Microwave Measurements:
Microwave connectors

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Outline

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- Why do use microwave connectors?
- Why are there so many different connectors?
- Characteristics of some connectors' families
- Connectors care
- Connector mounting

Why do we use microwave connectors?

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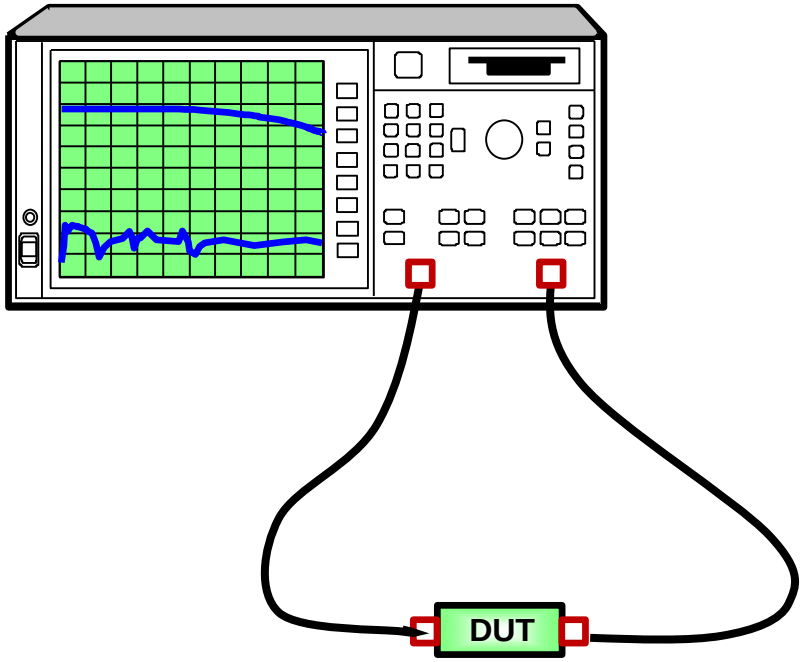
Connectors are used to **connect devices and circuits** made separately through transmission lines.



They are an **important** (sometimes decisive) in **repeatability and accuracy** of the measurement.

Why are there so many different connectors?

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BNC, SMB, OSMT, OSX, MCX, PCX, MMCX, SMC, SMA, TNC, N, APC-7, 7mm, OSP, 3.5mm, OSSP, SSMA, 2.92mm, K, GPO, OSMP, SMP, OS-50P, 2.4mm, 1.85mm, V, 1mm, …

From: www.microwave101.com

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Each manufacturer may use **proprietary interconnect standards** (i.e., specifically designed by the manufacturer).

However, to ensure compatibility with circuits made by others, **universally accepted connector standards** are generally used. The differences are in frequency range, environment of usage, history (when they have been designed and for which reasons) etc..

Families

Connector type	Frequency Limit	Dielectric	Comments and history
BNC	4 GHz	PTFE	"Bayonet type-N connector", or "Bayonet Neill-Concelman" according to Johnson Components. Developed in the early 1950s at Bell Labs. Could also stand for "baby N connector".
SMB	4 GHz	PTFE	"Sub-miniature type B", a snap-on subminiature connector, available in 50 and 75 ohms.
OSMT	6 GHz	PTFE	A surface mount connector
OSX, MCX, PCX	6 GHz	PTFE	MCX was the original name of the Snap-On"micro-coax" connector species. Available in 50 and 75 ohms.
MMCX		PTFE	Micro-miniature coax connector, popular in the wire industry because its small size and cheap price.
SMC	10 GHz	PTFE	Sub-miniature type C, a threaded subminiature connector, not widely used.
SMA	12.4 GHz	PTFE	Sub-miniature type A developed in the 1960s, perhaps the most widely-used microwave connector system in the universe.
TNC	15 GHz	PTFE	"Threaded Neill-Concelman" connector, according to Johnson Components, or simply "threaded N connector". Not used much today. Carl Concelman was an engineer at Amphenol.
N	11 GHz normal 18 GHz precision	PTFE	Named for Paul Neill of Bell Labs in the 1940s, available in 50 and 75 ohms. Cheap and rugged, it is still widely in use. Originally was usable up to one GHz, but over the years this species has been extended to 18 GHz, including work by Julius Botka at Hewlett Packard.
APC-7, 7 mm	18 GHz	PTFE	APC-7 stands for "Amphenol precision connector", 7mm. Developed in the swinging 60s, ironically a truly sexless connector, which provides the lowest VSWR of any connector up to 18 GHz.

