

## MegaPhase Application Note #1701

### Care and Handling of Cable Assemblies & Connectors

Cable assemblies are critical to obtaining correct test results and signal integrity. Proper care and handling of cable assemblies and connector interfaces is critical to insuring accurate operation. When connectors are not properly mated or cared for, there is a risk of damaging test ports and mating devices.



#### Interface Inspection

**Visual Inspection.** Be sure there is no visible damage or debris in the connector interfaces. Check center pins for concentricity. A good practice is to use a containerized compressed air, such as Tech Duster, to blow out any dust and debris prior to connection. Do not touch connector mating surfaces with your hands as this can propagate natural oils onto the mating surface. Only touch the outside surfaces.

**Inspecting Interfaces.** Be sure there is no scoring, dents, on outer conductor, center pins, and dielectric surfaces. Center contacts must be present, straight and centered. Contact shoulders need to be sharply defined with flat edges and no rolled or mushroomed edges. There should be no evidence of contact pin looseness or cross-threading. Cable Assemblies with damaged interfaces should not be used. Do not mate them with any connector or interface gauge.

**Inspecting Interface Threads.** There should be no evidence of cross-threading or broken or missing threads. Cable Assemblies with damaged threads should not be used. Do not mate them with any connector or interface gauge.

#### Interface Cleaning

**Cleaning Connector Threads.** Use a clean, soft, lint-free swab, such as a cotton swab, lightly moistened with isopropyl alcohol to remove dirt, dust, and other debris.

- Apply a *small amount* of isopropyl alcohol to the lint-free swab. Press excess alcohol out of swab on a clean lint-free cloth.
- Clean the connector threads. Do not allow alcohol to come into contact with dielectrics or gaskets. Do not allow alcohol to migrate into the connector. Migration can cause VSWR, phase, and insertion loss problems. If migration occurs, the cable assembly should be thermal cycled at +70° C for one hour.
- Allow the isopropyl alcohol to evaporate, then dry the threads using containerized compressed air. Make sure the connectors are completely dry before use.
- Re-inspect connector to be sure there is no visible debris.

#### Interface Gauging

Initial use of cable assemblies should start with clean interfaces that are within given specifications for pin depths (see Table I). Additionally, connectors should be gaged periodically as a preventative maintenance measure, on a fixed schedule such as every 100 mating cycles or every week. Be sure gages are calibrated. This will insure that cable connectors will not damage interfaces, especially test set ports.

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Interface gages are critical to insure that pin depths do not have excessive recession or protrusion, but short of a using a metrology lab they will only truly provide a rough measurement. Plug gages introduce more measurement uncertainty than threaded gages. See Figures A through D for an example of reference planes on connector interfaces.

<b>TABLE I: CONNECTOR INTERFACES AND TOLERANCES</b>		
Connector Interface	Reference Plane Recession, in (mm)	Specification
1.0mm female	0.000 / -0.002 (0.000 / -0.051)	IEEE STD 287
1.0mm male	0.000 / -0.002 (0.000 / -0.051)	IEEE STD 287
1.0mm port female	0.000 / -0.002 (0.000 / -0.051)	IEEE STD 287
1.0mm port male	0.000 / -0.002 (0.000 / -0.051)	IEEE STD 287
1.85mm female	0.000 / -0.002 (0.000 / -0.051)	IEEE STD 287
1.85mm male	0.000 / -0.002 (0.000 / -0.051)	IEEE STD 287
1.85mm port female	0.000 / -0.002 (0.000 / -0.051)	IEEE STD 287
1.85mm port male	0.000 / -0.002 (0.000 / -0.051)	IEEE STD 287
2.4mm female	0.000 / -0.001 (0.000 / -0.025)	IEEE STD 287
2.4mm male	0.000 / -0.0025 (0.000 / 0.0635)	IEEE STD 287
2.4mm port female	-.0001 / -0.001 (-.0025 / -.0254)	IEEE STD 287
2.4mm port male	-.0001 / -0.001 (-.0025 / -.0254)	IEEE STD 287
2.92mm female	0.000 / -0.003 (0.000 / -0.076)	IEEE STD 287
2.92mm male	0.000 / -0.003 (0.000 / -0.076)	IEEE STD 287
2.92mm port female	0.000 / -0.003 (0.000 / -0.076)	IEEE STD 287
2.92mm port male	0.000 / -0.003 (0.000 / -0.076)	IEEE STD 287
3.5mm female	0.000 / -0.003 (0.000 / -0.076)	IEEE STD 287
3.5mm male	0.000 / -0.003 (0.000 / -0.076)	IEEE STD 287
3.5mm port female	0.000 / -0.003 (0.000 / -0.076)	IEEE STD 287

