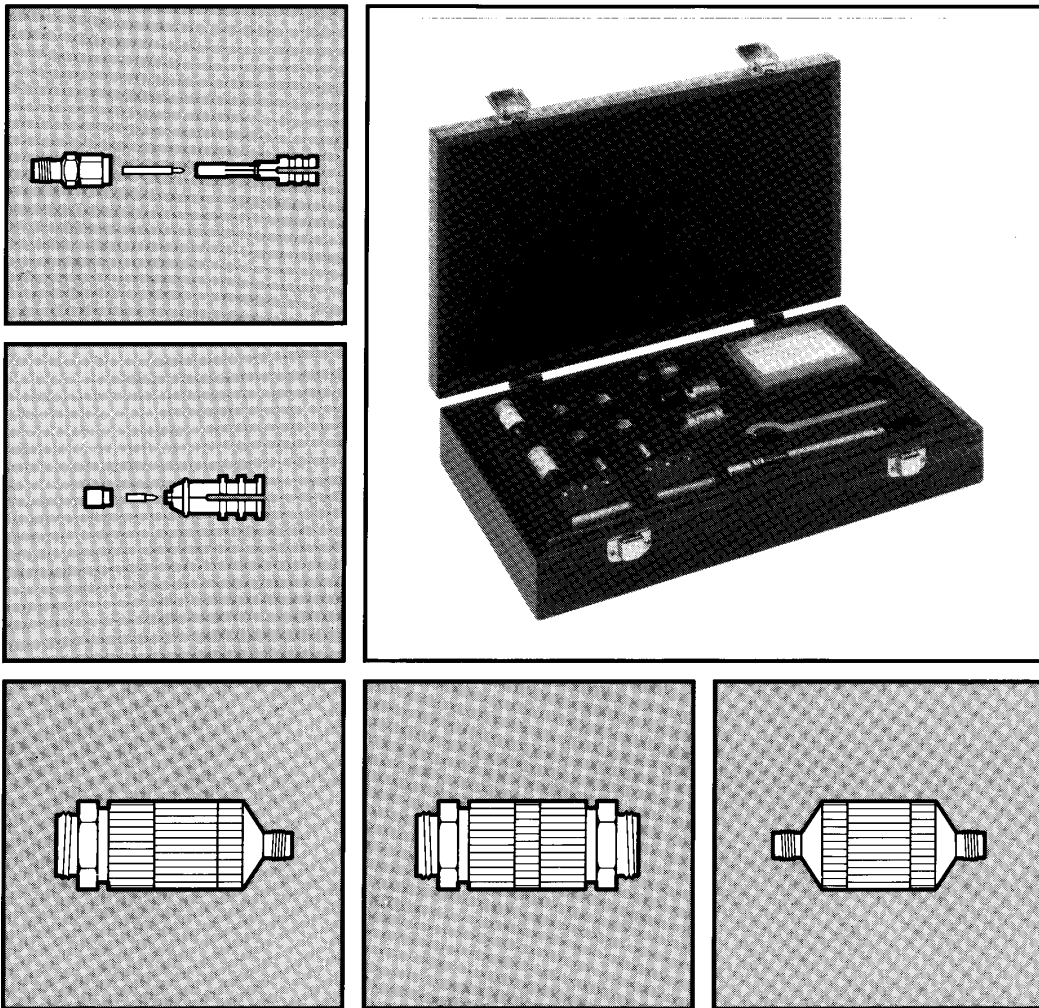


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# TRL Calibration Guide

## Agilent 85052C Precision Calibration Kit



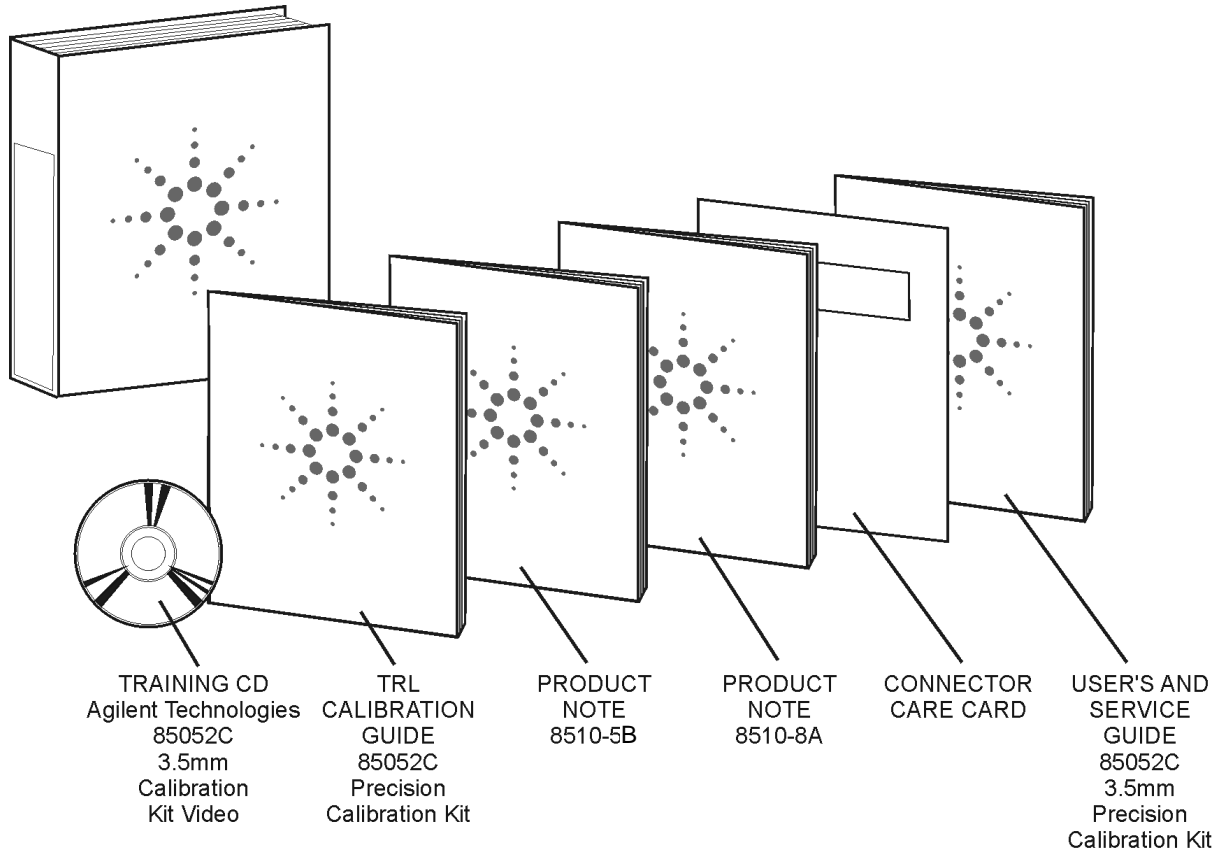
**Agilent Part Number: 85052-90059**

**Printed in USA**

**Print Date: October 2001**

**Supersedes: April 1995**

**Figure 1**      **85052C Precision Calibration Kit Operating and Service Package**



wk501c

# INTRODUCTION

- What's in This Guide** This guide describes how to use the 85052C calibration kit with the 8510 vector network analyzer to perform the TRL 2-Port measurement calibration technique, and how to evaluate the results of the calibration.
- Chapter 1** This chapter introduces the components of the kit, and describes important connection techniques.
- Chapter 2** In this chapter, detailed sequences describe how to set up the network analyzer system, and use the kit to perform the 3.5 mm TRL 2-Port calibration procedure.
- Chapter 3** Since many applications require measurement of devices that are not insertable, this chapter describes the theory of and how to use the kit to perform the Adapter Removal procedure for measurement of noninsertable devices.
- Chapter 4** This chapter, entitled "Other Calibrations," describes use of the network analyzer Modify Cal Kit function to redefine the calibration kit and how to use the Lowband Reflection option
- 85052C 3.5 mm Calibration Kit Video (Training CD)** This guide is supplemented by a video presentation that shows how an experienced operator uses the calibration kit parts. If you have access to this CD, view it along with this manual first.
- Before Proceeding...** The parts in this kit are delicate and must be handled with care to avoid damage that would affect the accuracy of the calibration. Check all test device connectors carefully before connecting to the TRL adapters.

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# **1 Introduction to the Calibration Kit**

The 85052C 3.5 mm Precision Calibration Kit is designed to be used in TRL 2-Port measurement calibration as implemented in vector network analyzers. TRL stands for Thru-Reflect-Line, naming the main standards used in the accuracy enhancement procedure.

