User's Guide

Agilent Technologies N1947A, N1948A, N1951A, N1953A, and N1957A Physical Layer Test Systems

With the N1930A Physical Layer Test System Software

Agilent Technologies

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Supersedes N1930-90001

Notice

LIMITED WARRANTY

Assistance

Product maintenance agreements and other customer assistance agreements are available for Agilent Technologies products. For any assistance, refer to “Contacting Agilent” on page 350.

Software Licensing

The Physical Layer Test System has node-locked licensing. Node-locked licenses are licenses that are tied to a personal computer and it's specific ID. Agilent software looks for that specific ID when it starts. If the ID is not found, the software is locked and does not start. Refer to Chapter 1, Installing your Physical Layer Test System, for the licensing procedure.

Software Compatibility

This user's guide is compatible with software revisions 1.101 and above.

Document Conventions

This document uses a few conventions to make reading easier.

- Menu and dialog box items are shown in bold face type. When described in text, menus and sub-menus are separated by right arrows, as in **File > Open > Data...**
- Window and dialog box names are shown in *italic* font.
- Keyboard entries are shown in `mono-spaced` typeface.
- Network analyzer keys are displayed in **condensed**, **bold** font.

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I Installation and Quick Start

Part I guides you through the initial steps of setting up and using the physical layer test system.

Chapter 1, "Installing your Physical Layer Test System"	Provides you a step-by-step physical layer test system installation procedure.
Chapter 2, "Becoming Familiar with your Physical Layer Test System"	Provides you detailed physical layer test system software and test equipment descriptions to familiarize you with the test system components.
Chapter 3, "Making a Measurement using the Sample Device"	Provides you with a step-by-step procedure to make a basic measurement using the physical layer test system.

1 Installing your Physical Layer Test System

The Physical Layer Test System (PLTS) consists of the following items:

- Personal computer (PC)
- Network analyzer
- S-parameter test set
- PLTS software

This installation procedure will lead you through a series of steps to set up your PLTS. The following is a list of the installation steps:

- Step 1. Set Up the Personal Computer
- Step 2. Verify your System Shipment
- Step 3. Set Up the Network Analyzer
- Step 4. Attach the Test Set to the Network Analyzer (N4464A/B – N4421A Only)
- Step 5. Install the S-Parameter Test Set on a Bench Top or in an Equipment Rack
- Step 6. Make the Interconnections between the S-Parameter Test Set and the Network Analyzer
- Step 7. Set Up the GPIB
- Step 8. Power up the Physical Layer Test System
- Step 9. Install the Physical Layer Test System Software
- Step 10. License the Physical Layer Test System Software
- Step 11. Start the Physical Layer Test System Software

NOTE These installation instructions were written specifically for customers who have just received their PLTS. If you have already been using our S-parameter test set and its corresponding network analyzer, you have probably completed most of these installation steps. Briefly review installation steps 1 through 8 to ensure that your system is currently set up as recommended. Then, begin the software installation process by starting at "Step 9. Install the Physical Layer Test System Software" on page 25.

Step 1. Set Up the Personal Computer

1. Make sure that your PC meets the following minimum system controller requirements:

   - 700 MHz Pentium[1] III (or better) PC compatible computer
     (1 GHz Pentium III is recommended)
   - Windows NT[2], Windows[3] 2000, or Windows XP
     (Windows 2000 or Windows XP is recommended)

     Windows should be run with the latest service pack available.
   - At least 256 megabytes of RAM
     (512 MB RAM is recommended)
   - CD-ROM Drive
   - Supported GPIB Interface
     - ❑ Agilent 82357A USB/GPIB Interface for Windows (which provides a direct connection from the USB port on your PC to GPIB instruments),

     or
     - ❑ Supported GPIB card
       (any National Instruments or Agilent 82340, 82341, or 82350 GPIB card)

     (Agilent 82357A USB/GPIB Interface for Windows or any National Instruments GPIB card is recommended)

2. Using the PC documentation, make sure that the PC is operating properly.
3. Make sure the GPIB card is installed in the PC and that it is operating properly.
4. Make sure the PC is located near where you will position the network analyzer and the test set. Later in this process, you will connect the GPIB card to the Physical Layer Test System (PLTS) using the GPIB cable.

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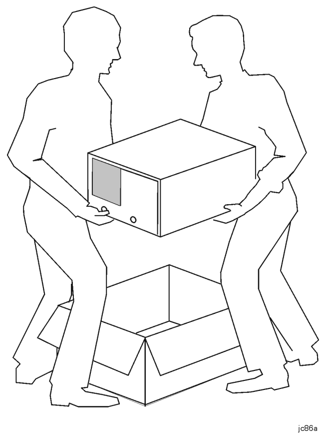
1. Pentium® is a U.S. registered trademark of Intel Corporation.
2. Windows NT® is a U.S. registered trademark of Microsoft Corporation.
3. Windows® and MS Windows® are U.S. registered trademarks of Microsoft Corporation.

Step 2. Verify your System Shipment

1. Unpack your system from the containers in which it was shipped.



WARNING **The test system hardware is heavy. The network analyzer can weigh between 53 lb. (24 kg) and 64 lb. (29 kg). The test set can weigh as much as 20 lb. (9 kg). Use proper lifting techniques.**

2. Carefully inspect the system hardware (the network analyzer and the test set) to make sure that it was not damaged during shipment.

NOTE If your test system was damaged during shipment, contact Agilent Technologies. Refer to "Contacting Agilent" on page 350.

3. Using Table 1-1, verify that your test set is compatible with your network analyzer and its installed options. Refer to "Step 3. Set Up the Network Analyzer" on page 10 for additional information regarding network analyzer options. If the installed options are not compatible, contact us before proceeding. Refer to "Contacting Agilent" on page 350.

Table 1-1 Physical Layer Test System Configurations

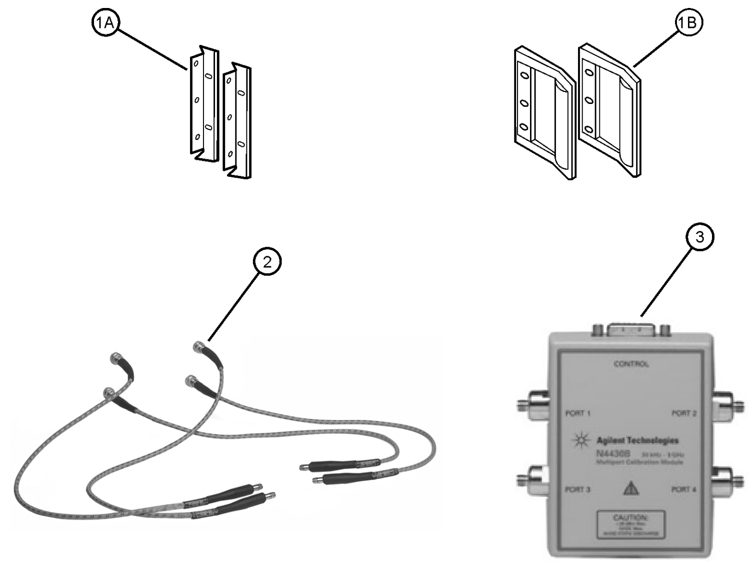
Test Set Model Number	System Frequency Range	Supported Network Analyzer			
		Model Number	Options[a]		
			Required	Compatible	Incompatible
N4415A	30 kHz to 6.0 GHz	8753ES	006[b], 014	002, 004, 010, 1D5	011, 075, H16
N4416A	300 kHz to 6.0 GHz	E8356A[c]/7A/8A	015	010, 1D5	
N4417A[d]	300 kHz to 9.0 GHz	E8356A[c]/7A[e]/8A	015	010	
		E8801A[c]/2A[e]/3A	014	010, 1E1, 1E5	
N4418A	50 MHz to 20 GHz	8720ES	H32 or H42	010, 012, 400	007, 085, 089
		8722ES[f]	H32 or H44	010, 012, 400	007, 085, 089
N4419A	45 MHz to 20 GHz	E8362A/B	014	010, 022, 711, UNL	
N4421A	45 MHz to 50 GHz	E8364A/B	014	010, 022, 711, UNL	

a. This table lists only the most specifically relevant options. For compatibility with options not listed here, contact the factory.
b. Option 006 required only for operation above 3 GHz.
c. Using this network analyzer, the maximum operating frequency is limited to 3 GHz.
d. E8356A family requires N4417A Option 103; E8801A family requires N4417A Option 104.
e. Using this network analyzer, the maximum operating frequency is limited to 6 GHz.
f. When an 8722ES is used with an N4418A, the N4418A requires Option 302. The system's maximum operating frequency is limited to 20.0 GHz.

4. Check the accessories that were shipped with your system. Your network analyzer accessories will be checked during the network analyzer setup.

Item Number	Part Number	Part Description
1	N1930-90002	User’s Guide (this document)
2	N1930A	Physical Layer Test System Software CD-ROM (in envelope with Agilent Software License Terms printed on exterior)
3	N/A	Software Entitlement Certificate (in envelope)
4	Unique to country	AC Power Cord (for the test set)
5	8120-3445	GPIB Cable (3 feet)
6	Varies by Test Set Model and Option	Semirigid interconnect cables (refer to Step 6. Make the Interconnections between the S-Parameter Test Set and the Network Analyzer for the appropriate number of cables)
7	N/A	“Port 3” Label
8	AD00658	Balanced Transmission Line PC Board Device (Sample DUT)
9	1600-1423	4 Lock Links (N4421A only) With 8 screws (0515-1499)
10	Left: Z5823-20239 Right: Z5823-20240	2 Rear Locking Feet (N4421A only) (With 4 Screws - 2 each - longer: 0515-0686 and shorter: 2680-0179)

5. If you ordered any of the following options, check the parts. Option 1CP is shipped in a separate container.



Option Number	Item Number	Part Description
1CP	1A 1B	Rack mount flange kit (For use with handles) Handles (set of 2)
B20	2	Precision 50-ohm cables (4)
060	3	4-Port Electronic Calibration Module/Kit (Not available as an option for the N1951A/53A/57A PLTS)
	Other Calibration Kits	
N/A	Not Shown	85033E 3.5mm Calibration Kit (30 kHz– 9 GHz) [1] 85052D 3.5mm Economy Calibration Kit (45 MHz – 26.5 GHz) [1] 85056A 2.4mm Precision Calibration Kit (45 MHz – 50 GHz) [1] 85050C 7 mm Precision Calibration Kit (45 MHz – 18 GHz) [2]

[1] Kit for SOLT Calibration; [2] Kit for TRL Calibration

Step 3. Set Up the Network Analyzer

1. Using Table 1-2, verify that your network analyzer options are compatible with the physical layer test system. Incompatible options are shaded.

Table 1-2 Common Hardware Option Number Descriptions for Network Analyzers

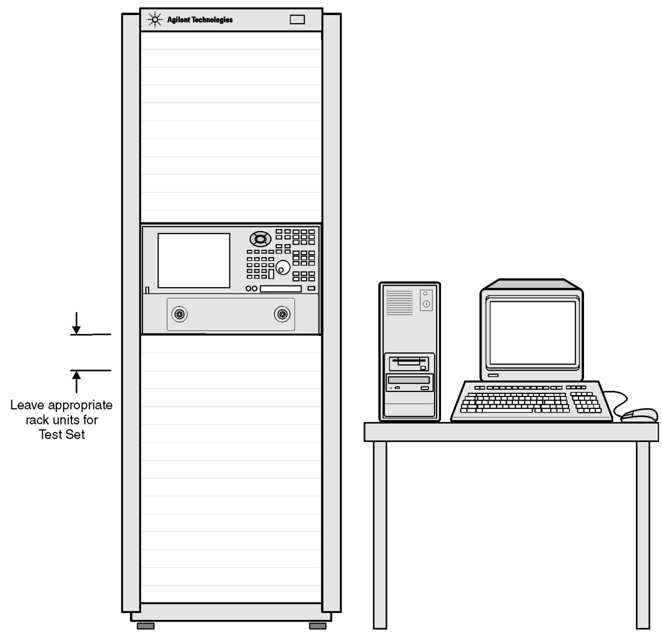
8753ES Network Analyzer Options			
002	Harmonic-Measurement Upgrade	004	Step Attenuator Upgrade
006	6 GHz Upgrade for Standard Units	010	Time Domain Capability
011	Receiver Configuration	014	Configurable Test Set
075	75 Ohm Impedance	1D5	High Stability Frequency Reference
H16	Low Noise Floor		
8720ES and 8722ES Network Analyzer Options			
007	Mechanical Transfer Switch	010	Time Domain Capability
012	Direct Sampler Access	085	High-Power Test System
089	Frequency Offset Mode	1D5	High Stability Frequency Reference
400	Four-Sampler Test Set	H32	Front panel access to A and B samplers and Port 1 and Port 2 switch and coupler
H42	8719/8720 only: Front panel access to all samplers and Port 1 and Port 2 switch and coupler (installs options 400 & 012)	H44	8722 only: Front panel access to R1, R2, A, and B samplers, and Port 1 and Port 2 switch and coupler ports (installs options 400 & 012)
E8356A, E8357A, and E8358A Network Analyzer Options			
010	Time Domain Capability	015	Configurable Test Set
E8801A, E8802A, and E8803A Network Analyzer Options			
010	Time Domain Capability	014	Configurable Test Set
1E1	Extended Power Range	1E5	High Stability Timebase
E8862A/B and E8864A/B Network Analyzer Options			
010	Time Domain Capability	014	Configurable Test Set
016[a]	Add Receiver Attenuators	022	Extended Memory

Table 1-2 Common Hardware Option Number Descriptions for Network Analyzers

080[a]	Frequency Offset	081[a]	External Reference Switch
083[a]	Frequency Converter Measurement Application	711	Standard Power Range
UNL	Extended Power Range with Bias Tees		

a. This option has not been tested and is not specified with the Physical Layer Test System.

2. Using the network analyzer's Installation and Quick Start Guide, set up the network analyzer.
3. If you are installing your network analyzer in an equipment rack, be sure to leave at least 2 rack units of space *below* the analyzer to install the test set.



NOTE For the N4421A test set, connect the E8364A/B network analyzer to the test set before placing in the rack as a single unit on one set of rails. Refer to "Step 4. Attach the Network Analyzer to the Test Set" on page 12 for instructions.

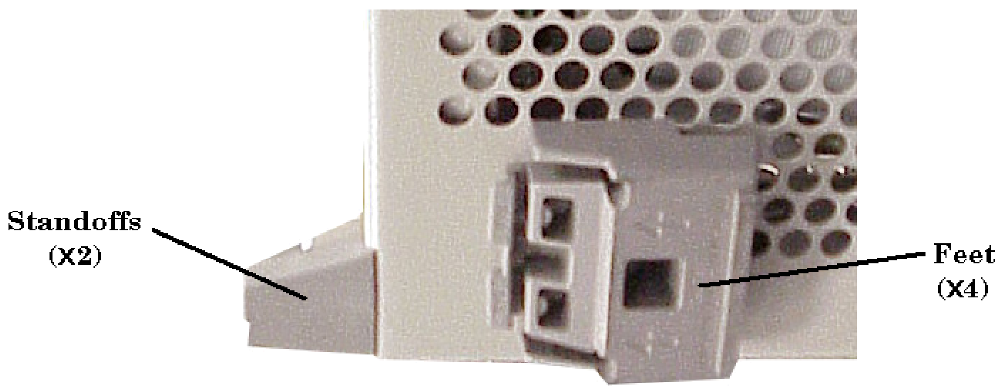
Step 4. Attach the Network Analyzer to the Test Set
(N4464A/B Network Analyzer – N4421A Test Set Only)

If your test set is not an N4421A, continue with "Step 5. Install the Test System on a Bench Top or in an Equipment Rack" on page 15.

The E8364A/B network analyzer is attached with the N4421A test set using lock links at the front and locking feet at the rear. This hardware is supplied with the N4421A test set. Other network analyzers are not attached to test sets (N4415A, N4416A, N4417A, N4418A, and N4419A) using this hardware.

Preparing the Network Analyzer

1. Remove the four feet from the bottom of the network analyzer.

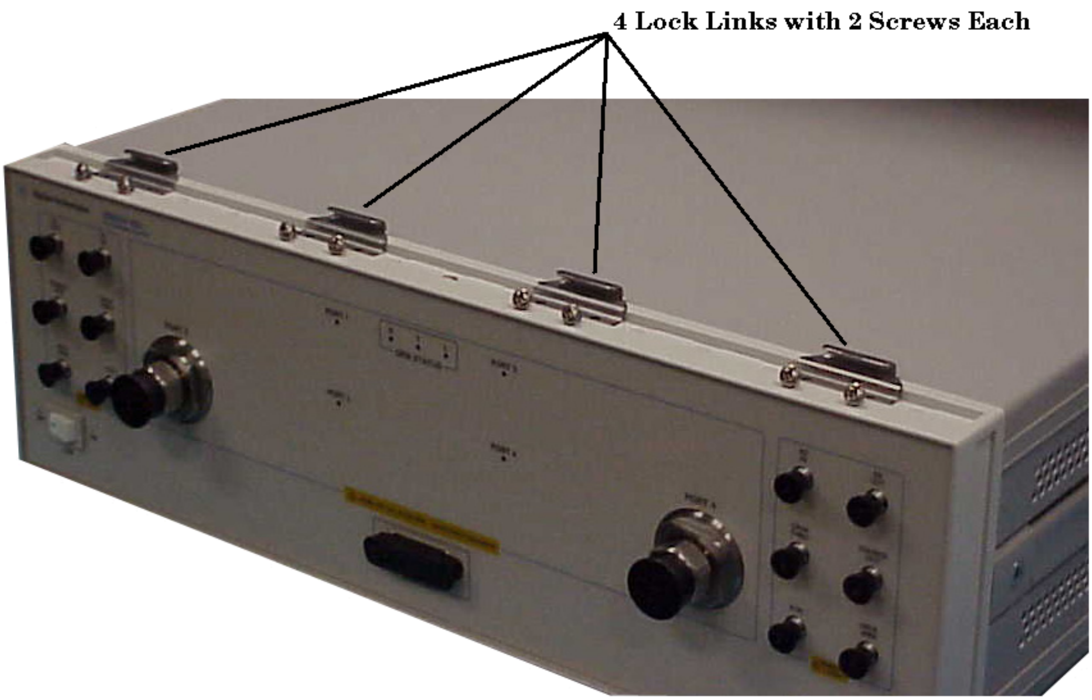


2. Remove the screws from the two lower rear panel standoffs.
3. Install the two rear locking feet where the standoffs were removed. Use part number Z5823-20239 on the left side of the analyzer and part number Z5823-20240 on the right side. Use the two longer screws to secure the feet to the analyzer.

Preparing the Test Set

4. Remove the trim strip from the top of the front frame.
5. Install the four lock links to the top of the front frame using eight screws.

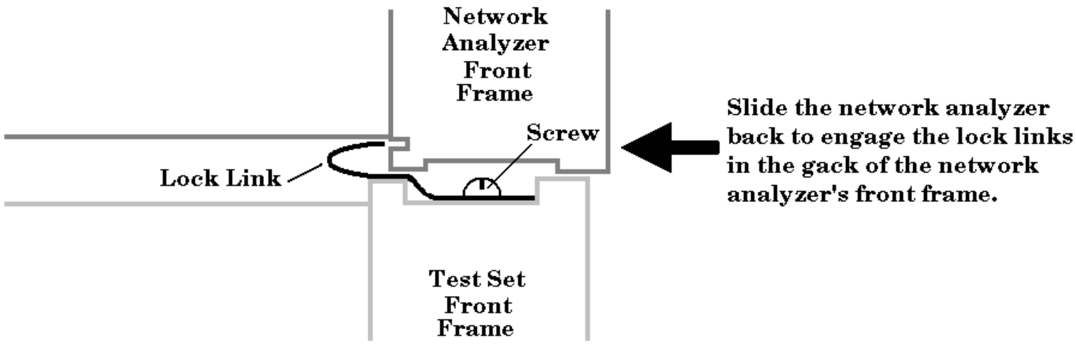
Lock Link Installation



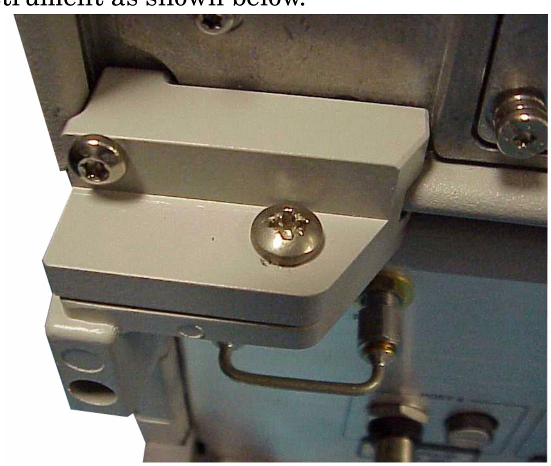
Attaching the Network Analyzer to the Test Set

6. Place the network analyzer on top of the test set ensuring that the front frame of the network analyzer is positioned slightly forward of the lock links that are attached to the the test set. Then slide the network analyzer back so the lock links engage the front frame of the analyzer.

Making the Lock Link Connection



7. Secure the network analyzer’s lower locking feet to the test set’s upper locking feet by inserting the shorter two screws between the two pairs of locking feet, one on each side of the instrument as shown below.



   If the screw holes between the network analyzer’s lower locking feet are not aligned with the screw holes in the test set’s upper locking feet, loosen the screws securing the feet to the instruments slightly to align.

8. Tighten all screws.

Step 5. Install the Test System on a Bench Top or in an Equipment Rack

The test system can be installed on a bench top or in an equipment rack.