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3.5mm port male	0.000 / -0.003 (0.000 / -0.076)	IEEE STD 287
4.3-10 female	-0.122 / -0.138 (-3.099 / -3.505)	IEC 60169-54
4.3-10 male	+0.305 / -0.315 (+7.747 / -8.001)	IEC 60169-54
7-16 female	-0.069 / -0.082 (-1.753 / -2.083)	IEC 60169-4
7-16 male	+0.058 / +0.069 (+1.471 / +1.770)	IEC 60169-4
7mm	-0.002 / +0.002 (-0.051 / +0.051)	IEEE STD 287
BNC female	+0.186 / +0.206 (+4.724 / +5.232)	MIL-STD-348
BNC male	-0.210 / -0.230 (-5.334 / -5.842)	MIL-STD-348
C female	+0.309 max. (+7.849)	MIL-STD-348
C male	+0.030 / 0.040 (+0.762 / +1.016)	MIL-STD-348
F female	+0.200 max. (+5.080)	ANSI/SCTE 01 2015
F male	+0.250 / +0.375 (+6.350 / +9.525)	ANSI/SCTE 124 2015
N Female	+0.187 / +0.207 (+4.749 / +5.258)	MIL-STD-348
N Male	+0.210 / -0.230 (+5.334 / -5.842)	MIL-STD-348
SMA female	0.000 / 0.010 (0.000 / +0.254)	MIL-STD-345
SMA male	0.000 / -0.010 (0.000 / -0.254)	MIL-STD-348
TNC female	+0.186 / +0.206 (+4.724 / +5.232)	MIL-STD-348
TNC male	-0.210 / -0.230 (-5.334 / -5.842)	MIL-STD-348

*\* Generally the tolerance for pin protrusion is 0.000.*

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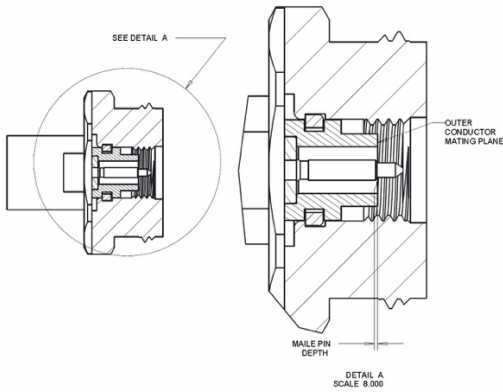