TRL represents a family of calibration techniques that measure various combinations of transmission lines and reflection standards to determine the 2-Port 12-term error coefficients. The specific calibration technique described here uses measurements of the zero-length thru connection, identical reflection standards at each port, and one or more transmission lines of appropriate impedance and length for the frequency range. Both the TRL 2-PORT and the Full 2-Port calibration types use the same accuracy enhancement mathematics to correct the measured data. TRL, as implemented with this calibration kit, brings convenience, accuracy, and repeatability to the error correction process because the typical TRL calibration requires fewer parts that are simpler to connect and disconnect.

The 3.5 mm geometry connector is the most frequently used connector when frequency coverage up to 26.5 GHz, reasonable commonality, and durability is desired. Well constructed connectors and transmission lines can work up to 34 GHz. Metrology grade versions of this connector are used for high performance test ports and for calibration standards. Whether the device uses SMA, SMA-compatible, or 3.5 mm, the 3.5 mm connectors used on the test ports, adapters, cables, and calibration standards provide the most accurate and repeatable solution.

All male connectors in this kit are precision with carefully controlled dimensions. All female connectors are of the precision slotless (PSC-3.5) type. These connector are designed for long repeatability when used with appropriate technique. This means careful inspection of the kit parts, familiarity with their use, and careful inspection of the Device Under Test (DUT) connectors. Refer to the "Specifications" chapter in the *Agilent 85052C 3.5 mm Precision Calibration Kit User's and Service Manual*, and "[Precision Connectors](#)" on page 9 for specific information about precision slotless connectors.

**Figure 1-1**      **85052C Precision Calibration Kit**



## Calibration Kit Components

The 85052C 3.5 mm Precision Calibration Kit contains components useful for several different calibration techniques. The parts used for the TRL 2-Port calibration are:

- longer precision air line for 2 to 7 GHz
- shorter precision air line for 7 to 32 GHz
- male and female short circuits
- male and female fixed loads

Other parts included are:

- three precision TRL adapters
- two adapter anti-rotation clamps
- calibration kit definition disk
- male and female open circuits
- tools

Note the reference card in the box and the material list on the bottom of the box.



## Air Lines

These are precision air lines. Each one is always stored in its installation tool to help prevent damage and preserve cleanliness.

The shorter air line is used for measurement calibration over the 7 to 32 GHz frequency range. The longer air line is used for measurement calibration over the 2 to 7 GHz range. Each air line is fully specified at all frequencies within its stated range.

**Figure 1-2 Line Standards — 7 to 32 GHz and 2 to 7 GHz Air Lines Installed in Tools with Storage Bottles**



**Figure 1-3 Polar Display Showing Phase Response of Longer Air Line Over 2 to 7 GHz Frequency Range**

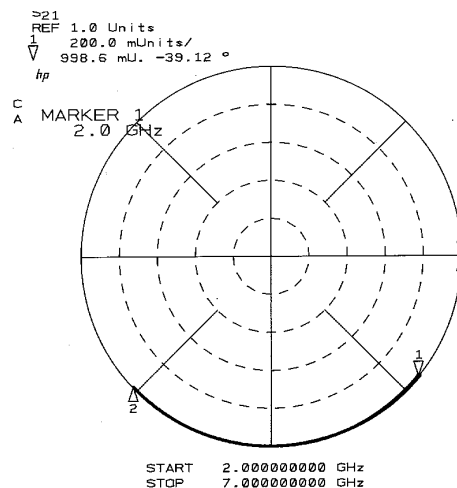
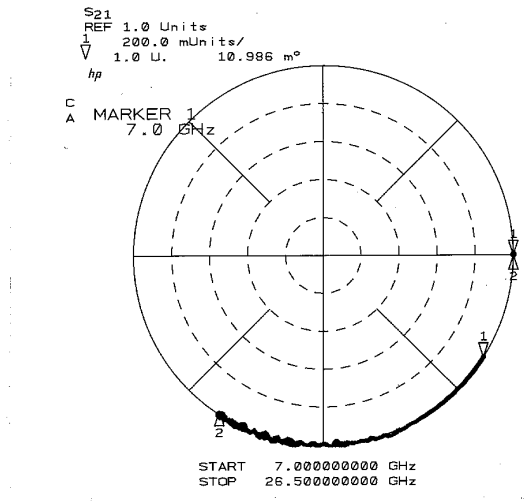


Figure 1-4

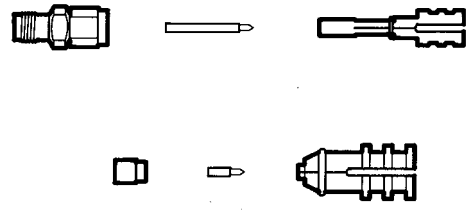
**Polar Display Showing Phase Response of Shorter Air Line Over 7 to 26.5 GHz Frequency Range**



Each air line consists of a separate outer conductor and center conductor and includes its own tool used for installing and removing the parts from the test port. Both are insertable. Each has a male end and a female end. The male end of the air line fits into the installation tool.

Figure 1-5

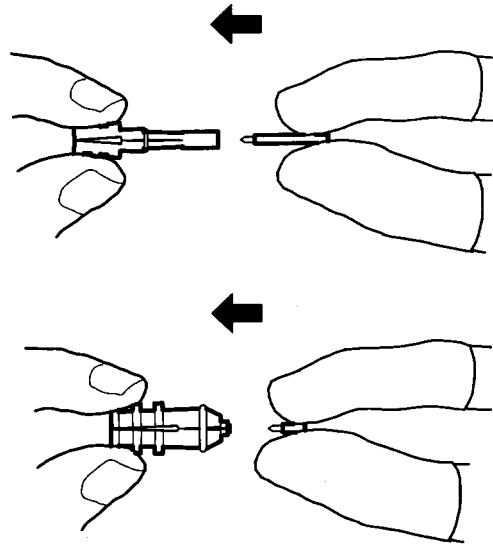
**Air Lines Removed from Installation Tools**



**CAUTION**

The parts may be removed for inspection, if necessary. The tool is always used to install the parts for calibration. Use extreme care in handling these parts. Use static dissipative finger sheaths, or "finger cots," to prevent contamination. Liquid or solid residue on the connector parts will degrade performance. In particular, the inner conductors can be easily deformed by squeezing. Do not use metal tweezers or other devices to pick up or hold the parts.

**Figure 1-6** Installing the Air Lines in Installation Tools



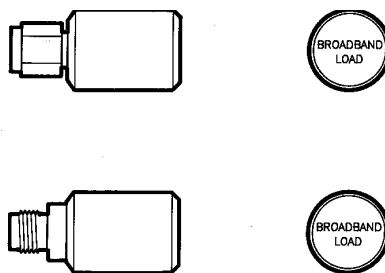
### 0 to 2 GHz Loads

This implementation of the TRL 2-Port calibration allows measurement of the loads to determine the error coefficients up to 2 GHz. Technically, the measurement is treated as an infinite-length transmission line whose input reflection is the reference impedance,  $Z_0$ .

**NOTE**

The male and female broadband loads are manufactured to tolerances that assure equivalent response at least below 2 GHz. If one is damaged or otherwise becomes defective, calibration errors will result.

**Figure 1-7** 0 to 2 GHz Loads — Male and Female Fixed Broadband Loads



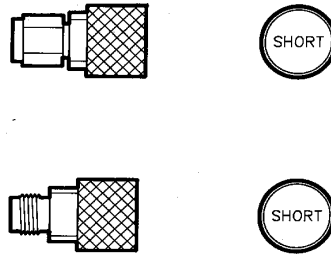
### Reflect Standards

In this TRL 2-Port calibration, the reflect standards are identical short circuits with one connected to Port 1 and one to Port 2.

The male short circuit and the female short circuit are manufactured to tolerances that assure equivalent responses. If one is damaged or

otherwise becomes defective, calibration errors will result. Errors will also result if the open circuits are used in the procedure instead of the short circuits (unless the calibration kit standard assignment definition is changed).

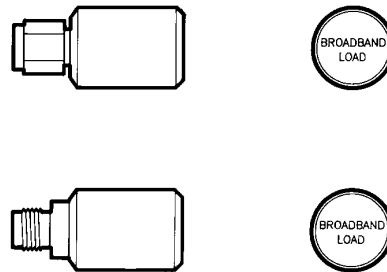
**Figure 1-8 Reflection Standards — Male and Female Short Circuits**



### Isolation Standards

The fixed loads used for the isolation part of the calibration are the same broadband loads as used for the 0-2 loads measurement. Exact equivalent responses are not required for this step.

