

# **User's and Service Guide**

## **Agilent Technologies 11644A R, Q, U, V, and W Waveguide Calibration Kits**

This manual applies to 11644A series calibration kits with  
serial number prefix 3032A.



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For any assistance, contact Agilent Technologies. Refer to [“Contacting Agilent” on page 6-5](#) for a list of Agilent contacts.

<b>1. General Information</b>	
Calibration Kit Overview	1-2
Kit Contents	1-2
Compatible Network Analyzers	1-2
Equipment Required but Not Supplied	1-3
Calibration Kit History	1-3
11644A Series Kits with Serial Prefix 3012A	1-3
Incoming Inspection	1-3
Recording the Device Serial Numbers	1-4
Preventive Maintenance	1-5
<b>2. Specifications</b>	
Environmental Requirements	2-2
Temperature—What to Watch Out For	2-2
Mechanical Characteristics	2-3
$\frac{1}{4}$ Wavelength Shims	2-3
Shorts	2-3
Electrical Specifications	2-4
Measurement Uncertainty	2-5
Certification	2-5
<b>3. User Information</b>	
Calibration Devices and Their Use	3-2
Short	3-2
Standard Section	3-2
Termination	3-2
$\frac{1}{4}$ Wavelength Shim	3-2
Waveguide Straight Section (verification device)	3-2
Waveguide Straight Section (port 1 and 2)	3-2
Measurement Applications	3-3
Isolation	3-3
Line	3-3
Load	3-4
Offset Load	3-4
Offset Short	3-5
Reflect	3-5
Short	3-5
Thru	3-6
$\frac{1}{4}$ Wavelength Load	3-6
$\frac{1}{4}$ Wavelength Short	3-6
Changing the $\frac{1}{4}$ Wavelength Shim Calibration Definition	3-7
<b>4. Use, Maintenance, and Care of the Devices</b>	
Electrostatic Discharge	4-2
Visual Inspection	4-3
Cleaning the Mating Plane Surfaces	4-3
Connections	4-5
Waveguide Devices	4-5

Precision Flanges . . . . .	4-5
Aligning Two Precision Flanges . . . . .	4-6
Aligning a Precision and a Non-Precision Flange . . . . .	4-7
Tightening a Flange Connection . . . . .	4-8
Inspecting a Flange Connection . . . . .	4-8
Handling and Storage . . . . .	4-9
<b>5. Performance Verification</b>	
Introduction . . . . .	5-2
How Agilent Verifies the Devices in Your Kit . . . . .	5-2
Recertification . . . . .	5-3
How Often to Recertify . . . . .	5-3
Where to Send a Kit for Recertification . . . . .	5-3
Performance Test . . . . .	5-4
Termination Return Loss Measurement . . . . .	5-4
In Case of Failure . . . . .	5-5
<b>6. Troubleshooting</b>	
Troubleshooting Process . . . . .	6-2
Returning a Kit or Device to Agilent . . . . .	6-4
Where to Look for More Information . . . . .	6-4
Contacting Agilent . . . . .	6-5
<b>7. Replaceable Parts</b>	
Introduction . . . . .	7-3
<b>A. Standard Definitions</b>	
Version Changes . . . . .	A-2
Standard Class Assignments . . . . .	A-3
Blank Forms . . . . .	A-6
Nominal Standard Definitions . . . . .	A-8
Setting the System Impedance . . . . .	A-8
Blank Forms . . . . .	A-19

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# 1 General Information

## Calibration Kit Overview

This waveguide calibration kit is used to calibrate network analyzer systems (such as the Agilent 8510, 872x, or PNA series). With the calibration data properly loaded in the network analyzer and a measurement calibration completed, systematic errors are minimized.

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**NOTE** TRL (thru-reflect-line) calibrations require Agilent 8510 operating system firmware revision B.05.12 or greater.

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### Kit Contents

Refer to [Chapter 7, “Replaceable Parts,”](#) for a complete list of kit contents and their associated part numbers.

The basic 11644A calibration kit includes the following items:

- user’s and service guide
- short, shim, termination, waveguide straight, and standard sections
- data disks that contain the calibration definitions of the devices in the calibration kit

The standards in this calibration kit allow you to perform simple 1- or 2-Port and TRM (thru-reflect-match) calibrations.

For your convenience, two different lengths of screws are provided in this kit. While you can use the long screws for any connection, the shorter screws provide a faster connection for two-flange connections.

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**NOTE** A backup copy of each data disk should be made immediately upon receipt of the waveguide calibration kit. Refer to your analyzer user’s guide for instructions on duplicating a disk.

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### Compatible Network Analyzers

The 11644A calibration kits are intended to be used with the following Agilent network analyzers:

- 8510 series
- 872x series
- PNA microwave series

If this calibration kit is used with other network analyzers, the calibration definitions must be manually entered into the network analyzer. Refer to your network analyzer user’s guide for instructions or embedded help for instructions.

## Equipment Required but Not Supplied

Cleaning supplies and various electrostatic discharge (ESD) protection devices are not supplied with the calibration kit but are required to ensure successful operation of the kit. Refer to [Table 7-6 on page 7-14](#) for their associated part numbers.

---

## Calibration Kit History

This manual applies to any Agilent 11644A series (R, Q, U, V, or W) waveguide calibration kits whose serial number prefix is listed on the title page. If your calibration kit has a different serial number prefix, refer to the next section for information on how this manual applies.

### 11644A Series Kits with Serial Prefix 3012A

These calibration kits did not have the calibration definitions disk to support the Agilent 8510C network analyzer. The part numbers provided in this manual are the recommended replacement parts for these kits. The devices in these kits should meet the specifications published in this manual.

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## Incoming Inspection

Refer to [“Kit Contents” on page 1-2](#) to verify a complete shipment. Use [Table 1-1](#) in this chapter to record the serial numbers of all serialized devices in your kit.

Verify that the case and its contents are not damaged. The foam-lined storage case provides protection during shipping. If the case or any device appears damaged, or if the shipment is incomplete, refer to [“Contacting Agilent” on page 6-5](#). Agilent will arrange for repair or replacement of incomplete or damaged shipments without waiting for a settlement from the transportation company. Refer to [“Returning a Kit or Device to Agilent” on page 6-4](#).

## Recording the Device Serial Numbers

In addition to the kit serial number, the devices in the kit are individually serialized (serial numbers are labeled onto the body of each device). Record these serial numbers in the appropriate table. Recording the serial numbers will prevent confusing the devices in this kit with similar devices from other kits.

**Table 1-1 V and W Band Serial Number Record**

Device	Serial Number
<b>Frequency band</b>	_____
<b>Calibration kit</b>	_____
Fixed load	_____
Straight section (5 cm)	_____
Straight section (5 cm)	_____
Straight section (5 cm)	_____
Shim	_____
Short	_____

**Table 1-2 R, Q, and U Band Serial Number Record**

Device	Serial Number
<b>Frequency band</b>	_____
<b>Calibration kit</b>	_____
Straight section (5 cm)	_____
Straight section (5 cm)	_____
Standard section (10 cm)	_____
Waveguide straight	_____
Shim	_____
Short	_____



## Preventive Maintenance

The best techniques for maintaining the integrity of the devices in the kit include:

- routine visual inspection
- routine cleaning
- proper gaging
- proper connection techniques

All of these are described in [Chapter 4](#). Failure to detect and remove dirt or metallic particles on a mating plane surface can degrade repeatability and accuracy and can damage any device mated to it. Improper connections resulting from poor connection techniques, can also damage these devices.



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## **2 Specifications**

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## Environmental Requirements

**Table 2-1 Environmental Requirements**

Parameter	Limits
Temperature	
Operating <sup>a</sup>	+20 °C to +26 °C
Storage	-40 °C to +75 °C
Error-corrected range <sup>b</sup>	±1 °C of measurement calibration temperature
Altitude	
Operating	< 4,500 meters (≈15,000 feet)
Storage	< 4,500 meters (≈15,000 feet)
Relative humidity	Always non-condensing
Operating	Up to 80% at 30°C
Storage	Up to 90% at 40°C

- a. The temperature range over which the calibration standards maintain performance to their specifications.
- b. The allowable network analyzer ambient temperature drift during measurement calibration and during measurements when the network analyzer error correction is turned on. Also, the range over which the network analyzer maintains its specified performance while correction is turned on.

### Temperature—What to Watch Out For

Changes in temperature can affect electrical characteristics. Therefore, the operating temperature is a critical factor in performance. During a measurement calibration, the temperature of the calibration devices must be stable and within the range shown in [Table 2-1](#).

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**IMPORTANT** Avoid unnecessary handling of the devices during calibration because your fingers act as a heat source and may increase the temperature of the device.

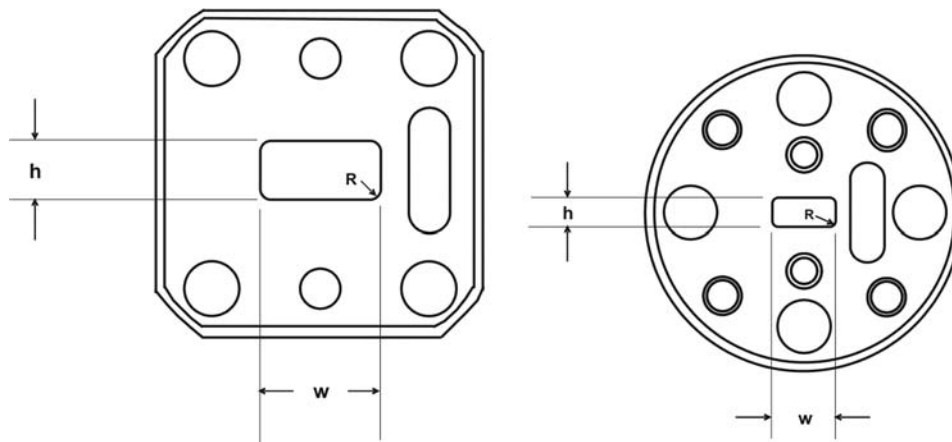
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## Mechanical Characteristics

Table 2-2 lists the typical characteristics of the  $\frac{1}{4}$  wavelength shims in your kit. These are *not* specifications, but are included as additional information.

### $\frac{1}{4}$ Wavelength Shims

**Figure 2-1**  $\frac{1}{4}$  Wavelength Shims



**Table 2-2** Mechanical Characteristics of  $\frac{1}{4}$  Wavelength Shims

Part Number	Waveguide Band	W (mm)	H (mm)	R (mm)	Thickness (mm)
11664-20003	WR28	7.112 ±0.006	3.556 ±0.006	0.043 max	3.018 ±0.013
11664-20001	WR22	5.690 ±0.006	2.845 ±0.006		2.422 ±0.013
11664-20002	WR19	4.775 ±0.006	2.388 ±0.006		1.991 ±0.013
11664-20013	WR15	3.759 ±0.006	1.880 ±0.006		1.611 ±0.005
11664-20014	WR10	2.540 ±0.006	1.270 ±0.006		1.085 ±0.005

### Shorts

All waveguide shorts are flat within 0.008 mm.

## Electrical Specifications

Table 2-3 through Table 2-5 list the electrical specifications of the terminations,  $\frac{1}{4}$  wavelength shims, and standard sections in your kit.

**Table 2-3 Electrical Specifications of Terminations**

Device	Frequency	Termination Specification
R11644A WR-28	26.5 to 40 GHz	Effective return loss $\geq 46$ dB <sup>a</sup>
Q11644A WR-22	33 to 50 GHz	Effective return loss $\geq 46$ dB <sup>a</sup>
U11644A WR-19	40 to 60 GHz	Effective return loss $\geq 46$ dB <sup>a</sup>
V11644A WR-15	50 to 75 GHz	Return loss $\geq 38.2$ dB
W11644A WR-10	75 to 110 GHz	Return loss $\geq 36.6$ dB

a. Effective return loss accounts for line section, connector, and load stability as used in a network analyzer to define directivity after calibration.