In all installations, consider the following ventilation requirements when deciding where to set up your test system.

CAUTION **Ventilation Requirements:**
When installing the product in a cabinet, the convection into and out of the product must not be restricted. The ambient temperature (outside the cabinet) must be less than the maximum operating temperature of the instrument by 4 °C for every 100 watts dissipated in the cabinet. If the total power dissipated in the cabinet is greater than 800 watts, then forced convection must be used.

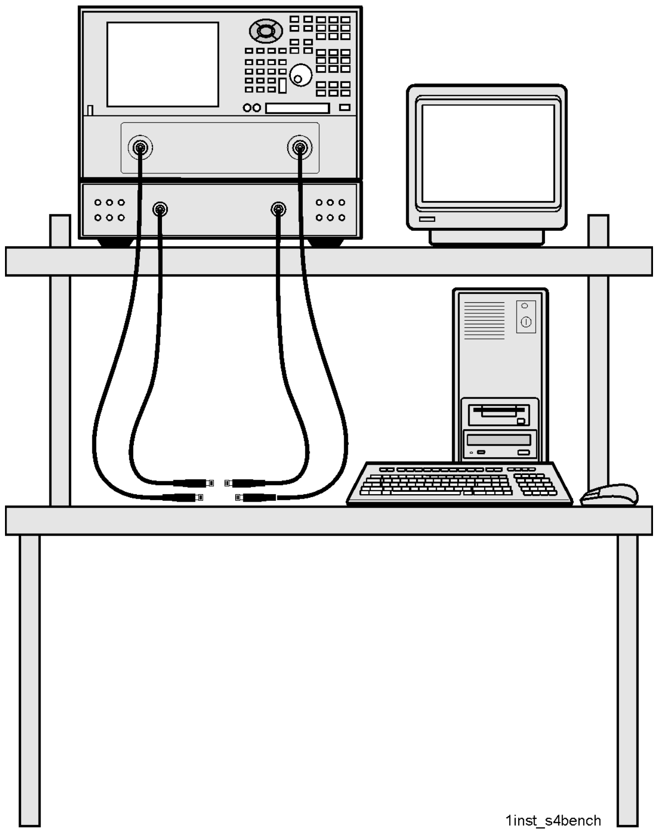
Refer to the section that applies to your installation.

- **For bench top installation**, continue on page 16.
- **For equipment rack installation**, continue on page 17.

To Install on a Bench Top

1. Place the test set and the network analyzer on a bench top. In the example illustration shown below, the system is placed on a riser as an alternative to the bench top. Make sure that there is at least four inches of clearance on the sides and back of the system for adequate ventilation.

   The front panel test cables are shown only as a reminder to make sure they can easily reach the test surface of the bench.



CAUTION Consider the ventilation requirement described on page 15 when selecting the location of your system.

2. Continue with "Step 6. Make the Interconnections between the S-Parameter Test Set and the Network Analyzer" on page 20.

To Install in an Equipment Rack

When you install the test set in an equipment rack, you will install rails in the rack to support the weight of the test set, attach the handles and the rack mount flanges to the test set, and secure the test set to the equipment rack.

1. Ensure that the front handle kit, the rack mount flange kit, and the rack mount rail set are complete.

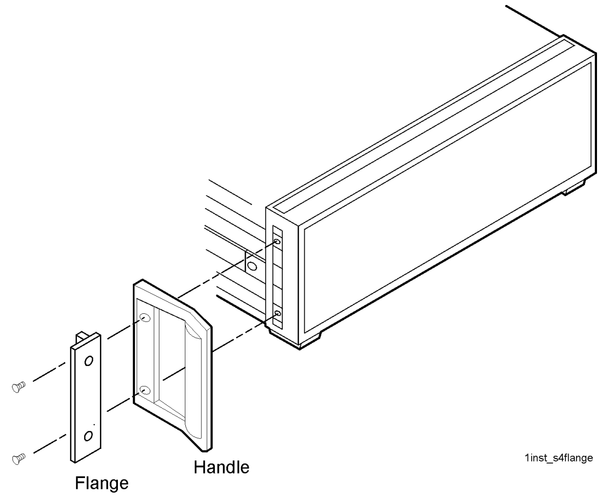
Handle Kit Contents	Flange Kit Contents
• 4 Screws • 2 Side Trim Strip • 2 Handles • Installation Instructions	• 4 Screws (Long) • 4 Screws with Washers • 4 Nuts with Metal Clips • 2 Flanges • Installation Instructions

NOTE If any items are damaged or missing from a kit, contact us (refer to "Contacting Agilent" on page 350) to order a replacement kit. Items within these kits are not individually available.

2. Install the rails into the equipment rack using the instructions provided. Consider that the test set is two rack units high (3.5 inches). Mount the test set immediately below the network analyzer.

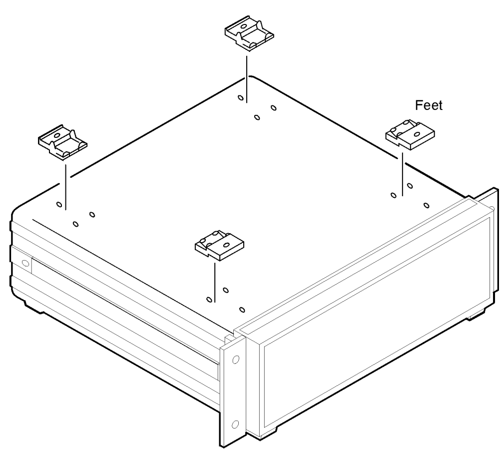
NOTE For the N4421A test set, connect the E8364A/B network analyzer to the test set before placing in the rack as a single unit on one set of rails.

3. Attach the cabinet mount flanges and the handles to the sides of the front panel, using two long screws per side. (Attach the flanges to the outside of the handles.)



WARNING **If an instrument handle is damaged, you should replace it immediately. Damaged handles can break while you are moving or lifting the instrument and cause personal injury or damage to the instrument.**

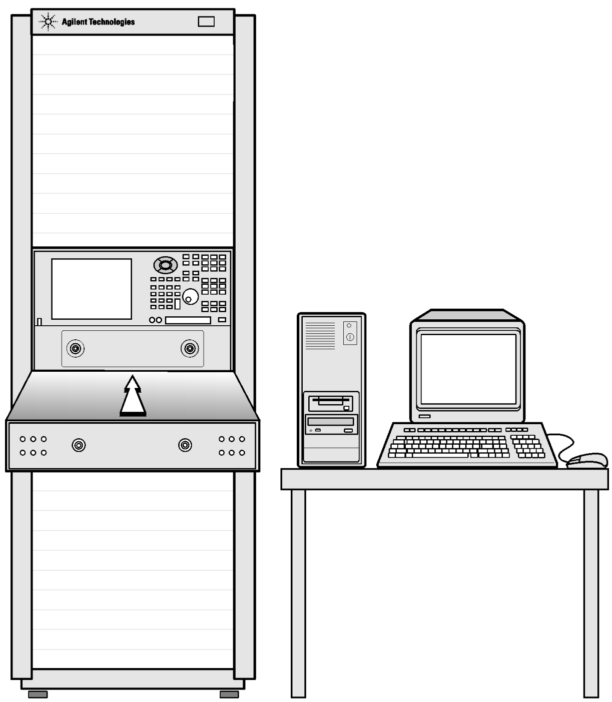
4. Remove the feet before cabinet mounting the analyzer using the directions imprinted on the feet.



5. Ensure there is adequate clearance between the system cabinet and the sides and back of the test system for adequate ventilation.

CAUTION Consider the ventilation requirements described in “Step 5. Install the Test System on a Bench Top or in an Equipment Rack” on page 15 when selecting the location of your system.

6. Lift the test set and slide it onto the rails that you installed earlier from the front of the equipment rack. Secure the test set to the equipment rack using the screws with washers and metal-clipped nuts provided in the flange kit.



1inst_s4rackts

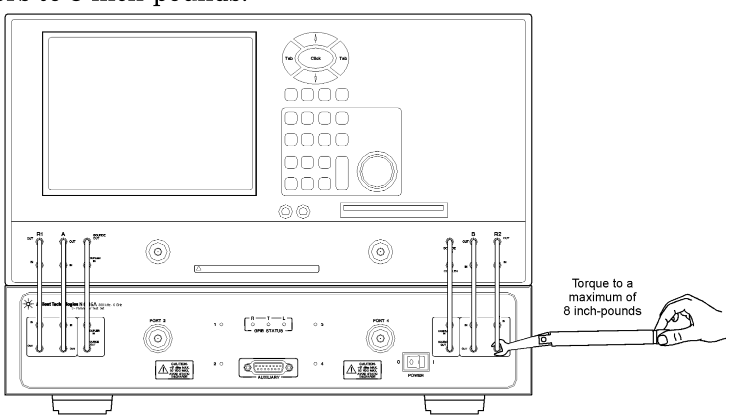
7. Continue with “Step 6. Make the Interconnections between the S-Parameter Test Set and the Network Analyzer” on page 20.

Step 6. Make the Interconnections between the S-Parameter Test Set and the Network Analyzer

1. Locate your system or test set and network analyzer listed below. Refer to the page indicated for information describing the interconnections between the test set and the network analyzer.

Test System Model Number	Test Set Model Number	Network Analyzer Model Number	Refer to:
N1947A	N4417A	E8801A, E8802A, E8803A	page 44
N1948A	N4417A	E8356A, E8357A, E8358A	page 46
N1951A	N4418A	8720ES, 8722ES	page 48
N1953A	N4419A	E8362A/B	page 50
N1957A	N4421A	E8364A/B	page 52
N/A	N4416A	E8356A, E8357A, E8358A	page 54
N/A	N4415A	8753ES	page 56

2. Using the illustration and table located on the page referenced above in step 1, connect the interconnect cables between the test set and the network analyzer. Torque the semirigid cable connectors to 8 inch-pounds.



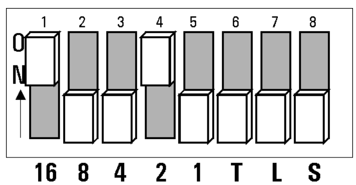
TIP If the test set and the network analyzer are rack mounted, the screws securing the rack mount flanges to the instrument rack may be loosened slightly to allow for minor repositioning of the instruments. Don't forget to retighten the screws when you are done.

Step 7. Set Up the General Purpose Interface Bus (GPIB)

The PC uses the General Purpose Interface Bus to communicate with the test system devices, the test set and the network analyzer. Each test system device has a unique GPIB address. GPIB addresses are five-bit binary numbers set with the switches labeled “16” through “1”, with “1” being the least significant digit. The five address switches allow for 32 GPIB addresses, numbered from 0 to 31. The test set has a default address of “18” that is set at the factory. While this address is a unique address in most cases, the address may be changed (if required) to avoid conflicts with other equipment on the same bus.

There are three other switches labeled “T”, “L”, and “S” which correspond to Talk, Listen, and Status. The factory default for these switches is off.

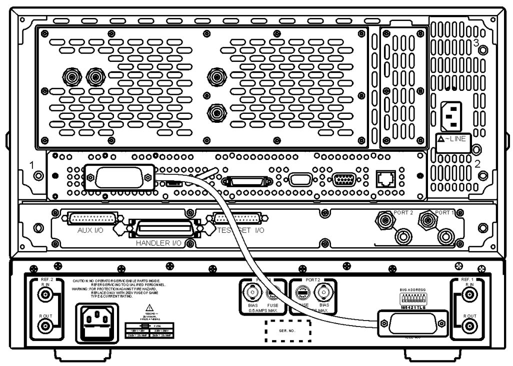
1. Make sure the GPIB address switch on the rear panel of the test set is set to the correct address. The illustration below shows the factory default setting of “18”, which is set by turning on switches “16” and “2”. Make sure the “T”, “L”, and “S” switches are set as shown (off).



2. Make sure that the network analyzer GPIB address is set to a unique address. The factory default address of the network analyzer is “16”. Refer to the network analyzer documentation for information about how to check and set the GPIB address of the analyzer.

3. Connect a GPIB cable from the rear panel GPIB connector on the network analyzer to the rear panel GPIB connector on the test set.

Network Analyzer



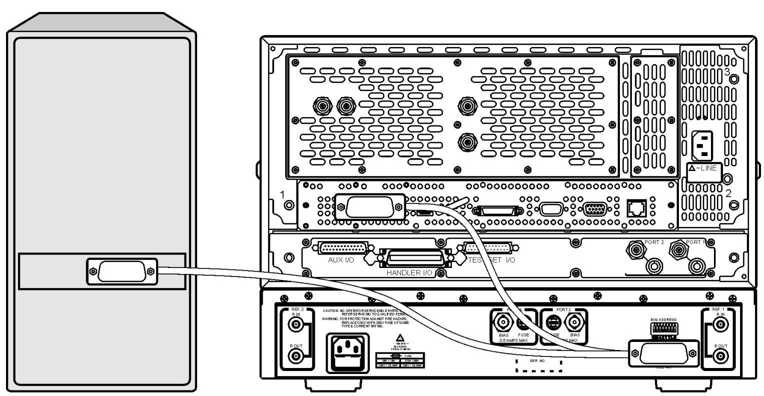
Test Set

1inst_s6gpib1

4. Connect a second GPIB cable from the PC GPIB card's connector to the GPIB connector on either end of the first cable that was connected (in step 3 above).

PC

Network Analyzer



Test Set

1inst_s6gpib2

NOTE After changing any GPIB address setting, cycle the ac power on all system equipment (PC, network analyzer, and test set) to establish the new GPIB address.

Step 8. Power up the S-Parameter Test Set

1. Ensure the available ac power supply meets the Power Source Requirements and the operating environment meets the Operating Environment Requirements listed below.

Power Source Requirements			
Input Voltage Range	100 – 120 Vac	- or -	220 – 250 Vac
Frequency Range	47 – 62 Hz / 400 Hz		
Power	40 VA maximum.		
Operating Environment Requirements			
Operating Environment	Indoor use		
Altitude	Operating: Storage:	0 to 2.0 km (6,560 ft.) 0 to 15.24 km (50,000 ft.)	
Temperature	0 °C to 40 °C		
Maximum Relative Humidity	80% for temperatures up to 31 °C; decreasing linearly to 50% for a temperature of 40 °C		

Refer to Chapter 11, “Specifications and Characteristics,” for the complete specifications.

2. Verify that the ac power cable is not damaged, and that the power-source outlet provides a protective earth contact.

CAUTION Always use the three-prong ac power cord supplied with this product. Failure to ensure adequate earth grounding by not using this cord may cause product damage.

3. Turn off the PC and the network analyzer.
4. Connect the ac power cable from the power-source outlet to the ac input on the rear panel of the test set.
5. Turn on the PC, the network analyzer, and the test set by pressing the ON/OFF button on the front panel of each device.
6. If your network analyzer is an N8362A/B or N8364A/B PNA, you will need to perform the Phase-Lock IF Gain Adjustment on the analyzer after it has been connected to the test set as a system. This routine adjusts the R Channel receivers ALC gain to ensure phase lock over the entire frequency range. Refer to **Phase-Lock IF Gain Adjustment** in the network analyzer’s online help system for details. Use the following steps to perform this adjustment:

a. On the network analyzer, from the **System** menu, click **Service**, then **Adjustments**, then **IF Gain Adjustment**.

   If you are unable to find these selections on your N836XA PNA, your analyzer firmware is a revision prior to 3.0. Follow the instructions in "IF Gain Adjustment" on page 382 to complete this adjustment.

b. Select any special test set options installed, otherwise leave the selection at **None**.

c. No connections to the test ports are required.

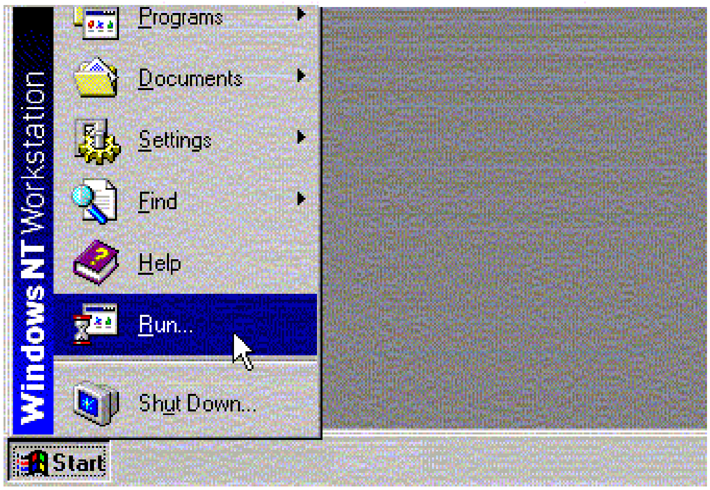
d. Click **Begin Adj**. The adjustment takes about a minute to complete.

   The advanced screen is for factory personnel only.

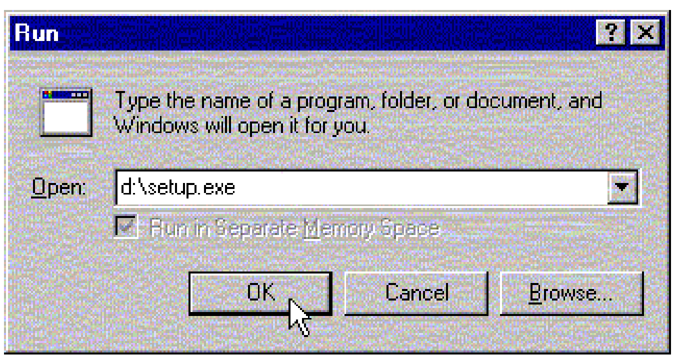
NOTE This adjustment must be performed before using the network analyzer each time the system is assembled or disassembled.

Step 9. Install the Physical Layer Test System Software

1. Insert the physical layer test system software CD-ROM in your PC. The software should begin the installation process automatically. Follow the prompts to complete the software installation.
2. In Windows, select **Start > Run...**



3. Click **OK** and follow the onscreen instructions.



Step 10. Licence the Physical Layer Test System Software

This procedure instructs you how to license your Physical Layer Test System Software which is required before it can be used. *The software is node-locked which means that license entitles you to use the software on only one personal computer (PC) and the software enforces that restriction.*

CAUTION The software is node-locked which means that license entitles you to use the software on only one personal computer and the software enforces that restriction. Make sure that you license the software to the correct PC.

During this procedure, you will identify the **Host ID** of that PC. The host ID is a unique identifier for that computer. Then, you will use the host ID to license the software to that unique identifier of your PC. Therefore, it is very important to affirm that you have loaded and are licensing the software to the correct PC.

1. In Windows, select **Start > Programs** and locate the **Command Prompt** selection on your PC. Open the **Command Prompt** window by clicking the **Command Prompt** selection.
2. In the **Command Prompt** window, change the directory to the **license** subdirectory in the **PLTS** subdirectory using the following command:

   cd *x*:*ddddssss*\PLTS\license**

where,		
	x	is the letter of the drive the software was installed on.
	dddd	is the directory name the software was installed on.
	ssss	is any subdirectories the software was installed on.

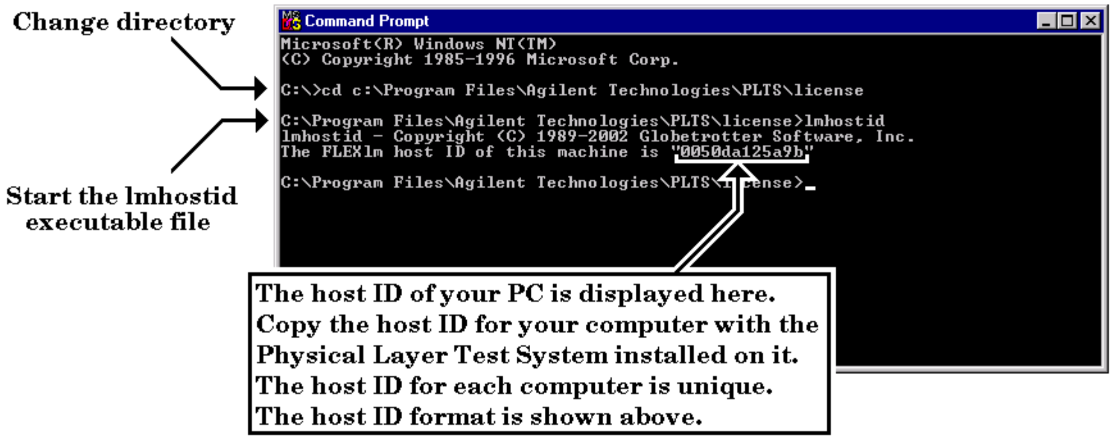
   The default directory that the software is loaded on is: C:\Program Files\Agilent Technologies. Therefore, enter the following command to change to the default directory:

   ```
   cd c:\Program Files\Agilent Technologies\PLTS\license
   ```

   Refer to the illustration in step 4 on page 27.
3. Run the lmhostid executable file that will display the host ID for the PC that you have installed the software on by entering the following command as shown in the figure below:

   ```
   lmhostid
   ```

4. The host ID of the computer is displayed in window opened by the **lmhostid.exe** file. Write the host ID for your computer in the space provided below. You will need the host ID to license the software.



Record the host ID for your computer here:

5. Locate the **Software Entitlement Certificate** that was shipped with your software.

   The certificate lists the **Order Number** and the **Certificate Number** for your software. These two numbers will also be used to license your software.

   The certificate also lists the web site where you must register your software.

6. Go to the Agilent web site listed on the **Software Entitlement Certificate**. Follow the instructions at the web site to receive your license file for the software. You will need to provide the following information:

   - **Order Number**
   - **Certificate Number**
   - **Host ID for your computer that will run the PLTS Software**

   The web site will also ask you provide your e-mail address. The license file will be e-mailed to you promptly.

