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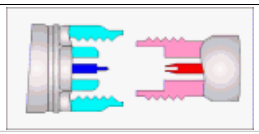
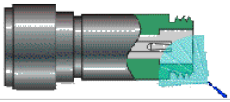
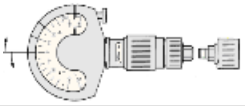
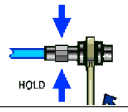
Millimeter Wave Connector Care

Agilent Technologies

Connectors, adapters, and calibration standards in the millimeter-wave frequency range (26 GHz to 70 GHz) are VERY expensive. Although all connectors eventually wear, with **knowledge, care,** and **proper technique**, you can easily maximize the accuracy, repeatability, and useful lifetime of coaxial connectors.

	**Connector Structure**
	**Avoid Mating Incompatible Connector Types**
	**Inspect and Clean Connectors**
	**Gauge Connectors**
	**Make Good Connections**

Please send suggestions or corrections to pna_help@am.exch.agilent.com

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APC-7 mm Connectors

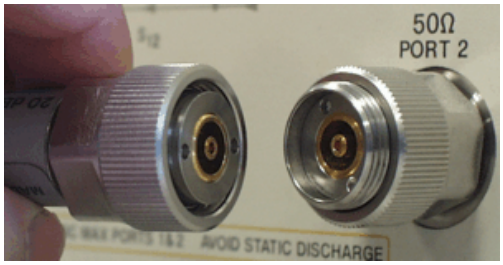
View All Topics

APC-7 mm connectors are not technically Millimeter Wave since their maximum frequency range is only 18 GHz. However, APC-7mm connectors are extremely durable, they have an extremely good VSWR specification, and they are very unique in that they are without gender. There are no male or female APC-7 mm connectors. They are ALL exactly alike. Because of this, it may not be obvious how to properly mate two APC-7 mm connectors.

How to properly mate two APC-7 mm connectors.

As in the example images below, it is easier to connect two APC-7 mm connectors if a bulkhead connector has the protruding threads and the device has recessed thread. Otherwise, it does not matter which connector has the protruding thread or recessed threads. Also, the terms Left and Right in the following are for illustration purposes only.

Recessed threads (Left)



Protruding threads (Right)

1. To prepare both connectors, spin the knurled nuts to cause the following:
   a. **Recessed** threads on one (**Left)** connector.
   b. **Protruding** threads on the other (**Right)** connector.
2. Insert left connector into right connector until seated.
3. Thread left connector nut onto the protruding threads of the right connector until snug.
   a. Do NOT turn the right nut.
   b. Do not turn the device body. Only the NUT.
   c. Finger-tight is usually enough to produce the necessary 12 in-lb of torque.
   d. **When complete, the right connector nut should be able to spin freely.**

Connector Structure

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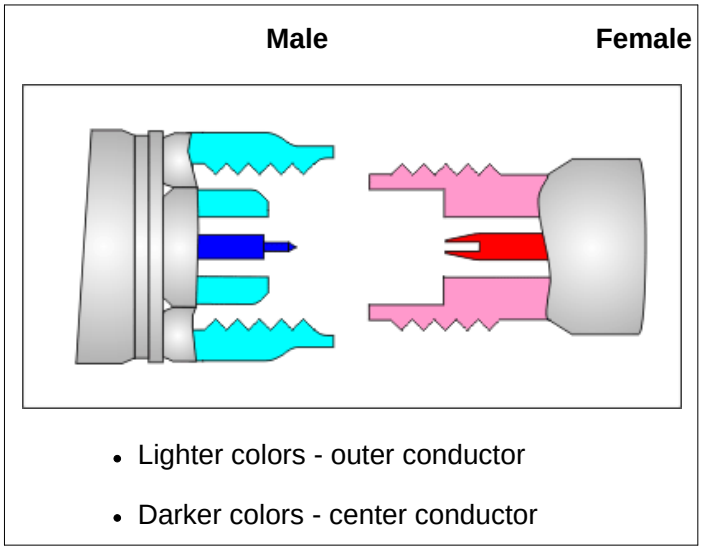
Cross-section of Connector

The following image is a cross section showing the major parts of a typical air-dielectric connector.