**Table 2-4 Electrical Specifications of  $\frac{1}{4}$  Wavelength Shims**

Part Number	Waveguide Band	Return Loss (dB) <sup>a</sup>
11664-20003	WR28	50
11664-20001	WR22	
11664-20002	WR19	
11664-20013	WR15	
11664-20014	WR10	46

a. Return loss specification is guaranteed by mechanical specifications.

**Table 2-5 Electrical Specifications of Standard Sections**

Device	Frequency	Standard Section Specification
R11644A WR-28	26.5 to 40 GHz	Return loss $\geq 42$ dB
Q11644A WR-22	33 to 50 GHz	Return loss $\geq 42$ dB
U11644A WR-19	40 to 60 GHz	Return loss $\geq 42$ dB
V11644A WR-15	50 to 75 GHz	Return loss $\geq 40$ dB
W11644A WR-10	75 to 110 GHz	Return loss $\geq 36.6$ dB

## Measurement Uncertainty

Vector Network Analyzer (VNA) measurement accuracy depends on the accuracy of the calibration standards, the calibration method employed, instrumentation accuracy and stability, environmental factors, and the actual characteristic of the device under test (DUT). Because of the complexity in these relationships, Agilent created uncertainty computation tools to calculate the overall measurement uncertainty of a VNA system. In the past, when the Agilent 8510 VNA system was being produced, a “Specification and Verification” RMB program was included to perform an uncertainty calculation. Currently, for the Agilent PNA and ENA families of network analyzers, a customer can download the VNA Uncertainty Calculator program. (To access this program from the Web, navigate to [www.agilent.com](http://www.agilent.com) and enter “calculator” in the Search function.) Explanations of the uncertainty model are provided in the PNA embedded Help files. Additional references on VNA measurements are available from the Agilent Applications Notes and Technical Papers Web page, accessed from [www.agilent.com](http://www.agilent.com) by clicking on the Application Notes and Technical Papers hyperlink.

## Certification

Agilent Technologies certifies that this product met its published specifications at the time of shipment from the factory. Agilent further certifies that its calibration measurements are traceable to the United States National Institute of Standards and Technology (NIST) to the extent allowed by the institute’s calibration facility, and to the calibration facilities of other International Standards Organization members. See “[How Agilent Verifies the Devices in Your Kit](#)” on page 5-2 for more information.





## **3 User Information**

## Calibration Devices and Their Use

The R, Q, U, V, and W11644 waveguide calibration kits may contain some or all of the following: short, standard section, termination loads, wavelength shim, and waveguide straights.

The following briefly describes the design and construction of all the calibration kit devices.

---

**IMPORTANT** To ensure calibration accuracy, you must use the alignment slip pins in the precision flanges. Refer to [“Precision Flanges” on page 4-5](#).

---

### Short

A short is also called a flush short. It is connected directly to the test port, or used as an offset short when combined with the  $\frac{1}{4}$  wavelength shim.

### Standard Section

A standard section is used to check system operation after you complete a calibration.

### Termination

A termination is also called a load. It is connected directly to the test port, or used as an offset load when combined with the  $\frac{1}{4}$  wavelength shim.

### $\frac{1}{4}$ Wavelength Shim

A  $\frac{1}{4}$  wavelength shim is also called an offset, or  $\frac{1}{4}$  wavelength section. The shim is terminated by the short, fixed load, or the second test port of the analyzer.

### Waveguide Straight Section (verification device)

A waveguide straight is included as a system verification device. Be sure to keep it protected from wear and damage. When using it, always connect the same side, in the same orientation, for consistent and accurate mating.

### Waveguide Straight Section (port 1 and 2)

Two waveguide straights, provided in this kit, are used as port 1 and port 2 measurement planes when properly connected to the directional couplers. Because these straight sections are used as port 1 and port 2 for device connections, they reduce wear that would otherwise occur to the coupler flanges. These particular straights should be replaced or renewed whenever the calibration devices are replaced or renewed.

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## Measurement Applications

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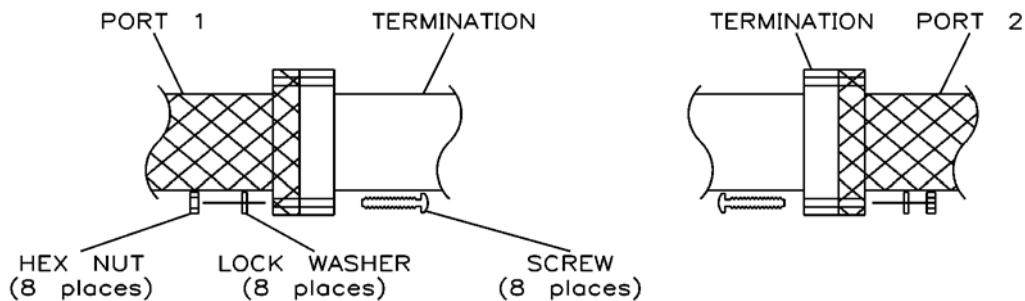
**NOTE** For your convenience, two different lengths of screws are provided in this kit. While you can use the long screws for any connection, the *shorter screws* provide a faster connection for two-flange connections.

---

### Isolation

In most cases, select the **OMIT ISOLATION** softkey on your network analyzer. You may also use the termination and the short as the port terminations by connecting one load to port 1 and the other load to port 2. See [Figure 3-1](#).

**Figure 3-1 Termination and Short**

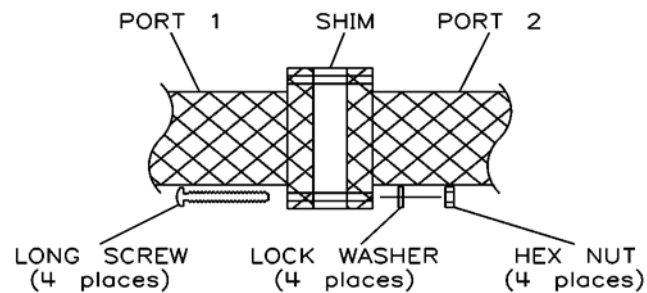


wx401a

### Line

Connect the shim between port 1 and port 2, as shown in [Figure 3-2](#).

**Figure 3-2 Connecting the Shim**

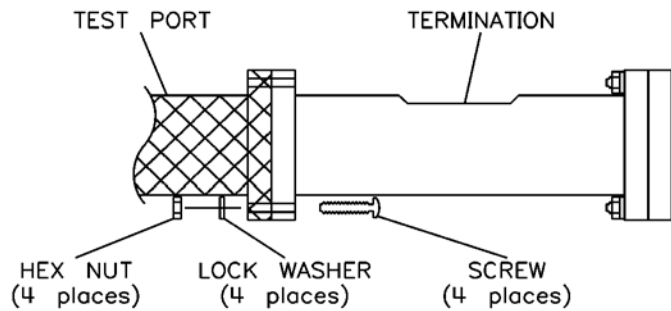


wx402a

## Load

Connect the termination to the appropriate test port, as shown in [Figure 3-3](#).

**Figure 3-3 Test Port and Termination**



wx403a

## Offset Load

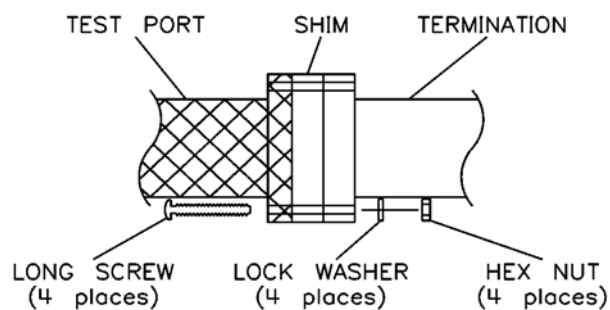
Connect the shim and the termination to the appropriate test port, as shown in [Figure 3-4](#)

---

**NOTE** For offset load calibration with the R11644A WR-28, Q11644A WR-22, and U11644A WR-19, the moving load must be in a locked position. For more information refer to your network analyzer user's guide.

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**Figure 3-4 Connect the Shim and the Termination to the Test Port**

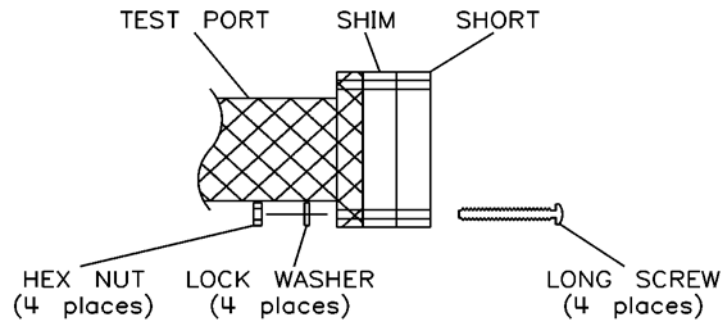


wx404a

## Offset Short

Connect the shim and the short to the appropriate test port, as shown in [Figure 3-5](#).

**Figure 3-5 Connect the Shim and the Short to the Test Port**

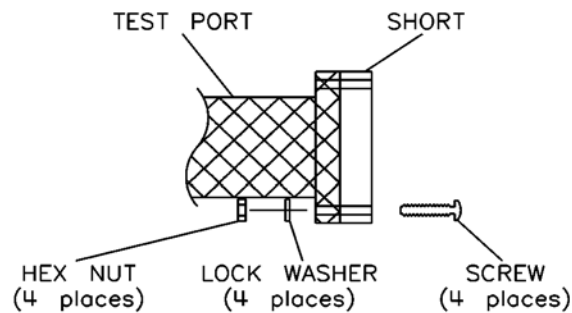


wx405a

## Reflect

Connect the short to the appropriate test port, as shown in [Figure 3-6](#).

**Figure 3-6 Connect the Short to the Test Port**



wx406a

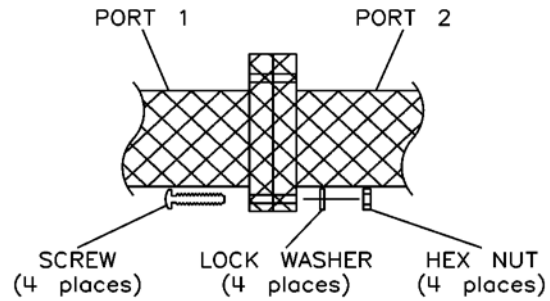
## Short

See [“Reflect”](#) above.

## Thru

No device is required for this. Connect port 1 to port 2, as shown in [Figure 3-7](#).

**Figure 3-7 Connect Port 1 to Port 2**



wx407a

## $\frac{1}{4}$ Wavelength Load

See [“Offset Load”](#).

## $\frac{1}{4}$ Wavelength Short

See [“Offset Short”](#).

---

## Changing the ¼ Wavelength Shim Calibration Definition

The calibration kit definition data provided with this kit has a nominal value for the ¼ wavelength shim offset delay. You may use the nominal value provided, or measure the exact thickness of the shim and use that value to calculate its exact offset delay. Use the following procedure to change the nominal value of the ¼ wavelength shim delay to reflect the specific device in your kit.

1. Load the calibration kit data into Cal Kit 1.
2. Using the formula below, calculate the offset delay:

$$\frac{\text{length of } \frac{1}{4} \text{ wavelength section (mm)}}{299.6953 \frac{\text{mm}}{\text{ns}} (\text{propagation velocity in air})} = \text{offset delay (ns)}$$

---

**NOTE** The value of the propagation velocity in air is corrected for a temperature of 23 °C, 50% relative humidity, and 760 mm Hg of pressure.