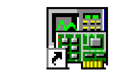
7. Once you receive the E-mail with the attached licence file, save the file to the "license" directory (the same directory that you used earlier to identify the host ID).

8. Make a back up of the license file and store in a safe location.

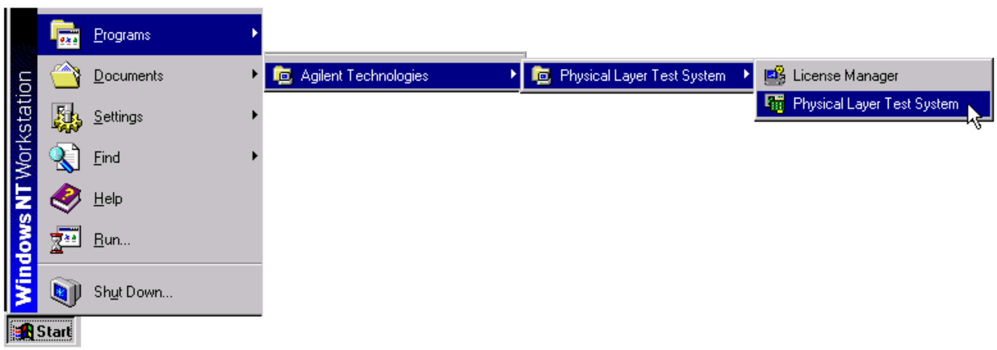
   This back up file is very important! You may need this back up file if encounter problems with your computer or if the licence file is lost or erased.

Step 11. Start the Physical Layer Test System Software

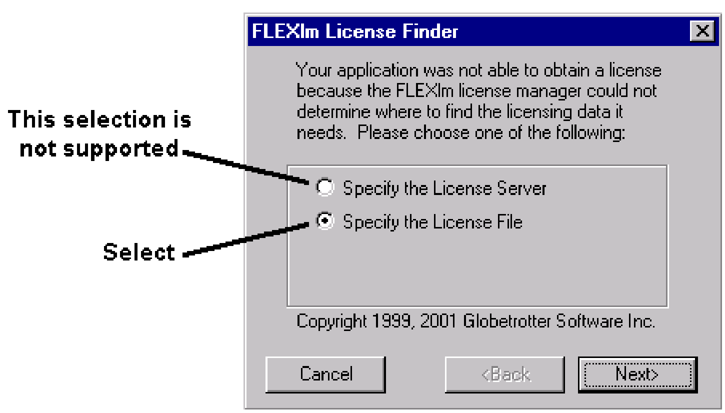
1. After the license file has been saved, start the PLTS software by double-clicking the **Physical Layer Test System** icon on the desktop.



You may also run the program by selecting **Start**, **Programs, Agilent Technologies**, **Physical Layer Test System**, **Physical Layer Test System**.



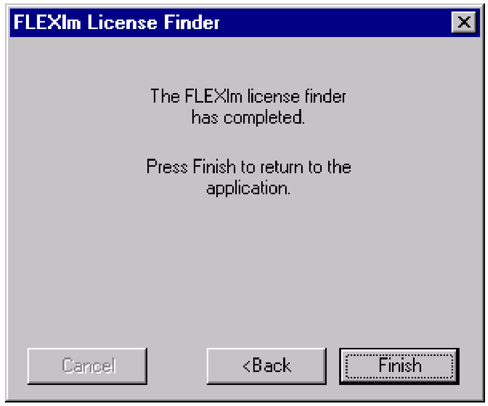
2. The first time you start the software, you will be asked to identify the license for the software. When the following dialog box is displayed, select **Specify the License File** and then click the **Next >** button.



3. When the *FLEXlm License Finder* dialog box is displayed asking you to choose the license filename, click the **Browse** button and select the license file in the directory that you copied the file to in "Step 10. Licence the Physical Layer Test System Software" on page 26.

4. Once the directory and the license file is identified, the directory path is displayed in the *FLEXlm License Finder* dialog box. Select the **Next>** button.

5. When the license is found and identified, select the **Finish** button to continue with starting the software.



NOTE Steps 2 through 5 in this procedure should only need be performed the first time the software is started. If the software requires these steps again, it is because the licence file may have been moved or deleted.

Make a back-up copy of the license file if you haven't already done so.

---

6. Continue with starting the software.
7. Familiarize yourself with the Physical Layer Test System by referring to Chapter 2, "Becoming Familiar with your Physical Layer Test System."

2 Becoming Familiar with your Physical Layer Test System

This chapter provides a graphical overview of the physical layer test system. It shows:

- **The Physical Layer Test System Software**

  The main screen of the physical layer test system software user interface as well as important lower level screens. The important features of each displayed screen are identified and briefly described.

  Refer to "Physical Layer Test System Software Features" on page 33 for information.

- **The Physical Layer Test System Hardware**

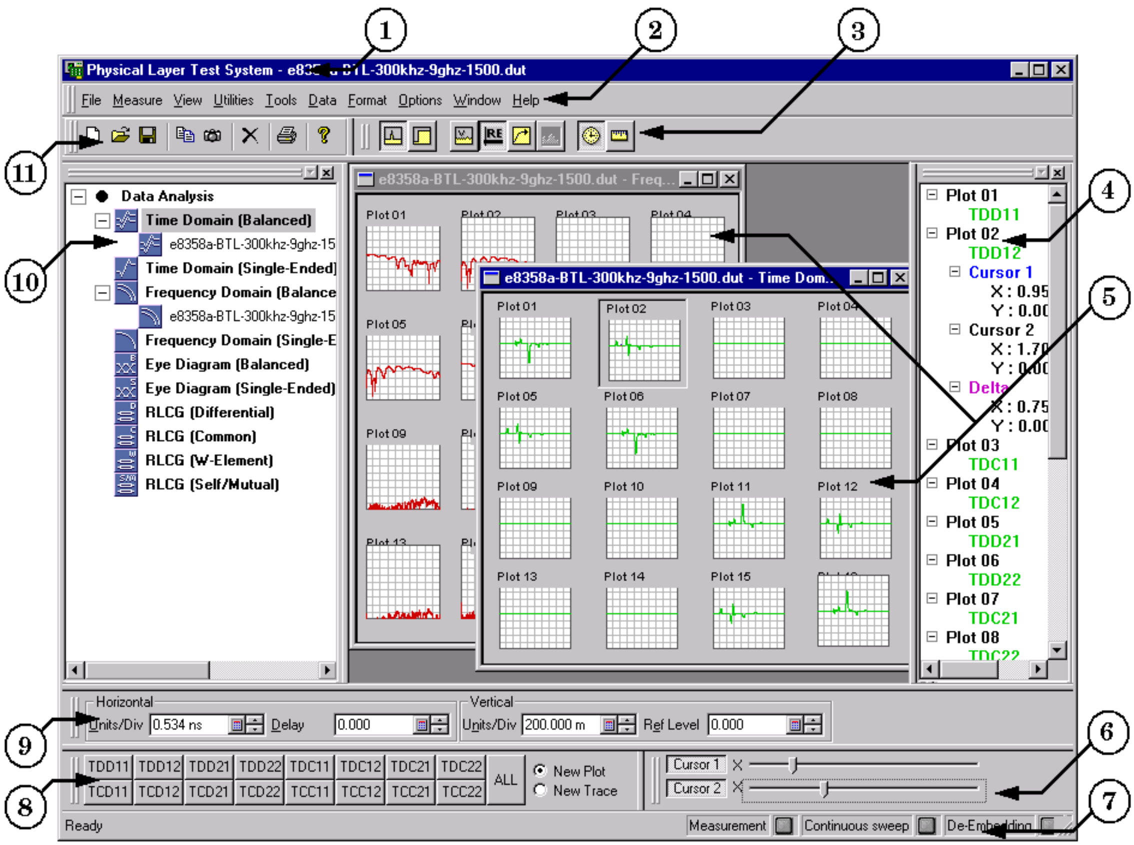
  The physical layer test system equipment is also shown, identifying each hardware product within the system and their interconnections.

  Refer to "Physical Layer Test System Hardware Features" on page 42 for information.

Physical Layer Test System Software Features

This section describes the features of the Physical Layer Test System software. Refer to Figure 2-1, Main Window, for the locations of each of the software's main features.

Figure 2-1 Main Window



1. **Title Bar**
2. **Menu Bar**
3. **Format Bar**
4. **Information Bar**
5. **Plot Windows**
6. **Cursor Bar**
7. **Status Bar**
8. **Parameter Bar**
9. **Scaling Bar**
10. **Browser**
11. **Toolbar**

1. Title Bar

The title bar (Figure 2-2) displays the title of the software. It also provides buttons to quickly perform tasks at the program level.

Figure 2-2 Title Bar

Clicking:	Performs:
	Minimizes the program window to the Windows task bar.
	Toggles the program window to full screen mode.
	Toggles the program window to partial screen mode.
	Closes the program.

2. Menu Bar

The menu bar (Figure 2-3) lists each of the drop down menu names currently available. When you click a menu name, the menu is displayed. The menu names and menus change to reflect appropriate choices for the selected plot window (analysis type.) Refer to Chapter 10, “Menu Reference,” for detailed information about each of the menu bar selections.

When the plot window is selected to completely fill its area, the menu bar also displays three buttons to control the plot window.

Figure 2-3 Menu Bar

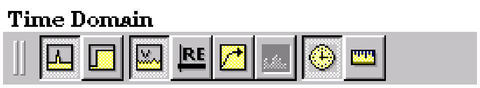
Clicking:	Performs:
	Minimizes the plot window within the plot windows display area.
	Toggles the plot window to partially fill the plot windows display area.
	Closes the plot window.

3. Format Bar

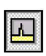
The format bars (Figure 2-4) allow you to format the parameters for the selected time domain or frequency domain plot window. The format bar is displayed by selecting Format Bar from the View menu. It is hidden with the same selection.

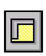
The format bar is only available when the selected plot window is a time domain or frequency domain selection. The time domain format bar differs from the frequency domain format bar. Each format bar matches its corresponding Format menu (selected in the Menu bar.) The format bar and the title of each button of both measurement methods is shown below.

Figure 2-4 Format Bars



For detailed information about each of the selections, refer to "Selecting Time Domain Display Formats" on page 157.

 Impulse

 Step

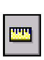
 Volts

 Real

 Log Mag

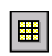
 Impedance

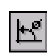
 ns

 cm

For detailed information about each of the selections, refer to "Selecting Frequency Domain Display Formats" on page 128.

 Log Mag

 Linear Mag

 Phase

 Group Delay

 Smith Chart

 Polar Chart

 Real

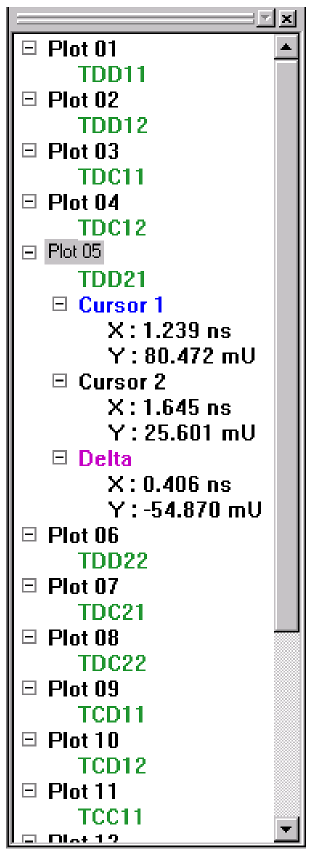
 Imaginary

4. Information Bar

The Information Bar (Figure 2-5) displays a listing of each plot window along with the associated parameters for each. If a plot window has multiple traces, all associated parameters are listed. In addition, any marker readout information is displayed in this area.

A lot of information may be displayed for each window. To hide the plot windows information, simply click the minus sign in front of the plot window listing. All of the information is hidden and the minus sign changes to a plus sign. To show the information again, click the plus sign.

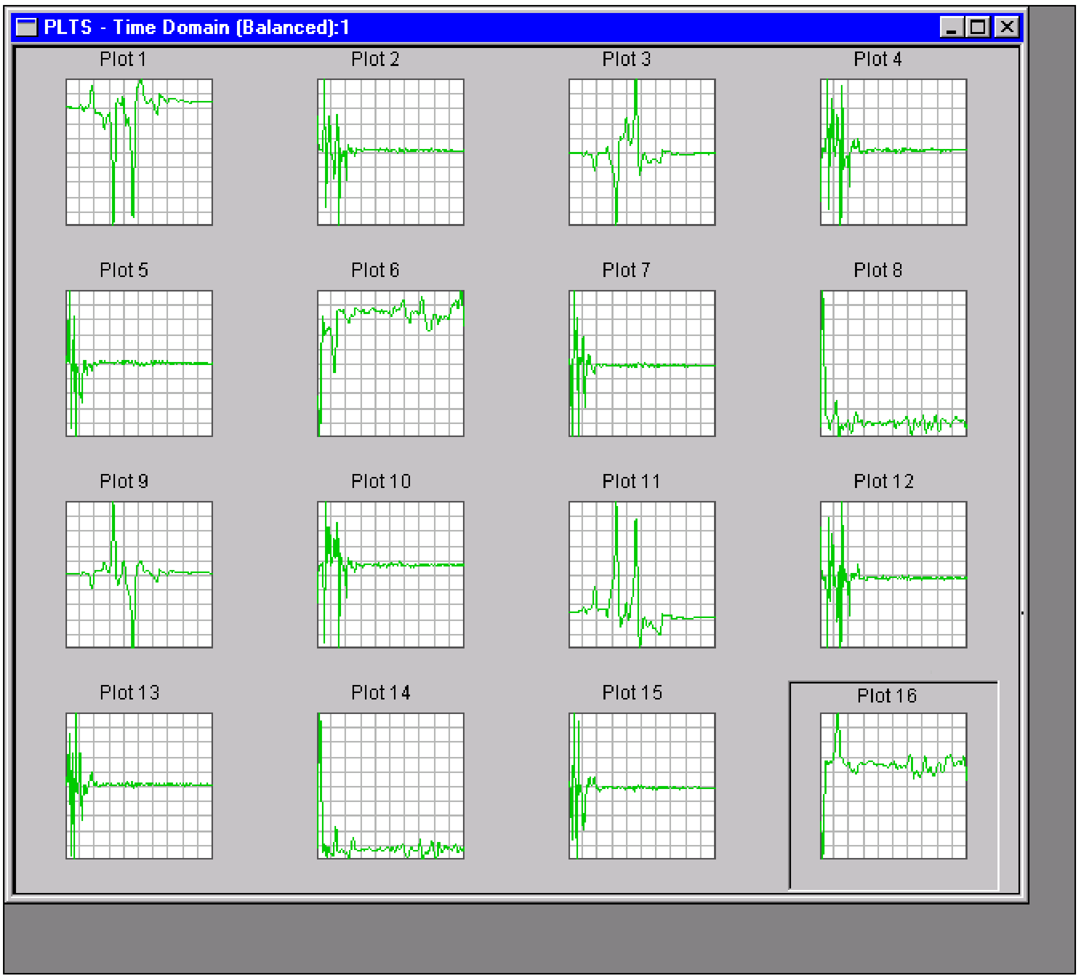
Figure 2-5 Information Bar



5. Plot Windows

The plot windows (Figure 2-6) displays the measurement results in the data analysis type selected. You select the data analysis type when you make a measurement, open existing data files, or make a selection in the browser. The Parameter Bar or the Data menu on the Menu bar allows you to display plots for all of the parameters or just the parameters you want to view. Multiple plot windows can be displayed in the plot window display area at the same time.

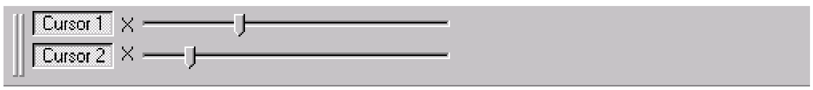
Figure 2-6 Plot Window



6. Cursor Bar

The cursor bar (Figure 2-7) allows you to add and display up to two markers to the active plot. The X-Y values of each cursor and the delta (the value of their difference) is displayed in the information bar.

Figure 2-7 Cursor Bar



7. Status Bar

The status bar (Figure 2-8) provides a visual indication of when conditions are happening within the software and the impedance associated with each system channel.

When any of the conditions listed below are active, an indicator adjacent to the condition title is displayed in a bright color. If the condition is not active, the color of the indicator is gray. The conditions are:

Measurement	is bright when a measurement is being performed by the software.
Continuous sweep	is bright when the measurement is being continuously swept.
De-Embedding	is bright when the active plot has de-embedding data applied.
Ref-Z	is bright when the active plot has reference impedance applied.
Hardware	is bright when the hardware has been identified by the software.

Figure 2-8 Status Bar

8. Parameter Bar

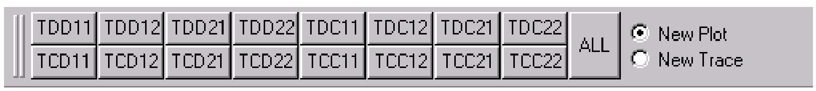
The parameter bar (Figure 2-9) allows you to open a new plot, or add a new trace to an existing plot. Figure 2-9 shows the parameter bar for the balanced time domain plots. Each analysis type has a unique parameter bar specific to that type of analysis. Refer to Figure 10-22, “Parameter Bars for Each Data Analysis Type” on page 243 to see all parameter bars.

Select **New Plot** and then click a parameter to display a new plot.

- or -

Select **New Trace** and then click a parameter to overlay a new trace to an existing plot. Clicking the parameter a second time removes the added trace from the plot.

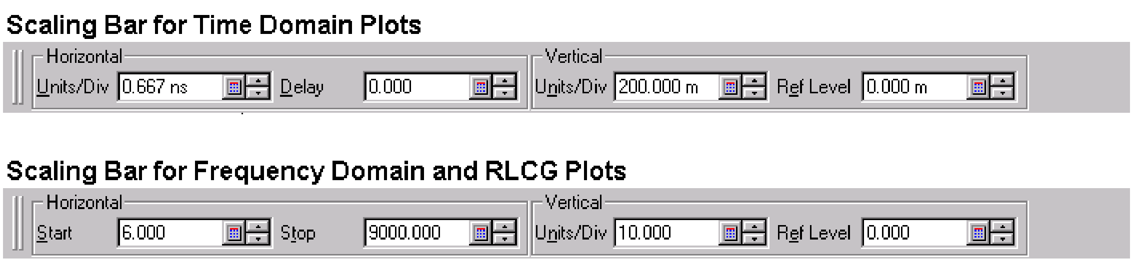
Figure 2-9 Parameter Bar for Balanced Time Domain Plots



9. Scaling Bar

The scaling bar (see Figure 2-10) allows you to change the scale on both the horizontal and vertical axis.

Figure 2-10 Scaling Bars



For time domain, the horizontal axis entries are units/division and delay. The vertical axis units are units/division and reference level.

For frequency domain and RLCG, the horizontal axis entries are the start frequency and the stop frequency. The vertical axis units are the units/division and the reference level.

10. Browser

The browser (Figure 2-11) provides access to each measurement and analysis type. Selecting a new Data Analysis type from the browser opens up a corresponding plot window. Each Data Analysis type may view multiple sets of data.

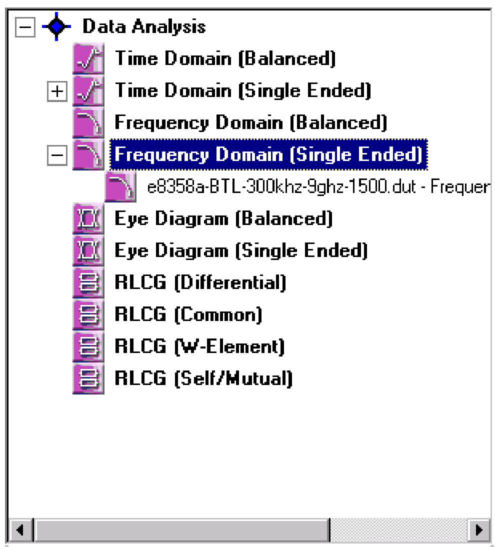
Clicking a bold label opens a new window in the plots area with that data analysis type.

Clicking a non-bold label displays that plot and makes it the active plot in the plots area.

Clicking the minus sign hides the data selections for a given data analysis type.

Clicking the plus sign shows the data selections.

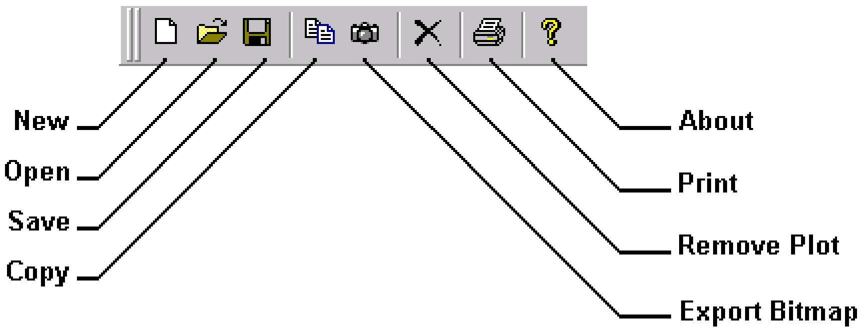
Figure 2-11 Browser



11. Toolbar

The toolbar (Figure 2-12) provides buttons for beginning a new measurement, opening existing files, saving current data, copying current data, exporting data, removing plots, and printing.

