the frequency of the first mode. At this frequency the transfer function exhibits a null. If the application is for broadband communication signals (i.e. PRBS or similar type of data) the impact of this first frequency null might be negligible. However, the first mode is potentially damaging the signal if the system is supposed to transmit narrowband RF signals at or around the moding regime.

The table on the following page shows these key specifications of the most commonly used high frequency coaxial connector interfaces.

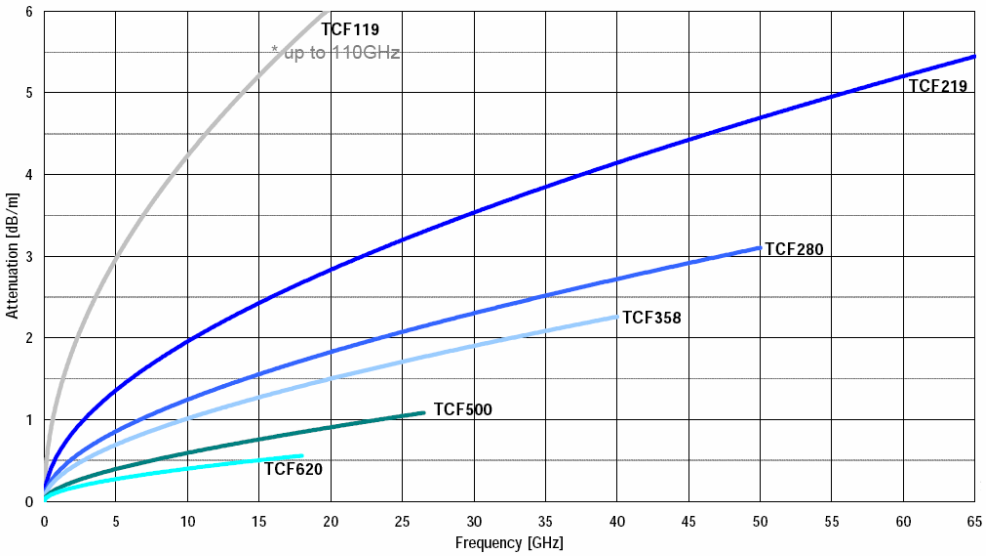
	Upper Frequency Specification (GHz)	Cut Off Frequency *fc* (GHz)	Torque Wrench (N cm / in lb)	Standard
SMA	12.4 – 27[1]		56 / 5	MIL-std-348A MIL-C-39012 IEC Std 169-15
3.5 mm	26.5	34	90 / 8	IEEE-std-287 IEC Std 169-23 IEC Std 457-5
2.92 mm **K©**	40	45	90 / 8	*IEEE-std-287*
2.4 mm	50	55	90 / 8	*IEEE-std-287*
1.85 mm **V©**	65	71	90 / 8	*IEEE-std-287*
1 mm **W1©**	110	133	45 / 4[2]	*IEEE-std-287*

Attenuation

From the above relation between cut off frequency and size it seems that the smaller a connector the better. However, there are two important reasons that prevent smaller connector and cable geometries:

Cost: very small connectors are difficult to manufacture and therefore expensive

Loss: the smaller the geometries are the more loss will be caused by the skin effect