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## **4 Use, Maintenance, and Care of the Devices**

## Electrostatic Discharge

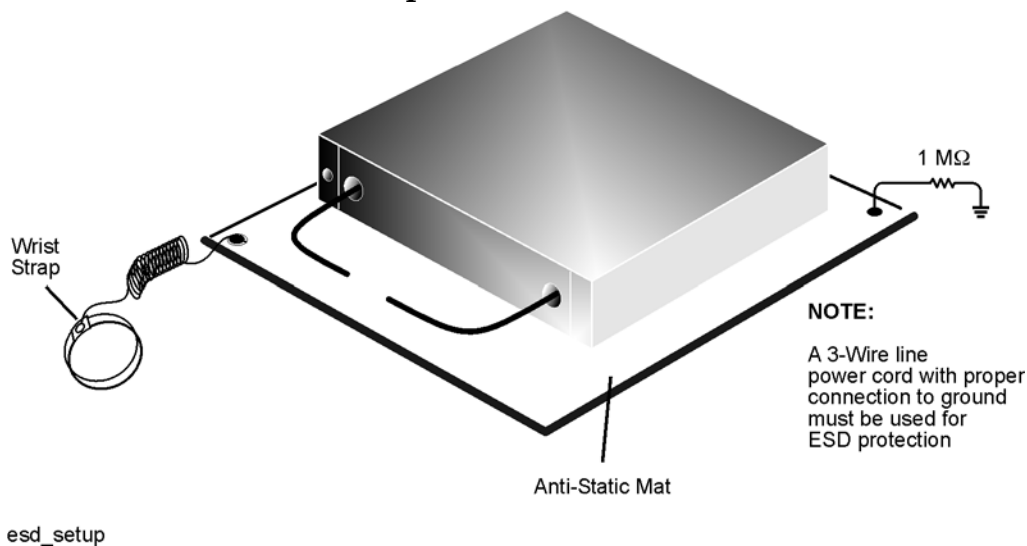
Protection against electrostatic discharge (ESD) is essential while connecting, inspecting, or cleaning connectors attached to a static-sensitive circuit (such as those found in test sets).

Static electricity can build up on your body and can easily damage sensitive internal circuit elements when discharged. Static discharges too small to be felt can cause permanent damage. Devices such as calibration components and devices under test (DUT), can also carry an electrostatic charge. To prevent damage to the test set, components, and devices:

- *Always* wear a grounded wrist strap having a 1 M $\Omega$  resistor in series with it when handling components and devices or when making connections to the test set.
- *Always* use a grounded antistatic mat in front of your test equipment.
- *Always* wear a heel strap when working in an area with a conductive floor. If you are uncertain about the conductivity of your floor, wear a heel strap.
- *Always* ground the center conductor of a test cable before making a connection to the analyzer test port or other static-sensitive device. This can be done as follows:
  1. Connect a short (from your calibration kit) to one end of the cable to short the center conductor to the outer conductor.
  2. While wearing a grounded wrist strap, grasp the outer shell of the cable connector.
  3. Connect the other end of the cable to the test port.
  4. Remove the short from the cable.

Figure 4-1 shows a typical ESD protection setup using a grounded mat and wrist strap. Refer to Table 7-6 on page 7-14 for information on ordering supplies for ESD protection.

**Figure 4-1 ESD Protection Setup**



---

## Visual Inspection

Visual inspection and, if necessary, cleaning should be done every time a connection is made. Inspect mating surfaces for dirt, dust, foreign particles, or scratches, which can degrade device performance. A damaged mating surface can damage any good surface connected to it. If necessary, clean all mating surfaces.

---

## Cleaning the Mating Plane Surfaces

### 1. Use Compressed Air or Nitrogen

---

**WARNING** Always use protective eyewear when using compressed air or nitrogen.

---

Use compressed air (or nitrogen) to loosen particles on the mating plane surfaces. Clean air cannot damage a device or leave particles or residues behind.

You can use any source of clean, dry, low-pressure compressed air or nitrogen that has an effective oil-vapor filter and liquid condensation trap placed just before the outlet hose.

Ground the hose nozzle to prevent electrostatic discharge, and set the air pressure to less than 414 kPa (60 psi) to control the velocity of the air stream. High-velocity streams of compressed air can cause electrostatic effects when directed into a device. These electrostatic effects can damage the device. Refer to [“Electrostatic Discharge”](#) earlier in this chapter for additional information.

---

**WARNING** Keep isopropyl alcohol away from heat, sparks, and flame. Store in a tightly closed container. It is extremely flammable. In case of fire, use alcohol foam, dry chemical, or carbon dioxide; water may be ineffective.

Use isopropyl alcohol with adequate ventilation and avoid contact with eyes, skin, and clothing. It causes skin irritation, may cause eye damage, and is harmful if swallowed or inhaled. It may be harmful if absorbed through the skin. Wash thoroughly after handling.

In case of spill, soak up with sand or earth. Flush spill area with water.

Dispose of isopropyl alcohol in accordance with all applicable federal, state, and local environmental regulations.

---

**2. Clean the Mating Plane Surfaces**

- a. Apply a small amount of isopropyl alcohol to a lint-free cleaning swab.
- b. Clean the mating plane surfaces.
- c. Let the alcohol evaporate, then blow the mating plane surface dry with a gentle stream of clean, low-pressure compressed air or nitrogen. Always completely dry a device before you reassemble or use it.

**3. Inspect**

- a. Inspect the mating plane surface to make sure that no particles or residue remain. [“Visual Inspection” on page 4-3.](#)

---

## Connections

Good connections require a skilled operator. Slight errors in operator technique can have a significant effect on measurements and measurement uncertainties. *The most common cause of measurement error is poor connections.*

The following procedures illustrate how to make good connections.

## Waveguide Devices

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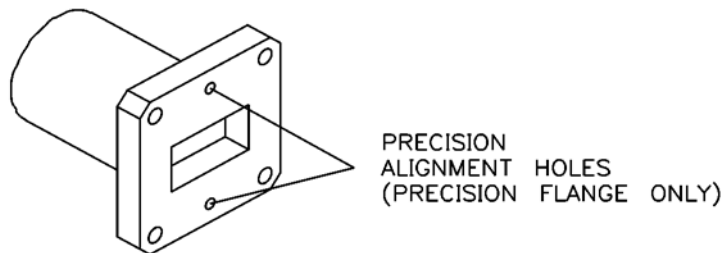
**IMPORTANT** Unlike threaded devices, the WR-28, WR-22, WR-19, WR-15, and WR-10 waveguide mating planes are flanges (often precision) that you must carefully screw together. Always connect waveguide in the same flange orientation. For example, use the label as a reference and always connect a device with the label facing the same direction.

---

## Precision Flanges

A precision flange has four corner screw holes *and* two precision alignment holes, as shown in [Figure 4-2](#). A non-precision flange has only four corner screw holes.

**Figure 4-2 Precision Alignment Holes**

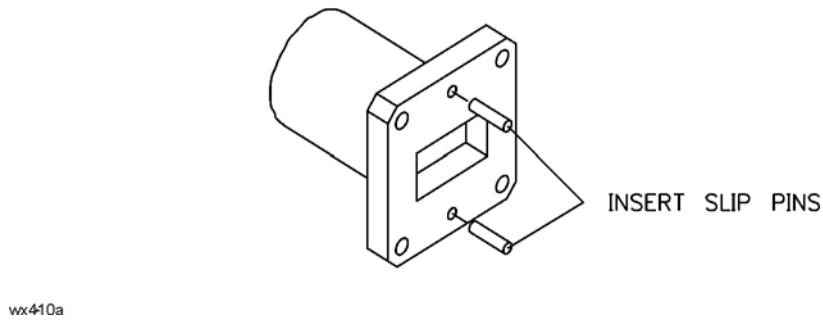


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## Aligning Two Precision Flanges

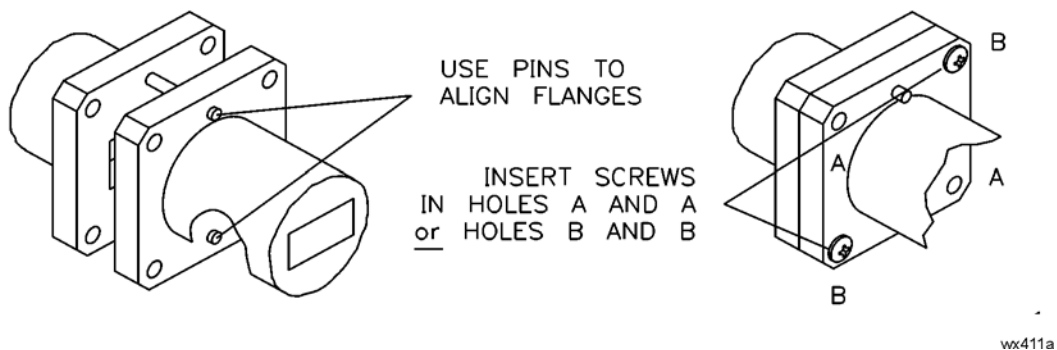
1. Place the slip pins in the top and bottom holes of one flange, as shown in [Figure 4-3](#).

**Figure 4-3** Inserting Slip Pins



2. Using the pins as guides, carefully align the flanges and insert two screws in the diagonal corner holes, as shown in [Figure 4-4](#).

**Figure 4-4** Aligning Flanges

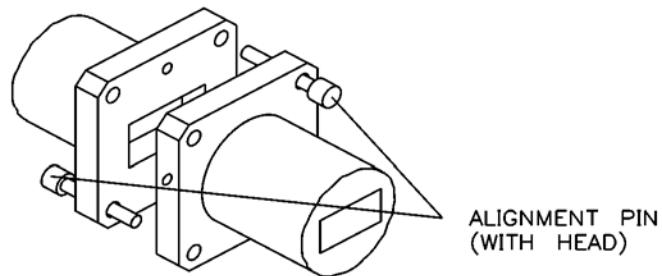


3. Place a lock washer and nut on each screw, and finger tighten.
4. Insert the remaining two screws.
5. Place a lock washer and nut on each screw, and finger tighten.
6. Remove the slip pins.
7. Go to [“Tightening a Flange Connection”](#) on page 4-8.

## Aligning a Precision and a Non-Precision Flange

1. Place an alignment pin (with head) in the corner hole of one flange. Place a second alignment pin in the diagonal corner hole of the second flange. See [Figure 4-5](#).

**Figure 4-5** Aligning Pins



wx412a

2. Using the pins as guides, carefully align the flanges and insert screws in the diagonal corner holes.
3. Place a lock washer and nut on each screw, and finger tighten.
4. Remove the alignment pins and insert the remaining two screws.
5. Place a lock washer and nut on each screws, and finger tighten.
6. Go to [“Tightening a Flange Connection”](#) on page 4-8.

## Tightening a Flange Connection

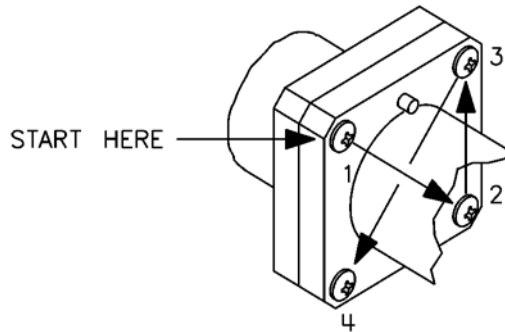
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**NOTE** The best connection has symmetrical pressure applied as you gradually tighten the screws.

---

1. In an “X” pattern (for equal compression), tighten all four screws using a hex ball driver. Do *not* over-tighten. See [Figure 4-6](#).
2. Visually inspect the connection. Refer to the following section “[Inspecting a Flange Connection](#)” on page 4-8

**Figure 4-6 “X” Screw Pattern**



wx413a

## Inspecting a Flange Connection

Inspect the flange connection as follows:

1. Place an electric light or white paper behind the connection.
2. Check the flange matings for any gap. A good connection has no gaps between the connected waveguide flanges, and the waveguide walls are flush. There is no step or offset.
3. Ensure that all four screws are equally tight.

---

**NOTE** The most common cause of measurement error is a poor connection.

---



## Handling and Storage

- Install the protective end caps and store the calibration devices in the foam-lined storage case when not in use.
- Never store devices loose in a box, or in a desk or bench drawer. This is the most common cause of device damage during storage.
- Keep devices clean.
- Do not touch mating plane surfaces. Natural skin oils and microscopic particles of dirt are easily transferred to a device and are very difficult to remove.
- Do not set devices contact-end down on a hard surface. The plating and the mating plane surfaces can be damaged if the interface comes in contact with any hard surface.