From: www.microwave101.com (slide 6 and 7)

Families

Connector type	Frequency Limit	Dielectric	Comments and history
OSP	22 GHz	PTFE	OSP stands for "Omni-Spectra push-on", a blind-mate connector with zero detent. Often used in equipment racks.
3.5 mm	26.5 GHz	Air	A precision (expensive) connector, it mates to cheaper SMA connectors.
OSSP	28 GHz	PTFE	OSP stands for "Omni-Spectra subminiature push-on", a smaller version of OSP connector.
SSMA	38 GHz	PTFE	Smaller than an SMA.
2.92 mm	40 GHz	Air	Precision connector, developed by Mario Maury in 1974. 2.92 mm will thread to cheaper SMA and 3.5 mm connectors. Often called "2.9 mm".
K	40 GHz	Air	The original mass-marketed 2.92 mm connector, made by Wiltron (now Anritsu). Named the "K" connector, meaning it covers all of the K frequency bands.
GPO, OSMP, SMP	40 GHz	PTFE	"Gilbert push-on", "Omni-spectra microminiature push-on"
OS-50P	40 GHz		Smaller version of OSP blind-mate connector.
2.4 mm	50 GHz	Air	2.4 mm, and 1.85 mm will mate with each other without damage. Developed by Julius Botka and Paul Watson in 1986, along with the 1.85 mm connector.
1.85 mm	60 GHz	Air	Mechanically compatible with 2.4 mm connectors.
V	60 GHz	Air	Anritsu's term for 1.85 mm connectors because they span the V frequency band.
1 mm	110 GHz	Air	The Rolls Royce of connectors. This connector species works up to 110 GHz. It costs a fortune! Developed at Hewlett Packard (now Agilent) by Paul Watson in 1989.

BNC

BNC is an acronym from "**B**ayonet **N**eil-**C**oncelman" or "**B**ayonet **N**avy **C**onnector" or "**B**aby **N**eil **C**onnector“ (it depends on the source). It has a bayonet to plug male to female connectors. At first, BNC was designed for military use then it has been used in video and **RF applications to 2 GHz**.

The outer conductor is slotted and, **above 4 GHz, the slots can radiate.**

Both 50 ohm and 75 ohm versions are available.

A **Threaded** version (TNC) limits the radiation losses with an extended usability **up to 12 GHz** (some particular TNT can be used up to 16GHz/18GHz). They are used in mobile phone RF/antenna connections. The mechanical stability is higher.

50 ohm male BNC connector,
Huber+Suhner

50 ohm male and female TNC connectors,
Huber+Suhner

Type N

The **Type N** connector was designed in the 1940s for military use **below 5 GHz** (now it is used up to higher frequencies).
N is related to **N**avy or over the designer Paul **Neill** of Bell Labs. It is a **waterproof** connector because it uses an internal gasket. It is an **hand-tighten** connector.

In the 1960s, improvements pushed performance up to **18 GHz** (it shouldn't be used at higher frequencies for unpredictable results). There are two versions: 50 and 75 Ohm.

These are **cheap and rugged;** you will find them all over our laboratory. It is **meatable** with the BNC but don't do it: it is not mechanically stable

SMA

The **SMA (sub-miniature A)** connector is very well known and used in the RF industry. The outer coax is a 4.2 millimeter diameter, filled with PTFE dielectric.