Figure 2-12 Toolbar



	Clicking:	Performs:
	**New**	Starts the setup wizard so that a new measurement may be made.
	**Open**	Opens the *Open* dialog box so that an existing file may be opened.
	**Save**	Opens the *Save As* dialog box so that a file may be saved.
	**Copy**	Copies the active plot to the clipboard.
	**Export Bitmap**	Saves the active plot as a bitmap file (bmp).
	**Remove Plot**	Deletes the active plots.
	**Print**	Prints the active plots.
	**About**	Opens the *About PLTS* information.

Physical Layer Test System Hardware Features

An illustration showing each physical layer test system and its interconnections is provided in this section. Other balanced-measurement systems supported by the physical layer test system software are also illustrated. Each illustration has a corresponding table that lists the sequence of each interconnection, the interconnect cable part number, and the connector label for the network analyzer and the S-parameter test set.

Along with each PLTS system model number, the individual test set and network analyzer model numbers comprising the system are listed. Refer to Table 1-1, "Physical Layer Test System Configurations," on page 7 and Table 1-2, "Common Hardware Option Number Descriptions for Network Analyzers," on page 10 for additional information about test set and network analyzer model and option requirements.

The following physical layer test systems are shown:

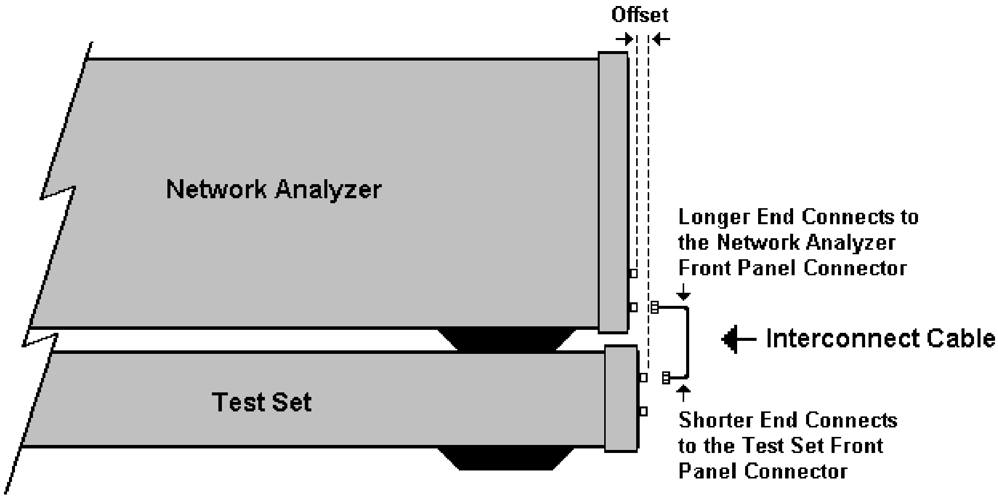
- "N1947A Test System Interconnections
  (or N4417A Option 103 Test Set with E8801A, E8802A, or E8803A Network Analyzer)" on page 44
- "N1948A Test System Interconnections
  (or N4417A Option 104 Test Set with E8356A, E8357A, or E8358A Network Analyzer)" on page 46
- "N1951A Test System Interconnections
  (or N4418A Test Set with 8720ES or 8722ES Network Analyzer)" on page 48
- "N1953A Test System Interconnections
  (or N4419A Test Set with E8362A/B Network Analyzer)" on page 50
- "N1957A Test System Interconnections
  (or N4421A Test Set with E8364A/B Network Analyzer)" on page 52

The following other test set/network analyzer systems are shown:

- "N4416A Test Set with the E8356A, E8357A, or E8358A Network Analyzer" on page 54
- "N4415A Test Set with the 8753ES Network Analyzer" on page 56

CAUTION When connecting the interconnect cables described in the remaining pages of this section, be careful to install the interconnect cables correctly. The longer end of the interconnect cable connects to the network analyzer front panel connector. Refer to Figure 2-13 for the correct orientation.

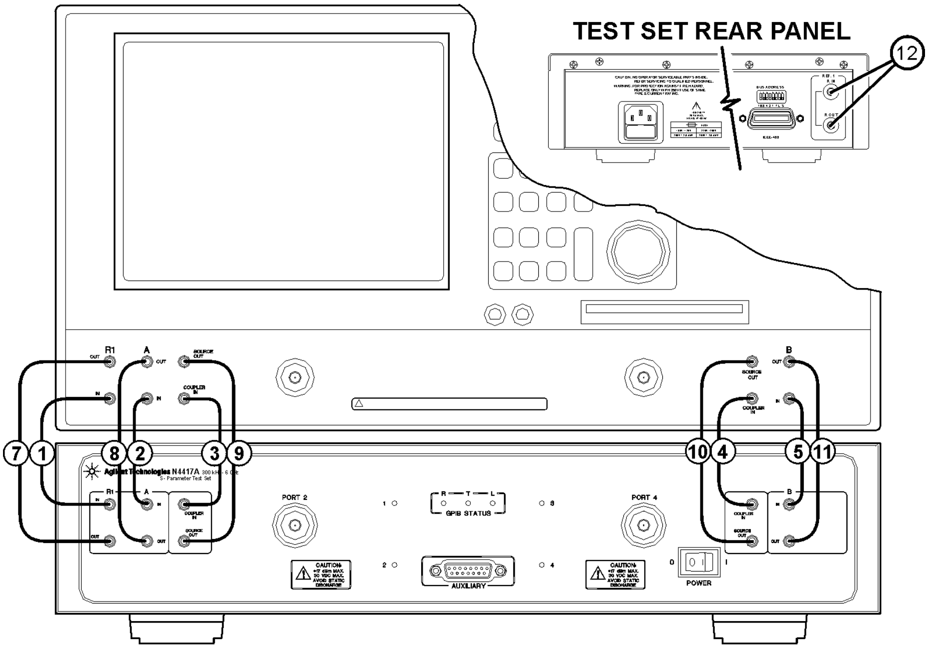
Figure 2-13 Interconnect Cable Orientation



Damage to the interconnect cable can result from improper connection of the cable.

N1947A Test System Interconnections

(or N4417A Option 103 Test Set with E8801A, E8802A, or E8803A Network Analyzer)



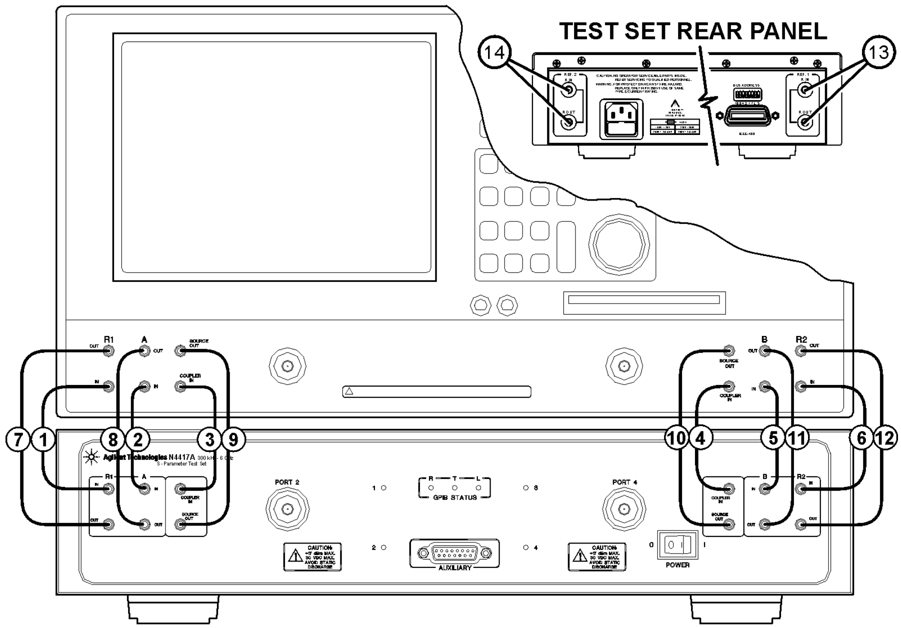
4417opt103_connections

CAUTION Damage to the interconnect cable can result from improper orientation of the cable. Refer to page 43 for detailed information regarding the correct cable orientation.

Installation Sequence	Cable Part Number	From E8801/E8802/E8803	To N4417A
1	AD00747-2-2	R1 IN	R1 IN
2	AD00747-2-2	A IN	A IN
3	AD00747-2-2	COUPLER IN	COUPLER IN
4	AD00747-2-2	COUPLER IN	COUPLER IN
5	AD00747-2-2	B IN	B IN
6	AD00747-2-1	R1 OUT	R1 OUT
7	AD00747-2-1	A OUT	A OUT
8	AD00747-2-1	SOURCE OUT	SOURCE OUT
9	AD00747-2-1	SOURCE OUT	SOURCE OUT
10	AD00747-2-1	B OUT	B OUT
11	AD00747-2-3	REF 1 on rear panel of the test set	

N1948A Test System Interconnections

(or N4417A Option 104 Test Set with E8356A, E8357A, or E8358A Network Analyzer)



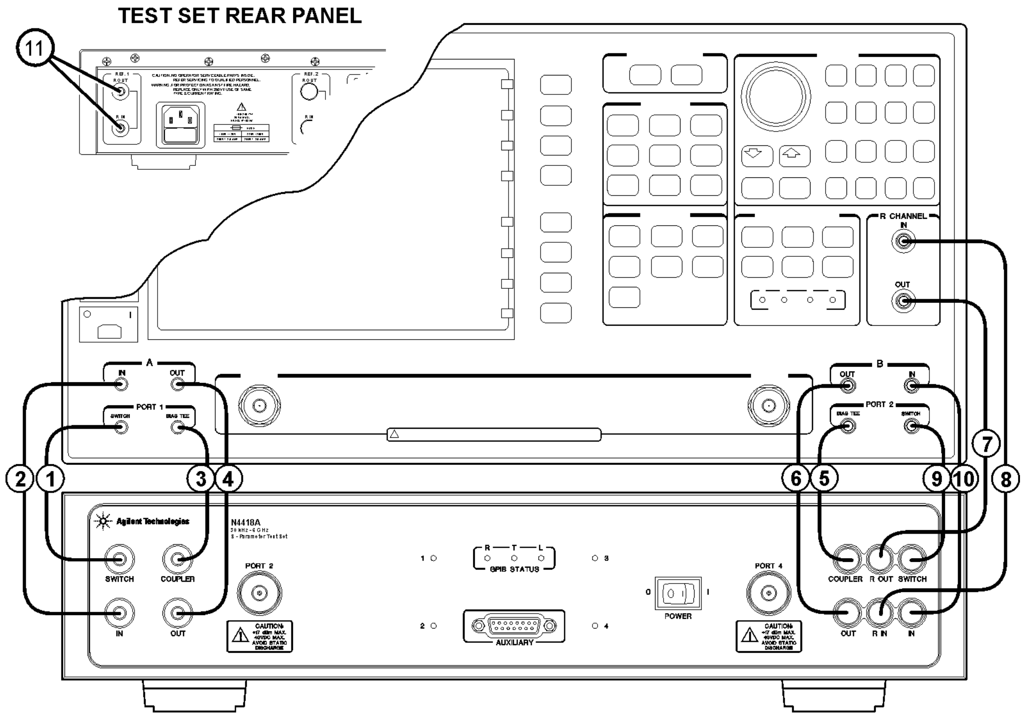
4417opt104 connections

CAUTION Damage to the interconnect cable can result from improper orientation of the cable. Refer to page 43 for detailed information regarding the correct cable orientation.

Installation Sequence	Cable Part Number	From E8356/E8357/E8358	To N4417A
1	AD00747-1-2	R1 IN	R1 IN
2	AD00747-1-2	A IN	A IN
3	AD00747-1-2	COUPLER IN	COUPLER IN
4	AD00747-1-2	COUPLER IN	COUPLER IN
5	AD00747-1-2	B IN	B IN
6	AD00747-1-2	R2 IN	R2 IN
7	AD00747-1-1	R1 OUT	R1 OUT
8	AD00747-1-1	A OUT	A OUT
9	AD00747-1-1	SOURCE OUT	SOURCE OUT
10	AD00747-1-1	SOURCE OUT	SOURCE OUT
11	AD00747-1-1	B OUT	B OUT
12	AD00747-1-1	R2 OUT	R2 OUT
13	AD00747-1-3	REF 1 on rear panel of the test set	
14	AD00747-1-3	REF 2 on rear panel of the test set	

N1951A Test System Interconnections

(or N4418A Test Set with 8720ES or 8722ES Network Analyzer)

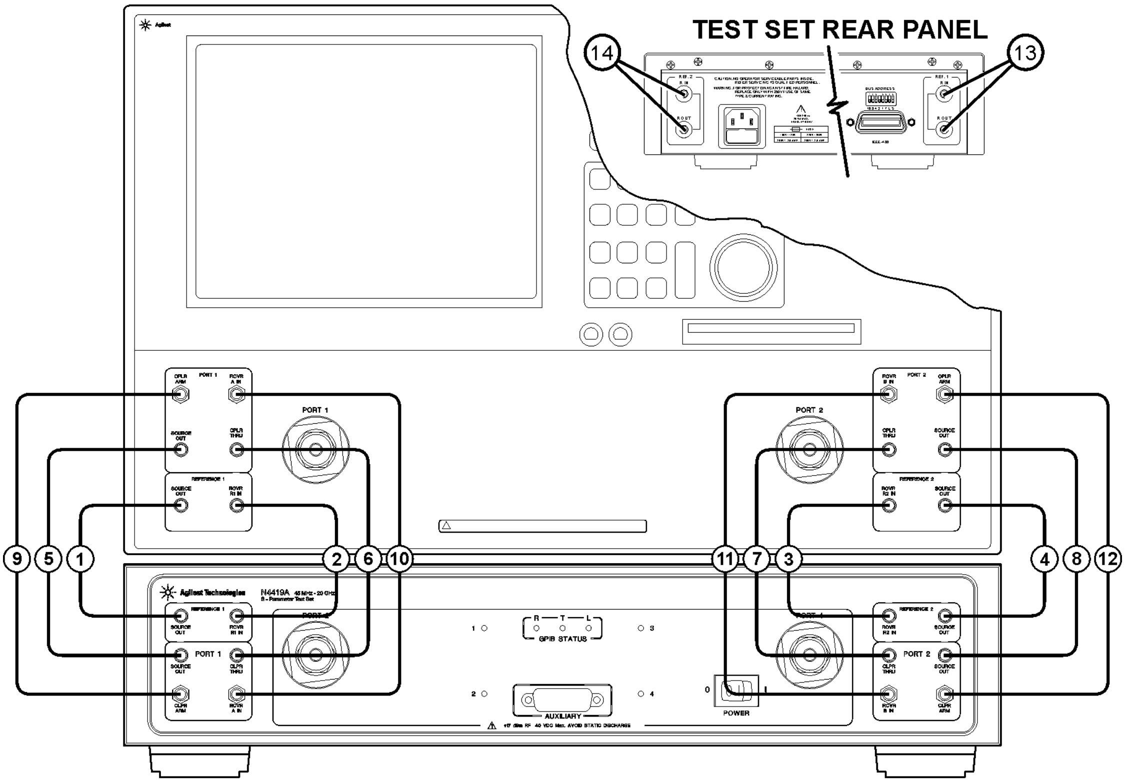


CAUTION Damage to the interconnect cable can result from improper orientation of the cable. Refer to page 43 for detailed information regarding the correct cable orientation.

Call Out Sequence	Cable Part Number	From 8720ES/8722ES	To N4418A
1	AD00599-2	PORT 1 SWITCH	PORT 1 SWITCH
2	AD00599-1	A IN	A IN
3	AD00599-2	PORT 1 BIAS TEE	PORT 1 COUPLER
4	AD00599-1	A OUT	A OUT
5	AD00599-2	PORT 2 BIAS TEE	PORT 2 COUPLER
6	AD00599-1	B OUT	B OUT
7	AD00599-4	R CHANNEL OUT	PORT 2 R OUT
8	AD00599-3	R CHANNEL IN	B R IN
9	AD00599-2	PORT 2 SWITCH	PORT 2 SWITCH
10	AD00599-1	B IN	B IN
11	AD00599-5	REF 1 on rear panel of the test set	

N1953A Test System Interconnections

(or N4419A Test Set with E8362A/B Network Analyzer)



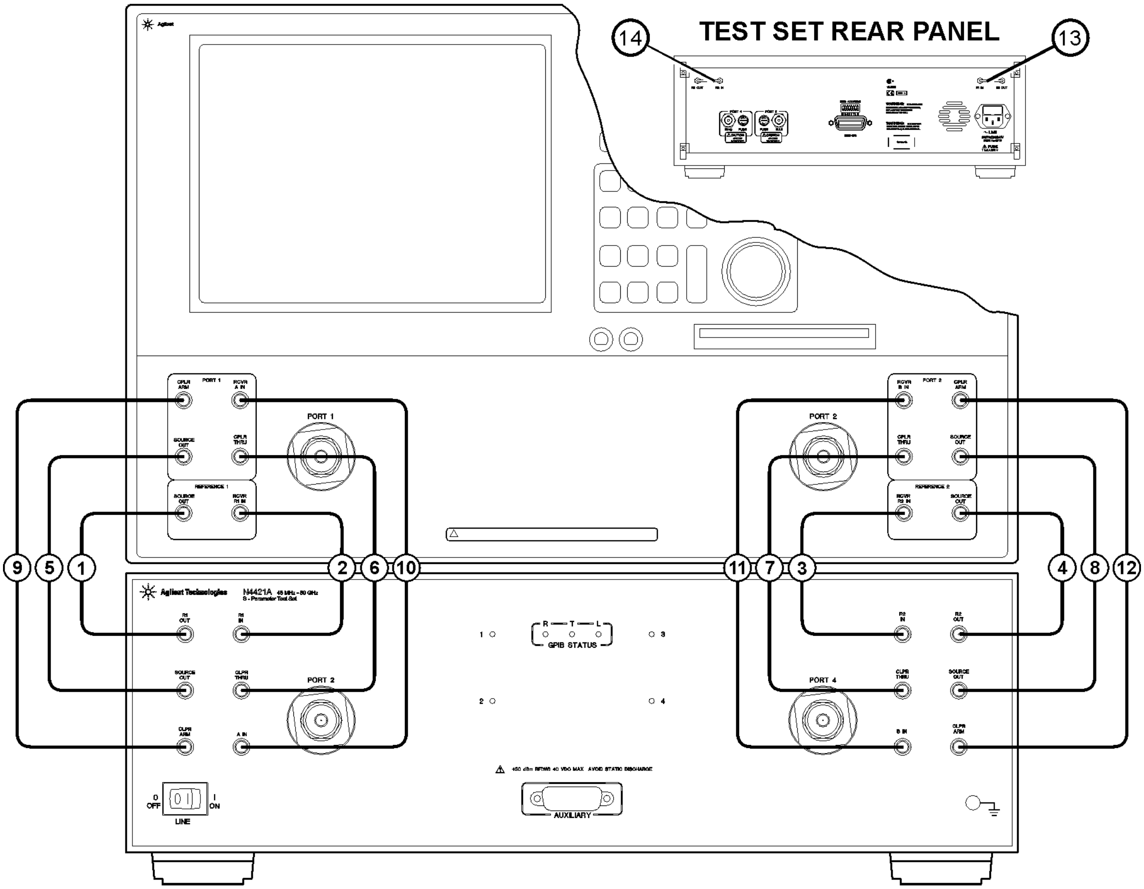
4419_connections

CAUTION Damage to the interconnect cable can result from improper orientation of the cable. Refer to page 43 for detailed information regarding the correct cable orientation.

Call Out Sequence	Cable Part Number	From E8362A/B	To N4418A
1	AD00756-1	REF 1 SOURCE OUT	REF 1 SOURCE OUT
2	AD00756-1	REF 1 RCVR R1 IN	REF 1 RCVR R1 IN
3	AD00756-1	REF 2 RCVR R2 IN	REF 2 RCVR R2 IN
4	AD00756-1	REF 2 SOURCE OUT	REF 2 SOURCE OUT
5	AD00756-2	PORT 1 SOURCE OUT	PORT 1 SOURCE OUT
6	AD00756-2	PORT 1 CPLR THRU	PORT 1 CPLR THRU
7	AD00756-2	PORT 2 SOURCE OUT	PORT 2 SOURCE OUT
8	AD00756-2	PORT 2 CPLR THRU	PORT 2 CPLR THRU
9	AD00756-3	PORT 1 CPLR ARM	PORT 1 CPLR ARM
10	AD00756-3	PORT 1 RCVR A IN	PORT 1 RCVR A IN
11	AD00756-3	PORT 2 RCVR B IN	PORT 2 RCVR B IN
12	AD00756-3	PORT 2 CPLR ARM	PORT 2 CPLR ARM
13	AD00756-4	REF 1 on rear panel of the test set	
14	AD00756-4	REF 2 on rear panel of the test set	

N1957A Test System Interconnections

(or N4421A Test Set with E8364A/B Network Analyzer)

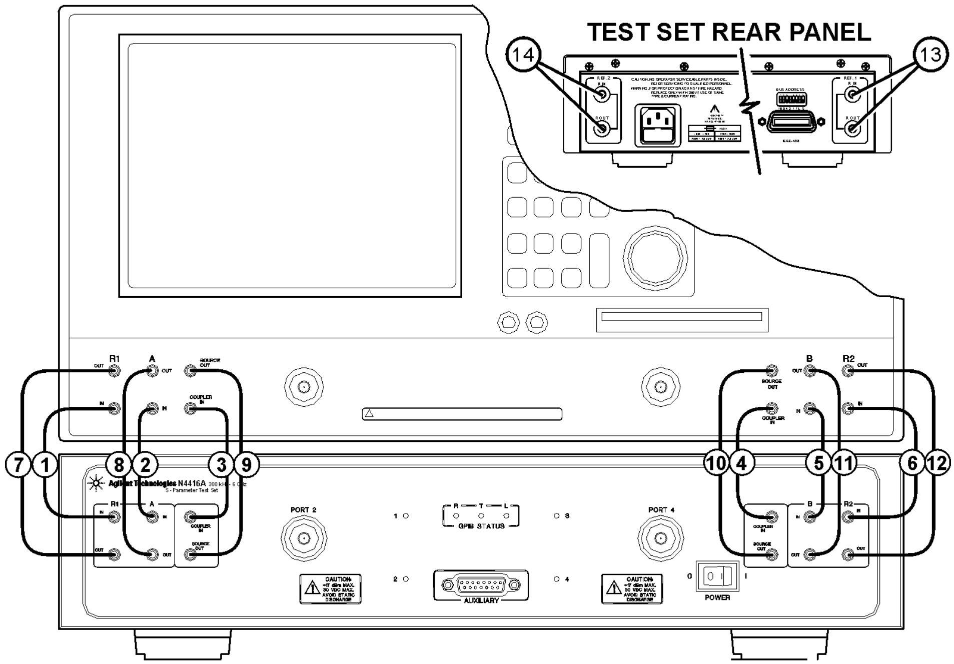


4421_connections

CAUTION Damage to the interconnect cable can result from improper orientation of the cable. Refer to page 43 for detailed information regarding the correct cable orientation.