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## **5 Performance Verification**

## Introduction

The performance of your calibration kit can only be verified by returning the kit to Agilent Technologies for recertification. The equipment and calibration standards required to verify the specifications of the limits of the devices in the kit have been specially manufactured and are not commercially available. However, you may check the performance of the terminations in this kit by following the procedure [“Termination Return Loss Measurement”](#) on page 5-4.

To confirm that your calibration kit is performing accurate calibrations, use the appropriate Agilent 11645A verification kit with the “Specifications & Performance Verification” disk included in this kit.

---

## How Agilent Verifies the Devices in Your Kit

Agilent verifies the specifications of these devices as follows:

1. The residual microwave error terms of the test system are verified with precision airlines and shorts that are directly traced to the National Institute of Standards and Technology (NIST). The airline and short characteristics are developed from mechanical measurements. The mechanical measurements and material properties are carefully modeled to give very accurate electrical representation. The mechanical measurements are then traced to NIST through various plug and ring gages and other mechanical measurements.
2. Each calibration device is electrically tested on this system. For the initial (before sale) testing of the calibration devices, Agilent includes the test measurement uncertainty as a guardband to guarantee each device meets the published specification. For recertifications (after sale), no guardband is used and the measured data is compared directly with the specification to determine the pass or fail status. The measurement uncertainty for each device is, however, recorded in the calibration report that accompanies recertified kits.

These two steps establish a traceable link to NIST for Agilent to the extent allowed by the institute’s calibration facility. The specifications data provided for the devices in the kit is traceable to NIST through Agilent Technologies.

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## Recertification

The following will be provided with a recertified kit:

- a new calibration sticker affixed to the case
- a certificate of calibration
- a calibration report for each device in the kit listing measured values, specifications, and uncertainties

---

**NOTE** A list of NIST traceable numbers may be purchased upon request to be included in the calibration report.

---

Agilent Technologies offers a *Standard* calibration for the recertification of the kit. For more information, contact Agilent Technologies. Refer to [“Contacting Agilent” on page 6-5](#).

### How Often to Recertify

The suggested initial interval for recertification is 12 months or sooner. The actual need for recertification depends on the use of the kit. After reviewing the results of the initial recertification, you may establish a different recertification interval that reflects the usage and wear of the kit.

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**NOTE** The recertification interval should begin on the date the kit is *first used* after the recertification date.

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### Where to Send a Kit for Recertification

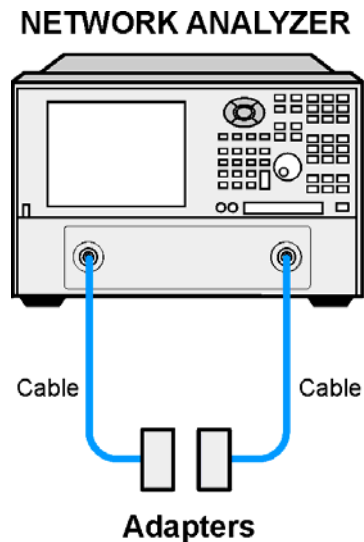
Contact Agilent Technologies for information on where to send your kit for recertification. Refer to [“Contacting Agilent” on page 6-5](#). Refer to [“Returning a Kit or Device to Agilent” on page 6-4](#) for details on sending your kit.

## Performance Test

### Termination Return Loss Measurement

Use this test to check the performance of the terminations in this kit.

**Figure 5-1 Return Loss Test Setup**



wx425a

1. Connect the equipment as shown in [Figure 5-1](#). Turn on and preset the network analyzer. Let the equipment warm up for at least one hour.

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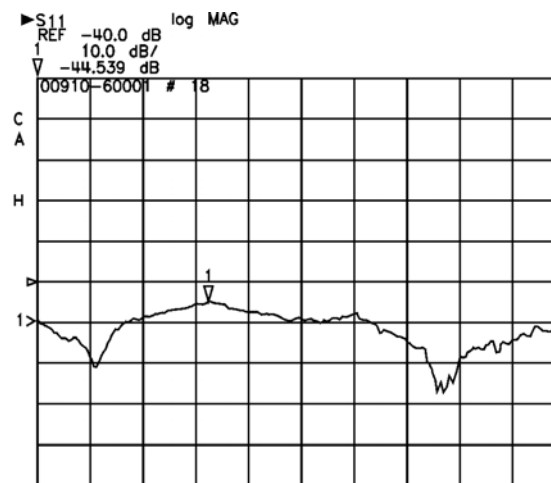
**NOTE** The calibration kit definitions must already be loaded in the analyzer. Refer to your analyzer user's guide for information on how to load the calibration kit definitions.

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2. Set the appropriate start frequency to:
  - 26.5 GHz (R-band)
  - 33 GHz (Q-band)
  - 40 GHz (U-band)
  - 50 GHz (V-band)
  - 75 GHz (W-band)

3. Set the appropriate stop frequency to:
  - 40 GHz (R-band)
  - 50 GHz (Q-band)
  - 60 GHz (U-band)
  - 75 GHz (V-band)
  - 110 GHz (W-band)
4. Set the averaging factor to 512.
5. At the adapter test port, perform a 2–port TRL calibration.
6. Turn on the calibration.
7. Connect the termination you wish to test to port 1.
8. Measure the return loss ( $S_{11}$ ) of the load.
9. After one complete measurement sweep, the displayed trace should look similar to that shown in [Figure 5-2](#).
10. If necessary, update the trace.
11. Use a marker to determine the maximum value on the trace. This marker determines worst-case return loss.

**Figure 5-2 Typical Termination Return Loss**



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## In Case of Failure

If a termination fails this test, clean all flanges and carefully reconnect the devices. Repeat the test. If the termination fails again, replace it. Refer to [Table 2-3](#).





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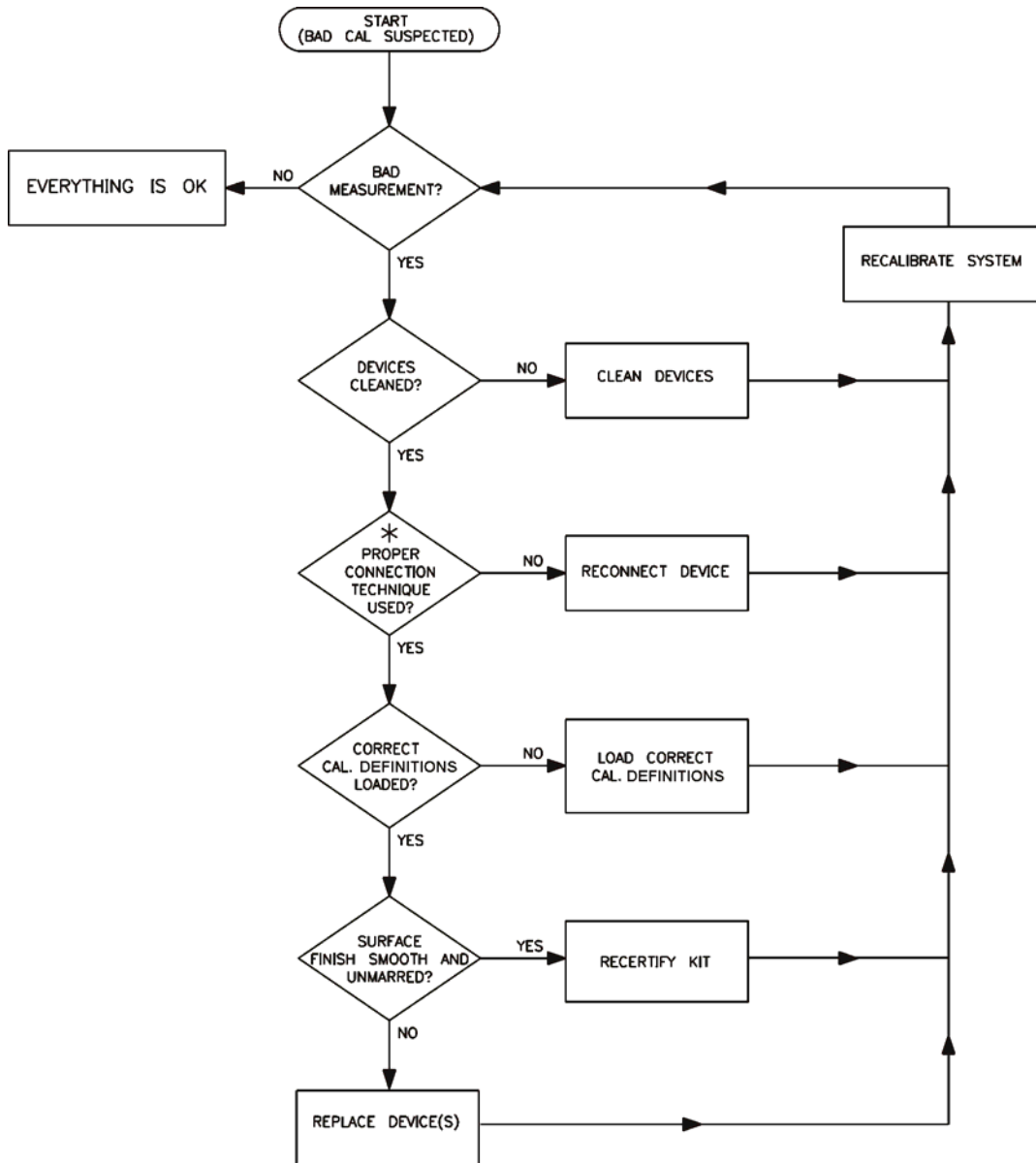
## **6 Troubleshooting**

## Troubleshooting Process

This manual contains limited information about network analyzer system operation. For complete information, refer to the instrument documentation.

If you suspect a bad calibration, or if your network analyzer does not pass performance verification, follow the steps in [Figure 6-1](#).

Figure 6-1 Troubleshooting Flowchart



\* NO GAPS; WAVEGUIDE WALLS FLUSH;  
EVEN AND SYMMETRICAL TIGHTENING.

wx416a

## Returning a Kit or Device to Agilent

If your kit or device requires service, contact Agilent Technologies for information on where to send it. See “[Contacting Agilent](#)” on page 6-5. Include a service tag (located near the end of this manual) on which you provide the following information:

- your company name and address
- a technical contact person within your company, and the person's complete telephone number
- the model number and serial number of the kit
- the part number and serial number of each device
- the type of service required
- a *detailed* description of the problem and how the device was being used when the problem occurred (such as calibration or measurement)

### Where to Look for More Information

This manual contains limited information about network analyzer system operation. For complete information, refer to the instrument documentation. If you need additional information, contact Agilent Technologies.

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## Contacting Agilent

Assistance with test and measurement needs and information on finding a local Agilent office are available on the Web at:

*[www.agilent.com/find/assist](http://www.agilent.com/find/assist)*

If you do not have access to the Internet, please contact your Agilent field engineer.

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**NOTE** In any correspondence or telephone conversation, refer to the Agilent product by its model number and full serial number. With this information, the Agilent representative can determine whether your product is still within its warranty period.

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## **7 Replaceable Parts**

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## Introduction

The following tables list the replacement part numbers for the Agilent R, Q, U, V, and W11644A waveguide calibration kits. [Table 7-6](#) lists the replacement part numbers for items *not* included in the calibration kit that are either required or recommended for successful operation of this kit.


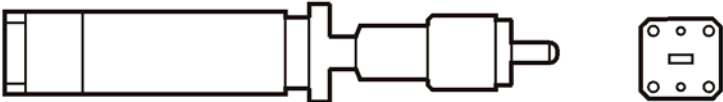
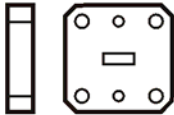

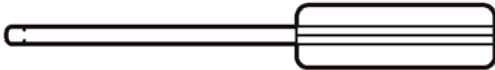
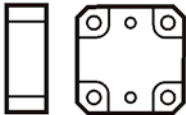


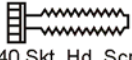



To order a listed part, note the description, part number, and the quantity desired. Telephone or send your order to Agilent Technologies. Refer to [“Contacting Agilent” on page 6-5](#) for further information.