They can be adopted **up to 18-26 GHz**, depending on the tolerances held during manufacturing.

They need a **5/16” wrench to be tightened** (and loosed), with a **specific torque** (not to damage the connector and have a certain repeatability).

PAY ATTENTION: SMA connectors will mate with 3.5mm and 2.92mm connectors. **Do not mix** them. 2.92mm are more expensive.

SSMA

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They are used to work at **higher frequency (from 26 GHz up to 40 GHz)** than SMA because of the **smaller geometry (about 70% size)**. The are sub-miniature of the SMA connectors.

PAY ATTENTION: they generally **can't handle the normal torque of the SMA** (when loosening and tightening).

Different platings are available: generally, **gold and stainless steel** are used. Cheap gold plating can flake off of connectors.

Iron soldering an SMA on microstrip lines is generally not possible with stainless steel connectors.

APC-7

The **APC-7 (Amphenol Precision Connector - 7 mm)** offers the **lowest reflection coefficient and the most repeatable measurement of all connectors up to 18 GHz** . Its characteristics make this connector usable for **demanding applications**.

The APC-7 is **sexless** (differently from the other connectors we saw): no adapters are needed. These connectors are designed to **perform repeatably for thousands of interconnect cycles** as long as the mating surfaces are kept clean. The APC-7 don't suffer from the frictions of the other gender connectors.

3.5mm & 2.92mm

There connectors use **air dielectric (instead of PTFE or other exotic materials)**. The **3.5 mm connector**
(outer conductor's diameter) can be seen as the evolution of the SMA. It works **up to 26 GHz**.

The **2.92 mm connector** (sometimes called simply "2.9 millimeter" for the outer conductor's diameter) can be used **up to 40 GHz**.

2.92mm and 3.5mm use the same center pin.

3.5 mm male connector
From: Rosnol

2.92 mm male connector
From: Thor labs

2.4mm & 1.85mm

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The **2.4 and 1.85** connectors are **mechanically compatible with each other, but neither one will thread onto an SMA, 3.5 or 2.92 mm connector.** This is on purpose, so you won't mix these expensive connectors in with less precise connectors such as SMA and cause them irreparable harm.

The **2.4mm** can be used up to **50GHz** and the **1.85mm** up to **70GHz.**

The 1.85 connector is often called the "V connector". Both the 2.4 and 1.85 mm connector require a 5/16 inch wrench.
The price keeps climbing as you go up in frequency. A **V-connector can cost $500!**

2.4 mm male connector
From: Radiall

1.85 mm (V) male connector
From: Halbert Bastian

1mm

The **1.0 mm** (originally it was an Hp design) can be used up to **110/120 GH**z. The outer conductor's diameter is 1mm!! This connector is also often used on semiconductor probe stations for the evaluation of millimeter-wave RF MMICs.

You won't see 1mm connectors all around the laboratories; they are **very very expensive**!!!

The use of coaxial connections **greatly simplifies** what would **otherwise** require several **sets of waveguide-based** measurements to a single step.

1 mm end launch
From: Frontlynk

Special: H-UFL, I-PEX MHF, AMC or UMCC

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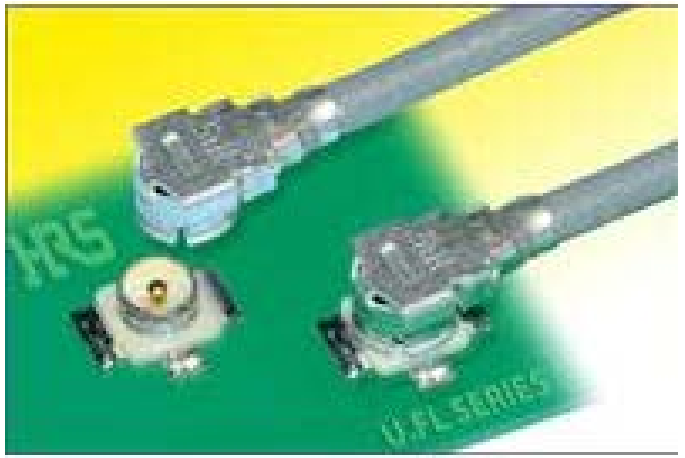
The **H-Uf.l (Hirose UF.L) or I-Pex MHF, AMC and UMCC** (different names in relation with the different product manufacturers) is a **miniature surface mounted** connector used up to 6GHz.