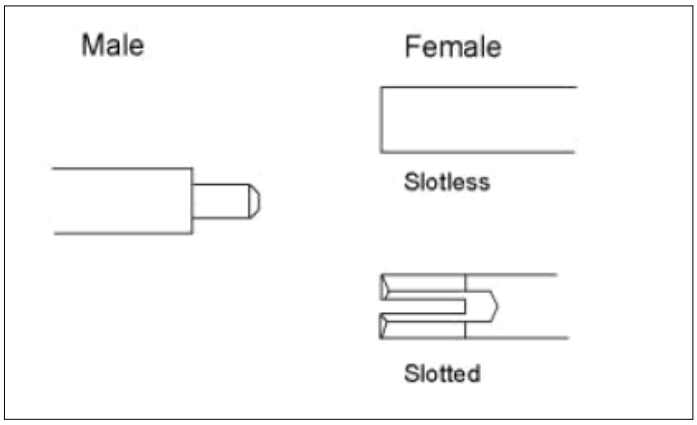


- Lighter colors - outer conductor
- Darker colors - center conductor

Notes

- The measurement reference plane is defined as the mating plane of the outer conductors.
- The diameter of the air dielectric determines the size for which the connector is named. View all connectors.
- **Critical:** While the connectors are engaged, rotate **ONLY** the outer nut of the male connector; **NEVER** rotate either connector. This will damage one or both center conductors. Learn more.

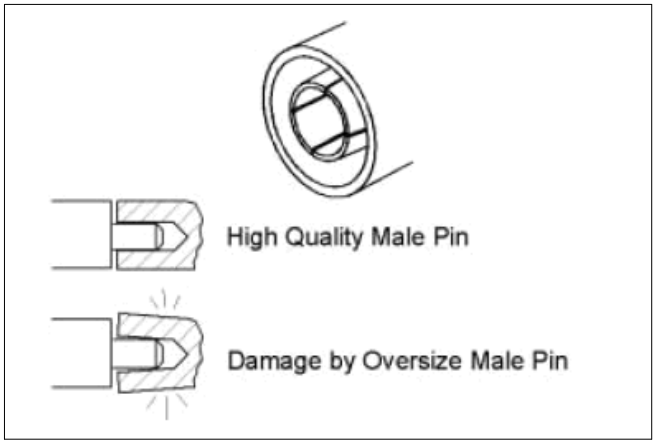
The Male and Female Center Connectors



The male center conductor is machined to form a shoulder. The diameter of the mating portion of the pin is reduced size and it may be tapered at the end for easy insertions. For high quality, precision male connectors, all of these dimensions are closely controlled.

There are two types of female center conductors: Slotted and Slotless.

The Slotted Female Connector

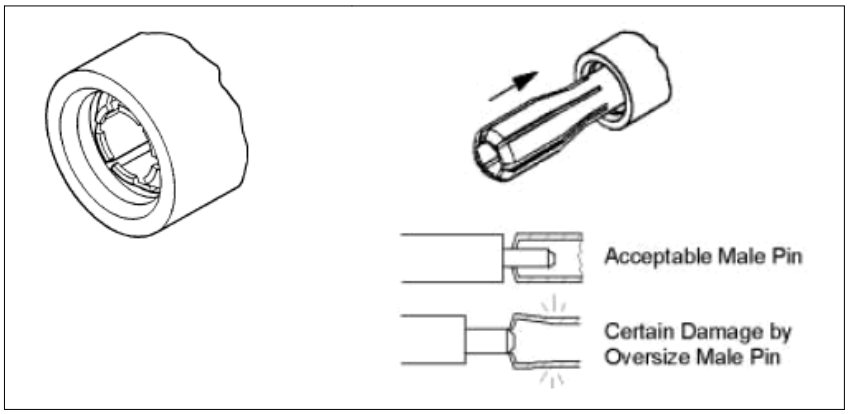


The slotted female center conductor has a set of "fingers" that allow the female contact to expand to accept the male pin. The fingers flex into whatever position the male pin diameter dictates.