Call Out Sequence	Cable Part Number	From E8364A/B	To N4421A
1	Z5623-20215	REF 1 SOURCE OUT	REF 1 SOURCE OUT
2	Z5623-20215	REF 1 RCVR R1 IN	REF 1 RCVR R1 IN
3	Z5623-20215	REF 2 RCVR R2 IN	REF 2 RCVR R2 IN
4	Z5623-20215	REF 2 SOURCE OUT	REF 2 SOURCE OUT
5	Z5623-20216	PORT 1 SOURCE OUT	PORT 1 SOURCE OUT
6	Z5623-20216	PORT 1 CPLR THRU	PORT 1 CPLR THRU
7	Z5623-20216	PORT 2 SOURCE OUT	PORT 2 SOURCE OUT
8	Z5623-20216	PORT 2 CPLR THRU	PORT 2 CPLR THRU
9	Z5623-20217	PORT 1 CPLR ARM	PORT 1 CPLR ARM
10	Z5623-20217	PORT 1 RCVR A IN	PORT 1 RCVR A IN
11	Z5623-20217	PORT 2 RCVR B IN	PORT 2 RCVR B IN
12	Z5623-20217	PORT 2 CPLR ARM	PORT 2 CPLR ARM
13	E8364-20059	REF 1 on rear panel of the test set	
14	E8364-20059	REF 2 on rear panel of the test set	

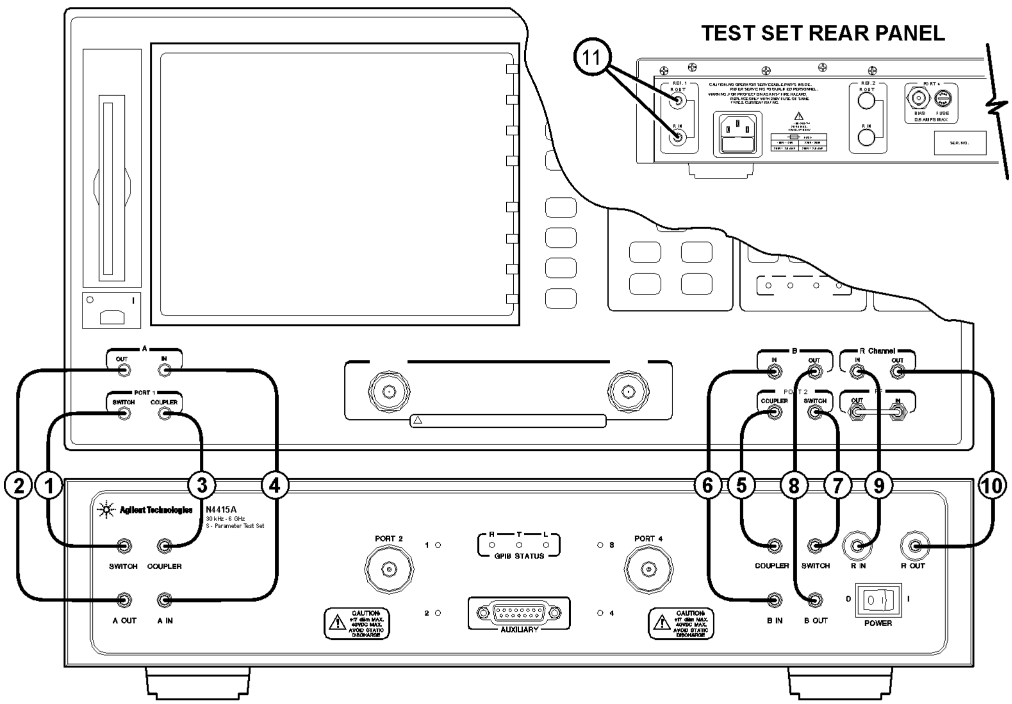
N4416A Test Set with the E8356A, E8357A, or E8358A Network Analyzer



CAUTION Damage to the interconnect cable can result from improper orientation of the cable. Refer to page 43 for detailed information regarding the correct cable orientation.

Installation Sequence	Cable Part Number	From E8356/E8357/E8358	To N4416A
1	AD00653-2	R1 IN	R1 IN
2	AD00653-2	A IN	A IN
3	AD00653-2	COUPLER IN	COUPLER IN
4	AD00653-2	COUPLER IN	COUPLER IN
5	AD00653-2	B IN	B IN
6	AD00653-2	R2 IN	R2 IN
7	AD00653-1	R1 OUT	R1 OUT
8	AD00653-1	A OUT	A OUT
9	AD00653-1	SOURCE OUT	SOURCE OUT
10	AD00653-1	SOURCE OUT	SOURCE OUT
11	AD00653-1	B OUT	B OUT
12	AD00653-1	R2 OUT	R2 OUT
13	AD00653-3	REF 1 on rear panel of the test set	
14	AD00653-3	REF 2 on rear panel of the test set	

N4415A Test Set with the 8753ES Network Analyzer



4415_frtpnl_connections

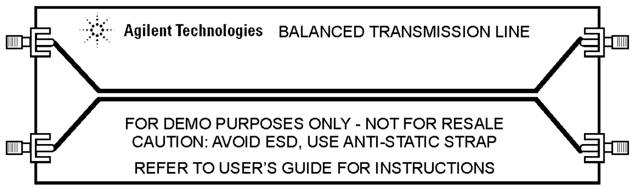
CAUTION Damage to the interconnect cable can result from improper orientation of the cable. Refer to page 43 for detailed information regarding the correct cable orientation.

Installation Sequence	Cable Part Number	From 8753ES	To N4415A
1	AD00632-2	Port 1 Switch	Switch
2	AD00632-1	A OUT	A OUT
3	AD00632-2	Port 1 Coupler	Coupler
4	AD00632-1	A IN	A IN
5	AD00632-2	Port 2 Coupler	Coupler
6	AD00632-1	B IN	B IN
7	AD00632-2	Port 2 Switch	Switch
8	AD00632-1	B OUT	B OUT
9	AD00632-3	R Channel In	R IN
10	AD00632-3	R Channel Out	R OUT
11	AD00632-4	REF 1 on rear panel of the test set	

3 Making a Measurement using the Sample Device

This chapter guides you through setting up the initial measurement definitions, performing the system calibration, making a measurement, and analyzing the measurement results. It uses a simple balanced transmission line that was supplied with the system as a sample device-under-test (DUT). See Figure 3-1.

Figure 3-1 Balanced Transmission Line Sample DUT



The **Startup Wizard** steps you through the initial setup, the calibration, and the first measurement.

1. **Initial setup** includes:
   - System Hardware Verification
   - Calibration Level Selection
   - Calibration and Measurement Parameter Selection
2. **Calibration** includes:
   - Calibration Type Selection and Calibration Kit Selection
   - SOLT Mechanical Calibration, SOLT Electronic Calibration, or TRL Calibration
   - Adapter Characterization
3. **Measurement** includes:
   - Analysis Type Selection
   - Stimulus Verification
   - Running Measurement

After the measurement has been made, the main Physical Layer Test System (PLTS) window gives you the flexibility to perform analysis on the measured data in a variety of ways.

- **Frequency Domain.** The Frequency Domain analysis may be analyzed in Balanced or Single-Ended mode. This chapter contains some basic information. Refer to Chapter 5, "Analyzing Data in the Frequency Domain," on page 115 for more information.
- **Time Domain.** The Time Domain analysis may be analyzed in Balanced or Single-Ended mode. This chapter contains some basic information. Refer to Chapter 6, "Analyzing Data in the Time Domain," on page 137 for more information.

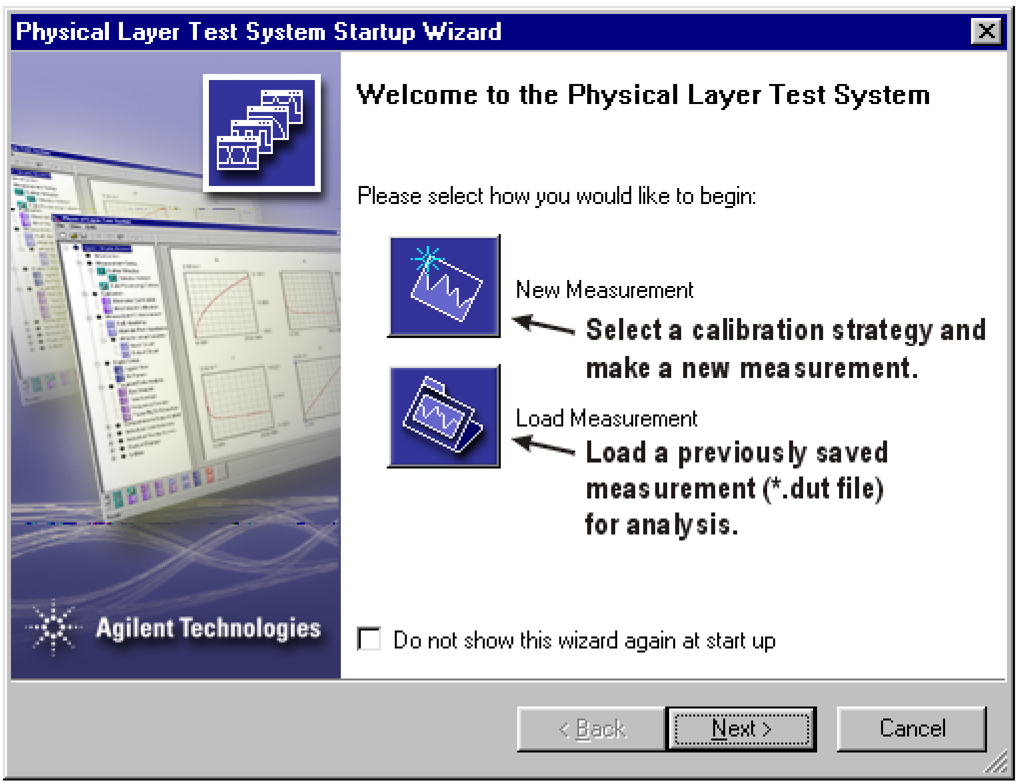
- **Eye Diagram.** The Eye Diagram analysis may be analyzed in Balanced or Single-Ended mode. This chapter contains some basic information. Refer to Chapter 7, “Analyzing Data using Eye Diagrams,” on page 165 for more information.
- **Transmission Line (RLCG).** The RLCG analysis may be analyzed in Differential, Common, W-Element, and Self/Mutual modes. This chapter contains some basic information. Refer to Chapter 8, “Extracting Transmission Line (RLCG) Parameters,” on page 181 for more information.

Navigating the Startup Wizard

By default, when PLTS is first started, the Startup Wizard is displayed. It is also displayed anytime a new measurement is initiated, such as after selecting **New** from the **File** menu, or clicking on the new file icon on the toolbar. See Figure 3-2.

The Startup Wizard Welcome Screen gives you two choices, **New Measurement** or **Load Measurement**. **Load Measurement** loads the existing data. However, for the purpose of this exercise, select **New Measurement**.

Figure 3-2 Startup Wizard Welcome Screen



NOTE It is recommended that you use the startup wizard, however, selecting the **Do not show this wizard again at start up** check box prevents the wizard from being displayed each time the software is started. The software goes directly to the main window at start up. Refer to "User Preferences" on page 273 to deactivate this selection.

When you select **New Measurement**, the Startup Wizard will guide you through:

- Initial Setup
- Calibration
- First Measurement

At the end, the wizard will ask you for the initial analysis format of interest (time domain, frequency domain, etc.), and perform the data transformations and display the measurement results.

How to Perform the Initial Setup

The Initial Setup process includes:

1. Verifying that the software recognizes your PLTS system hardware.

   This step uses the left portion of the *Hardware Auto-Detection Summary* dialog box to verify that the software recognizes the correct system hardware. This portion of the dialog box displays the model number, GPIB address, and serial number of the network analyzer and the test set. You may re-scan to look for changes automatically or you may manually make changes to the hardware settings.

2. Selecting the appropriate level of calibration for the upcoming measurement.

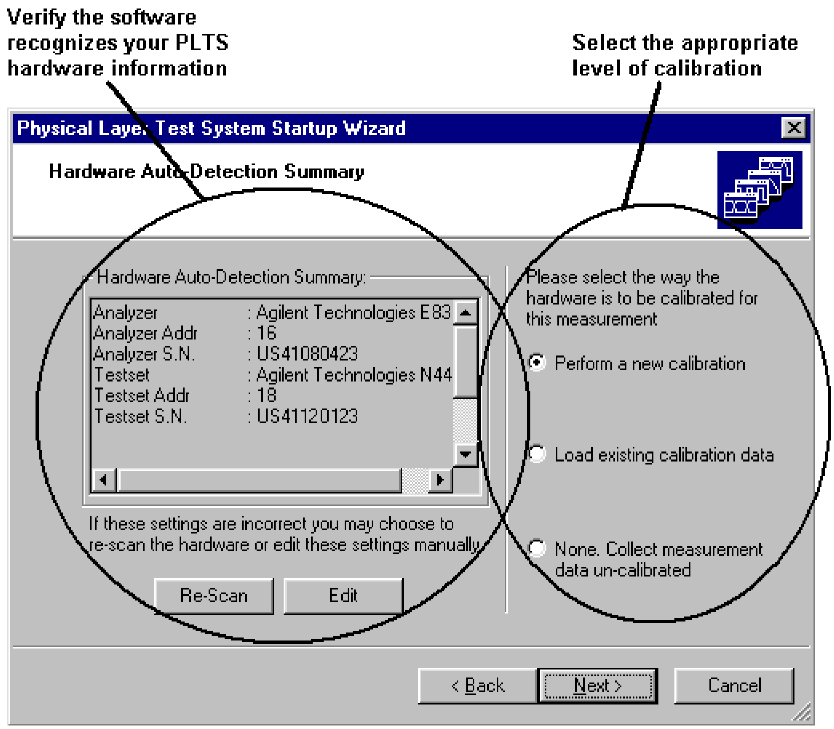
   This step uses the right portion of the *Hardware Auto-Detection Summary* dialog box to select the appropriate level of calibration to be performed. You may perform a new calibration, reuse existing calibration data, or perform measurements without calibration.

3. Setting up calibration and measurement parameters.

   This step uses the *Calibrate Hardware for Measurement* dialog box to display the default measurement parameters. These default parameters are based on the hardware capabilities of your PLTS. You may modify these defaults as required.

When you select the **New Measurement** button shown in Figure 3-2 on page 62, the *Hardware Auto-Detection Summary* dialog box is displayed. See Figure 3-3.

Figure 3-3 Hardware Auto-Detection Summary Dialog Box



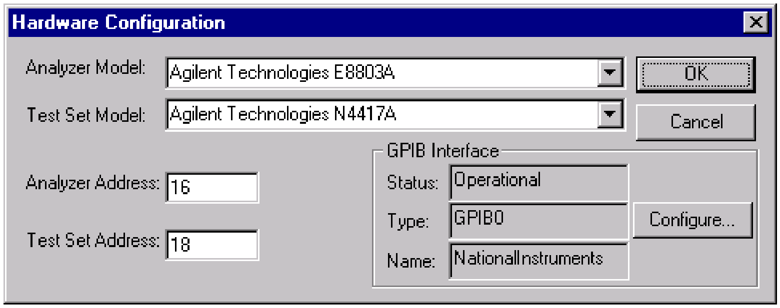
Verifying the Software Recognizes the PLTS Hardware

On the left portion of the *Hardware Auto-Detection Summary* dialog box, the model number, the GPIB address, and the serial number for the network analyzer and test set are displayed. These are the test equipment that the software finds connected to the GPIB bus. If this information seems incorrect, check your system hardware connections and power status, then select **Re-Scan**.

To force PLTS to recognize other instruments, or re-configure the GPIB interface manually, select **Edit** to display the *Hardware Configuration* dialog box. Refer to Figure 3-4. In this dialog box, you can select the model number and enter the GPIB address for your network analyzer and test set. You can also set up the GPIB Interface card by selecting the **Configure**… button.

Select the **OK** button when the dialog box contains the correct information.

Figure 3-4 **Hardware Configuration Dialog Box**



Selecting the Appropriate Level of Calibration

On the right portion of the *Hardware Auto-Detection Summary* dialog box (Figure 3-3), select your calibration strategy:

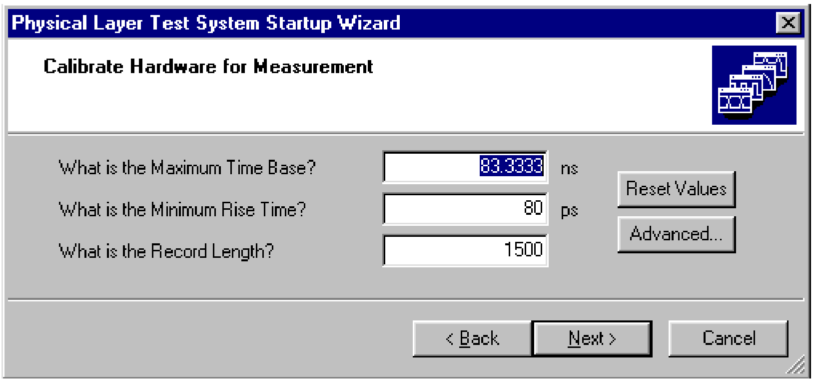
- **Perform a new calibration** continues with the Startup Wizard performing a new calibration before making a measurement.
- **Load existing calibration data** allows you to select a previously saved calibration (*.cal) file to be used for the new measurement. See Chapter 4, "Calibrating for Measurement Accuracy," for guidance on calibration intervals, etc.
- **None. Collect measurement data uncalibrated** allows you skip the calibration, select measurement parameters (see Figure 3-6 on page 68), and then proceed directly to the measurement screen. This option is ***not recommended*** for qualitative data collection.

Select the **Perform a new calibration** choice for this example exercise.

Setting Up the Calibrate and Measure Parameters

When you select **Perform a new calibration**, and then select **Next >**, the first of three *Calibrate Hardware for Measurement* dialog boxes is displayed as shown in Figure 3-5.

Figure 3-5 Calibrate Hardware for Measurement



This dialog box initially displays the calculated **Maximum Time Base**, **Minimum Rise Time**, and **Record Length** which were calculated based on the equipment found on the system bus. You may accept or modify these values. Modifying these values directly will also modify other associated values interactively. For example, when changing the **Minimum Rise Time**, the **Record Length** will change appropriately.

At any time, you can return to the original default values by selecting **Reset Values**.

For further options, select **Advanced...** to display the screen shown in Figure 3-6.

Modifying Time and Frequency Parameters To enter calibration and measurement parameters in a frequency-domain-based interface, to see all parameter details, or just to see how the time-domain and frequency-domain parameters interact, select **Advanced...** from the previous display (Figure 3-5). Selecting **Advanced...** displays the *Modify Time and Frequency Parameters* dialog box shown in Figure 3-6.

The *Modify Time and Frequency Parameters* dialog box allows modification of the calculated parameters in both time domain and frequency domain terms. As with the previous dialog box, you may accept or modify these values.

Modifying these values also modifies other associated values interactively. To modify a parameter, enter the value in associated value box and then select the **Recalculate Parameters** button to update each parameter. Refer to Table 3-1 for a description of each time-domain and frequency-domain parameter.

Figure 3-6 Modify Time and Frequency Parameters

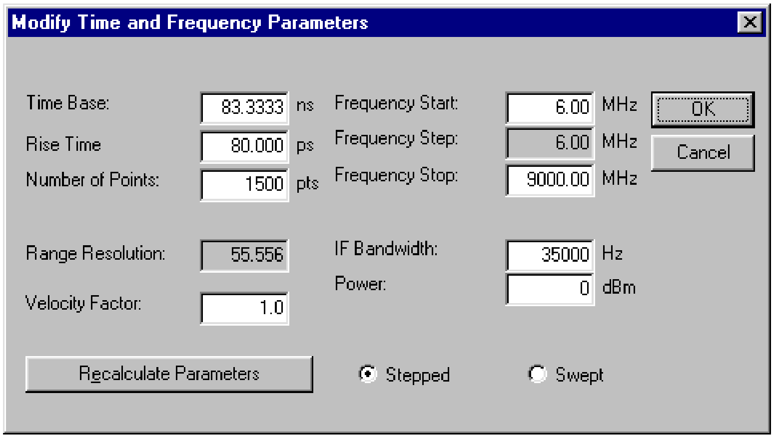


Table 3-1 Time and Frequency Parameter Descriptions

Parameter	Description
Time Base	Sets the maximum time base (in ns). Time base calculated as $\frac{1}{2 \times F_{min}}$ where F_{min} is the start frequency.
Rise Time	sets the transition time (in picoseconds) of the stimulus signal rising from 10 to 90% of the maximum signal amplitude.
Number of Points	sets the number of measured points per sweep.
Range Resolution	describes how close in time two responses can be distinguished; depends on the width of the impulse response, which is inversely related to the measurement bandwidth.
Velocity Factor	is the numerical value related to the speed of energy through transmission lines with different dielectrics.
Frequency Start	sets the start frequency of the sweep.
Frequency Step	sets the step size between points. This value is locked to (is the same as) the Frequency Start value.
Frequency Stop	sets the stop frequency of the sweep.