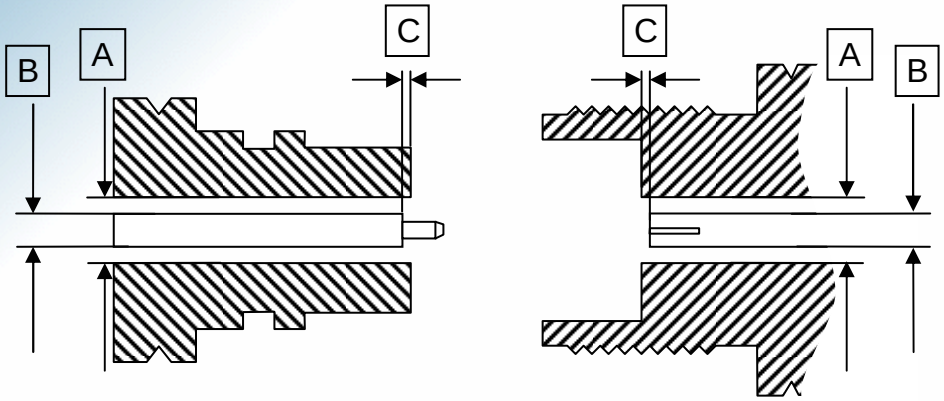


Attenuation of the TCF flexible cable assemblies series
The number behind the TCF is the outer diameter ($\cdot 10^{-2}$mm)

[1] *Some SMA connectors are only useful to 12.4 GHz, most SMA connectors go up to 18 GHz. IEC Std 169-15 specifies up to 24 GHz and some manufacturers specify up to 27 GHz.*

[2] *IEEE 287 specification may still be 34 N-cm, however Agilent found out, that 45 N-cm gives adequate repeatability.*

Connector Compatibility



This is the schematic of a microwave connector (male and female connector is shown). The important dimensions are:

A: Inner diameter of outer conductor (together with the diameter of the center conductor and the dielectric constant of the insulator determines the maximum frequency up to which the connector will have mode free operation. From this diameter the name of many connectors derives (e.g. 2.92mm or 2.4mm).

B: Diameter of the center conductor. At a given outer conductor diameter this determines the Impedance of the connector ($Z = 120 \cdot \pi\ \Omega \cdot \ln(A/B) / (2 \cdot \pi \cdot \sqrt{\varepsilon r})$).

C: Center pin recess: It is very important to make sure, that this recess is within the specified tolerances. If you connect a connector with excessive center pin protrusion not only the other connector might be damaged but also the mechanics inside the component or system!

Due to these mechanical restrictions, the following connectors are compatible:

	SMA[3]	3.5 mm	2.92 mm	K©	2.4 mm	1.85 mm	V©	1 mm	W1©
SMA[3]	✓	✓	✓	✓	---	---	---	---	---
3.5 mm	✓	✓	✓	✓	---	---	---	---	---
2.92 mm	✓	✓	✓	✓	---	---	---	---	---
K©	✓	✓	✓	✓	---	---	---	---	---
2.4 mm	---	---	---	---	✓	✓	✓	---	---
1.85 mm	---	---	---	---	✓	✓	✓	---	---
V©	---	---	---	---	✓	✓	✓	---	---
1 mm	---	---	---	---	---	---	---	✓	✓
W1©	---	---	---	---	---	---	---	✓	✓

[3] *Use caution when mating SMA connectors to precision connectors; especially female precision connectors can be damaged easily.*

Bending / Cleaning Of Coaxial Cables

Important to know about coaxial cables is that bending the cable might move the center conductor. In other words: after bending the cable a center pin protrusion on one end and excessive center pin recess on the other end could be observed.

A professional tool for bending semi rigid cables:
KMCO Hand Bender 2200

Center pin recess degrades the return loss. Center pin protrusion is more harmful as it might damage the component that is connected to this end.

Before bending:

After bending:

The position of the center pin should be measured by using a gauge. If no gauge is available the center pin recess should at least be verified by microscope (20 times magnified).

It should always be kept in mind: An excessive recess will only degrade the return loss, whereas center pin protrusion might cause damage!

It is also highly recommended that regularly visually inspection of the cleanliness of the connector is performed.

Connector Cleaning Procedures:

- Before using a Microwave connector it should be visually inspected. Recommended magnification: 20x.
- If it is necessary to clean it, all devices and persons have to be grounded!
- Avoid using connectors that are mechanically damaged (scratched mating surface, eccentric or bended center conductor)!
- For cleaning, a swap with clean isopropyl alcohol that is free of water should be used. Applying too much force on the center conductor or flowing alcohol over the insulator bead causes damage.
- Any alcohol and particles must be blown off with clean compressed air. The spray can has to be in an upright position otherwise the propellant might leave a residue on the connector.

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