This type of female connector is NOT recommended for use at the test port when high accuracy is required. The outer diameter of the female center conductor can change depending upon the size of the male pin. This changes the characteristic impedance of the test port. For example, when the male pin of the calibration standard is a precise size, the impedance of the connection will be exactly known. Yet, when the device under test is connected, its male pin may not be the same size as that of the standard’s connector. Thus, the impedance of the connection will be different. This increases uncertainty and limits traceability of the measurement.

Finally, due to the flex built into the slotted female connector, repeatability will not be as good as slotless types. This is because the materials have a certain ‘memory function’. Once they are bent or deformed to accommodate a different size male pin, the fingers will not completely return to the original diameter.

The Precision Slotless Contact (PSC)



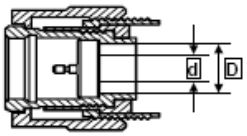
The PSC center conductor consists of a precision machined outer shell which accepts the replaceable inner contact assembly. The fingers of the inner contact are constrained by the tubular inner conductor. If the male pin is of an acceptable diameter, the fingers of the inner contact can flex to make proper contact without changing the outer diameter of the female center conductor. An advantage of this design is that, within damage limits, the impedance of the connection remains constant over a wide range of male pin diameters.

Because this type of connector is more expensive than the slotted connector, using this type of center conductor for the test port should only be used when the best accuracy and complete traceability is required.

Currently, of the connectors discussed in this document, only the **PSC 3.5 mm** and **PSC 2.4 mm** connectors are offered.

Characteristic Impedance and Frequency Range

Connector dimensions determine both its characteristic impedance and frequency limits.



D = Inner diameter of outer conductor

d = Outer diameter of center conductor

Characteristic Impedance (Z0) - In very simplified terms, the ratio of (D/d) determines the characteristic impedance of the connector and is the single external influence on Z0. Thus the precision of these dimensions also determines the precision of the connector's impedance.

Frequency range - Mode-free transmission depends upon several characteristics of the line including the actual impedance of the transmission line, characteristics of the dielectric support, and the geometry of the mating pin.

However, the frequency range in GHz can be represented in simple form as about 120 divided by the inner diameter of the outer conductor (mm). In general, the larger the conductor cross section, the more limited the frequency range.

Example:

120 / 3.5 mm = 34 GHz

What Mates With What

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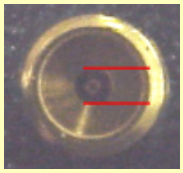
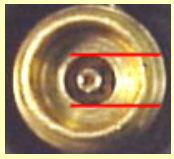
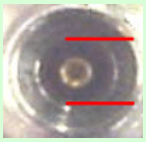
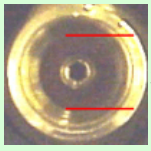
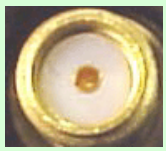
The outer conductor size of these connectors prevents the mating of incompatible connectors. Connectors in each of the shaded areas below have the same size outer conductor and therefore can safely be mated together.

However, damage to connectors occurs from wear, lack of cleaning, improper connection techniques, and poor handling techniques. When mated, a damaged connector can cause another connector to also become damaged. Therefore, clean and inspect all connectors before mating.

In addition, up to three different grades in each connector type are usually available. Production grade connectors can damage metrology grade connectors when mated. Learn more about connector grades.

The first five connector types in the table below use an air dielectric. The name of a connector (ex: 1.85) is determined by the diameter of the air dielectric. This, along with the notes in the following table, is the easiest way to identify these connector types.