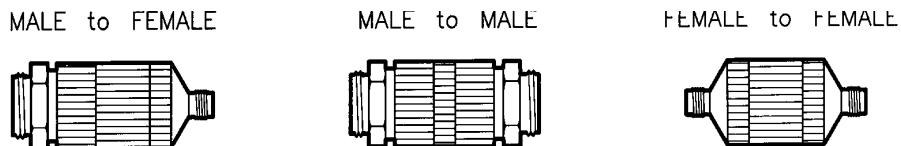
**Figure 1-9 Isolation Standards — Male and Female Brodband Loads**



### Precision Adapters

Three precision adapters are included in this kit. Two are always recommended for the 3.5 mm TRL 2-Port measurement calibration. All three can be used in the adapter removal calibration for measurement of noninsertable devices. Complete performance verification assumes use of the precision adapters in this kit as the test ports.

**Figure 1-10 Precision TRL Test Port Adapters**



**Recession Limits**

The female receptacle recession and the male pin recession, along with other mechanical specifications of Port 1 and Port 2, must be within limits to meet complete measurement specifications. The precision adapters supplied in this kit are manufactured to metrology standards in order to obtain the best measurement accuracy specifications. If other connectors than these precision adapters are used as the test ports, they must be fully inspected. Using other than the highest quality connectors as the test ports will reduce accuracy and repeatability as well as possibly damaging the calibration standards.

**Precision Connectors**

For general use, any 3.5 mm precision slotless female connector can be used for the female test port. The 3.5 mm precision male connector used on the male end of these adapters is always required for measurements between 7-32 GHz in order to connect the 7-32 GHz air line in this kit. Any 3.5 mm precision male connector can be used at frequencies less than 7 GHz.

**Installation Feature**

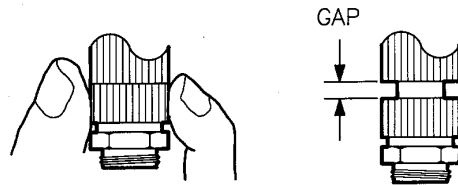
The precision adapter male connector has a special feature to allow installation of the 7-32 air line.

- Grasp the knurled sleeve and move the nut to its extended position by pulling on it.

This is the position used for measurement of the 7-32 GHz air line.

**Figure 1-11**

**Extended Position**

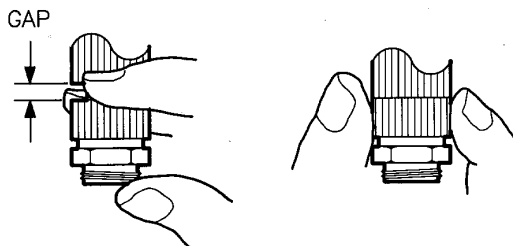


- Now move the sleeve forward and push the nut back into its standard position.

This position is used to install the short air line, for connecting the other calibration standards, and for connecting the device under test.

**Figure 1-12**

**Standard Position**



## Tools

A torque wrench and spanner wrench are included in the kit to loosen and tighten the connectors. The small torque wrench is used for the 3.5-mm nuts. The large torque wrench is used for the 20-mm nuts on the precision adapters. It is included with the test set. The spanner wrench is used to hold the precision adapter while using the appropriate torque wrench to tighten the connection.

Also included is the hex wrench for tightening and loosening the adapter anti-rotation clamp securing screws.

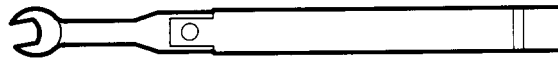
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**CAUTION**

When making connections, turn the nut on the device, never turn the device itself. Turning the device will cause excessive wear of both connector mating surfaces and cause debris to collect in the female receptacle.

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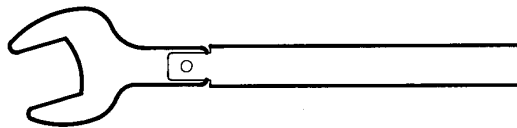
**Figure 1-13**      **Torque Wrench**



**Figure 1-14**      **Spanner Wrench**



**Figure 1-15**      **Torque Wrench (not included)**



**Figure 1-16**      **Hex Wrench for Adapter Anti-Rotation Clamp**



When making a connection:

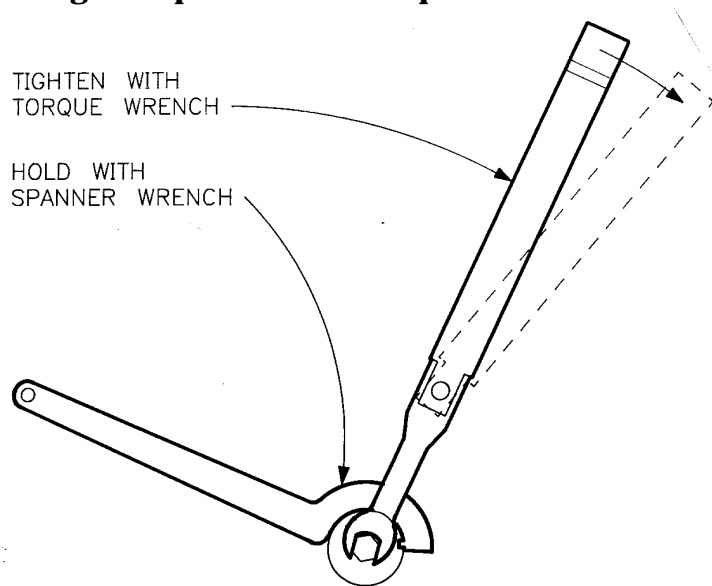
1. Carefully engage the male and female contacts, and then tighten the nut by hand.
2. If necessary, use the spanner to hold one device stationary against the direction of torque.
3. Hold the torque wrench with your thumb and index finger near the end of the handle.

4. Tighten the connection until the ball in the handle crests on the cam (as the handle begins to "break," releasing tension).

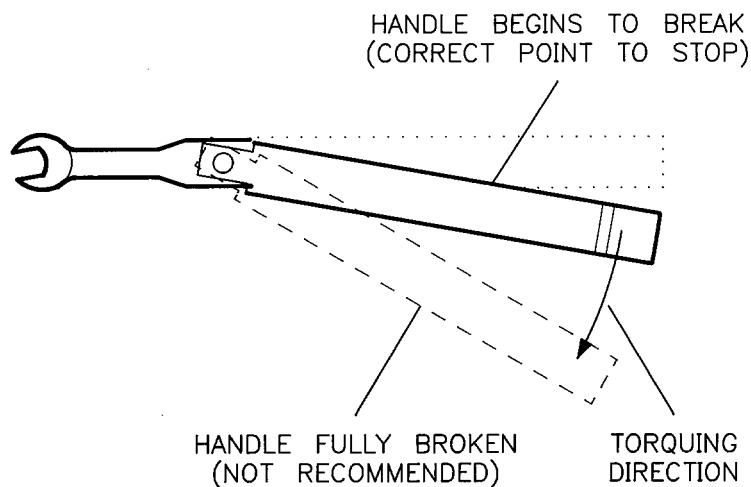
It is not recommended or necessary to fully "break" the handle of the torque wrench to reach the fully-specified torque. As soon as the handle moves out of alignment, the connection is properly torqued.

Reverse the above procedure to disconnect the connectors.

**Figure 1-17 Using the Spanner and Torque Wrench**



**Figure 1-18 Correct Torque Value**







---

**2** **Performing a TRL 2-Port  
Measurement Calibration**

This example describes use of the 3.5 mm precision calibration kit to measure an insertable device. When the test device is insertable, the test ports can be connected together to establish the Thru connection during calibration.

The procedure used for performing any measurement calibration is as follows:

1. Clean and inspect all connectors.
2. Initiate measurement calibration procedure and measure standards.
3. Verify the calibration.
4. Connect the device under test.

The rest of this section explains the above steps.

---

## Electrostatic Discharge

When you make connections to the network analyzer, either directly to the test set port or indirectly through a cable that is connected to the test set port, protect the instrument against electrostatic discharge (ESD). Always wear a grounding wrist strap connected to a conductive bench mat when working near sensitive equipment.

---

### CAUTION

The human body almost always has some static charge. You are not usually aware of this charge because the human threshold for the perception of a static discharge shock is about 30 kV. ESD as low as 60 volts can damage sensitive microcircuits.