Table 3-1 Time and Frequency Parameter Descriptions

Parameter	Description
IF Bandwidth	allows you to change the IF bandwidth. Narrow IF bandwidths allow you to view low-level signal, however, require more data samples per point and thus slow the measurement time.
Power	sets the signal level at the source appropriate for measurement of the device. You can measure the signal level available at the test port directly using a power meter.
Stepped	takes data while sweeping through defined frequency points.
Swept	takes data while sweeping linearly and continuously across the frequency range.

To accept the parameters and return to the previous screen, select **OK**.

From the *Calibrate Hardware for Measurement* dialog box (shown in Figure 3-5), select **Next >** to continue to the calibration kit selection.

How to Perform a Calibration

For the details for performing a calibration, continue with "Selecting a Calibration Type" on page 83. "When Is Calibration Needed" on page 80 describes how often the calibration needs to be performed.

As mentioned earlier, the calibration procedure includes:

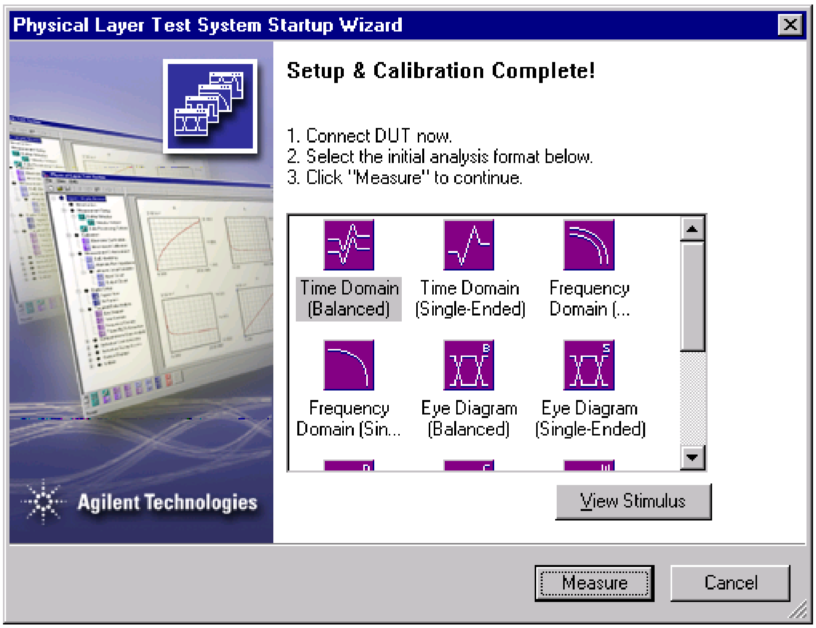
- Calibration Type Selection and Calibration Kit Selection
- SOLT Mechanical Calibration, SOLT Electronic Calibration, or TRL Calibration
- Adapter Characterization

This procedure will guide you through these calibration steps. When you are finished with the calibration, it refers you back to "How to Make a Measurement" on page 70.

How to Make a Measurement

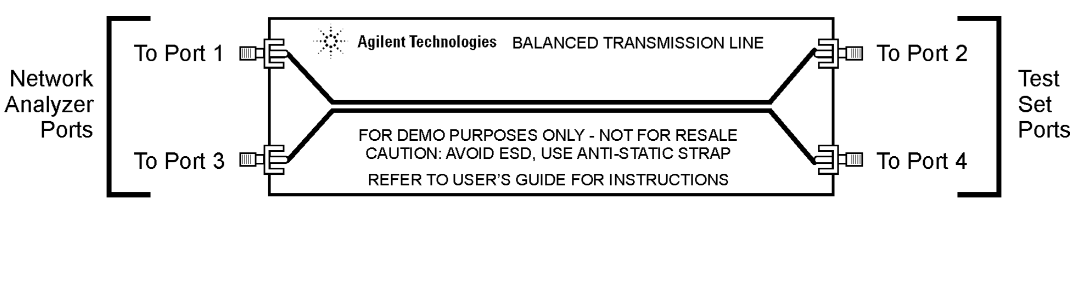
After saving the calibration data and selecting the **Next >** button, the final Startup Wizard window is displayed. See Figure 3-7. This window allows you to select the type of analysis that you want to display and initiates the measurement.

Figure 3-7 Setup & Calibration Complete! Window

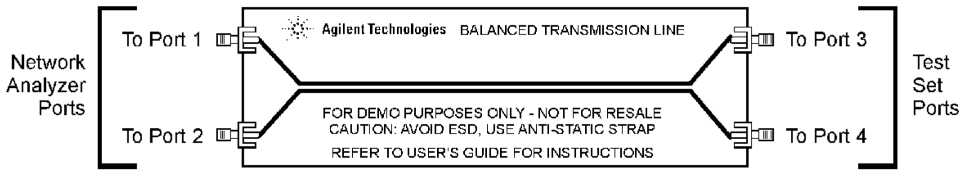


1. To make the measurement, connect the PLTS to the device under test. In this example, the supplied simple balanced transmission line is used. Figure 3-8 shows how the balanced transmission line is connected to the system hardware after a 4-port SOLT calibration.

Figure 3-8 Connecting the Balanced Transmission Line DUT



NOTE If you were connecting the balanced transmission line after a TRL calibration, ports 2 and 3 would be interchanged as shown below.



Observe the change in ports 2 and 3 from Figure 3-8.

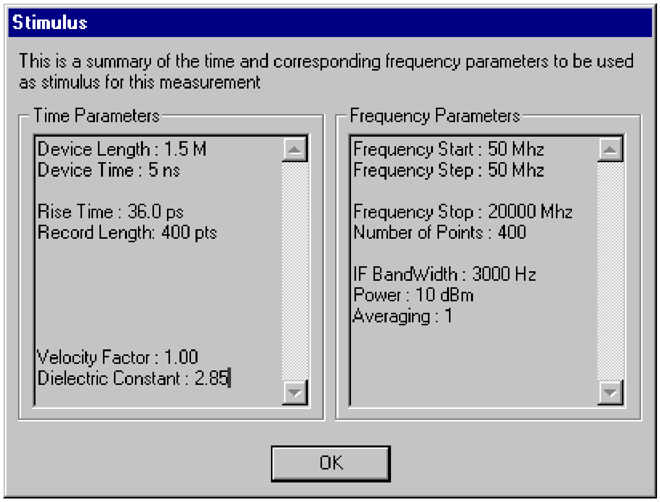
2. The *Setup & Calibration Complete!* window displays the ten available analysis formats:

- Time Domain (Balanced)
- Frequency Domain (Balanced)
- Eye Diagram (Balanced)
- RLCG (Differential)
- RLCG (W-Element)
- Time Domain (Single-Ended)
- Frequency Domain (Single-Ended)
- Eye Diagram (Single-Ended)
- RLCG (Common)
- RLCG (Self/Mutual)

   For the purpose of this example, the **Time Domain (Balanced)** icon is selected.

3. If you wish to review or confirm the measurement parameters prior to performing the measurement, press the **View Stimulus** button. The *Stimulus* dialog box (see Figure 3-9) displays the selected parameters in both time and frequency formats. To modify any of these parameters, return to "Setting Up the Calibrate and Measure Parameters" on page 67.

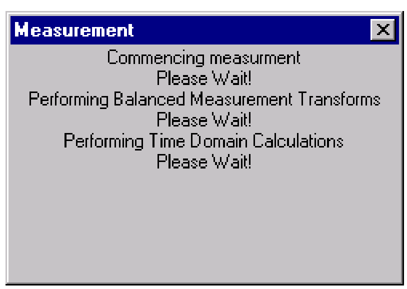
Figure 3-9 Stimulus Dialog Box



4. Select **OK** to leave the *Stimulus* dialog box and return to the final Startup Wizard window.
5. To start the measurement, select the **Measure** button on the *Setup & Calibration Complete!* window.

   The measurement then begins and a progress message is displayed. See Figure 3-10.

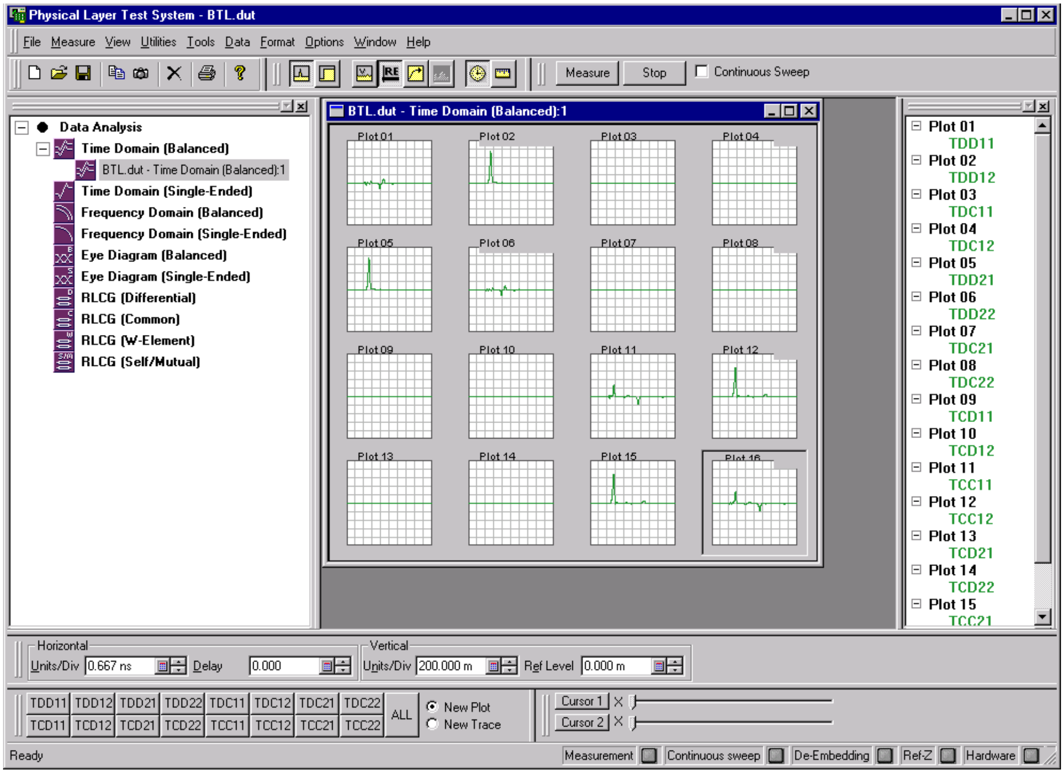
Figure 3-10 Progress Message



Analyzing the Measurement Results

Now that you have measured the device under test, its results are displayed in Figure 3-11 using **Time Domain (Balanced)** format, the same analysis format selected in step 2.

Figure 3-11 Displayed Measurement in Time Domain Balanced Format



Refer to the four chapters listed below for information about each analysis format:

- Chapter 5, "Analyzing Data in the Frequency Domain," on page 115
- Chapter 6, "Analyzing Data in the Time Domain," on page 137
- Chapter 7, "Analyzing Data using Eye Diagrams," on page 165
- Chapter 8, "Extracting Transmission Line (RLCG) Parameters," on page 181

II Measurements

Part II provides detailed information about optimizing and making measurements and analyzing the measured data using the physical layer test system.

Chapter 4, "Calibrating for Measurement Accuracy"	Provide information about performing test system calibrations.
Chapter 5, "Analyzing Data in the Frequency Domain"	Provides information about analyzing measured data in the frequency domain.
Chapter 6, "Analyzing Data in the Time Domain"	Provides information about analyzing measured data in the time domain.
Chapter 7, "Analyzing Data using Eye Diagrams"	Provides information about analyzing measured data using the Eye diagram.
Chapter 8, "Extracting Transmission Line (RLCG) Parameters"	Provides information about extracting transmission line R, L, C, G parameters from the measured data.
Chapter 9, "Enhancing the Measurement"	Provides information about using measurement enhancement features such as gating, phase skew, and de-embedding.

4 Calibrating for Measurement Accuracy

What Is Measurement Calibration

Measurement calibration is an accuracy enhancement procedure that effectively removes the systematic errors (repeatable measurement variations) that cause uncertainty in measuring a device under test (DUT). During measurement calibration, the physical layer test system measures actual, well-defined standards and mathematically compares the results with ideal “models” of these standards. Calibration measurements, which characterize the test system, are made with all cables and connections in place but without the DUT.

Systematic Errors are related to signal leakage, signal reflections, and frequency response of the test system. There are six types of systematic errors.

- Directivity and crosstalk related to signal leakage
- Source and load impedance mismatches related to signals being reflected
- Frequency response error caused by reflection and transmission tracking with the test receivers

Other factors that can impact the measurement accuracy of any measurement system are drift errors and random errors.

- **Drift Errors** are due to the instrument or test-system performance changing after a calibration has been done. Drift is primarily caused by temperature variation and it can be removed by recalibration. The timeframe over which a calibration remains accurate is dependent on the rate of drift that the test system undergoes in the test environment. A stable ambient temperature usually minimizes the rate of drift significantly. Allowing equipment to warm up and stabilize prior to calibration and properly ventilating equipment helps reduce drift errors.
- **Random Errors** are unpredictable since they vary with time in a random fashion. Therefore, they *cannot* be removed by calibration. The main contributors to random error are instrument noise such as, source phase noise, sampler noise, and IF noise. The accurate source and phase-locked receiver of the network analyzer greatly minimizes these random errors. There are also external contributors to random errors such as switching power supplies, EMI, etc.

Why Is Calibration Needed

Components of the measurement setup such as imperfect connectors, cabling, and even the response of the test instruments can introduce errors into measurements. For both transmission and reflection measurements, impedance mismatches within the test setup cause measurement uncertainties that appear as ripples superimposed on the measured data. These errors can distort the signal and make it difficult to determine which reflections are from the DUT and which are from other sources.

Calibration is required for accurate measurements. Even though calibration does take a few minutes to complete, it saves time and money compared to costs associated with erroneous measurement data. Even mechanical (non-electronic) calibration is reasonably quick once you become familiar with the process.

TIP **Understanding How Changes Affect Measurements**

No two measurements and environmental conditions are exactly the same. The best way to understand your conditions is to experiment and see how your test equipment behaves over a period of time. A good way of doing this is to measure the same device (i.e., a known standard) hourly throughout the day. Save or print the measurement results of each measurement. Compare these results to gain an understanding of how the ambient environment and drift affect the measurements. Watch for trends with regard to the device meeting specifications or measuring within guard band limits.

When Is Calibration Needed

We recommend that you perform a calibration on your physical layer test system when the following conditions occur:

- When connectors are cleaned, repaired, or replaced.
- If test cables have any changes, such as:
  - When a test cable is replaced
  - When any connection is changed except the connections to the DUT
  - When test cables are flexed excessively (kinked or unkinked)
- If the frequency range is changed beyond the limits of the previous calibration
- If the number of measurement points is increased to more than the number of points of the previous calibration
- When ambient temperature changes more than ±3 °C
- Any other ambient environmental changes of significance
- If none of the previous conditions apply, calibrate according to the intervals shown below due to drift:
  - Check the calibration daily at a minimum (twice daily is recommended). Refer to "How to Verify a Calibration" on page 81.
  - Calibrate weekly (daily calibration recommended).

How to Verify a Calibration

A good method of checking calibration is to establish a *Golden Device*, which is a device that meets all specifications and is saved for comparison of the measured results in the future.

Establishing a Golden Device

Follow these steps to establish a golden device:

1. Calibrate the system.
2. Perform the complete set of measurements on the golden device.
3. Save and print all of the test results from these initial measurements.

Now you can measure the golden device when you suspect that your system may need to be calibrated. Compare the results of these measurements against the results that you saved and printed from the initial measurements.

How to Perform a Calibration

You will first select a calibration kit and then you will perform a calibration (either mechanical or electronic, depending on your calibration kit). After you finish the calibration, you will be ready to make a measurement.

Use the following procedure to calibrate the Physical Layer Test System.

1. If you are referring to this chapter from the example measurement in Chapter 3, skip to "Selecting a Calibration Type" on page 83.
2. Open the Physical Layer Test System Startup Wizard by doing any of the following:
   - Start the Physical Layer Test System software.
     (The startup wizard will open at start up unless the "**Do not show this wizard again at start up**" option has been selected.)
   - Select **New** from the **File** menu.
   - Select **Calibration** from the **Utilities** menu. Then select **Calibrate**.
3. Press the **Next >** button until you reach the startup wizard's *Calibrate Hardware for Measurement* dialog box displaying the default parameters, such as the maximum time base, minimum rise time, and number of point settings. See Figure 3-5 on page 67.

   Use this dialog box to check these calibration parameter settings. These default settings are based on the equipment limitations of your Physical Layer Test System.

   Selecting the **Advanced**… button to display all of the calibration parameters in the *Modify Time and Frequency Parameter* dialog box. Refer to Figure 3-6 on page 68.

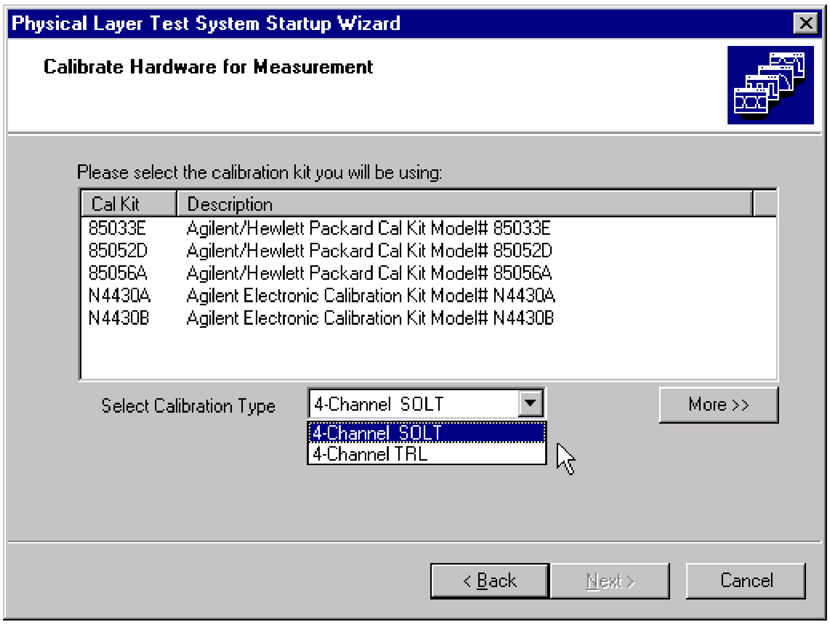
   You can change any of the time domain or frequency domain parameters, and then by selecting the **Recalibrate Parameters** button, the remaining parameters are recalibrated and displayed. Once all of the parameters are set to your satisfaction, select **OK** to return to the *Calibrate Hardware for Measurement* dialog box.

   If you decide you want to reset all changed values to their default settings, select the **Reset Values** button.
4. Once the parameters are set, select the **Next >** button to display the calibration type selection dialog box shown in Figure 4-2.

Selecting a Calibration Type

The dialog box shown in Figure 4-2 is the window that is used to select the calibration type and the calibration kit. It opens in the default SOLT (Short-Open-Load-Thru) calibration type, showing the 4-Channel SOLT calibration type along with the SOLT calibration kits that have been determined by the auto-detection to be appropriate for the system hardware. Some calibration kits listed here may not be displayed.

Figure 4-1 Select Calibration Type Dialog Box



The **Select Calibration Type** list allows you to choose the calibration type. **4-Channel SOLT** is the default calibration type. Opening the list displays that the **4-Channel TRL** (Thru- Reflect-Line) calibration type is also available. If you select **4-Channel TRL**, no calibration kit choices are available. You will first need to define a calibration kit that covers your measurement parameter start and stop frequency range.

Select the calibration type from the list and refer to the appropriate section listed below.

- If you selected **4-Channel SOLT** calibration, refer to "Performing an SOLT Calibration" on page 84.
- If you selected **4-Channel TRL** calibration, refer to "Performing a TRL Calibration" on page 96.