Connector Type	Frequency Range	Mates with...	Notes
 **1.0 mm**	To 110 GHz	1.0 mm	Much smaller connector than any of those below.
 **1.85 mm**	To 70 GHz	2.4 mm	The outer thread size of the 1.85 and 2.4 connectors is bigger than SMA, 3.5, and 2.92. This makes the area of the outer conductor mating surface look very large compared to the relatively small air dielectric.
 **2.4 mm**	To 50 GHz	1.85 mm	The 1.85 mm connector that is manufactured at Agilent has a **groove** in the male nut and female shoulder to distinguish these two connector types.
 **2.92 mm**	To 40 GHz	3.5mm and SMA	These two connectors use the same center pin.
 **3.5 mm**	To 34 GHz	2.92 mm and SMA	
 **SMA**	To 24 GHz	2.92 mm and 3.5 mm	Uses a Teflon dielectric.

Note: SMA connectors are a common and inexpensive type, but their lack of precision affects their durability and performance, and can cause increased wear when mated with other (precision) connectors. SMA connectors are only rated for a very limited number of connection cycles and should be examined before each use.

Use Connector Savers

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The small size and precise geometry of mmWave connectors means that they are more delicate and more costly than the larger connectors used at lower frequencies. Millimeter-wave analyzers often have male connectors on their front panels to encourage users to semi-permanently attach a female-to-female adapter as a connector saver. Measurement cables and test devices are then attached to the connector saver.

The connector saver can be easily replaced after it becomes worn or damaged with far less cost and down-time than replacing the test port connector on the test instrument.

- Be sure to fully inspect the connector saver before connecting to the test instrument.
- Because the calibration standards are connected to the connector saver, it should be instrument grade, or better. Learn more about connector grades.

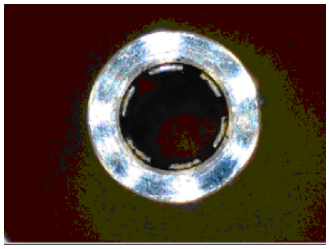
Inspecting Connectors

View All Topics

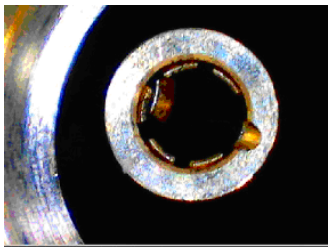
Because of the very small and precise mechanical tolerances of mmWave connectors, minor defects, damage, and dirt can significantly degrade repeatability and accuracy. In addition, a dirty or damaged connector can destroy connectors that are mated to it. For this reason, NEVER use a damaged connector.

To Inspect Connectors:

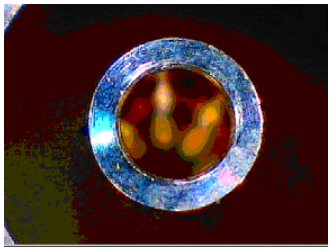
- Wear a grounded wrist strap having a 1 MΩ series resistor.
- Use a ≥10X magnifying glass. A trained, naked eye will normally notice defects in a connector, but many times it is necessary to use a magnifying glass to observe more subtle defects such as small fibers, bent pins, and damaged female slotless connectors.
- Inspect BOTH connectors to be mated for the following:

Threads	• The connector nuts should move smoothly. • All threads should be free of burrs, loose metal particles, and rough spots. • Damaged threads will usually cause metal flakes to be deposited into other parts of the connector, causing severe damage.
Outer Conductor Mating Surface	• Inspect for deep scratches, evidence of misalignment, or excess torque. • Deep scratches generally indicate that one or both of the mating surfaces was not clean or has a high spot or burr. • Any scratch that goes through the plating should be carefully inspected under magnification to see if the scratch has left a high spot of displaced metal. This will damage other connectors.
Center Conductor • Male pins should be straight and centered appropriately to engage the female contact. • Female contacts should all be straight and aligned.	
Normal	 Light burnishing of the mating plane surface consisting of uniform, shallow concentric scratches distributed evenly over the plated surface is normal.