---

## Clean and Inspect

The accuracy of error-corrected measurements using the network analyzer depends upon the quality of the measurement calibration. In turn, the quality of the calibration depends on the condition and cleanliness of the test ports and calibration standards, and the operator's skill in making connections. Repeatability and accuracy are improved by removing contaminants from mating surface during cleaning.

Carefully inspect the following for cleanliness and damage. Look for deformation of the male pin or the female receptacle, and for metallic and organic residue on the mating surfaces.

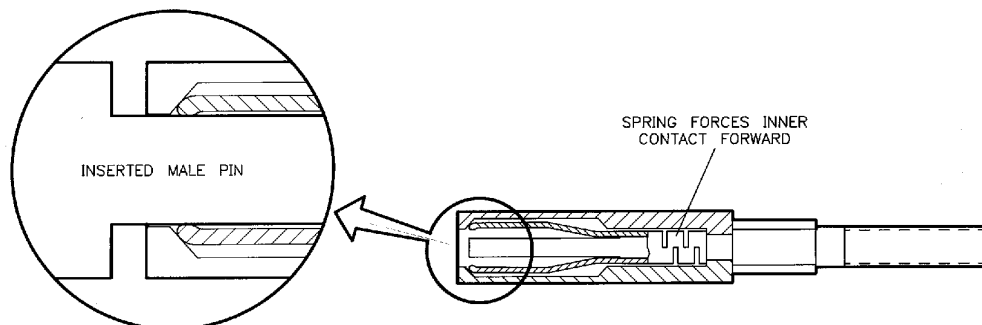
- test set test ports
- test port cables
- precision adapters
- calibration standards
- DUT Connectors

A low power magnifier, less than 6x, is adequate to inspect the parts. Do not be concerned with minor defects such as scratches visible only with the magnifier; these will probably not affect performance. If inspection shows moisture, oil, or other residue, clean the parts.

When examining the female connector, look at the inner contact to see that the gripping fingers are not bent.

The greatest variable in the accuracy and repeatability for these demanding measurements is the experience and attention to detail of the person actually making the connections. Before going on, examine all parts carefully.

**Figure 2-1**      **Detail of Precision Slotless Female Connector**



## **Cleaning**

The parts must be clean in order to achieve best results. Use isopropyl alcohol, dry air or nitrogen, and lint-free swabs to remove contaminants.

In general, do not force cleaning materials into connector parts and do not immerse the part in cleaning fluids. Just moisten the swab and wipe the surface lightly. To dry the part, use a dry swab or light pressure from a dry air or nitrogen source.

Do not leave lint or particles of the swab in the connector.

If there is doubt about the condition of the connector, use the connector gages to check the connector dimensions. The same care should be used for all connectors, especially the device under test.

## Using Connector Gages

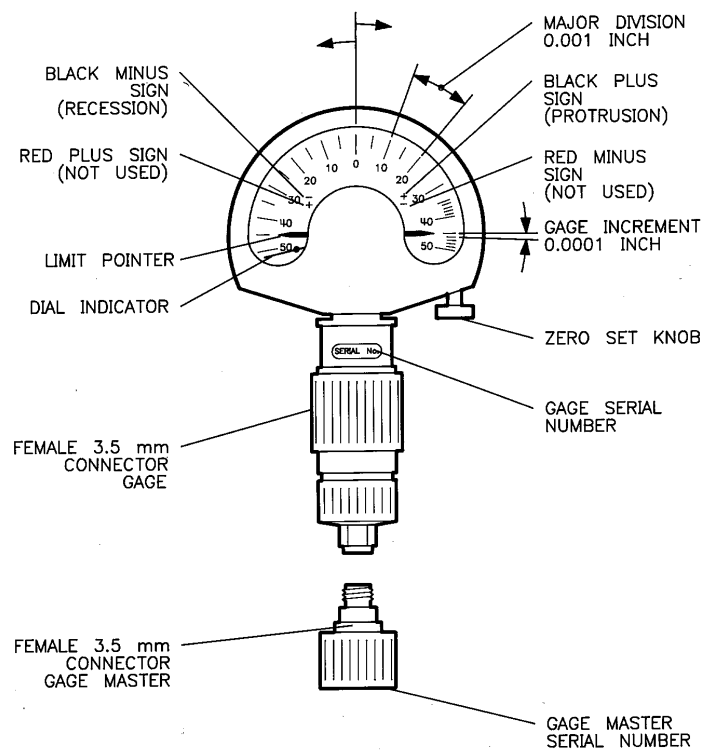
Gaging is optional for the precision connectors in this calibration kit if the male and female center conductors are concentric and do not show physical damage.

### Before Connecting

However, due to the large range of dimensions found on most DUT connectors, the DUT connectors must always be inspected and gaged before connecting them to the precision adapters. This is not usually a problem for the DUT female connectors, but may be a problem for DUT male connectors, especially the economical SMA and SMA-compatible types.

Figure 2-2

### Connector Gage



### Measurement Errors

The gage measures the pin depth (recession) of the connectors. If the pin depth is too far negative, errors will result from excessive air gap in the connection.

### Connector Damage

If the pin depth is positive (protrusion), both mating connectors will almost certainly be damaged.

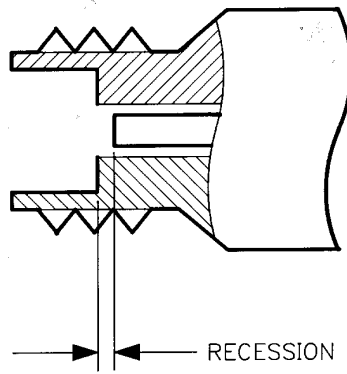
Also, if the male pin diameter is greater than the maximum 3.5 mm specification, it will cause permanent damage to the female receptacle. If you try to measure the pin depth and the gage will not fit over the pin, it is an immediate indication that the pin is too large and must not

be connected to the precision adapters. The male pin of the DUT connector may fit into the gage and give a correct measurement, but still be slightly too large for the precision adapter female receptacle.

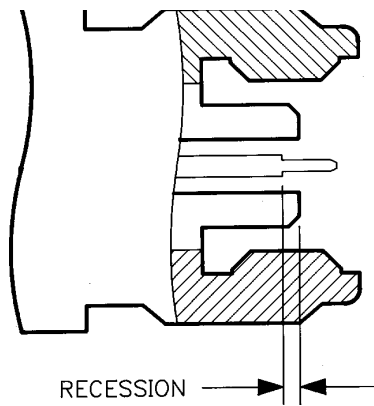
**Repair and Replacement**

In general, bent or deformed parts cannot be repaired in the field. It is necessary to return the part to a service center for repair or replacement. The air line center and outer conductors must be replaced as a set. Refer to the replaceable parts chapter in the service manual supplied with the calibration kit for replacement part numbers and ordering information.

**Figure 2-3 Cross Section of Female Connector Showing Recession Limits**



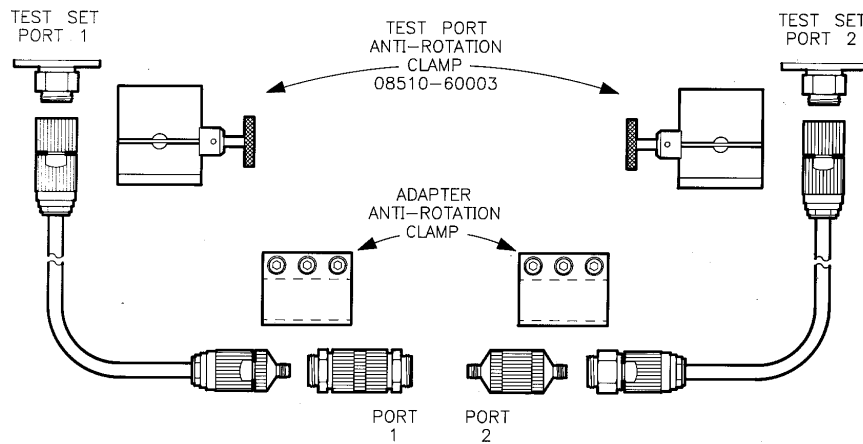
**Figure 2-4 Cross Section of Male Connector Showing Recession Limits**



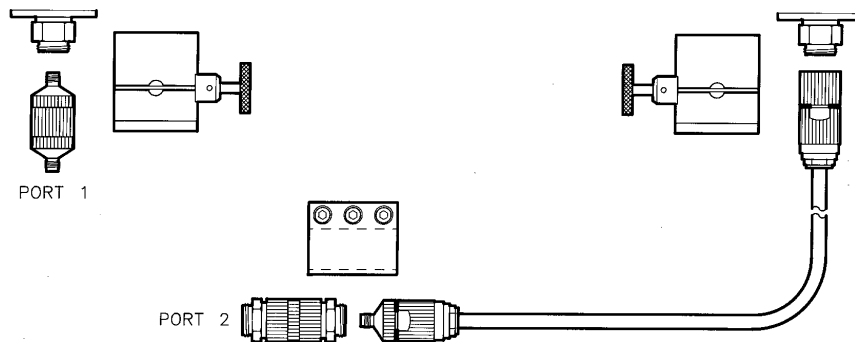
## Configure Port 1 and Port 2

Several configurations are possible, depending upon the frequency range, available cables, operator convenience, and DUT requirements. Following is an example hookup using the two-cable set and two examples using a single cable. The appropriate precision adapters are installed on the ends of the cables and become Port 1 and Port 2.