Fig. A: Port Ruggedized Male

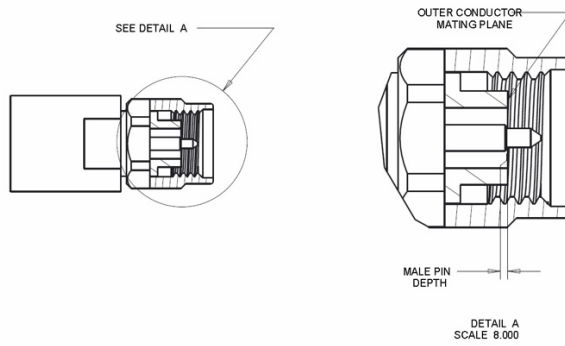


Fig. B: Straight Male

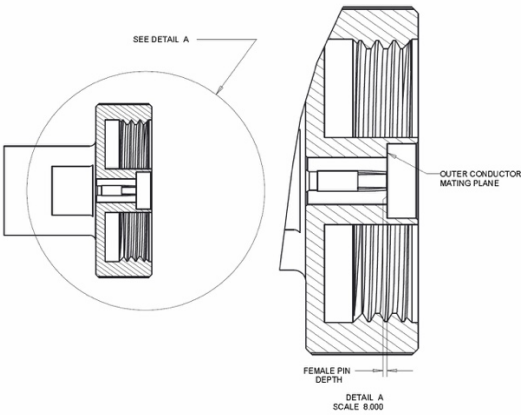


Fig. C: Port Ruggedized Female

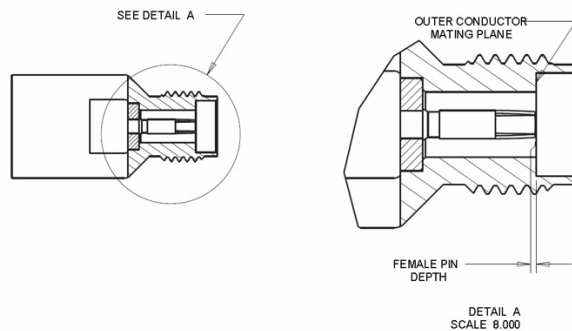
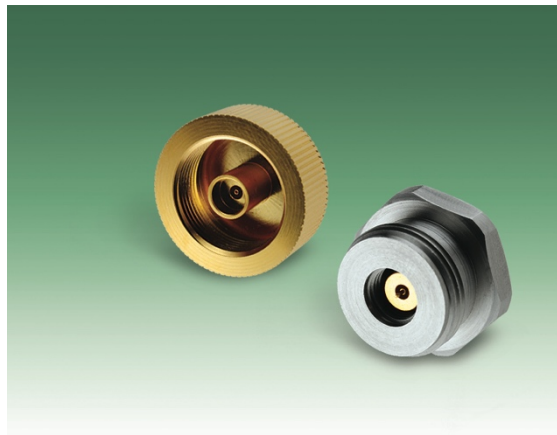


Fig. D: Straight Female

### About Port Ruggedized Connectors

Many vector network analyzers feature ruggedized port connectors (Keysight refers to these as “NMD” connectors, which stands for “Network Measurement Division” of Hewlett-Packard, the foundation of today’s Keysight Technologies). Ruggedized port connectors on VNA’s are typically male connectors, with large standard coupling threads to insure the mechanical stability of the connection to the VNA port. The mating female connector is common on many test port extension cables. With standard cables, many labs utilize “port savers,” which are adapters from standard straight connectors to the VNA ruggedized port.



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### Between-Series Mating of Connectors

The 2.92mm, 3.5mm, and SMA connectors interface with one another without significant degradation in performance. These connectors share a common coupling nut. The center conductors are slightly different in size, resulting in a pin gap difference that could account for a difference in return loss of up to 3dB, depending on frequency. Likewise the 2.4mm and 1.85mm connectors will interface with one another, sharing a common coupling nut.

### Cable Assembly Mating

**Interface Alignment.** Contact pins and dielectrics can be damaged if misaligned connectors are mated. Make sure that mating interfaces are parallel and on-center prior to and during mating cycles. If necessary, lift cable behind connector to align the interfaces before mating and torque, then restore to a natural bend configuration only after recommended coupling torque has been achieved (see Table II). Always connect angled connectors, such as a 90° sweep, before straight connectors.

**Interface Rotation.** Both the outer conductor and center contacts can be damaged if connector bodies rotate during mating cycles. Hold the connector body stationary using a flat wrench on the connector wrench flats while rotating coupling nut, *using a proper torque wrench*, during mating cycles.

### Recommended Mating Torque

Incorrect torque can produce inaccurate measurements and over-torque coupling can damage test devices, adapters, and test ports. Calibrated torque wrenches should be used for all mating cycles. When mating a specific connector type, use the correct torque value (see Table II). Using a torque wrench also insures consistency between measurements. Break-over torque wrenches are recommended.

Table II: Recommended Coupling Torque	
Interface type	Coupling torque, in-lbs. (N-m)
1.0mm	4 (0.45)
3.5mm, 2.92mm, 2.4mm, 1.85mm	8 (0.90)
TNC	5 (0.57)
SMA (Brass)	5 (0.57)
SMA (Stainless)	8 (0.90)
7mm, N	12 (1.36)
F	15 (1.70)
C	14 (1.58)
7-16 DIN	222-267 (25.09-30.17)
4.3-10	44 (5.00)

### Cable Routing

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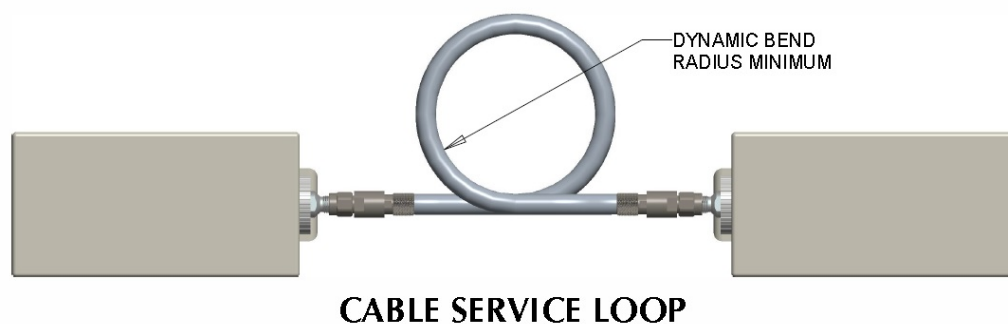
**Bend Radius.** Avoid bending cables beyond the minimum recommended bend radius. Bending beyond the recommended radius can move the center conductor out of concentricity and can deform the outer conductor or center conductor to the point of kinking and fracture. Bending can result in degraded insertion loss and VSWR performance. Most manufacturers specify different bend radii for cable assemblies, a *dynamic* bend radius and a *static* bend radius. A rule of thumb for dynamic bend radius is 4 times the static radius. Generally a larger diameter cable has a larger bend radius.