**Table 7-1 Replaceable Parts for the R11644A WR-28**

Description	Qty Per Kit	Agilent Part Number
<b>Calibration Devices</b>		
Straight section (5 cm)	2	11644-60016
Standard section (10 cm)	1	11644-60001
Waveguide load	1	11644-60004
Short	1	11644-20005
Shim	1	11644-20003
<b>Hardware</b>		
Alignment pin	6	11644-20009
Slip pin (2.367 mm diameter)	6	11644-20006
4-40 Hex nut (0.094 inch)	12	2260-0002
4-40 SKT HD screw (0.750 inch)	12	3030-0721
Lock washer (0.115 inch)	12	2190-0030
Open end wrench	1	8720-0013
Hex ball driver	1	8710-0523
<b>Miscellaneous Items</b>		
User's and service guide	1	11644-90369
Calibration definitions disk for the 8510 series (R)	1	11644-10012
Specifications and performance verification disk set (8510 series) <sup>a</sup>	1	08510-10033
<b>Calibration Kit Storage Case</b>		
Storage case	1	5181-5517
Box	2	1540-0034
Foam pad (set)	1	11644-80040
Disk holder	1	5180-8491

a. See the 8510C *On-Site Service Manual* (08510-90282) for instructions on using this disk.

**Figure 7-1 R-Band Component Identification Sheet**

<p>Standard Section (10 cm)</p> <p>Used for system verification only.</p> 		
<p>Waveguide Load</p> 		
<p>1/4 Wavelength Section</p>  <p>Has mechanical length labeled on side or recessed area.</p>	<p>Straight Section (5 cm)</p>  <p>Used as port 1 and 2</p> <p>3/32 inch Hex Ball Driver</p> 	
<p>Flush Short</p> 	<p>Slip Pin (2.367 mm diameter)</p>  <p>Alignment Pin (long)</p>  <p>4-40 Skt. Hd. Screw</p>  <p>Lock Washer</p>  <p>4-40 Hex Nut</p> 	<p>Data Disc</p> 


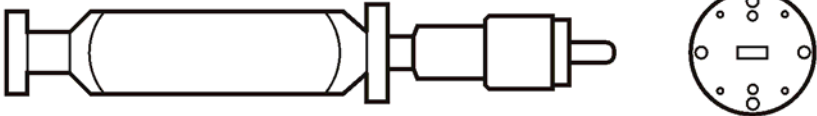
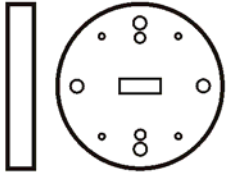

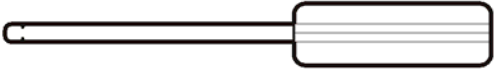
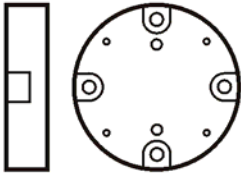


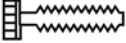

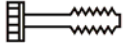

Note: Short pins used on calibration devices, long pins used on DUTs.

**Table 7-2 Replaceable Parts for the Q11644A WR-22**

Description	Qty Per Kit	Agilent Part Number
<b>Calibration Devices</b>		
Straight section (5 cm)	2	11644-60017
Standard section (10 cm)	1	11644-60002
Waveguide load	1	11644-60005
Shim	1	11644-20001
Short	1	11644-20004
<b>Hardware</b>		
Slip pin (1.645 mm diameter)	6	11644-20008
Slip pin (2.367 mm diameter)	6	11644-20006
4-40 captive screw (0.31 inches long)	24	1390-0671
4-40 captive screw (0.43 inches long)	12	1390-0764
4-40 SKT HD screw (0.50 inches long)	12	3030-0203
Hex ball driver	1	8710-0523
<b>Miscellaneous Items</b>		
Calibration definitions disk for the 8510 series (Q-band)	1	11644-10013
Specifications and performance verification disk set (8510 series) <sup>a</sup>	1	08510-10033
User's and service guide	1	11644-90369
<b>Calibration Kit Storage Case</b>		
Storage case	1	5181-5517
Box	2	1540-0034
Foam pad (set)	1	11644-80041
Disk holder	1	5180-8491

a. See the 8510C *On-Site Service Manual* (08510-90282) for instructions on using this disk.

**Figure 7-2 Q-Band Component Identification Sheet**

<p>Standard Section (10 cm)</p> <p>Used for system verification only.</p> 		
<p>Waveguide Load</p> 		
<p>Wavelength Section</p>  <p>Has mechanical length labeled on side or recessed area.</p>	<p>Straight Section (5 cm)</p>  <p>Used as port 1 and 2</p> <p>3/32 inch Hex Ball Driver</p> 	
<p>Flush Short</p> 	<p>Slip Pin (2.367 mm diameter)</p>  <p>Slip Pin (1.645 mm diameter)</p>  <p>4-40 Socket Head Screw</p>  <p>4-40 Captive Screw</p>  <p>4-40 Captive Screw</p> 	<p>Data Disc</p> 

Note: Short pins used on calibration devices, long pins used on DUTs.


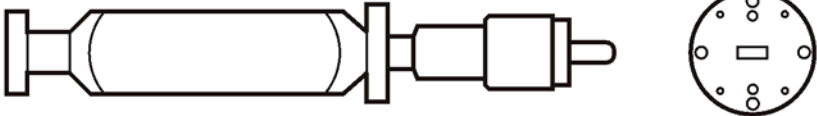
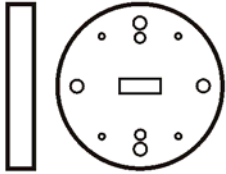

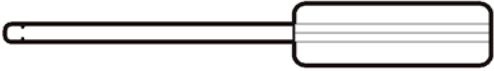
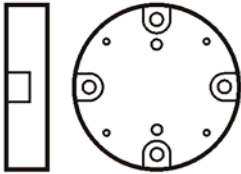


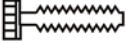

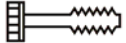

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**Table 7-3 Replaceable Parts for the U11644A WR-19**

Description	Qty Per Kit	Agilent Part Number
<b>Calibration Devices</b>		
Straight section (5 cm)	2	11644-60018
Standard section (10 cm)	1	11644-60003
Waveguide load	1	11644-60006
Shim	1	11644-20002
Short	1	11644-20004
<b>Hardware</b>		
Slip pin (1.645 mm diameter)	6	11644-20008
Slip pin (2.367 mm diameter)	6	11644-20006
4-40 captive screw (0.31 inches long)	24	1390-0671
4-40 captive screw (0.43 inches long)	12	1390-0764
4-40 SKT HD screw (0.50 inches long)	12	3030-0203
Hex ball driver	1	8710-0523
<b>Miscellaneous Items</b>		
Calibration definitions disk for the 8510 series (U-band)	1	11644-10014
Specifications and performance verification disk set (8510 series) <sup>a</sup>	1	08510-10033
User's and service guide	1	11644-90369
<b>Calibration Kit Storage Case</b>		
Storage case	1	5181-5517
Box	2	1540-0034
Foam pad (set)	1	11644-80041
Disk holder	1	5180-8491

a. See the 8510C *On-Site Service Manual* (08510-90282) for instructions on using this disk.

**Figure 7-3 U-Band Component Identification Sheet**

<p>Standard Section (10 cm)</p> <p>Used for system verification only.</p> 		
<p>Waveguide Load</p> 		
<p>Wavelength Section</p>  <p>Has mechanical length labeled on side or recessed area.</p>	<p>Straight Section (5 cm)</p>  <p>Used as port 1 and 2</p> <p>3/32 inch Hex Ball Driver</p> 	
<p>Flush Short</p> 	<p>Slip Pin (2.367 mm diameter)</p>  <p>Slip Pin (1.645 mm diameter)</p>  <p>4-40 Socket Head Screw</p>  <p>4-40 Captive Screw</p>  <p>4-40 Captive Screw</p> 	<p>Data Disc</p> 

Note: Short pins used on calibration devices, long pins used on DUTs.

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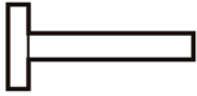
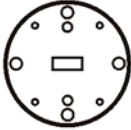

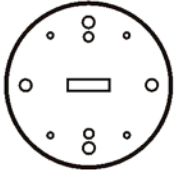
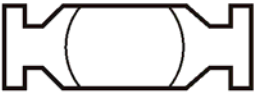
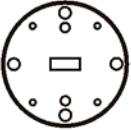
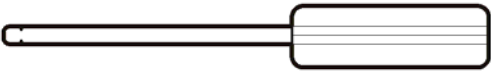

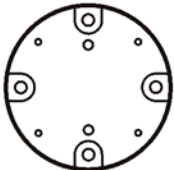


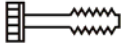

**Table 7-4 Replaceable Parts for the V11644A WR-15**

Description	Qty Per Kit	Agilent Part Number
<b>Calibration Devices</b>		
Fixed load	1	11643-60025
Standard section (5 cm)	3	11644-60012
Shim	1	11644-20013
Short	1	11644-20015
<b>Hardware</b>		
Slip pin (1.567 mm diameter)	6	11644-20007
4-40 captive screw (0.41 inch)	12	1390-0765
4-40 captive screw (0.31 inch)	24	1390-0671
Hex ball driver	1	8710-0523
<b>Miscellaneous Items</b>		
Calibration definitions disk for the 8510 series (V-band)	1	11644-10015
Specifications and performance verification disk set (8510 series) <sup>a</sup>	1	08510-10033
User's and service guide	1	11644-90369
<b>Calibration Kit Storage Case</b>		
Storage case	1	5181-5517
Box	2	1540-0034
Foam pad (set)	1	11644-80042
Disk holder	1	5180-8491

a. See the 8510C *On-Site Service Manual* (08510-90282) for instructions on using this disk.



**Figure 7-4 V-Band Component Identification Sheet**

<p>Fixed Load</p>  		
<p>Shim</p>   <p>Has mechanical length labeled on side or recessed area.</p>	<p>Standard Section (5 cm)</p>   <ul style="list-style-type: none"> <li>• Used for system verification only (1)</li> <li>• Used as port 1 and 2 (2)</li> </ul>	<p>3/32 inch Hex Ball Driver</p> 
<p>Flush Short</p>  	<p>Slip Pin (1.567 mm diameter)</p>  <p>4-40 Captive Screw</p>  <p>4-40 Captive Screw</p> 	<p>Data Disc</p> 

Note: Short pins used on calibration devices, long pins used on DUTs.

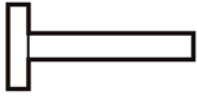
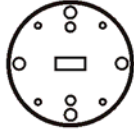

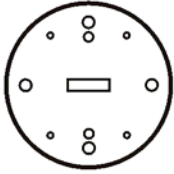
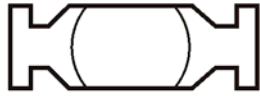
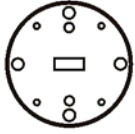
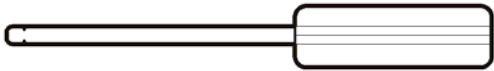

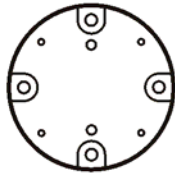



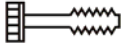
wx419a

**Table 7-5 Replaceable Parts for the W11644A WR-10**

Description	Qty Per Kit	Agilent Part Number
<b>Calibration Devices</b>		
Fixed load	1	11643-60026
Standard section	3	11644-60013
Shim	1	11644-20014
Short	1	11644-20015
<b>Hardware</b>		
Slip pin (1.567 mm diameter)	6	11644-20007
4-40 captive screw (0.41 inch)	12	1390-0765
4-40 captive screw (0.31 inch)	24	1390-0671
Hex ball driver	1	8710-0523
<b>Miscellaneous Items</b>		
Calibration definitions disk for the 8510 series (W-band)	1	11644-10016
Specifications and performance verification disk set (8510 series) <sup>a</sup>	1	08510-10033
User's and service guide	1	11644-90369
<b>Calibration Kit Storage Case</b>		
Storage case	1	5181-5517
Box	2	1540-0034
Foam pad (set)	1	11644-80042
Disk holder	1	5180-8491

a. See the 8510C *On-Site Service Manual* (08510-90282) for instructions on using this disk.