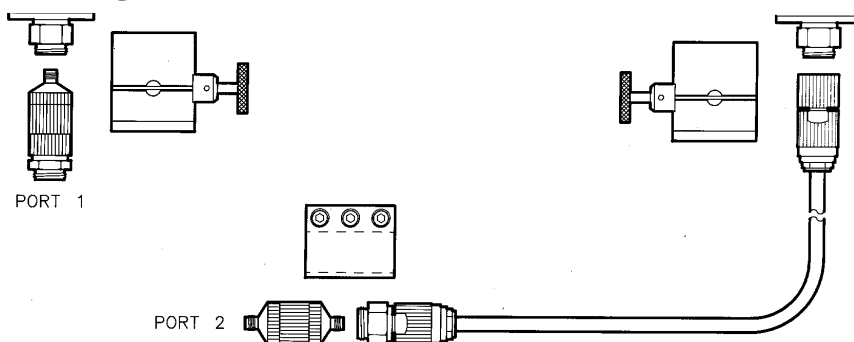
**Figure 2-5 Dual Cable Set**



**Figure 2-6 Single Cable, Port 1 Female**



**Figure 2-7 Single Cable, Port 1 Male**



## **Install Test Port Return Cables**

When all parts are ready for use, connect the test port extension cables. To connect a cable to the test set:

- Loosen the test port anti-rotation clamp securing screw and slide the clamp over the cable far enough to provide access to the cable connector.
- Connect the cable to the test port and tighten using the torque wrench.
- Slide the clamp toward the port, aligning it so that the flats on the clamp mate with flats around the test port. Tighten the clamp securing screw. This clamp keeps the cable from becoming loose from the test set connector.



---

## Install Precision Adapters

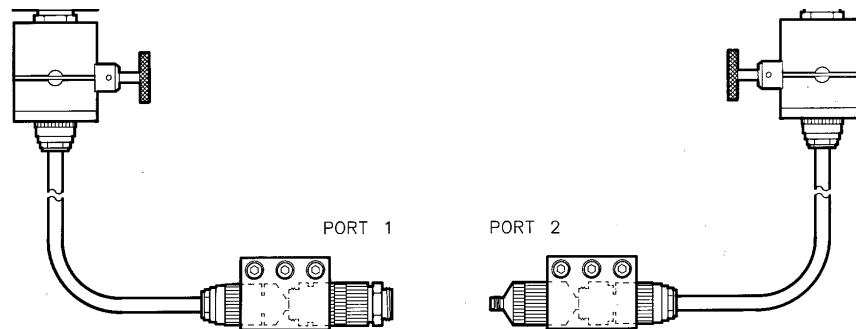
To install the precision adapters and adapter anti-rotation clamp:

- Connect the adapter to the cable, tighten finger tight, and then use the spanner and the torque wrench to achieve the final torque.
- Loosen the adapter anti-rotation clamp securing screws and slide the clamp over the adapter. Align the clamp so that it can grip both the cable connector body and the adapter body. Tighten the clamp securing screws. The screw tightening order is not important.

The adapter anti-rotation clamp assures that the TRL adapter does not become loose during calibration and measurement.

- Connect the second TRL adapter and its anti-rotation clamp to serve as Port 2.

**Figure 2-8 Two Cable Setup with All Components**

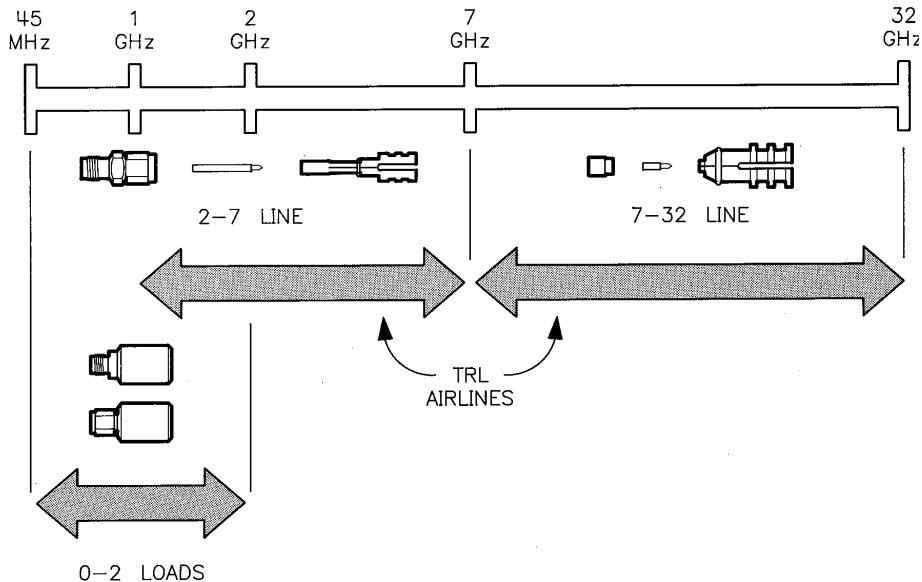


## Air Line Frequency Coverage

This illustration shows the frequency range covered by the air line and fixed loads for the Lines part of the TRL 2-Port calibration procedure. If measuring over the entire frequency range, measure the 7-32 Line first, then the 2-7 Line, then the 0-2 Loads. If measuring over a reduced frequency range, only those standards for that frequency range need to be measured. For example, if you are testing over the 3-22 GHz range, only the 7-32 Line and the 2-7 Line must be measured.

The standard label for the 2-7 Line would indicate that its data is valid only from 2 to 7 GHz. However, you may choose to use data from the 2-7 Line down to the 1 GHz by simply not measuring the 0-2 Loads. If the 0-2 Loads are measured after the 2-7 Line, the 0-2 Loads data will replace data from the 2-7 Line.

**Figure 2-9** Frequency Coverage for Line Part of Measurement Calibration



## **Load Calibration Kit Definition**

To begin measurement calibration, first load the calibration kit definition from disk.

Press:

**DISC**  
**LOAD**  
**CAL KIT 1-2**  
**CAL KIT 1**  
**FILE 1**

When the calibration kit definition is loaded, the CAL 1 softkey label will read 3.5 mm C. 1.

---

## Measure Standards

Now perform the TRL 2-Port measurement calibration procedure using the 85052C 3.5 mm. Precision Calibration Kit.

---

**NOTE**

The standards are measured in the order: Thru, Reflect, Line, Isolation in order to connect the load standards just once.

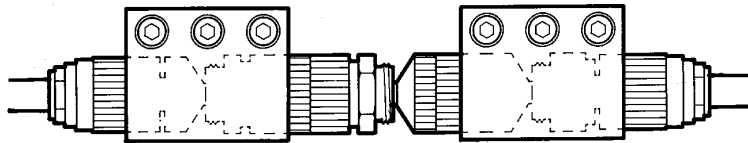
Press:

**CAL**  
**CAL 1**  
**TRL 2-PORT**

- Connect the TRL male adapter (Port 1) to the TRL female adapter (Port 2).
- Press **THRU**. The 8510 makes six measurements; they are  $S_{11}$ ,  $S_{21}$ ,  $S_{12}$ ,  $S_{22}$ , and two specially redefined user parameters.

**Figure 2-10**

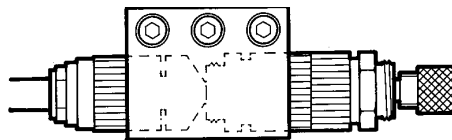
### Thru Standards



- Connect the Short circuit to Port 1.
- Press **S<sub>11</sub> REFLECT SHORT**.  $S_{11}$  is measured.