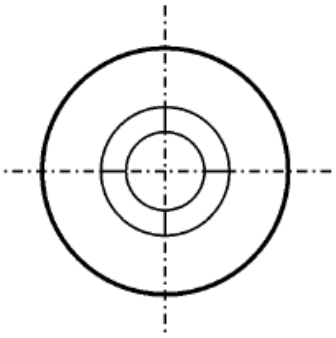
Bent and gouged contacts



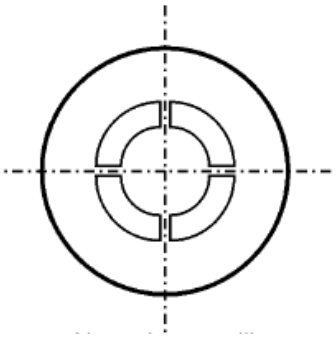
Missing contacts



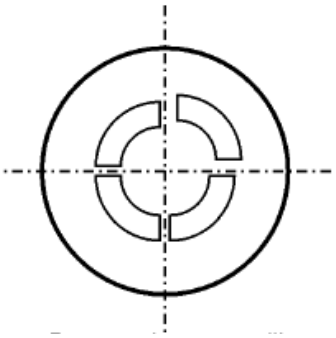
Contact Integrity



Perfectly formed contacts

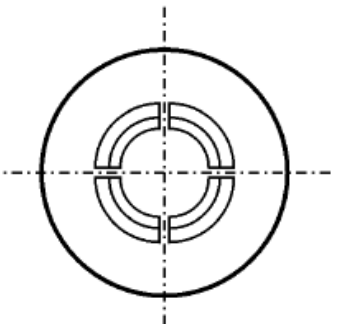


Normal wear will spread contacts slightly

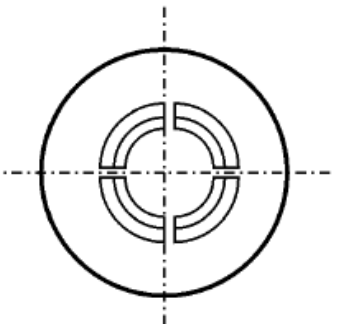


Damaged contact will look electrically capacitive

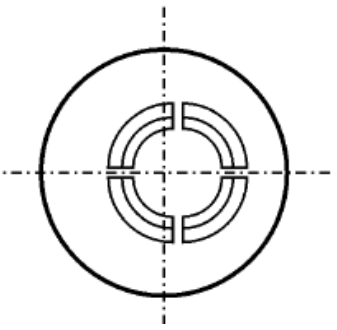
Concentricity (Female)



Perfectly concentric

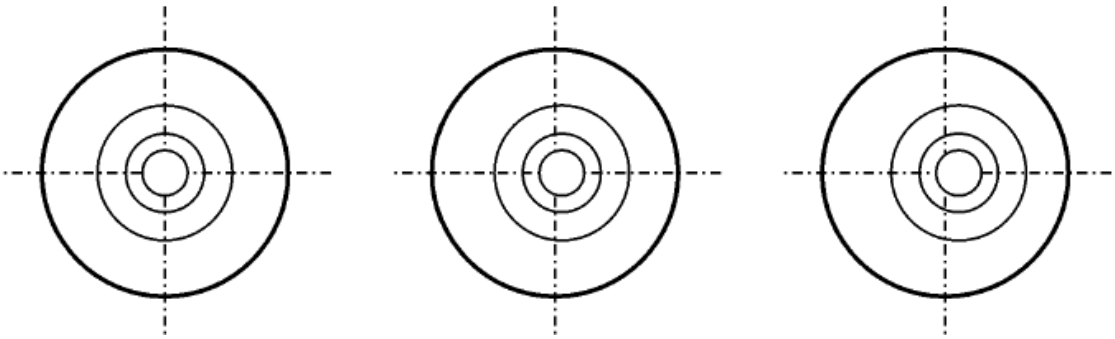


Slightly off center



Excessively off-center
Do NOT use

Concentricity (Male)