It is used for example in PCB test (**footprint is 3.0 × 3.1 mm²**). The life cycle (considering the connections and disconnection of the connectors) is around 30 cycles.

From: I-pex



From: Digi key

How to connect genders?

When you want to connect different genders within the same connector family **adapters** are necessary.

For example: the DUT is female and the coaxial cable connector is female.

Male-to-male adapter is called “**barrel**” adapter and it refers to an adapter with two male ends.

Female-to-female adapter has two female ends; it is often referred to as a "**bullet**" adapter.

Male to male
From: Southwest

Female to female
From: Southwest

Connector saver

There is one adapter that is used as a **"connector saver“** with **one male end and one female end**. It is used to really connect different genders. Moreover, it helps protecting the termination of expensive cables such as VNA coaxial cables. The repetitive loosening and tighting of the DUT connectors to the VNA cable’s connector reduce the life cycle of the connectors: the use of connector saver protects the more expensive cables. **Use them.**

Male to female
From: Centric RF

Which families are directly mateable?

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SMA, 3.5mm and 2.92mm

2.4mm and 1.85mm

1mm

How to connect different families?

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It is possible to **connect different families** that are not directly mateable (keeping in mind the operational frequency).

E.g. 2.4mm to 2.92mm, APC 7 to 3.5mm

APC 7 to 3.5mm
From: Centric RF

2.4mm to 2.92mm
From: Johnson

Connectors care

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Your connectors and adapters can cost a lot of money.

Show some respect!

From: Microwave 101

1. Don't use pliers on a "stuck" connector for any reason. There are wrenches for every size adapter, even SMA bullets. If you can't fit a wrench to your stuck connector, see below.
2. Learn how to clean connectors with alcohol and cotton swabs. Cleaning the threads is good practice, but stay away from cleaning the center conductor of an air dielectric connectors such as 3.5mm, 2.9mm and 2.4mm.
3. Learn how to gage connectors to determine if they are out of spec. One bad connector can damage many.
4. Don't use higher frequency connector than you need. Save the 2.9mm and 2.4mm parts for millimeter-wave measurements.
5. Never use any part of a calibration kit as an adapter. Ever. If you need a special adapter, buy it, borrow it or steal it, but not from the cal kit.
6. Use a torque wrench. For most connectors with 5/16 inch hex nuts, use 6-8 inch-pounds. It's OK to use less torque, but not more.
7. Remember, righty-tighty, lefty-losey! The total damage done by people turning stuff in the wrong direction is second only to damage caused by klutzes who "thumb" hybrids.
8. Remember, you are not tightening lug nuts. The hardware you hold in your hands could very well be worth more than your automobile. So be gentle with it. Pretend it is made of eggshells and filled with explosives!
9. When you are tightening or loosening a connector, try not to spin the mating surfaces against each other. You should only be turning the threaded sleeve. Turning the mating surfaces means you are wearing out the connector for no reason.