**Figure 2-11**

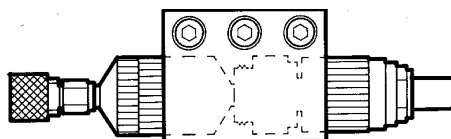
### S<sub>11</sub> Reflection Short Standard



- Connect the Short circuit to Port 2.
- Press **S<sub>22</sub> REFLECT SHORT**.  $S_{22}$  is measured.
- Press **LINES**.

**Figure 2-12**

### S<sub>22</sub> Reflection Short Standard

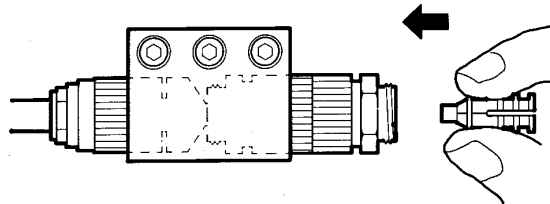


## When Stop Frequency Is Greater than 7 GHz

If the stop frequency is greater than 7 GHz, install the 7-32 GHz air line as follows:

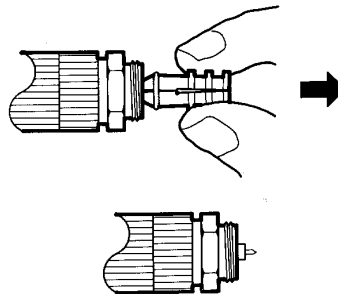
- Move the Port 1 nut to its standard position and carefully insert the air line into the male connector using the installation tool.

**Figure 2-13 Insert Air Line**



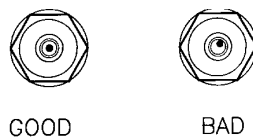
- Squeeze the installation tool (closing the slot) to release the center conductor. Then pull the tool away from the connector, leaving the outer and the center conductors in place.

**Figure 2-14 Squeeze Tool to Release, Then Pull**



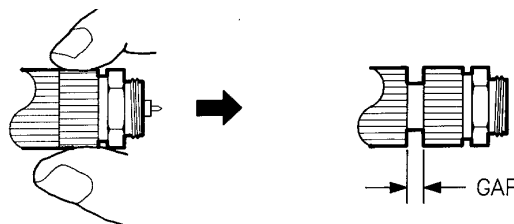
- Examine the outer and center conductors to see that they are in place and concentric. If the center conductor is not centered, use the installation tool to align it.

**Figure 2-15 Check Concentricity**



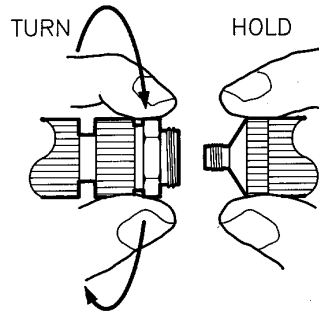
- Move the adapter nut to its extended position.

**Figure 2-16 Extended Position with Air Lines Installed**



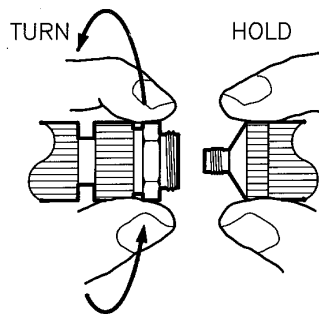
- Carefully align and engage the Port 2 female contact with the Port 1 male contact.
- Tighten finger tight, then use the spanner and torque wrenches to achieve the final torque.

**Figure 2-17 Connect Port 2**



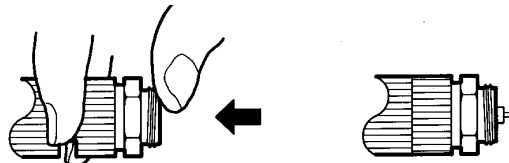
- Press **7-32 LINE**. The 8510 makes six measurements. All frequencies of the current range are measured, but only data from 7 to 32 GHz is used to compute error coefficients.
- To remove the 7-32 GHz air line: Loosen the Port 1 nut, and then carefully move the Port 2 adapter away.

**Figure 2-18 Disconnect Port 2**



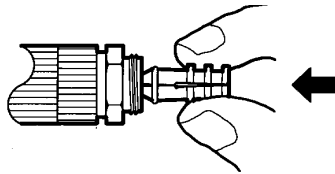
- Move the adapter nut to its standard position.

**Figure 2-19 Standard Position with Air Line Installed**



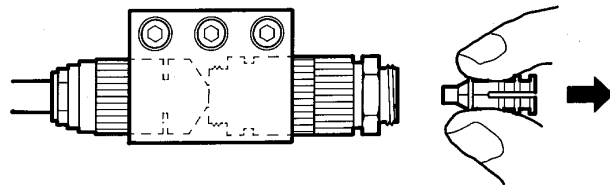
- Examine the outer and center conductors to see that they are in place.
- Carefully press the insertion tool onto the connector.

**Figure 2-20 Connect the Insertion Tool**



- Hold the tool close to the connector without squeezing the tool. Carefully pull the assembly away from the connector.

**Figure 2-21 Remove the 7-32 Line**



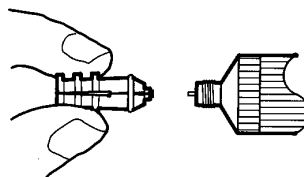
- Check to see that both the inner and the outer conductor have been removed and are secure in the installation tool.

If any part of the air line remains attached to the male port, first press the tool back onto the connector. Then, try to withdraw the tool and the air line parts again without closing the slot.

If the air line center conductor remains with the female port, use the installation tool to remove it as follows:

- Squeeze the tool and push it to engage the center conductor.
- Hold the tool close to the connector, squeeze the tool without closing the slot, and pull the assembly away.
- Use your fingers to remove the center conductor from the tool.

**Figure 2-22 Remove Center Conductor from Port 2 (if necessary)**



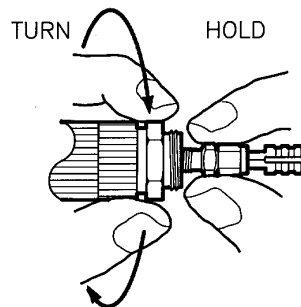
- Carefully insert the center conductor back into the installation tool, male end first.

## When Start Frequency Is Less Than 7 GHz

If the start frequency is less than 7 GHz, install the 2-7 GHz air line as follows:

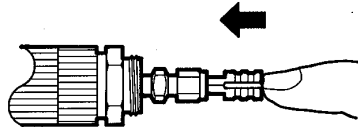
- Move the Port 1 nut to its standard position. Carefully insert the air line outer conductor and center pin into the male connector using the installation tool.
- Hold the air line outer conductor and tighten the Port 1 nut finger tight. Use the torque wrench to achieve the final torque.

**Figure 2-23** Connect the 2-7 Line



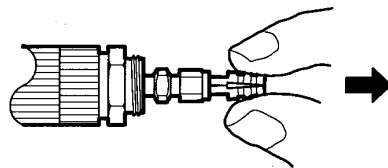
- Press the tool lightly to engage the center conductor.

**Figure 2-24** Engage the Center Conductor



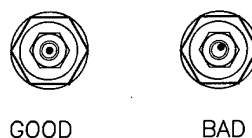
- Squeeze the tool to close the slot, then pull the tool away from the connector, leaving the center conductor.

**Figure 2-25** Remove the Tool



- Examine the outer and center conductors to see that they are in place and concentric. If the center conductor is not centered, use the tip of the installation tool to align it.

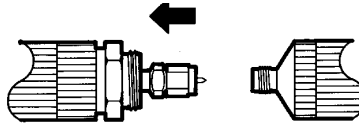
**Figure 2-26** Check the Concentricity





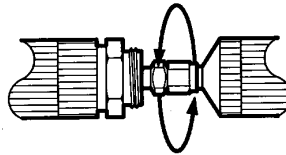
- Move the air line nut back to expose the center conductor. Carefully engage the Port 2 female contact with the Port 1 male contact. Be patient when making this connection because it is easy to move the center conductor off center.

**Figure 2-27 Move the Nut Back**



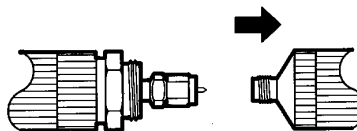
- Move the nut forward to engage the threads, tighten finger tight, then use the spanner and the torque wrench to achieve the final torque.