**Figure 7-5 W-Band Component Identification Sheet**

Fixed Load		 	
Shim	 	Standard Section (5 cm)	  <ul style="list-style-type: none"> <li>• Used for system verification only (1)</li> <li>• Used as port 1 and 2 (2)</li> </ul>
		3/32 inch Hex Ball Driver	
Flush Short	 	Slip Pin (1.567 mm diameter)	Data Disc
			
		 <p>4-40 Captive Screw</p>  <p>4-40 Captive Screw</p>	

Note: Short pins used on calibration devices, long pins used on DUTs.

wx419a

**Table 7-6 Items Not Included in the Calibration Kit**

<b>Description</b>	<b>Qty</b>	<b>Agilent Part Number</b>
<b>ESD Protection Devices</b>		
Grounding wrist strap	1	9300-1367
5 ft grounding cord for wrist strap	1	9300-0980
2 ft by 4 ft conductive table mat with 15 ft grounding wire	1	9300-0797
ESD heel strap	1	9300-1308
<b>Cleaning Supplies</b>		
Isopropyl alcohol	30 ml	8500-5344
Foam-tipped cleaning swabs	100	9301-1243

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# **A Standard Definitions**

## Version Changes

Class assignments and standard definitions may change as more accurate model and calibration methods are developed. You can download the most recent class assignments and standard definitions from Agilent's Calibration Kit Definitions Web page at <http://na.tm.agilent.com/pna/caldefs/stddefs.html>.

For a detailed discussion of calibration kits, refer to the Agilent Application Note, "Specifying Calibration Standards and Kits for Agilent Vector Network Analyzers." This application note covers calibration standard definitions, calibration kit content and its structure requirements for Agilent vector network analyzers. It also provides some examples of how to set up a new calibration kit and how to modify an existing calibration kit definition file. To download a free copy, go to [www.agilent.com](http://www.agilent.com) and enter literature number 5989-4840EN in the Search window.

## Standard Class Assignments

Class assignment organizes calibration standards into a format compatible with the error models used in the measurement calibration. A class or group of classes corresponds to the systematic errors to be removed from the measured network analyzer response. Tables A-1 through A-3 list the classes of the devices in the kit for the 8510 and PNA series respectively. The 8510 information resides on the calibration definitions disk included in the kit. The PNA has the information stored in memory.

**Table A-1 Standard Class Assignments for the 8510 (WR-19, WR-22, and WR-28)**

Disk File Name: CK_WR-28, or CK_WR-22, or CK_WR-19				Calibration Kit Label: WR-28 A.2, or WR-22 A.2, or WR-19 A.2				
Class	A	B	C	D	E	F	G	Standard Class Label
S <sub>11</sub> A	1							Short
S <sub>11</sub> B	3							Offset
S <sub>11</sub> C	9	10	20					Loads
S <sub>22</sub> A	1							Short
S <sub>22</sub> B	3							Offset
S <sub>22</sub> C	9	10	20					Loads
Forward transmission	11							Thru
Reverse transmission	11							Thru
Forward match	11							Thru
Reverse match	11							Thru
Frequency response	1	11						Response

**Table A-2 Standard Class Assignments for the 8510 (WR-10 and WR-15)**

Disk File Name: CK_WR-15, or CK_WR-10				Calibration Kit Label: WR-15 A.2, or WR-10 A.2				
Class	A	B	C	D	E	F	G	Standard Class Label
S <sub>11</sub> A	1							Short
S <sub>11</sub> B	3							Offset
S <sub>11</sub> C	9	20						Loads
S <sub>22</sub> A	1							Short
S <sub>22</sub> B	3							Offset
S <sub>22</sub> C	9	20						Loads
Forward transmission	11							Thru
Reverse transmission	11							Thru
Forward match	11							Thru
Reverse match	11							Thru
Frequency response	1	11						Response



**Table A-3 Standard Class Assignments for the PNA Series Network Analyzer**

<b>SOLT Class Assignments</b> Calibration Kit Name: R11644A, Q11644A, U11644A, V11644A, W11644A		<b>TRL Class Assignments<sup>a</sup></b> Calibration Kit Name: R11644A, Q11644A, U11644A, V11644A, W11644A	
<b>Class</b>		<b>Class</b>	
S <sub>11</sub> A	4	TRL thru	6
S <sub>11</sub> B	5	TRL reflect	4
S <sub>11</sub> C	1, 2	TRL line/match	7, 2
Forward transmission <sup>b</sup>	6, 7	Isolation	2
S <sub>22</sub> A	4	–	–
S <sub>22</sub> B	5	–	–
S <sub>22</sub> C	1, 2	Cal Ref Z0 = Line Z0	
Isolation	2	Transport Ref Plane = Thru Standard	

- a. Select the LRL line auto characterization checkbox to compute the propagation characteristics of the thru standard from the computed propagation characteristics of the line standard and the defined delays for both the thru and line standards. Note, LRL line auto characterization will only be used at frequencies where both the THRU and LINE standards are delay lines and where the offset impedance of the THRU and LINE standards are equal.
- b. Forward match, reverse match, and reverse transmission usually use the same class assignments as forward transmission. You can select these same class assignments in the PNA calibration menu titled “Modify SOLT Calibration Class Assignments.” Select the checkbox titled “Link FWD TRANS, FWD MATCH, REV TRANS and REV MATCH.”

## Blank Forms

The standard class assignments may be changed to meet your specific requirements. The following two tables are provided to record the modified standard class assignments.

**Table A-4 Blank Form for the 8510 Network Analyzer**

Disk File Name: _____				Calibration Kit Label: _____				
Class	A	B	C	D	E	F	G	Standard Class Label
S <sub>11</sub> A								
S <sub>11</sub> B								
S <sub>11</sub> C								
S <sub>22</sub> A								
S <sub>22</sub> B								
S <sub>22</sub> C								
Forward transmission								
Reverse transmission								
Forward match								
Reverse match								
Frequency response								

**Table A-5 Blank Form for the PNA Series Network Analyzer**

SOLT Class Assignments		TRL Class Assignments <sup>a</sup>	
Calibration Kit Name: _____		Calibration Kit Name: _____	
Class		Class	
S <sub>11</sub> A		TRL thru	
S <sub>11</sub> B		TRL reflect	
S <sub>11</sub> C		TRL line/match	
Forward transmission <sup>b</sup>		Isolation	
S <sub>22</sub> A		–	–
S <sub>22</sub> B		–	–
S <sub>22</sub> C		Cal Ref Z0 = Line Z0	
Isolation		Transport Ref Plane = Thru Standard	

- a. Select the LRL line auto characterization checkbox to compute the propagation characteristics of the thru standard from the computed propagation characteristics of the line standard and the defined delays for both the thru and line standards. Note, LRL line auto characterization will only be used at frequencies where both the THRU and LINE standards are delay lines and where the offset impedance of the THRU and LINE standards are equal.
- b. Forward match, reverse match, and reverse transmission usually use the same class assignments as forward transmission. You can select these same class assignments in the PNA calibration menu titled “Modify SOLT Calibration Class Assignments.” Select the checkbox titled “Link FWD TRANS, FWD MATCH, REV TRANS and REV MATCH.”

## Nominal Standard Definitions

Standard definitions provide the constants needed to mathematically model the electrical characteristics (delay, attenuation, and impedance) of each calibration standard. The nominal values of these constants are theoretically derived from the physical dimensions and material of each calibration standard, or from actual measured response. These values are used to determine the measurement uncertainties of the network analyzer. The standard definitions in [Tables A-6](#) through [A-15](#) list typical calibration kit parameters used by the 8510 and PNA series to specify the mathematical model of each device. The 8510 information resides on the calibration definitions disk included in the kit. The PNA has the information stored in memory.

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**NOTE**        The values in the standard definitions table are valid *only* over the specified operating temperature range.

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## Setting the System Impedance

This kit contains only waveguide devices. Ensure the system impedance ( $Z_0$ ) is set to 1 ohm. Refer to your network analyzer user's guide for instructions on setting system impedance.

**Table A-6 Standard Definitions for the 8510 with R-band (WR-28)**

Standard <sup>b</sup>		$C0 \times 10^{-15} \text{ F}$	$C1 \times 10^{-27} \text{ F/Hz}$	$C2 \times 10^{-36} \text{ F/Hz}^2$	$C3 \times 10^{-45} \text{ F/Hz}^3$	Fixed, Sliding, or Offset <sup>c</sup>	Offset			Frequency in GHz <sup>d</sup>		Coax or Waveguide	Standard Label
Number	Type	$L0 \times 10^{-12} \text{ H}$	$L1 \times 10^{-24} \text{ H/Hz}$	$L2 \times 10^{-33} \text{ H/Hz}^2$	$L3 \times 10^{-42} \text{ H/Hz}^3$		Delay in ps	$Z_0 \Omega$	Loss in GΩ/s	Min	Max		
1	Short <sup>e</sup>						0	1	0	21.071	42.142	WG	Short
2													
3	Short <sup>e</sup>						10.0702	1	0	21.071	42.142	WG	λ/4 Offset
4													
5													
6													
7													
8													
9	Load					Fixed	0	1	0	21.071	42.142	WG	Fixed
10	Load					Sliding	0	1	0	21.071	42.142	WG	Sliding
11	Delay/ thru						0	1	0	21.071	42.142	WG	Thru
12													
13	Undefined												
14	Delay/ thru						0	1	0	21.069	42.138	WG	Thru
15	Delay/ thru						10.0702	1	0	21.069	42.138	WG	λ/4 Delay
16													
17													
18													
19													
20	Load					Offset	10.0702	1	0	21.071	42.142	WG	λ/4 Offset
21													

- a. Ensure system  $Z_0$  of network analyzer is set to this value.
- b. Open, short, load, delay/thru, or arbitrary impedance.
- c. Load or arbitrary impedance only.
- d. For waveguide, the lower frequency is the same as  $F_{CO}$ .
- e. Typical values only. Disk values may be different.

**Table A-7 Standard Definitions for the 8510 with Q-band (WR-22)**

System $Z_0^a = 1 \Omega$ Calibration Kit Label: WR-22 A.3													
Disk File Name: CK_WR-22													
Standard <sup>b</sup>		$C0 \times 10^{-15} F$	$C1 \times 10^{-27} F/Hz$	$C2 \times 10^{-36} F/Hz^2$	$C3 \times 10^{-45} F/Hz^3$	Fixed, Sliding, or Offset <sup>c</sup>	Offset			Frequency in GHz <sup>d</sup>		Coax or Waveguide	Standard Label
Number	Type	$L0 \times 10^{-12} H$	$L1 \times 10^{-24} H/Hz$	$L2 \times 10^{-33} H/Hz^2$	$L3 \times 10^{-42} H/Hz^3$		Delay in ps	$Z_0 \Omega$	Loss in G $\Omega/s$	Min	Max		
1	Short <sup>e</sup>						0	1	0	26.338	52.676	WG	Short
2													
3	Short <sup>e</sup>						8.082	1	0	26.338	52.676	WG	$\lambda/4$ Offset
4													
5													
6													
7													
8													
9	Load					Fixed	0	1	0	26.338	52.676	WG	Fixed
10	Load					Sliding	0	1	0	26.338	52.676	WG	Sliding
11	Delay/thru						0	1	0	26.338	52.676	WG	Thru
12													
13	Undefined												
14	Delay/thru						0	1	0	26.338	52.676	WG	Thru
15	Delay/thru						8.084	1	0	26.338	52.676	WG	$\lambda/4$ Delay
16													
17													
18													
19													
20	Load					Offset	8.082	1	0	26.338	52.676	WG	$\lambda/4$ Offset
21													

- a. Ensure system  $Z_0$  of network analyzer is set to this value.
- b. Open, short, load, delay/thru, or arbitrary impedance.
- c. Load or arbitrary impedance only.
- d. For waveguide, the lower frequency is the same as  $F_{CO}$ .
- e. Typical values only. Disk values may be different.