Performing an SOLT Calibration

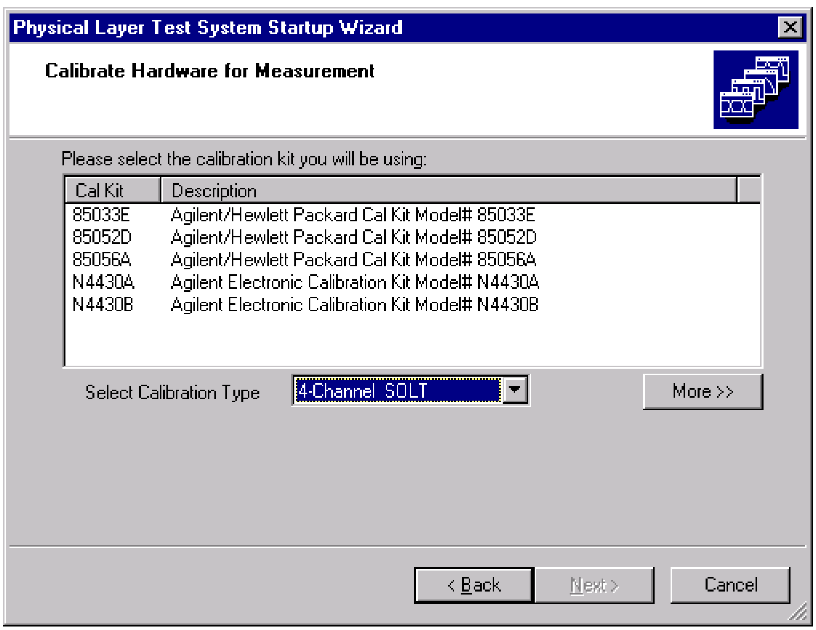
You have selected the **4-Channel SOLT** calibration type. You will first select a calibration kit and then you will perform a calibration (either mechanical or electronic, depending on your calibration kit). After you finish the calibration, you will be ready to make a measurement.

Selecting a Calibration Kit

The dialog box shown in Figure 4-2 lists the calibration kits that have been determined by the auto-detection to be appropriate for the system hardware.

Additional calibration kits, including user-defined kits, may be added by selecting **Calibration** then **Edit Cal Kit** from the **Utilities** menu. See "Edit Cal Kit" on page 248 for details.

Figure 4-2 Select Calibration Kit Dialog Box



NOTE Some calibration kits listed here may not be displayed. This dialog box displays each calibration kit that meets the requirements set by the calibration parameters set previously.

Selecting the **More >>** button displays the connector type for each of the four ports.

1. Select your calibration kit. Refer to Table 4-1 for the appropriate calibration kit.

Table 4-1 Default Calibration Kit Parameters

Model Number	Frequency Range
Mechanical Calibration Kits include:	
85033E	30 kHz to 9 GHz
85052D	45 MHz to 26.5 GHz
85056A	45 MHz to 50 GHz
Electronic Calibration Kits include:	
N4430A[a]	30 kHz to 6 GHz
N4430B	30 kHz to 9 GHz

a. Also applies to the ATN-4801 Multiport Calibration Module.

2. Once the calibration kit is selected, click the **Next >** button to display the calibration window.
   - If you selected a mechanical calibration kit, refer to "Performing a Mechanical SOLT Calibration" on page 85 for additional information.
   - If you selected an electronic calibration kit, refer to "Performing an Electronic Calibration" on page 92 for additional information.

Performing a Mechanical SOLT Calibration

NOTE For maximum accuracy and repeatability, the system (network analyzer and test set) should be stabilized at room temperature for a minimum of 24 hours before calibration.

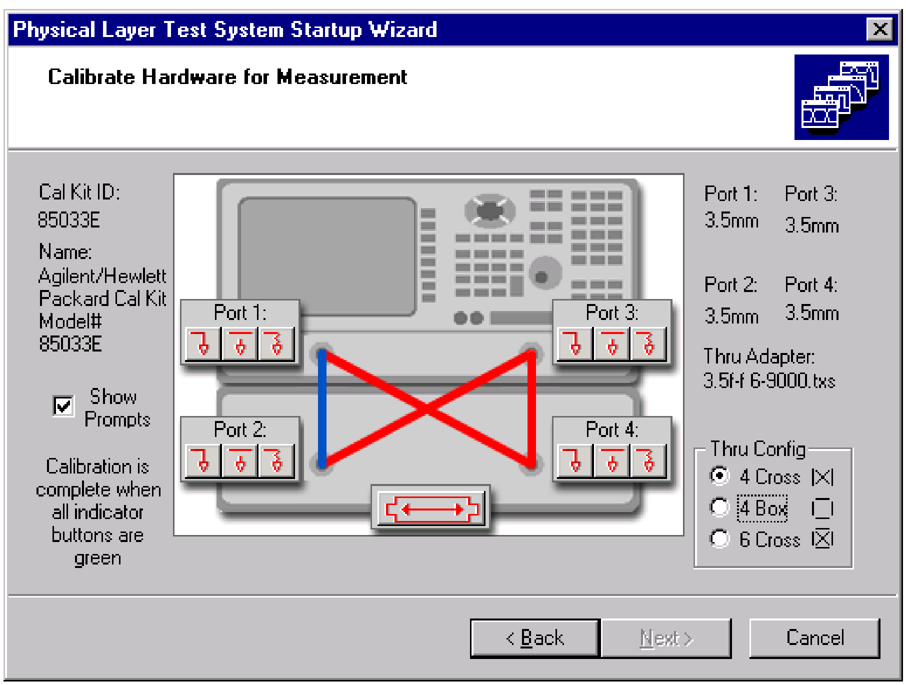
The 4-port (channel) Short/Open/Load/Thru (SOLT) calibration type is one of the most comprehensive calibrations. This calibration effectively removes the directivity error, crosstalk, source match error, load match error, frequency response reflection tracking error, and frequency response transmission tracking error from the test setup in a transmission or reflection test using these ports.

It has two unique components: the Thru component and the Short/Open/Load (SOL) component.

- The Thru component consists of connecting a through (Thru) adapter between the ends of the test cables connected to the system ports. The Thru adapter is also part of the calibration kit.
- The SOL component consists of connecting a short standard, an open standard, and a 50-ohm load standard to the end of the test cable connected to each system port. Each of these standards is part of the calibration kit.

Figure 4-3 is the mechanical calibration interface that steps you through the calibration. It displays calibration configuration information—such as the calibration kit selection, the test port connector types, the selected thru adapter, and the thru configuration—as well as a graphical representation of the test ports. This graphical representation includes a set of icons for each port, corresponding to a short, open, and load (see "The Short/Open/Load (SOL) Component" on page 89). In the center of the screen, the selected thru configuration is displayed (see "The Thru Component" on page 87).

Figure 4-3 The SOLT Calibration Interface

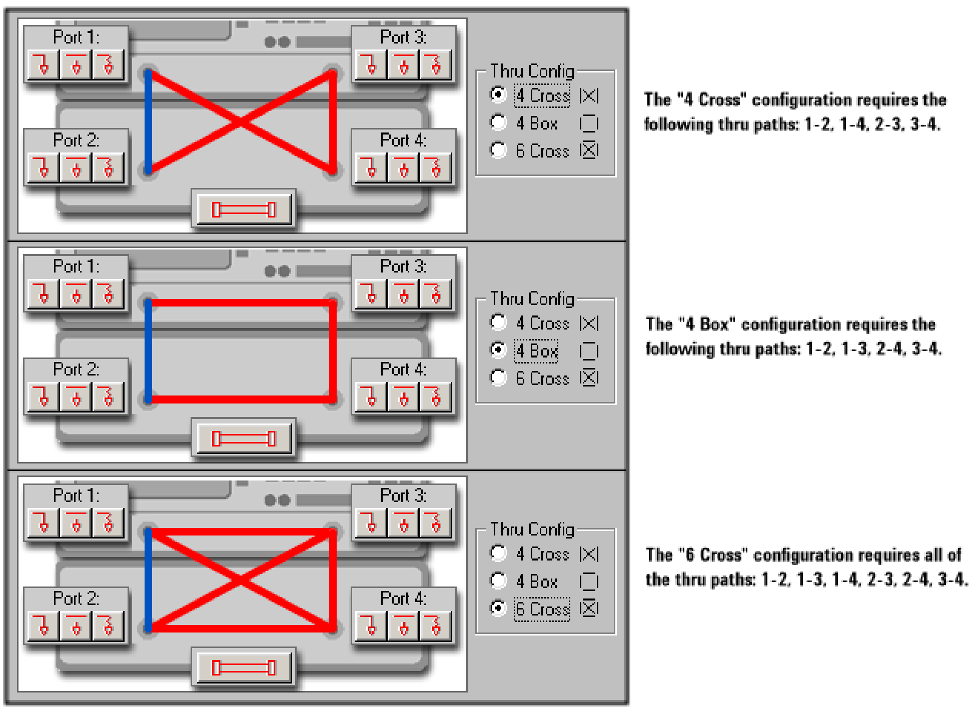


Note that all of the icons and the thru configuration are displayed in red at the start of the calibration (except the first thru to be connected, which is shown in blue). As each calibration standard is connected and measured, the color of its corresponding icon will change to green. This is also true of the thru configuration.

The Thru Component In addition to the SOL component of the calibration, a series of through (thru) measurements are required. For a 4-port calibration, it can be assumed that six thru-path calibrations are required (1-2, 1-3, 1-4, 2-3, 2-4, 3-4). However, some test setups, particularly probing setups, may make thru connections for all six paths physically impossible.

PLTS provides an alternative, and only requires four thru-paths measurements to perform an accurate four-port calibration.

Figure 4-4 "Thru Config" Options



The selection in the **Thru Config** area of the *Calibrate Hardware for Measurement* window (shown in Figure 4-3 on page 86) dictates the calibration pattern of the thru calibration. Figure 4-4 shows the Thru calibration pattern for each **Thru Config** selection.

There are minor trade-offs to consider when deciding between a four or six thru-path calibration. With a four thru-path calibration, the non-measured thru-paths are calculated (simulated) in the software. Although this calculation has been proven to be extremely accurate, the simulated paths have a fractional amount of ripple across the band that would not be present if the full six thru-path calibration were performed. This ripple is insignificant in all but extremely low-loss DUT specifications.

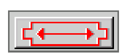
TIP **Comparing Thru Path Calibrations**

For the sake of convenience, the four thru-path calibrations are recommended in most situations. If you are concerned about the difference, you may choose to perform two calibrations, one four thru-path and one six thru-path, and compare the results with your particular DUT specifications in mind.

Note that when a **Thru Config** choice is selected, the color of the first Thru measurement path changes from red to blue. When that Thru path calibration is complete, the path color changes from blue to green and the next Thru measurement path is displayed in blue.

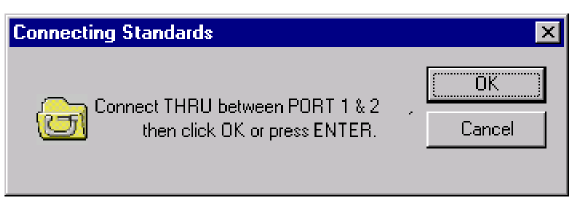
To Perform the Thru Calibration Component 1.Connect the test cables and any adapters that you will use for your measurements to the Physical Layer Test System test ports.

The calibration is made with all cables and connectors in place but without the DUT.

2. With the *Calibrate Hardware for Measurement* window (see Figure 4-3 on page 86) displayed, select the following Thru icon: 

3. Once the Thru icon is selected, a prompt is displayed telling you which connections must be made for the Thru calibration. An example is shown in Figure 4-5.

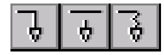
Figure 4-5 Example Prompt for Thru



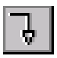
4. Continue to select the Thru icon following the instructions as each prompt is displayed. The Thru component of the calibration is complete once the color of all of the Thru paths have changed to green.

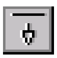
5. Continue with “The Short/Open/Load (SOL) Component” to complete the calibration.

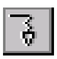
The Short/Open/Load (SOL) Component Performing the SOL portion of the calibration consists of connecting each of the standards to each of the ports for a reference measurement. Any sequence may be used, and multiple connections may be made simultaneously for convenience (for example: connect the short to port 1, load to port 2, and open to port 3, then continue). The icons will change color from red to green as each standard is completed.

Each of the four ports on the window has an associated set of icons as shown: 

Each of the three icons in the set represents a different part of the SOL calibration component.

 represents the short standard from the calibration kit

 represents the open standard from the calibration kit

 represents the 50-ohm load standard from the calibration kit

As each standard is connected to each port and characterized during the calibration, the color of the associated icon changes from red to green.

To Perform the Short/Open/Load (SOL) Calibration Component 1.With the *Calibrate Hardware for Measurement* window (see Figure 4-3 on page 86) displayed, ensure that the **Show Prompts** check box is checked.

TIP **To perform the SOL calibration without using prompts:**

Prompts are used to guide you through the steps for this calibration. It is not required that this calibration be performed using prompts, such as the one shown in Figure 4-6. These prompts may be disabled by clearing the **Show Prompts** checkbox. Until you become familiar with the calibration procedure, it is recommended that you use the prompts.

1. Ensure that the **Show Prompts** check box is cleared.
2. Select a short, open, or load standard from the calibration kit and connect it to one of the test ports. Note: You may save time by connecting more than one standard (for example: connect the short to port 1, load to port 2, and open to port 3, then continue).
3. Click the corresponding icon to perform the appropriate measurement.
4. The system will perform a reference measurement, and the color of the icon will change to green, indicating completion.

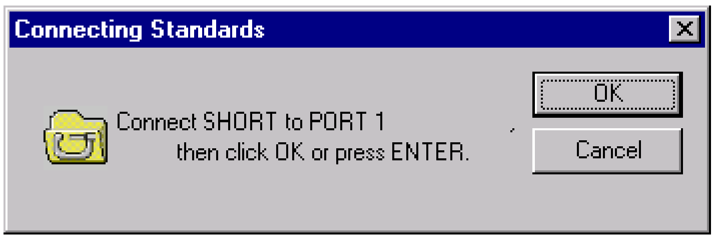
5. Repeat for the remaining standards and ports until all of the icons have changed to green.

After you have finished the SOL calibration, select the **Next >** button to the save the calibration data. See "To Save the Calibration" on page 91.

---

2. Click on any one of the icons, at any one of the test ports.
3. A dialog box is displayed confirming the required standard and port. An example is shown in Figure 4-6.

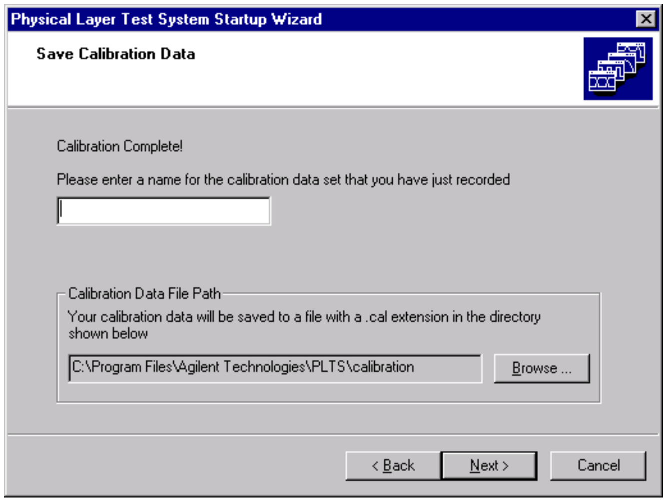
Figure 4-6 Example Prompt for Shorts, Opens, and Loads



4. Make the requested connection and click **OK**.
5. The system will perform a reference measurement, and the color of the icon will change to green, indicating completion.
6. Repeat for the remaining standards and ports until all of the icons have changed to green.
7. After you have finished the SOL calibration, select the **Next >** button to the save the calibration data. See "To Save the Calibration" on page 91.

To Save the Calibration Once you have completed both components of the SOLT calibration, the *Save Calibration Data* dialog box is displayed as shown in Figure 4-7.

Figure 4-7 Save Calibration Data Dialog Box



1. Enter a file name for the calibration data set.

   The calibration data file will be saved in the directory displayed in the **Calibration Data File Path** box. You may change the directory by entering the directory path in the box or selecting the **Browse**… button and navigating through your computer's directory structure to the desired directory. The calibration data is automatically saved with a ".cal" file extension.

2. Save the calibration data by selecting the **Next >** button.

   When the calibration data is saved, the calibration is complete.

3. If you started the calibration:

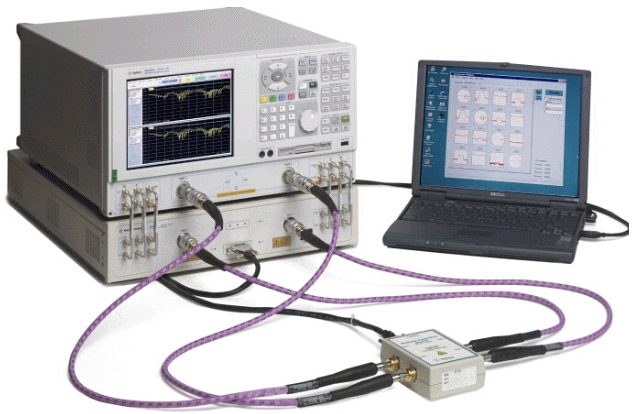
   - As part of the example measurement of Chapter 3, return to "How to Make a Measurement" on page 70.
   - By entering the startup wizard at startup or by selecting **New** from the **File** menu, the software sends you to the Startup Wizard's *Setup & Calibration Complete!* window where you can make a measurement.
   - By selecting **Calibration** from the **Utilities** menu and then selecting **Calibrate**, the software returns to the main software window.

Performing an Electronic Calibration

You can perform a 4-port electronic calibration (ECal) using the Agilent N4430A 6 GHz 4-Port ECal Module[1] or the N4430B 9 GHz 4-Port ECal Module.

With a one-time connection, the ECal procedure cycles through all of the impedance states and six thru paths required for a full, four-port, vector error-corrected SOLT calibration, and can transfer factory-calibration accuracy to the Physical Layer Test System. The software controls the electronic calibration. Refer to Figure 4-8 for a typical equipment setup.

Figure 4-8 Typical Equipment Setup for ECal



NOTE For maximum accuracy and repeatability, the system (network analyzer, test set, and ECal module) should be stabilized at room temperature for a minimum of 24 hours before calibration.

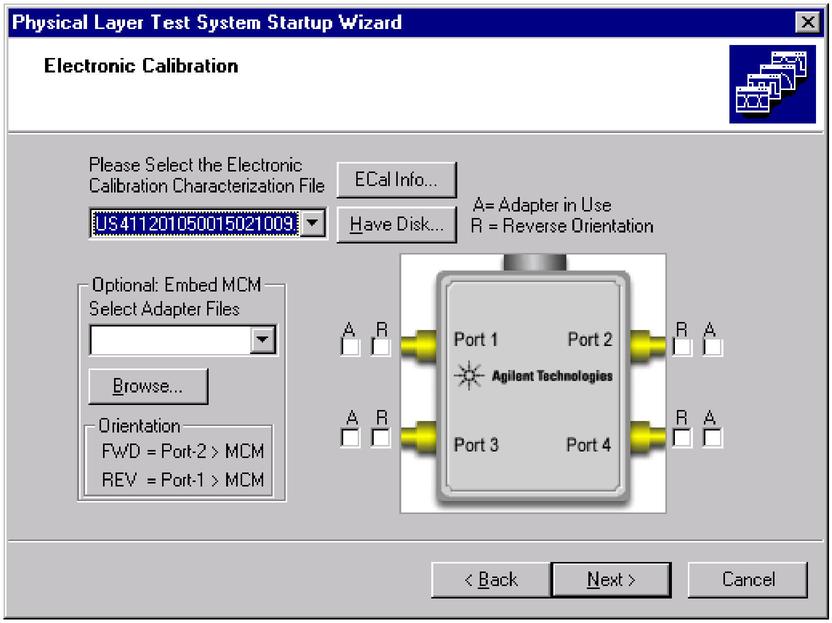
Using standard alignment precautions, the test set may have the ECal module connected and disconnected in any power state. After calibration, the ECal module may remain connected or may be disconnected from the test set Auxiliary connector with no effect on the calibration.

To perform the ECal with the physical layer test system:

1. Once you select an electronic calibration kit and then click the **Next >** button as instructed on the last step of the "Selecting a Calibration Kit" procedure on page 85, the *Electronic Calibration* is displayed. See Figure 4-9.

1. The ATN-4801 Multiport Calibration Module may also be used.

Figure 4-9 Electronic Calibration Dialog Box



2. Connect the test cables and adapters that you will use for your measurements to the Physical Layer Test System test ports.

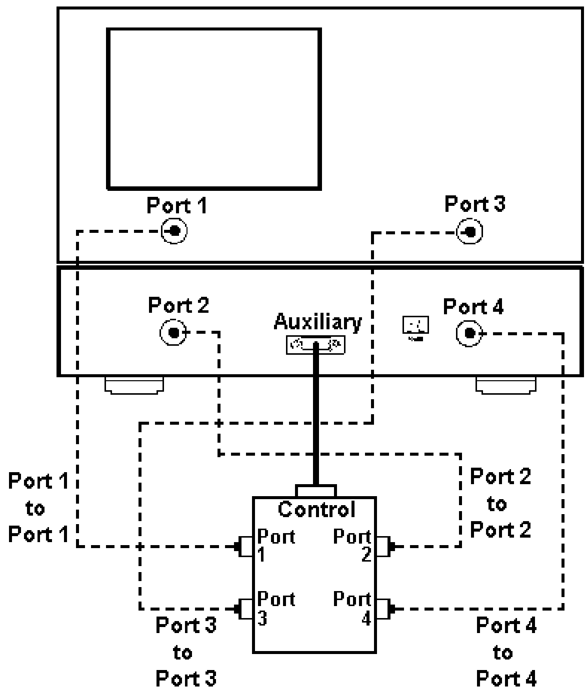
3. Connect the other end of the test cables and adapters to the ECal module so that the connections identified in Table 4-2 are made. If adapters are required to make the connections from the test cable/adapter setup to the ECal module, use the adapters in the ECal module kit.