Perfectly concentric

Slightly off center

Excessively off-center
Do NOT use

Cleaning Connectors

View All Topics

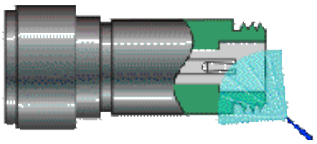
Safety reminders

When cleaning connectors:

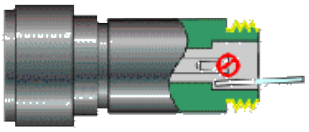
- Always use protective eyewear when using compressed air or nitrogen.
- Keep isopropyl alcohol away from heat, sparks, and flame. Use with adequate ventilation. Avoid contact with eyes, skin, and clothing.
- Avoid electrostatic discharge (ESD). Wear a grounded wrist strap having a 1 MΩ series resistor when cleaning device, cable, or test port connectors.
- Cleaning connectors with alcohol shall only be done with the instruments power cord removed, and in a well-ventilated area. Allow all residual alcohol moisture to evaporate, and the fumes to dissipate prior to energizing the instrument.

Procedure

1. Use clean, low-pressure air to remove loose particles from mating plane surfaces and threads. Avoid directing the air directly into the connector, which will force the debris into the connector, but pass air over the end of the connector as you would when blowing a flute. After air cleaning, inspect the connector thoroughly. If additional cleaning is required, continue with the following steps.



2. Moisten–do not saturate–a lint-free swab with isopropyl alcohol. Excellent results can be achieved by using a 1.2 mm toothpick wrapped with a single layer of lint-free cloth.
3. Connectors should be cleaned in a way that will minimize the wicking of the solvent into the connector. Wicking of the solvent causes several problems. It can carry contaminants such as oil and microscopic dirt into the connector structure and affect the RF performance. This places the contaminants where they cannot be easily removed. Solvents in the connector also change the SWR of the connector until the solvent has evaporated. It may be helpful to hold the connector with the mating face down to reduce the wicking effect.
4. Clean any contamination and debris from mating plane surfaces and threads. When cleaning interior surfaces, avoid exerting pressure on the center conductor. Especially avoid the female center conductor as fibers can become trapped in the contact fingers.



5. Let alcohol evaporate, then use compressed air to blow surfaces clean.
6. Inspect the connector. Make sure no particles or residue remains.
7. If defects are still visible after cleaning, the connector itself may be damaged and should not be used. Determine the cause of damage before making further connections.

Cleaning Supplies

The following is a list of connector cleaning suppliers:

Description	Web Site
Swabs	http://www.berkshire.com/swabs.shtml
Lint Free Cloths **Air dusters**	http://www.ccrwebstore.com
Isopropyl	http://www.techspray.com
Nitrilite Gloves and Finger Cots	http://www.techni-tool.com

Last Modified:

March 2, 2007	Misc updated info.

Gauging Connectors

View All Topics

Because coaxial connector mechanical tolerances can be very precise, even a perfectly clean connector can cause trouble if out of mechanical specification.

Important - Connector Gauge Accuracy

Hand-held connector gauges, such as the one shown below, are only capable of performing coarse measurements on mmWave connectors. This is due to the uncertainties of the measurement versus the extremely precise mechanical tolerances of the connectors. Only special gauging processes performed in a calibration lab can accurately verify the mechanical characteristics of these devices.

Therefore, before making pin depth measurements, it is necessary to know the uncertainty of your gauge and the specifications of the connector you are gauging. These values are supplied in Agilent Cal Kit manuals. You may not be able to definitively determine if your connector is within specifications - only to identify gross failures.