**Figure 2-28 Connect Port 2**



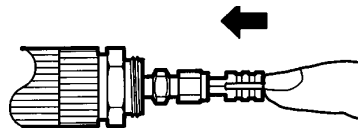
- Press 2-7 LINE. The 8510 makes six measurements. All frequencies of the current range are measured, but data from 1 GHz to 7 GHz is used to compute error coefficients.
- To remove the 2-7 GHz air line: Loosen the air line nut and carefully move Port 2 away from Port 1.

**Figure 2-29 Disconnect Port 2**



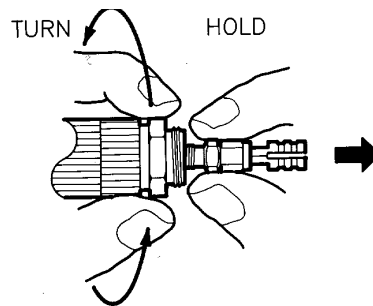
- Insert the tool and lightly press it to engage the center conductor.

**Figure 2-30 Engage the Tool**



- Loosen the adapter nut and then disconnect the outer conductor from the adapter. The center conductor will be removed with the outer conductor.

**Figure 2-31 Remove 2-7 Line**



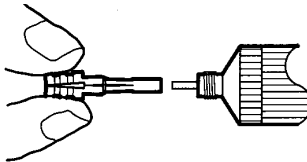
---

**NOTE**

It is important to be very careful to move Port 2 away in a straight motion because the center conductor may stay Port 2. If the center conductor remains with the female port, use the installation tool to remove it. Carefully insert the center conductor back into the insertion tool, male end first.

---

**Figure 2-32 Remove Center Conductor from Port 2 (if necessary)**

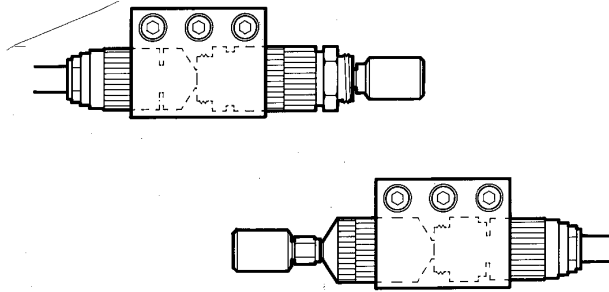


### **When Start Frequency Is Less than 2 GHz**

If the start frequency is less than 2 GHz, measure the 0-2 Loads as follows:

- Connect a fixed load to Port 1 and a fixed load to Port 2.
- Press **0-2 LOADS**. The 8510 makes six measurements. All frequencies are measured, but only data up to 2 GHz are used. These measurements replace error coefficients obtained from measurement of the 2-7 GHz air line below 2 GHz. Leave the loads connected for the Isolation step.

**Figure 2-33 Connect the 0-2 Loads**



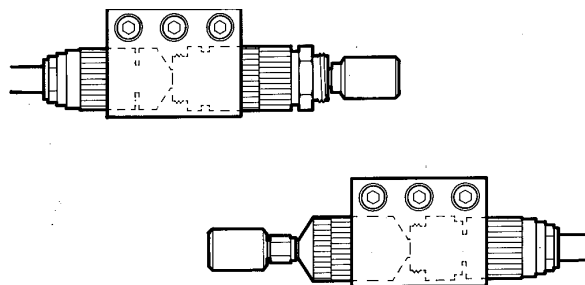
- Press **LINES DONE**.
- Press **ISOLATION**.

If maximum transmission dynamic range is not required, skip the isolation part of the calibration by pressing **OMIT ISOLATION** and then **ISOLATION DONE**.

Or, to obtain maximum transmission dynamic range, perform the isolation part of the calibration as follows:

- Connect a fixed load to Port 1 and a fixed load to Port 2.
- Increase the **AVERAGING FACTOR** for the isolation measurement to at least 128. Then press **FWD. ISOL'N ISOL'N STD.**  $S_{21}$  is measured.
- Press **REV. ISOL'N ISOL'N STD.**  $S_{12}$  is measured.
- Press **ISOLATION DONE**. You may wish to reduce the averaging factor for measurement of the device under test.
- Press **SAVE TRL 2-PORT**.

**Figure 2-34 Reverse Isolation Standards**



When the computation of error coefficients is complete, press **CAL SET 1** (or any other cal set). Error coefficients derived from measurement of the TRL standards are computed and saved, and then 2-Port correction is turned on.

---

**CAUTION**

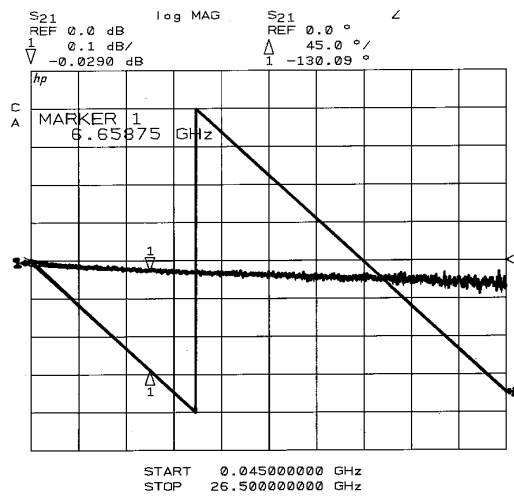
Carefully inspect the connectors on the device under test and measure their center conductor pin depth before connecting the device under test to the system. Device under-test connectors with incorrect pin size, pin depth, or pin alignment can damage the test port adapters.

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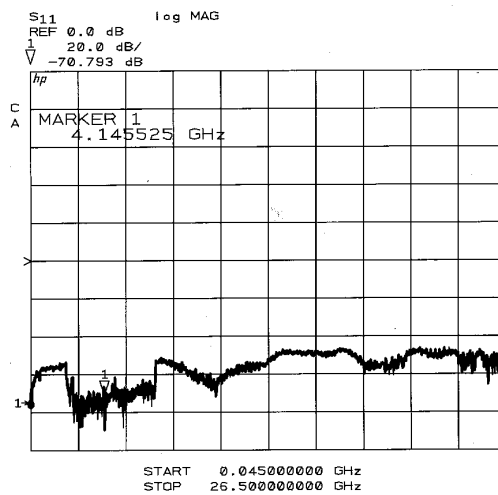
## Check the Calibration

A good first check of the calibration is to measure the transmission and reflection characteristics of the longer air line. Connect the air line between Port 1 and Port 2 and view the  $S_{21}$  magnitude and phase and the  $S_{11}$  magnitude. The air line should exhibit low insertion loss and linear phase. The  $S_{11}$  should be constant over the entire frequency range.

**Figure 2-35** 2-7 Line  $S_{11}$  Magnitude



**Figure 2-36** 2-7 Line  $S_{21}$  Magnitude and Phase

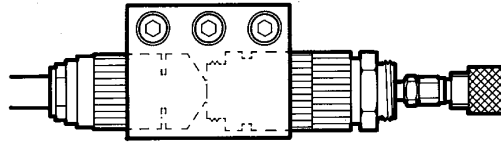


For a second check, connect the 2-7 Line to Port 1, then connect the Short circuit to the end of the air line, and view the reflection response.

Select:

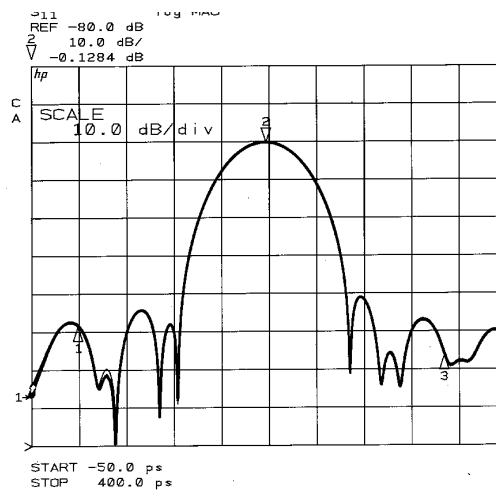
**S<sub>11</sub>**  
**DOMAIN**  
**TIME BAND PASS**

**Figure 2-37** Line with Short Circuit



View the S<sub>11</sub> response. Use the marker to measure the responses at 0 seconds (a rough measure of effective directivity) and the mismatch at twice the length of the air line (a rough measure of effective source mismatch). The trace should appear as shown below. If not, the calibration has not been performed correctly or the calibration devices are defective.