**Table A-8 Standard Definitions for the 8510 with U-band (WR-19)**

System $Z_0^a = 1 \Omega$		Calibration Kit Label: WR-19 A.3											
Disk File Name: CK_WR-19													
Standard <sup>b</sup>		$C0 \times 10^{-15} \text{ F}$	$C1 \times 10^{-27} \text{ F/Hz}$	$C2 \times 10^{-36} \text{ F/Hz}^2$	$C3 \times 10^{-45} \text{ F/Hz}^3$	Fixed, Sliding, or Offset <sup>c</sup>	Offset			Frequency in GHz <sup>d</sup>		Coax or Waveguide	Standard Label
Number	Type	$L0 \times 10^{-12} \text{ H}$	$L1 \times 10^{-24} \text{ H/Hz}$	$L2 \times 10^{-33} \text{ H/Hz}^2$	$L3 \times 10^{-42} \text{ H/Hz}^3$		Delay in ps	$Z_0 \Omega$	Loss in GΩ/s	Min	Max		
1	Short <sup>e</sup>						0	1	0	31.386	62.772	WG	Short
2													
3	Short <sup>e</sup>						6.643	1	0	31.386	62.772	WG	$\lambda/4$ Offset
4													
5													
6													
7													
8													
9	Load					Fixed	0	1	0	31.386	62.772	WG	Fixed
10	Load					Sliding	0	1	0	31.386	62.772	WG	Sliding
11	Delay/ thru						0	1	0	31.386	62.772	WG	Thru
12													
13	Undefined												
14	Delay/ thru						0	1	0	31.386	62.772	WG	Thru
15	Delay/ thru						6.646	1	0	31.386	62.772	WG	$\lambda/4$ Delay
16													
17													
18													
19													
20	Load					Offset	6.643	1	0	31.386	62.772	WG	$\lambda/4$ Offset
21													

- a. Ensure system  $Z_0$  of network analyzer is set to this value.
- b. Open, short, load, delay/thru, or arbitrary impedance.
- c. Load or arbitrary impedance only.
- d. For waveguide, the lower frequency is the same as  $F_{CO}$ .
- e. Typical values only. Disk values may be different.

**Table A-9 Standard Definitions for the 8510 with V-band (WR-15)**

Standard <sup>b</sup>		$C0 \times 10^{-15} \text{ F}$	$C1 \times 10^{-27} \text{ F/Hz}$	$C2 \times 10^{-36} \text{ F/Hz}^2$	$C3 \times 10^{-45} \text{ F/Hz}^3$	Fixed, Sliding, or Offset <sup>c</sup>	Offset			Frequency in GHz <sup>d</sup>		Coax or Waveguide	Standard Label
Number	Type	$L0 \times 10^{-12} \text{ H}$	$L1 \times 10^{-24} \text{ H/Hz}$	$L2 \times 10^{-33} \text{ H/Hz}^2$	$L3 \times 10^{-42} \text{ H/Hz}^3$		Delay in ps	$Z_0 \Omega$	Loss in GΩ/s	Min	Max		
1	Short <sup>e</sup>						0	1	0	39.873	79.745	WG	Short
2													
3	Short <sup>e</sup>						5.376	1	0	39.873	79.745	WG	$\lambda/4$ Offset
4													
5													
6													
7													
8													
9	Load					Fixed	0	1	0	39.873	79.745	WG	Fixed
10													
11	Delay/thru						0	1	0	39.873	79.745	WG	Thru
12													
13	Undefined												
14	Delay/thru						0	1	0	39.873	79.745	WG	Thru
15	Delay/thru						5.378	1	0	39.873	79.745	WG	$\lambda/4$ Delay
16													
17													
18													
19													
20	Load					Offset	5.376	1	0	39.873	79.745	WG	$\lambda/4$ Offset
21													

- a. Ensure system  $Z_0$  of network analyzer is set to this value.
- b. Open, short, load, delay/thru, or arbitrary impedance.
- c. Load or arbitrary impedance only.
- d. For waveguide, the lower frequency is the same as  $F_{C0}$ .
- e. Typical values only. Disk values may be different.



**Table A-10 Standard Definitions for the 8510 with W-band (WR-10)**

System $Z_0^a = 1 \Omega$		Calibration Kit Label: WR-10 A.3											
Disk File Name: CK_WR-10													
Number	Standard <sup>b</sup> Type	$C0 \times 10^{-15} \text{ F}$	$C1 \times 10^{-27} \text{ F/Hz}$	$C2 \times 10^{-36} \text{ F/Hz}^2$	$C3 \times 10^{-45} \text{ F/Hz}^3$	Fixed, Sliding, or Offset <sup>c</sup>	Offset			Frequency in GHz <sup>d</sup>		Coax or Waveguide	Standard Label
		$L0 \times 10^{-12} \text{ H}$	$L1 \times 10^{-24} \text{ H/Hz}$	$L2 \times 10^{-33} \text{ H/Hz}^2$	$L3 \times 10^{-42} \text{ H/Hz}^3$		Delay in ps	$Z_0 \Omega$	Loss in GΩ/s	Min	Max		
1	Short <sup>e</sup>						0	1	0	59.024	118.05	WG	Short
2													
3	Short <sup>e</sup>						3.620	1	0	59.024	118.05	WG	$\lambda/4$ Offset
4													
5													
6													
7													
8													
9	Load					Fixed	0	1	0	59.024	118.05	WG	Fixed
10													
11	Delay/ thru						0	1	0	59.024	118.05	WG	Thru
12													
13	Undefined												
14	Delay/ thru						0	1	0	59.024	118.05	WG	Thru
15	Delay/ thru						3.620	1	0	59.024	118.05	WG	$\lambda/4$ Delay
16													
17													
18													
19													
20	Load					Offset	3.620	1	0	59.024	118.05	WG	$\lambda/4$ Offset
21													

- a. Ensure system  $Z_0$  of network analyzer is set to this value.
- b. Open, short, load, delay/thru, or arbitrary impedance.
- c. Load or arbitrary impedance only.
- d. For waveguide, the lower frequency is the same as  $F_{CO}$ .
- e. Typical values only. Disk values may be different.

**Table A-11 Standard Definitions for the PNA Series with R-band (WR-28)**

System $Z_0^a = 1 \Omega$						Calibration Kit Label: R-band							
Standard <sup>b</sup>		$C0 \times 10^{-15} \text{ F}$	$C1 \times 10^{-27} \text{ F/Hz}$	$C2 \times 10^{-36} \text{ F/Hz}^2$	$C3 \times 10^{-45} \text{ F/Hz}^3$	Fixed, sliding, or offset load or arbitrary impedance	Offset			Frequency in GHz <sup>c</sup>		Coax or Waveguide	Standard Label
Number	Type	$L0 \times 10^{-12} \text{ H}$	$L1 \times 10^{-24} \text{ H/Hz}$	$L2 \times 10^{-33} \text{ H/Hz}^2$	$L3 \times 10^{-42} \text{ H/Hz}^3$		Delay in ps	$Z_0 \Omega$	Loss in GΩ/s	Min	Max		
1	Offset load					Offset				21.071	42.142	WG	Offset load
2	Load					Fixed	0	1	0	21.071	42.142	WG	Fixed Load
3	Load					Sliding				21.071	42.142	WG	Sliding Load
4	Short	0	0	0	0		0	1	0	21.071	42.142	WG	Short
5	Offset short	0	0	0	0		10.07	1	9	21.071	42.142	WG	$\lambda/4$ Offset short
6	Thru						0	1	0	21.071	42.142	WG	Thru
7	$\lambda/4$ line						10.07	1	9	21.071	42.142	WG	$\lambda/4$ line

- Ensure system  $Z_0$  of network analyzer is set to this value.
- Open, short, load, delay/thru, or arbitrary impedance.
- For waveguide, the lower frequency is the same as  $F_{CO}$ .

**Table A-12 Standard Definitions for the PNA Series with Q-band (WR-22)**

System $Z_0^a = 1 \Omega$						Calibration Kit Label: Q-band							
Standard <sup>b</sup>		$C0 \times 10^{-15} \text{ F}$	$C1 \times 10^{-27} \text{ F/Hz}$	$C2 \times 10^{-36} \text{ F/Hz}^2$	$C3 \times 10^{-45} \text{ F/Hz}^3$	Fixed, sliding, or offset load or arbitrary impedance	Offset			Frequency in GHz <sup>c</sup>		Coax or Waveguide	Standard Label
Number	Type	$L0 \times 10^{-12} \text{ H}$	$L1 \times 10^{-24} \text{ H/Hz}$	$L2 \times 10^{-33} \text{ H/Hz}^2$	$L3 \times 10^{-42} \text{ H/Hz}^3$		Delay in ps	$Z_0 \Omega$	Loss in G $\Omega$ /s	Min	Max		
1	Offset load					Offset				26.338	52.676	WG	Offset load
2	Load					Fixed	0	1	0	26.338	52.676	WG	Fixed Load
3	Load					Sliding				26.338	52.676	WG	Sliding Load
4	Short	0	0	0	0		0	1	0	26.338	52.676	WG	Short
5	Offset short	0	0	0	0		8.082	1	12.77	26.338	52.676	WG	$\lambda/4$ Offset short
6	Thru						0	1	0	26.338	52.676	WG	Thru
7	$\lambda/4$ line						8.082	1	12.77	26.338	52.676	WG	$\lambda/4$ line

- a. Ensure system  $Z_0$  of network analyzer is set to this value.
- b. Open, short, load, delay/thru, or arbitrary impedance.
- c. For waveguide, the lower frequency is the same as  $F_{CO}$ .

**Table A-13 Standard Definitions for the PNA Series with U-band (WR-19)**

System $Z_0^a = 1 \Omega$		Calibration Kit Label: U-band											
Standard <sup>b</sup>		$C0 \times 10^{-15} \text{ F}$	$C1 \times 10^{-27} \text{ F/Hz}$	$C2 \times 10^{-36} \text{ F/Hz}^2$	$C3 \times 10^{-45} \text{ F/Hz}^3$	Fixed, sliding, or offset load or arbitrary impedance	Offset			Frequency in GHz <sup>c</sup>		Coax or Waveguide	Standard Label
Number	Type	$L0 \times 10^{-12} \text{ H}$	$L1 \times 10^{-24} \text{ H/Hz}$	$L2 \times 10^{-33} \text{ H/Hz}^2$	$L3 \times 10^{-42} \text{ H/Hz}^3$		Delay in ps	$Z_0 \Omega$	Loss in GΩ/s	Min	Max		
1	Offset load					Offset				31.386	62.772	WG	Offset load
2	Load					Fixed	0	1	0	31.386	62.772	WG	Fixed Load
3	Load					Sliding				31.386	62.772	WG	Sliding Load
4	Short	0	0	0	0		0	1	0	31.386	62.772	WG	Short
5	Offset short	0	0	0	0		6.643	1	16.65	31.386	62.772	WG	$\lambda/4$ Offset short
6	Thru						0	1	0	31.386	62.772	WG	Thru
7	$\lambda/4$ line						6.643	1	16.65	31.386	62.772	WG	$\lambda/4$ line

- Ensure system  $Z_0$  of network analyzer is set to this value.
- Open, short, load, delay/thru, or arbitrary impedance.
- For waveguide, the lower frequency is the same as  $F_{CO}$ .