When to Gauge Coaxial Connectors

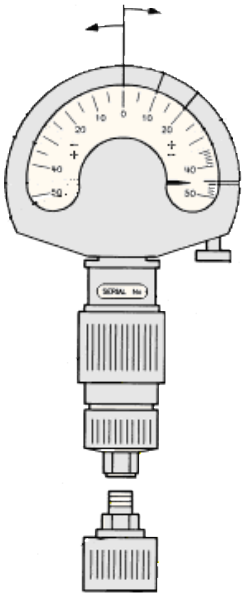
Gauge a connector:

- Before you use it for the first time.
- If either visual inspection or electrical performance suggests that the connector interface may be out of specification.
- If someone else uses the device.
- If you use the device on another piece of equipment.
- Routinely: initially after every 100 connections, and after that as often as experience suggests.

Note: Gauge 2.4 mm, 3.5 mm, and SMA connectors more often than other connectors because the center pins can pull out during disconnect.

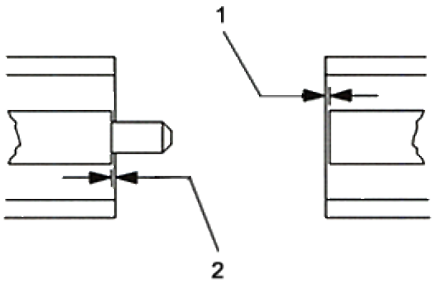
Typical Connector Gauge

RECESSION PROTRUSION



Pin Depth Recession and Protrusion

- Pin depth is negative (recession) if the center conductor is recessed below the outer conductor mating plane, usually referred to as the reference plane.
- Pin depth is positive (protrusion) if the center conductor projects forward from the connector reference plane.



1. Recession of female contact
2. Recession of male pin shoulder

Agilent Gauge Part Numbers

Each connector has a specific gauge part number for measurement of both the male and the female connector. Each gauge uses a special precision gauge master to zero the gauge.

Type	Male	Female
APC 7 mm	85050-80012	
3.5 mm	11752-60106	11752-60105
2.4mm	11752-60108	11752-60107
2.4mm short (for airlines)	85056-60020	N/A
1.85 mm	11752-60108	11752-60107

Gauging Procedure

1. Wear a grounded wrist strap having a 1 MΩ series resistor.
2. Select the proper gauge for your connector.
3. Inspect and clean gauge, gauge master, and device to be gauged.
4. Zero the connector gauge.
    a. While holding gauge by the barrel, carefully connect gauge master to gauge. Finger-tighten connector nut only.
    b. Use proper torque wrench to make final connection. If needed, use additional wrench to prevent the gauge master from turning. Gently tap the barrel to settle the gauge.
    c. The gauge pointer should line up exactly with the zero mark on gauge. If not, adjust "zero set" knob until gauge pointer reads zero. On gauges having a dial lock screw and a movable dial, loosen the dial lock screw and move the dial until the gauge pointer reads zero. Gauges should be zeroed before each set of measurements to make sure zero setting has not changed.
    d. Remove gauge master.
5. Gauge the device connector.
    a. While holding gauge by the barrel, carefully connect DUT to gauge. Finger-tighten connector nut only.
    b. Use proper torque wrench to make final connection and, if needed, use additional wrench to prevent DUT body from turning. Gently tap the barrel to settle the gauge.
    c. Read the gauge indicator dial for recession or protrusion and compare reading with device specifications.

Caution: If the gauge indicates excessive protrusion or recession, the connector should be disposed of or repaired.

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6. For maximum accuracy, measure the device a minimum of three times and take an average of the readings. After each measurement, rotate the gauge a quarter-turn to reduce measurement variations.

7. If there is doubt about measurement accuracy, be sure the temperatures of the parts have stabilized. Then perform the cleaning, zeroing, and measuring procedure again.

Making Good Connections

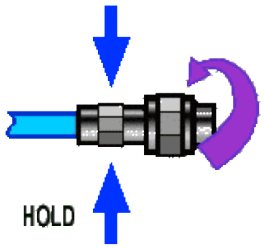
View All Topics

Good connections require a skilled operator. The most common cause of measurement error is bad connections. The following procedures illustrate how to make good connections.