**Twisting.** Twisting cables should be avoided at all times. Excessive twisting, or rotational torque, can damage the cable assembly at the cable/connector junction or even mid-cable depending on how the twist is applied. Lower level twist can also cause measurement problems. Induced stresses on test ports and device ports can damage the ports. Low level stresses can cause connections to loosen up. Connecting angled connectors before straight connectors will help to avoid twisting.

**Flexure.** Even though cables are flexible, flex them as little as possible to insure a long life. If the stability is very sensitive in your measurement, use a fixture to prevent excessive movement after calibration. The more the cable is flexed, the more the phase and amplitude will change. Cables have a “natural lie” or curvature. Connect cables to test sets and use with the natural curvature of the cable, avoiding bending against the natural curvature.

**Over-bending.** Most cable damage is from over-bending of cables, beyond the minimum bend radius. This is especially true directly behind the connectors, as over-bending close to the connector can break the solder joint at the connector termination point. Leave a service loop if connections are too close (Figure E).

Figure E



**Flex Life.** Cables have a limited number of bend cycles. While many manufacturers publish minimum bend cycles—some over 100,000 cycles—it is important to know what constitutes a *cycle*. Is it 2in (5cm) wrapped 90 degrees around a mandrel? Or is it +/- 5 degrees around a 12in (30cm) mandrel? Obviously

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there is a nearly unlimited number of configurations, so minimum bend cycles can be misleading. Each application is different, so use your judgment. Cables will not last forever, but with proper handling and routing you can extend the life of your cables substantially.

#### **Storage**

- Use end caps to protect the cables and adapters from dust and debris when the cable is not in use.
- Store cables in the same shape as when used on the test set.
- Do not allow cables to hang down off a test set or bench while not in use. This puts unnecessary strain on the port connector and cable, especially if the cable is pulled. This will exert force and potentially over-bend the cable behind the connector, causing breakage. Worse yet this could damage the instrument port.

#### **Electrostatic Discharge (“ESD”)**

Protect against electrostatic discharge (ESD) while connecting, inspecting, or cleaning cables and connectors especially while attached to a test set. This is best achieved by wearing a grounded wrist strap, a grounded conductive table mat, and a heel strap; preferably on a conductive floor.

#### **Electrical Inspection**

Electrical evaluation of cable assemblies is performed primarily to preclude measurement inaccuracies associated with unstable test cables. It is a good practice to evaluate cables and record baseline data prior to use. Likewise a preventative maintenance schedule should be established to evaluate cable performance periodically, such as every 100 cycles or weekly.

**In-Process Stability Checks.** These tests are performed on the test cable in the “as calibrated” configuration. They should be performed immediately after calibration and periodically thereafter to verify stability of the test cables and validate the calibration.

**Dynamic Stability (“Thrum Test”).** Grasp cable lightly between first and second finger while resting forearm on the test bench. Thrum the cable by flexing the wrist at approximately 2 beats per second (forearm remaining on test bench).

**Dynamic Stability (“Stress Test”).** Perform this test on cables that show evidence of abuse. Grasp cable lightly between thumb and first finger of each hand around the area of concern. Flex the cable around that area being careful not exceed the minimum bend radius. Repeat the stress test for all areas of concern noted in visual inspection of cable/connector junction.

**360 Degree Wrap Test.** Perform this test on test cable assemblies that are longer than 18 inches. Store the  $S_{21}$  insertion loss and  $S_{21}$  phase data in memory and then display math divide data. Disconnect test cable assembly at the port two end and wrap the cable 360 degrees at a 4.75-inch or supplier-specified diameter. Reconnect test cable assembly at port two end. Cable assembly should meet the supplier’s

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specifications. Disconnect test cable assembly at the port two end and return cable to its original configuration. Reconnect cable assembly at the end of port two.

**Four Quadrant Flex Test.** Perform this test  $S_{11}$  Reflection test on all test cable assemblies longer than 12 inches. Install a precision short on the port 2 end of the cable assembly. Position the cable assembly in a straight configuration perpendicular to the test equipment. Store the  $S_{11}$  phase data in memory and then display math divide data. Flex the cable 180 degrees at a 4.75-inch or supplier-specified diameter, and verify that the cable meets the supplier's specifications. Return the cable to the straight position and verify that the cable meets specifications. Repeat test in each quadrant for a total of four quadrants, plus and minus 180 degrees in the XY and YZ planes.

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