Connectors care

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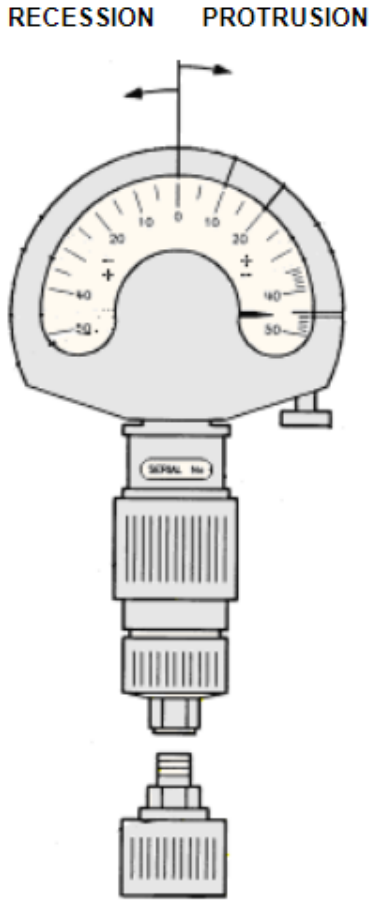
Do	Don’t
Clean the connectors with isopropyl alcool and compressed air	Don’t store all connectors together
Clean the threads	Don’t touch mating-plane surfaces
If you have a APC 7 cover the mating face	Don’t use abrasive paper
Use the dust caps during storage	Don’t put in liquids

Gauging

From: Anritsu

Before using a connector for the **first time** you should **gauge** it to verify it is in its specifications.

It is useful to do **every 100 connections** routinarly as to checking the device.



From: Keysight

How to tight and loose a connector?

Start tightening with your **fingers** without putting extra torque and **then** use a **torque wrench.**

Use the right one in relation with the connectors you are using. If you want to remove stuck connectors use soft-jaw pliers.

Never use common pliers or exceed in torque.

Remember: righty-tighty, lefty-losey!

From: Atlantic microwave

From: Thorlabs

Product specification: example

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1.85mm

Product Specifications

The Johnson 1.85mm Series Connector provides an excellent solution for demanding applications requiring high frequency transmission.

- Precision manufacturing allows superior electrical performance to 67GHz with VSWR performance to 1.35
- Connector mating interface per MIL-STD-348
- Mating interface control provides consistent electrical performance
- Available in end launch, 2 hole and 4 hole flange mount styles

Materials

Bodies	Stainless steel/passivated per QQ-8-626, gold-plated per MIL-G-45204 0.00005" minimum
Contacts	Female - beryllium copperper QQ-C-530, gold-plated per MIL-G-45204 0.00005" minimum
Insulater	Peek; Ultem 1000, PCTFF, KEL-F

Environmental (Meets of exceeds the applicable paragraph of MIL-C-39012)

Temperature Range	-65ºC to +165ºC
Thermal Shock	MIL-STD-202, Method 107, Condition B
Corrosion	MIL-STD-202, Method 101, Condition B
Shock	MIL-STD-202, Method 213, Condition I
Vibration	MIL-DTL-202, Method 204, Condition D
Moisture Resistance	MIL-DTL-202, Method 106

Electrical (Meets of exceeds the applicable paragraph of MIL-C-39012)

Impedance	50 Ohm	
Frequency Range	0 - 67 GHz	
VSWR	1.3 maximum	
Working Voltage	150 (VRMS maximum at sea level)	
Dielectric Withstanding Voltage	500 (VRMS maximum at sea level)	
Insertion Loss	0.05 x $\sqrt{f\ (GHz)}$ (dB maximum)	
Insulation Resistance	5000 (megohms minimum)	
Insulation Resistance	Center Contact: 4.0 (milliohms maximum)	Outer Contact: 2.5 (milliohms maximum)
RF Leakage	-90dB (dB minimum, tested at 2.5GHz)	

Mechanical

Engagement Design	MIL-STD-348, series 1.85mm
Engagement/Disengagement Force	2 inch-pounds maximum
Mating Torque	7 to 10 inch-pounds
Coupling Proof Torque	15 inch-pounds minimum
Coupling Nut Retention	60 pounds minimum
Contact Retention	6 pounds minimum axial force (captivated contacts)

*Note:
SV Microwave supplies adapters to mate 1.85mm connectors to SMA and 2.92mm connectors

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From: Johnson