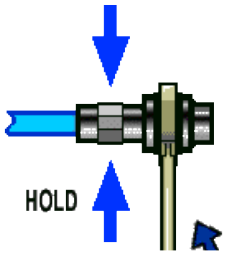
Making a Connection

1. Wear a grounded wrist strap having a 1 MΩ series resistor.
2. Inspect, clean, and gauge connectors. All connectors must be undamaged, clean, and within mechanical specification.
3. Carefully align center axis of both devices. Push the connectors straight together so they can engage smoothly. The male center conductor pin must slip concentrically into the contact finger of the female connector.

4. **CRITICAL:** Rotate only the connector nut - **NOT THE DEVICE OR CONNECTOR BODY** - until finger-tight, being careful not to cross the threads. Damage to both connectors will occur if the male center pin is allowed to rotate in the female contact fingers.



5. Use a torque wrench to make final connection. Tighten until the "break" point of the torque wrench is reached. Do **not** push beyond initial break point. Use additional wrench, if needed, to prevent device body from turning.



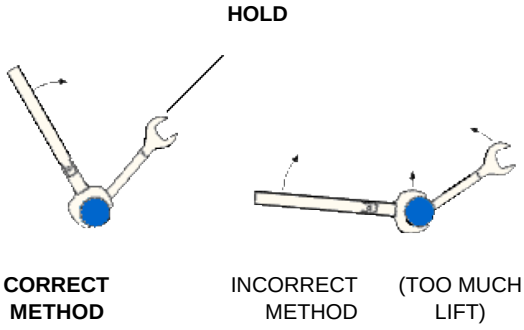
Separating a Connection

1. Support the devices to avoid any twisting, rocking or bending force on either connector.
2. Use an open-end wrench to prevent the device body from turning.
3. Use another open-end wrench to loosen the connector nut.
4. Complete the disconnection by hand, turning only the connector nut.
5. Pull the connectors straight apart.

Using a Torque Wrench

Proper torque on the connector improves measurement repeatability and extends connector life. The tightening torque on connectors has a significant effect on measurements at mm-wave frequencies. Repeatable measurements require consistent torque on all the connections in a setup. A torque wrench avoids damage due to over-tightening and helps connectors achieve their rated lifetimes.

1. Make sure torque wrench is set to the correct torque setting.
2. Position torque wrench, and a second wrench to hold the device or cable, within 90° of each other before applying force. Make sure to support the devices to avoid putting stress on the connectors.



3. Hold torque wrench lightly at the end of handle. Then apply force perpendicular to the torque wrench handle. Tighten until the "break" point of the torque wrench is reached. Do **not** push beyond initial break point.

Torque Settings

Types	Torque Setting	Wrench Part Number
1.0 mm	4 in–lb (45 N–cm)	8710–2079
1.85 mm	8 in–lb (90 N-cm)	8710-1765
2.4 mm	8 in–lb (90 N-cm)	8710-1765
2.92 mm	8 in–lb (90 N-cm)	8710-1765
3.5 mm	8 in–lb (90 N-cm)	8710-1765
SMA	8 in–lb (90 N-cm)	8710-1765

Handling and Storing Connectors

View All Topics

- Install protective end caps when connectors are not in use.
- Never store connectors, airlines, or calibration standards loose in a box. This is a common cause of connector damage.
- Keep connector temperature the same as the test instrument. Holding the connector in your hand or cleaning connector with compressed air can significantly change the temperature. Wait for connector temperature to stabilize before using in calibration or measurements.
- Do not touch the mating plane surfaces. Natural skin oils and microscopic particles of dirt are difficult to remove from these surfaces.
- Do not set connectors contact-end down on a hard surface. The plating and mating plane surfaces can be damaged if the interface comes in contact with any hard surface.
- Wear a grounded wrist strap and work on a grounded, conductive table mat. This helps protect the analyzer and devices from electrostatic discharge (ESD).

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