**Table A-14 Standard Definitions for the PNA Series with V-band (WR-15)**

System $Z_0^a = 1 \Omega$		Calibration Kit Label: V-band											
Number	Type	$C0 \times 10^{-15} \text{ F}$	$C1 \times 10^{-27} \text{ F/Hz}$	$C2 \times 10^{-36} \text{ F/Hz}^2$	$C3 \times 10^{-45} \text{ F/Hz}^3$	Fixed, sliding, or offset load or arbitrary impedance	Offset			Frequency in GHz <sup>c</sup>		Coax or Waveguide	Standard Label
		$L0 \times 10^{-12} \text{ H}$	$L1 \times 10^{-24} \text{ H/Hz}$	$L2 \times 10^{-33} \text{ H/Hz}^2$	$L3 \times 10^{-42} \text{ H/Hz}^3$		Delay in ps	$Z_0 \Omega$	Loss in GΩ/s	Min	Max		
1	Offset load					Offset				39.873	79.745	WG	Offset load
2	Load					Fixed	0	1	0	39.873	79.745	WG	Fixed Load
3													
4	Short	0	0	0	0		0	1	0	39.873	79.745	WG	Short
5	Offset short	0	0	0	0		5.376	1	24.23	39.873	79.745	WG	$\lambda/4$ Offset short
6	Thru						0	1	0	39.873	79.745	WG	Thru
7	$\lambda/4$ line						5.376	1	24.23	39.873	79.745	WG	$\lambda/4$ line

- a. Ensure system  $Z_0$  of network analyzer is set to this value.
- b. Open, short, load, delay/thru, or arbitrary impedance.
- c. For waveguide, the lower frequency is the same as  $F_{CO}$ .

**Table A-15 Standard Definitions for the PNA Series with W-band (WR-10)**

System $Z_0^a = 1 \Omega$		Calibration Kit Label: W-band											
Number	Type	$C0 \times 10^{-15} \text{ F}$	$C1 \times 10^{-27} \text{ F/Hz}$	$C2 \times 10^{-36} \text{ F/Hz}^2$	$C3 \times 10^{-45} \text{ F/Hz}^3$	Fixed, sliding, or offset load or arbitrary impedance	Offset			Frequency in GHz <sup>c</sup>		Coax or Waveguide	Standard Label
		$L0 \times 10^{-12} \text{ H}$	$L1 \times 10^{-24} \text{ H/Hz}$	$L2 \times 10^{-33} \text{ H/Hz}^2$	$L3 \times 10^{-42} \text{ H/Hz}^3$		Delay in ps	$Z_0 \Omega$	Loss in GΩ/s	Min	Max		
1	Offset load					Offset				59.024	118.05	WG	Offset load
2	Load					Fixed	0	1	0	59.024	118.05	WG	Fixed Load
3													
4	Short	0	0	0	0		0	1	0	59.024	118.05	WG	Short
5	Offset short	0	0	0	0		3.620	1	64.85	59.024	118.05	WG	$\lambda/4$ Offset short
6	Thru						0	1	0	59.024	118.05	WG	Thru
7	$\lambda/4$ line						3.620	1	64.85	59.024	118.05	WG	$\lambda/4$ line

- a. Ensure system  $Z_0$  of network analyzer is set to this value.
- b. Open, short, load, delay/thru, or arbitrary impedance.
- c. For waveguide, the lower frequency is the same as  $F_{CO}$ .

## Blank Forms

The standard definitions may be changed to meet your specific requirements. The following two tables are provided to record the modified standard definitions.

**Table A-16 Blank Form for the 8510 Network Analyzer**

System $Z_0^a =$ _____		Calibration Kit Label: _____											
Disk File Name: _____													
Number	Standard <sup>b</sup> Type	Standard <sup>b</sup>				Fixed, Sliding, or Offset <sup>c</sup>	Offset			Frequency in GHz <sup>d</sup>		Coax or Waveguide	Standard Label
		$C0 \times 10^{-15} F$	$C1 \times 10^{-27} F/Hz$	$C2 \times 10^{-36} F/Hz^2$	$C3 \times 10^{-45} F/Hz^3$		Delay in ps	$Z_0 \Omega$	Loss in GΩ/s	Min	Max		
		$L0 \times 10^{-12} H$	$L1 \times 10^{-24} H/Hz$	$L2 \times 10^{-33} H/Hz^2$	$L3 \times 10^{-42} H/Hz^3$								
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													

- a. Ensure system  $Z_0$  of network analyzer is set to this value.
- b. Open, short, load, delay/thru, or arbitrary impedance.
- c. Load or arbitrary impedance only.
- d. For waveguide, the lower frequency is the same as  $F_{CO}$ .

**Table A-17 Blank Form for the PNA Series Network Analyzer**

System $Z_0^a =$ _____		Calibration Kit Label: _____											
Number	Type	Standard <sup>b</sup>				Fixed, sliding, or offset load or arbitrary impedance	Offset			Frequency in GHz <sup>c</sup>		Coax or Waveguide	Standard Label
		$C0 \times 10^{-15} F$	$C1 \times 10^{-27} F/Hz$	$C2 \times 10^{-36} F/Hz^2$	$C3 \times 10^{-45} F/Hz^3$		Delay in ps	$Z_0 \Omega$	Loss in GΩ/s	Min	Max		
1		$L0 \times 10^{-12} H$	$L1 \times 10^{-24} H/Hz$	$L2 \times 10^{-33} H/Hz^2$	$L3 \times 10^{-42} H/Hz^3$								
2													
3													
4													
5													
6													
7													

- a. Ensure system  $Z_0$  of network analyzer is set to this value.
- b. Open, short, load, delay/thru, or arbitrary impedance.
- c. For waveguide, the lower frequency is the same as  $F_{CO}$ .



## Symbols

$\frac{1}{4}$  wavelength shims, 2-4

## A

Agilent Technologies  
  contacting, 6-5  
Agilent Technologies application  
  note, A-2  
alcohol  
  isopropyl  
    part number, 7-14  
    precautions for use of, 4-3  
aligning  
  non-precision and precision  
    flanges, 4-7  
  precision flanges, 4-6  
altitude, specifications, 2-2  
analyzers, compatible, 1-2  
assistance  
  contacting agilent, 6-5

## B

blank forms  
  standard class assignments, A-6  
  standard definitions, A-19  
box, part number, 7-4, 7-6, 7-8,  
  7-10, 7-12

## C

cal kit  
  contents, 1-2  
  overview, 1-2  
  verifying, 5-2  
calibration  
  bad, 6-2  
  certificate of, 5-3  
  constants, A-8  
  definitions  
    disk, part number, 7-6, 7-8,  
      7-10  
    part number, 7-12  
  devices, 3-2  
  kits, intended use, 1-3  
  report, 5-3  
  standards, 5-2  
  sticker, 5-3  
  temperature, 2-2  
calibration applications, 3-3  
  1/4 load, 3-4  
  1/4 short, 3-5  
  isolation, 3-3  
  line, 3-3  
  load, 3-4  
  offset load, 3-4  
  offset short, 3-5  
  reflect, 3-5

  short, 3-5  
  thru, 3-6  
  calibration definition, wavelength  
    shim, 3-7  
  calibration kit  
    Agilent Application Note, A-2  
    contents, 1-2  
    drawing of, 7-5, 7-7, 7-9, 7-11,  
      7-13  
    modifying definition files, A-2  
    overview, 1-2  
    parts not included, 7-14  
    performance  
      how Agilent verifies, 5-2  
  case, storage, 7-4, 7-6, 7-8, 7-10,  
    7-12  
  certificate of calibration, 5-3  
  certification, device specifications,  
    2-5  
  characteristics  
    mechanical, 2-3  
  class assignments  
    blank forms, A-6  
    downloading from Agilent Web  
      site, A-2  
  class assignments, standard, A-3,  
    A-4, A-6  
  cleaning  
    connectors, 4-3  
    mating plane surfaces, 4-4  
    supplies, 1-3  
    part number, 7-14  
  compatible analyzers, 1-2  
  component identification sheets  
    Q and U-band, 7-7, 7-9  
    R-band, 7-5  
    V and W-band, 7-11, 7-13  
  compressed air  
    for cleaning, 4-3  
  conductive table mat, part  
    number, 7-14  
  connecting  
    flanges, 4-5, 4-8  
    for ESD protection, 4-2, 7-14  
    waveguides, 4-5  
  connections, 4-5  
  connector  
    cleaning, 4-3  
    mating plane surfaces, 4-4  
  constants, A-8  
  part numbers, 7-4, 7-8, 7-12  
  contacting Agilent Technologies,  
    6-5  
  contents  
    calibration kit, 1-2  
    drawing of, 7-5, 7-7, 7-9, 7-11,  
      7-13

incomplete, 1-3

## D

damage  
  caused by electrostatic  
    discharge, 4-2  
data, recertification, 5-3  
definitions  
  calibration, 3-7  
  standard, A-8, A-9, A-10, A-11,  
    A-12, A-13, A-14, A-15,  
    A-16, A-17, A-18  
device  
  calibration, 3-2  
  cleaning, 4-3  
  compatible analyzers, 1-2  
  connecting, 4-5  
  handling, 4-9  
  maintenance, 1-5  
  performance, verifying, 5-2  
  specifications  
    certification of, 2-5  
    electrical, 2-4  
    traceability, 5-2, 5-3  
  storage, 4-9  
  temperature, 2-2  
  visual inspection, 4-3  
disk  
  calibration definitions  
    part number, 7-4, 7-6, 7-8,  
      7-10, 7-12  
  specifications and performance  
    part number, 7-4, 7-6, 7-8,  
      7-10, 7-12  
documentation warranty, -ii  
documented kits, 1-3

## E

electrical  
  characteristics  
    effects of temperature, 2-2  
  specifications of shims, 2-4  
  specifications of standard  
    sections, 2-4  
  specifications of terminations,  
    2-4  
electrostatic discharge, *See* ESD  
environmental  
  regulations, 4-3  
  requirements, 2-2  
  specifications, 2-2  
equipment required, 1-3  
ESD, 4-2  
  protection, 4-2  
  supplies, part number, 7-14



temperature, [2-2](#)  
traceability, [5-2](#), [5-3](#)  
standard class assignments, [A-3](#)  
8510, [A-3](#), [A-4](#), [A-6](#)  
blank forms, [A-6](#)  
standard definitions, [A-8](#), [A-19](#)  
blank forms, [A-19](#)  
downloading from Agilent Web  
site, [A-2](#)  
nominal, [A-8](#)  
PNA series, [A-14](#), [A-15](#), [A-16](#),  
[A-17](#), [A-18](#)  
Q-band (WR-22), [A-10](#), [A-15](#)  
R-band (WR-28), [A-9](#), [A-14](#),  
[A-15](#)  
U-band (WR-19), [A-11](#), [A-16](#),  
[A-17](#), [A-18](#)  
V-band (WR-15), [A-12](#), [A-17](#),  
[A-18](#)  
W-band (WR-10), [A-13](#), [A-18](#)  
standard section, [3-2](#)  
standards  
international, [2-5](#)  
National Institute of Standards  
and Technology (NIST), [2-5](#),  
[5-2](#)  
static electricity, [4-2](#)  
storage, [4-9](#)  
storage case, part number, [7-4](#),  
[7-6](#), [7-8](#), [7-10](#), [7-12](#)  
strap  
heel and wrist, part number,  
[7-14](#)  
supplies  
cleaning, [1-3](#)  
part number, [7-14](#)  
system impedance, [A-8](#)

## T

table mat  
for ESD protection, [4-2](#)  
part number, [7-14](#)  
tag, service, [5-3](#), [6-4](#)  
temperature  
affect on electrical performance,  
[2-2](#)  
cautions about, [2-2](#)  
environmental requirements,  
[2-2](#)  
error-corrected, [2-2](#)  
measurement, [2-2](#)  
specifications, [2-2](#)  
verification and measurement,  
[2-2](#)  
termination, [3-2](#)  
test data, [5-3](#)  
test, performance, [5-4](#), [5-5](#)

thru, [3-6](#)  
traceability  
of device specifications, [5-2](#), [5-3](#)  
troubleshooting, flowchart, [6-2](#)

## U

uncertainty, measurement, [2-5](#)  
user's and service guide  
part number, [7-6](#), [7-8](#), [7-10](#),  
[7-12](#)

## V

verification  
device, [5-2](#)  
performance, [5-3](#)  
temperature, [2-2](#)  
version changes, [A-2](#)  
visual inspection, [4-3](#)

## W

warranty, documentation, [-ii](#)  
waveguide straight  
port 1 and 2, [3-2](#)  
verification device, [3-2](#)  
waveguide, connecting, [4-5](#)  
wavelength shim, [3-2](#)  
wavelength shim, calibration  
definition, [3-7](#)  
wrist strap  
for ESD protection, [4-2](#)  
part number, [7-14](#)