**Figure 2-38** Plot of Time Band with Shorted Air Line



Performing a TRL 2-Port Measurement Calibration  
**Check the Calibration**

---

## **3 Noninsertable Devices**

## General Theory

The following sequence describes the adapter removal method of calibration for measurement of a noninsertable device. This procedure is the most complete and effective calibration procedure for measurement of noninsertable devices. Although this technique does require two separate 2-Port calibrations, it remains the only traceable method for minimizing the uncertainty in this measurement. The three precision adapters in this calibration kit provide the parts required to make the process relatively easy.

Detailed information about the adapter removal calibration is contained in Product Note 8510-13, available from your local Sales Office.

The previous calibration sequence assumed that the device under test is insertable; it has a male connector on one port and a female connector on the other port. Thus, the measurement system can be calibrated and then the test device inserted without changing the system test port connectors.

However, the majority of devices used in microwave systems are noninsertable. Of interest here are devices having either both male or both female 3.5 mm connectors on Port 1 and Port 2.



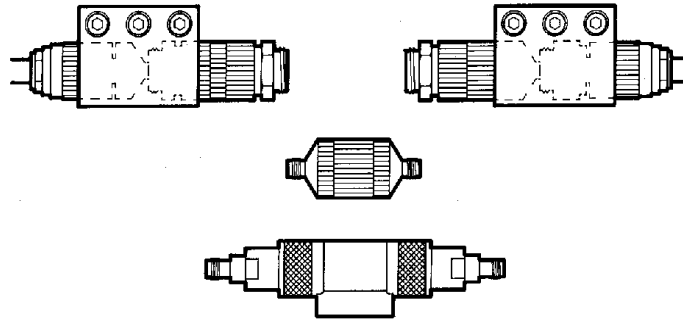
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## Noninsertable Device Configurations

### Female to Female

If the device you are measuring has two female connectors, your setup would look like the figure below. The female-to-female precision adapter is substituted for the device under test to accomplish this calibration.

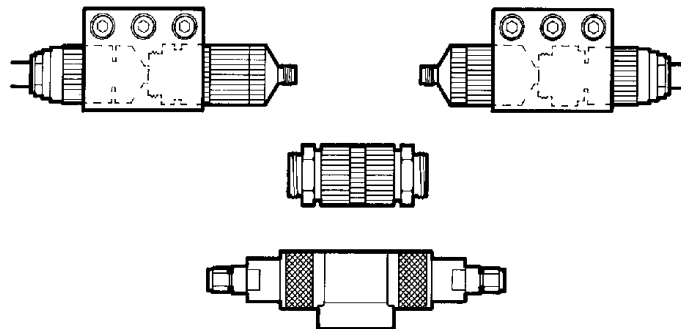
**Figure 3-1** Female-Female Device Under Test



### Male to Male

If the device you are measuring has two male connectors, your setup would look like the figure below. The male-to-male precision adapter is substituted for the device under test to accomplish this calibration.

**Figure 3-2** Male-Male Device Under Test



---

## Adapter Removal Calibration Procedure

### Create Cal Set for Port 1

First create the Port 1 calibration set by performing the TR 2-Port calibration between Port 1 and the adapter. Keep the adapter connected to Port 2 during the entire procedure. Save the calibration in Cal Set 1.

Figure 3-3

### Port 1 Cal Set



### Create Cal Set for Port 2

Next create the Port 2 calibration set by performing the TRL 2-Port calibration between Port 2 and the adapter. Keep the adapter connected to Port 1 during the entire procedure. Save the calibration in Cal Set 2.

Figure 3-4

### Port 2 Cal Set



### Adapter Removal Mathematics

The Adapter Removal function mathematically combines the Port 1 cal set with the Port 2 cal set to produce a third cal set having the effects of the adapter removed. The resulting cal set is as if Port 1 and Port 2 could be connected together.

When the two calibrations have been saved, proceed with the adapter removal sequence as follows:

Press:

**CAL**  
**MORE**  
**MODIFY CAL SET**  
**ADAPTER REMOVAL**

- Press **CAL SET** for **PORT 1**, then **CAL SET 1**.
- Press **CAL SET** for **PORT 2**, then **CAL SET 2**.
- Press **ADAPTER 3.5 mm C.1**. This specifies the calibration kit that includes the length specification for the precision adapter.
- Press **MODIFY & SAVE**, then **CAL SET 3**.

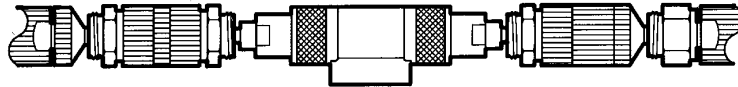
The new calibration set is computed and stored. 2-Port correction is turned on.

Now remove the third adapter and connect the device under test.

The display should now show an accurate S-parameter measurement of the device.

**Figure 3-5**

**Remove the Adapter and Connect the DUT**



Noninsertable Devices  
Adapter Removal Calibration Procedure

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## **4 Other Calibrations**

## Changing the Air Line Frequency Range

If your application requires a frequency range slightly beyond the standard frequency range of one of the precision air lines, you may extend the frequency range of one of the air lines in order to accomplish the calibration by connecting only one of the air lines.

The error coefficients are determined with best accuracy when the Thru and the Line phase response is separated by  $\pm 90$  degrees at corresponding frequencies. When the transmission phase response of a line standard is the same or gets very close to zero or 180 degrees of the Thru standard at the same frequency, the result becomes less certain. The correct result cannot be determined when the phase response is exactly equal or 180 degrees apart. This is why a particular length air line covers a specific frequency range.

To evaluate the phase response, first do a simple transmission frequency response calibration using the Thru standard (Port 1 connected directly to Port 2), then measure the  $S_{21}$  phase of the air line. The standard air line frequency specifications provide for greater than 20 degrees separation.

Experiment with this by using the Modify Cal Kit function to change the Minimum Frequency or Maximum Frequency specification for the air line, and then performing the TRL 2-Port calibration procedure. With correction on, trace noise on the error-corrected trace may increase at the points where the phase of the air line used for calibration approaches the phase of the thru, often showing large discontinuities at the point where the phase of both standards are identical or separated by 180 degrees.

If this error is acceptable in your measurement, change the standard label for the air line and save the redefined cal kit on disk for later use. If the error is not acceptable, reload the standard cal kit definition.

## **Lowband Reflection Instead of 0-2 Loads or 2-7 Line**

The Lowband Reflection part of the TRL 2-Port procedure is optional. If used, error coefficients obtained by this procedure replace measurements of the 0-2 loads.

For this calibration kit, the lowband reflection part of the calibration is typically not used because measurement of the 0-2 Loads provides better accuracy (given that the loads are in good condition and repeatable).

If you do not select LOWBAND REFLECTION, the error coefficients obtained from measurement of the TRL standards are used over the complete current frequency range. If you do select LOWBAND REFLECTION, error coefficients obtained from these additional calibration steps will be used up to 2 GHz.

In actual measurement applications, the Lowband Reflection option will not produce greater accuracy than using the 0-2 Loads. If you are uncertain, it is relatively simple to compare measurement results using the different techniques.

## Lowband Reflection Procedure

Selecting the Lowband Reflection part of the procedure guides you through these additional steps to measure an open circuit, short circuit, and fixed load at Port 1 and an open circuit, short circuit, and fixed load at Port 2. So, if start frequency is less than 2 GHz and you wish to use the open/short/load technique for calibration below 2 GHz, then after measuring the Thru, Reflect, Isolation and Line standards and before pressing **SAVE TRL 2-PORT**, perform the following lowband reflection sequence.

Measure Thru, Reflect, Isolation, and Line standards. If the start frequency is less than 2 GHz, press **LOWBAND REFLECTION**.

- Press **LOWBAND REFLECTION**
- Connect the Short circuit to Port 1 and then press (**S<sub>11</sub>**): **SHORT**.
- Connect the Open circuit to Port 1 and then press (**S<sub>11</sub>**): **OPEN**.
- Connect the Fixed Load to Port 1 and then press (**S<sub>11</sub>**): **LOAD**.
- Connect the Short circuit to Port 2 and then press (**S<sub>22</sub>**): **SHORT**.
- Connect the Open circuit to Port 2 and then press (**S<sub>22</sub>**): **OPEN**.
- Connect the fixed load to Port 2 and then press (**S<sub>22</sub>**): **LOAD**.
- Press **REFLECT'N DONE**.
- Press **SAVE TRL 2-PORT**, and then **CAL SET 1**, (or any other cal set).

When **SAVE** is pressed, error coefficients from measurement of the Open, Short, and Load are used for frequencies below GHz, and coefficients from measurement of the Thru, Reflect and Line are used for frequencies above 2 GHz.