Table 4-2 ECal Module Connections

ECal Module Connector	PLTS Connector	Cable Type	Specified Torque
CONTROL	AUXILIARY	DB-15	N/A
PORT 1	PORT 1	Coax	8 in/lb
PORT 2	PORT 2	Coax	8 in/lb
PORT 3	PORT 3	Coax	8 in/lb
PORT 4	PORT 4	Coax	8 in/lb

CAUTION Make sure that test port 2 of the system is connected to Port 2 of the ECal module and that test port 3 of the system is connected to Port 3 of the ECal module. Connecting to the wrong port will lead to incorrect calibration results. Refer to Figure 4-10 for test cable connections to the ECal module.

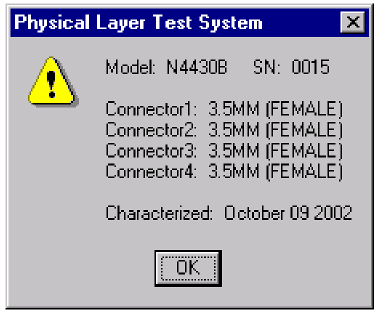
Figure 4-10 Connecting Test Cables to the ECal Module



4. Select the electronic calibration characterization file for your ECal module from the list. Refer to Figure 4-9. Verify that the file name matched the serial number of your ECal module.

   If your characterization file was not located by the software, load the characterization file from the floppy disk provided with the ECal module. Load the file from the floppy disk by inserting the floppy disk in the PC, selecting the **Have Disk** … button, and locating the characterization file from the floppy disk directory using the *Open* dialog box. Each module characterization file is unique, so verify that the file name matches the ECal module serial number. The characterization file has an ".ecl" extension. The ECal module should be loaded into the C:\Program Files\Agilent Technologies\PLTS\ecal, where C is the hard drive where the PLTS is stored.

NOTE Select the **ECal Info**… button to display the following ECal module information dialog box for the selected module.



5. If your system's test cable setup won't connect directly to the ECal module, you may use an adapter that has already been characterized. To use the adapter, select the adapter's characterization file from the **Select Adapter Files** list. Refer to "Characterizing Adapters" on page 107 for detailed information.

NOTE If you use one or more of the 3.5 mm male to male adapters in the ECal kit, you may select one of the 3.5m-m.txs files from the **Select Adapter Files** list.

- If you are connecting the adapter in the forward orientation (with the adapter's characterized port 2 connected to the ECal module), just select the checkbox labeled **A** (representing Adapter) for the port to which it is being connected.
- If you are connecting the adapter in the reverse orientation (with the adapter's characterized port 1 connected to the ECal module), select the checkbox labeled **A** (representing Adapter) and the checkbox labeled **R** (representing Reverse) for the port to which it is being connected.

NOTE The Adapter **(A)** checkbox must be selected before the program accounts for the Reverse **(R)** checkbox being selected.

6. Once the system is connected to the ECal module, select **Next >** to start the electronic calibration. A small window showing the calibration progress is displayed.

   Once the calibration is complete, it should be saved. See "To Save the Calibration" on page 91.

Performing a TRL Calibration

You have selected the 4-Channel TRL calibration type. Unless you have defined a TRL calibration kit previously, you will need to define a TRL calibration kit before proceeding. Refer to “Defining a TRL Calibration Kit”. After you complete the definition, you may return to the startup wizard using the procedure that you have followed to get to this point.

NOTE TRL calibration on physical layer test systems with the 8753ES or the 872XES network analyzers is not supported.

If you already have a TRL calibration kit defined and displayed in the window, continue with “Selecting a TRL Calibration Kit” on page 100.

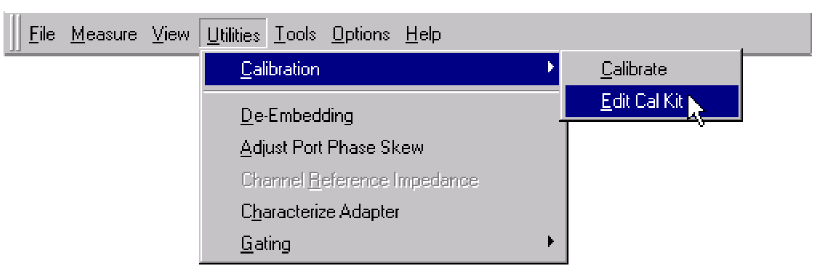
Additional calibration kits, including user-defined kits, may be added as shown in “Defining a TRL Calibration Kit”.

Defining a TRL Calibration Kit

The dialog box shown in Figure 4-12 shows only the **USER_DEF** selection. This indicates that a TRL calibration kit must be defined before a TRL calibration may be performed.by selecting **Calibration** then **Edit Cal Kit** from the **Utilities** menu. See “Edit Cal Kit” on page 248 for details.

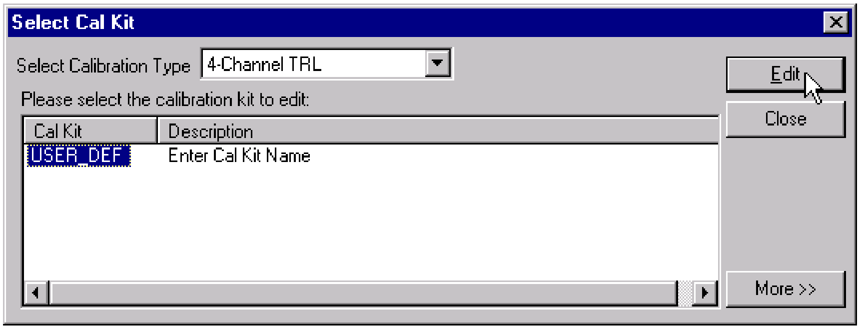
1. If you have no TRL calibration kit displayed, exit the startup wizard by clicking the close button in the upper right corner of the wizard: 
2. From the **Utilities** menu, select **Calibration, Edit CalKit** as shown in Figure 4-11.

Figure 4-11 Selecting Edit CalKit



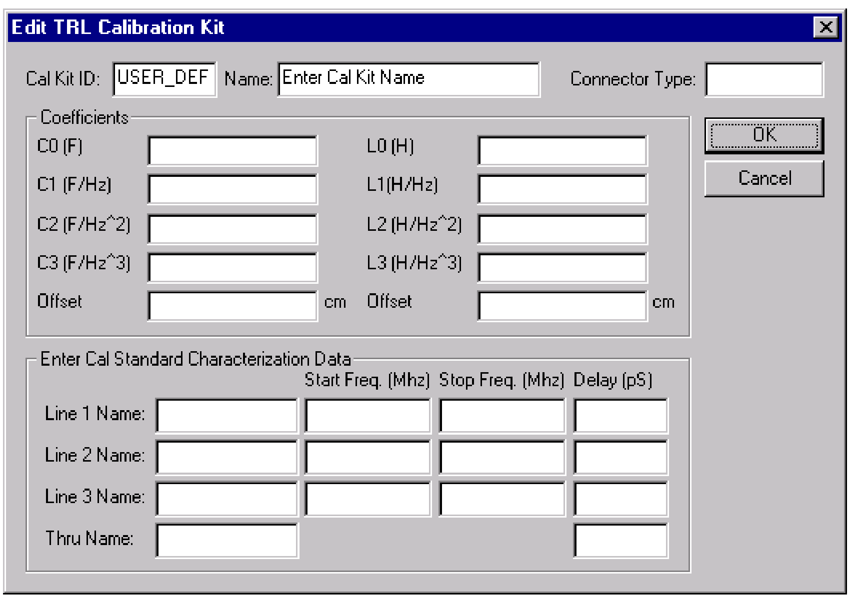
3. In the *Select Cal Kit* dialog box, select **4-Channel TRL** from the **Select Calibration Type** list, then select the **USER_DEF** selection and click **Edit** to start the definition process. See Figure 4-12.

Figure 4-12 Select Cal Kit Dialog Box



4. The calibration kit definition is performed in the *Edit TRL Calibration Kit* dialog box. See Figure 4-13.

Figure 4-13 Blank Edit TRL Calibration Kit Dialog Box



5. Enter **Cal Kit ID**, **Name**, and **Connector Type** into the appropriate entry boxes in the header.

   Referring to Figure 4-12, **Cal Kit ID** is listed in the **Cal Kit** column and **Name** is listed in the **Description** column of the calibration kit selection window.

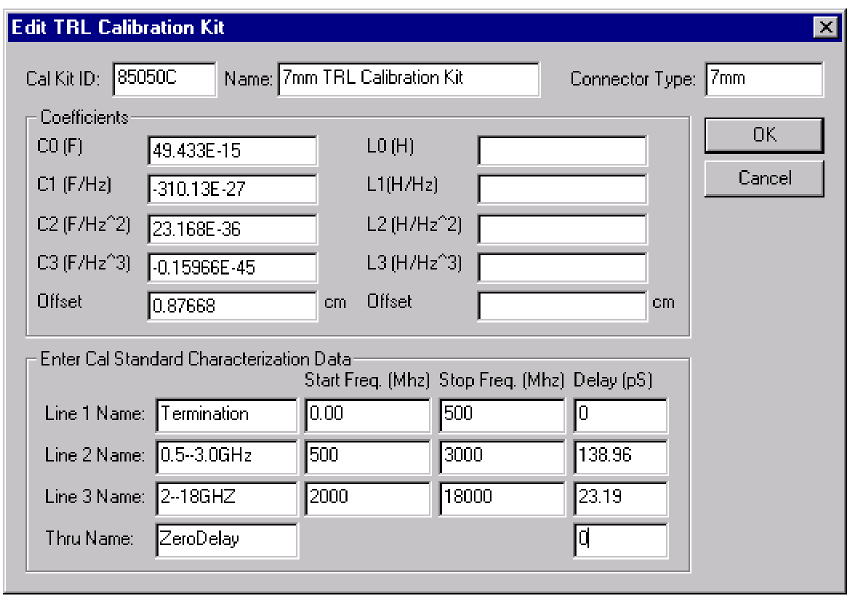
In this example, **Cal Kit ID** is defined as "85050C", **Name** is defined as "7mm TRL Cal Kit", and **Connector Type** is defined as "7mm". Refer to Figure 4-16.

6. Complete of the *Edit TRL Calibration Kit* dialog box. Figure 4-14 shows the data that is used in this example.

   For the **Coefficients** area, enter the values for the type of **Reflective** device that you are using. For example, if you are using an open as a reflective device, enter the device's capacitive values from it's calibration coefficients along with the offset value (in cm). This information can be located in the calibration kit from which the device was taken. If you are using a short as the reflective device, enter it's inductive values along with the offset value. Use only one column when entering values for your Reflective device.

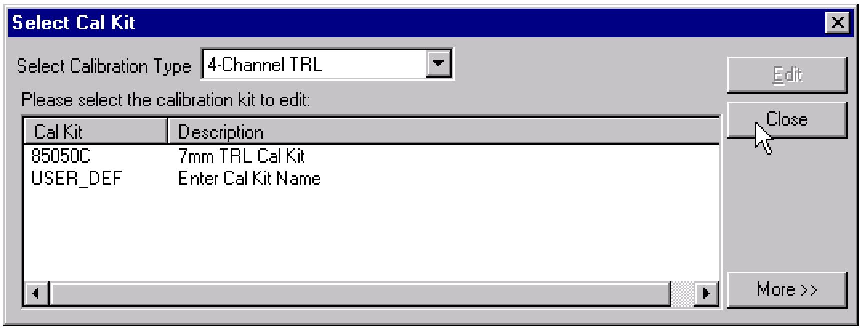
   For the **Enter Cal Standard Characterization Data** area, enter a name for each **Line** along with each line's start and stop frequency (in MHz) and delay (in ps). Information for up to three lines can be entered into this area. If the delay of a line is entered as 0 ps, the line is assumed to be a load (50Ω termination). Also enter the name and delay of the **Thru** device which is typically 0 ps.

Figure 4-14 Completed Edit TRL Calibration Kit Dialog Box



7. Once the TRL calibration kit data has been entered into the dialog box, select **OK** to save the calibration kit data. Once the TRL calibration kit data has been saved, select **Close** to close the *Select Cal Kit* dialog box.

Figure 4-15 Close the Select Cal Kit Dialog Box

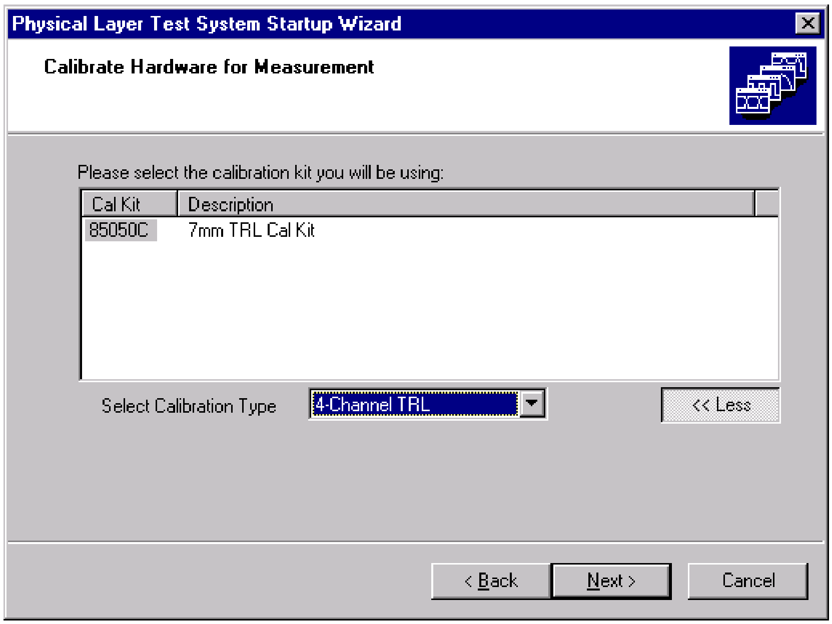


Return to the startup wizard to complete the TRL calibration procedure. You can select **New** from the **File** menu to restart the wizard. If you need help completing the startup wizard, return to Chapter 3 on page 59. If you do not need assistance, continue with "Selecting a TRL Calibration Kit".

Selecting a TRL Calibration Kit

Figure 4-16 shows the dialog box listing the TRL calibration kits that are defined for the measurement parameters. If a TRL calibration kit does not match or exceed the frequency range of the measurement parameters, it is not listed is this dialog box.

Figure 4-16 Select TRL Calibration Kit Dialog Box



Selecting the **More >>** button displays the connector type for each of the four ports.

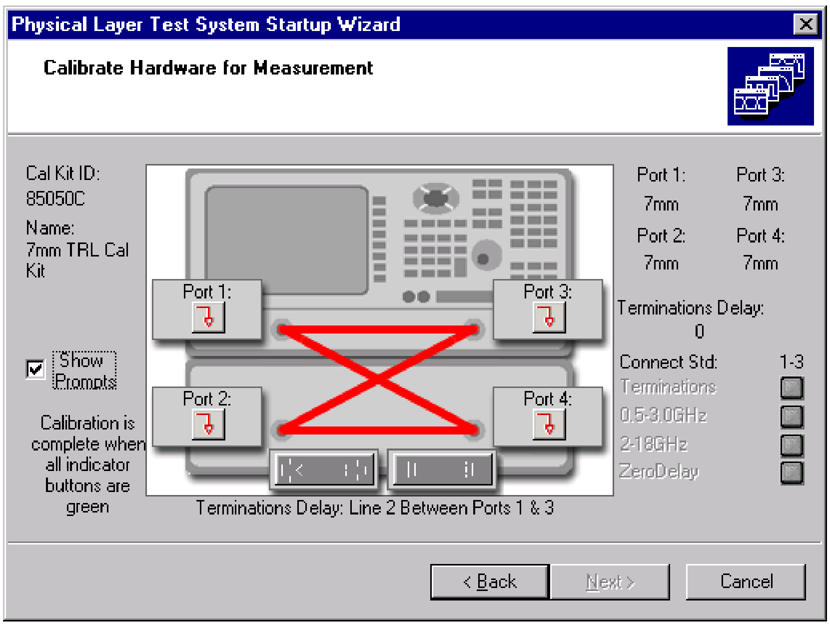
1. Select your calibration kit.
2. Once the calibration kit is selected, click the **Next >** button to display the calibration window. Continue with "Performing a TRL Calibration".

Performing a TRL Calibration

NOTE For maximum accuracy and repeatability, the system (network analyzer and test set) should be stabilized at room temperature for a minimum of 24 hours before calibration.

As indicated by its name, the Thru-Reflection-Line (TRL) calibration consists of three portions. First, the reflection portion is performed by connecting a short to each system port. The Line portion is performed by connecting the three lines and a thru between system ports 1 and 3 and then by connecting the same lines and thru between ports 2 and 4. Finally, the Thru portion is performed by connecting the thru between system ports 1 and 4 and then by repeating the connection between ports 2 and 3.

Figure 4-17 Initial TRL Calibration Display



1. Select the following icon to start the Reflection portion of the calibration:

Figure 4-18 Displaying the Port 1 Reflection Prompt

2. As described in the prompt shown in Figure 4-18, connect the short from your calibration kit to Port 1 and click **OK**.

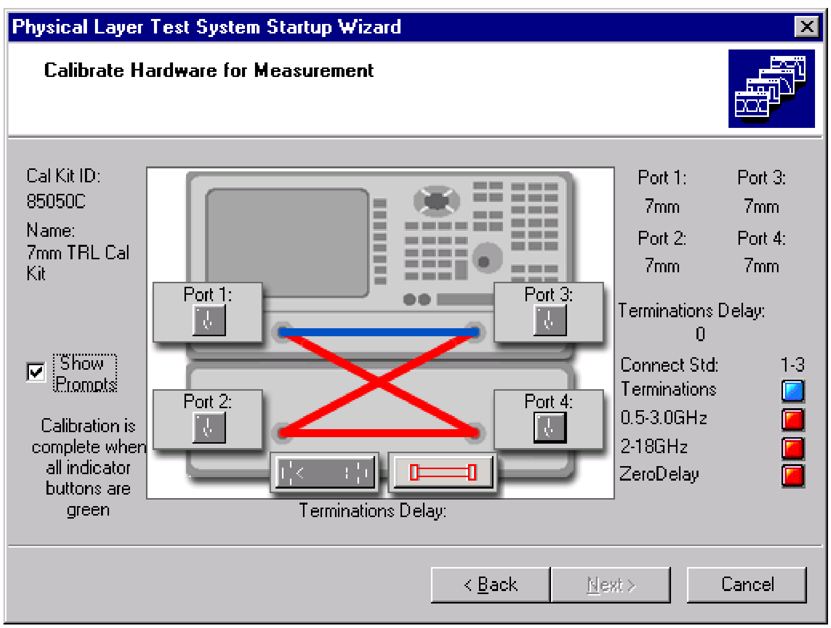
   As the portion of the calibration is complete, the Port 1 icon color changes from red to green.

3. Repeat steps 1 and 2 for each of the remaining ports.

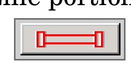
   The order that the ports are calibrated does not matter.

   Once all four of the ports are calibrated using the short, the color of the line between port 1 and port 3 changes from red to blue indicating that this path is the next to be measured. The color of the Terminations (Line 1 in the calibration kit definition) indicator on the right edge of the display changes from red to blue indicating that this measurement is the next to be made. See Figure 4-19.

Figure 4-19 Reflection Portion of Calibration Complete



4. Select the following icon to start the Line portion of the calibration:



   A prompt is displayed advising you to connect Line 1 between Port 1 and Port 3.

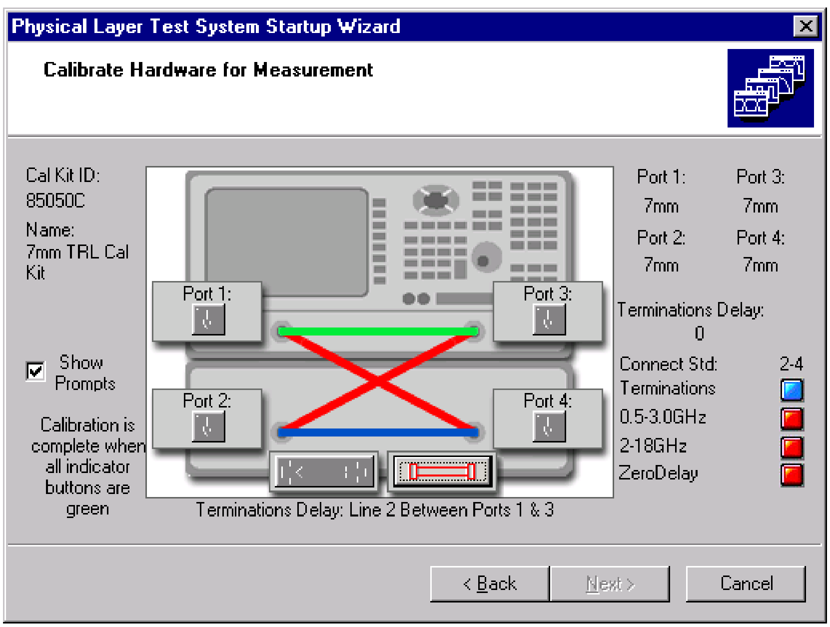
5. Click **OK** after the line is connected between ports 1 and 3.

   After the measurement is made on Line 1, the color of the Line 1 indicator (Terminations) at the right edge changes from blue to green to indicate that this measurement is complete. The color of the Line 2 indicator (0.5-3.0GHz) changes from red to blue indicating that this measurement is the next to be made.

6. Repeat steps 4 and 5 for Lines 2 (0.5-3.0GHz), Line 3 (2-18GHz), and the Thru (ZeroDelay).

   Once these measurements are taken, the calibration between ports 1 and 3 are complete. On the display, the color of the line between ports 1 and 3 changes from blue to green indicating that this path is complete. The color of the line between ports 2 and 4 changes from red to blue indicating that this path is the next to be measured. See Figure 4-20.

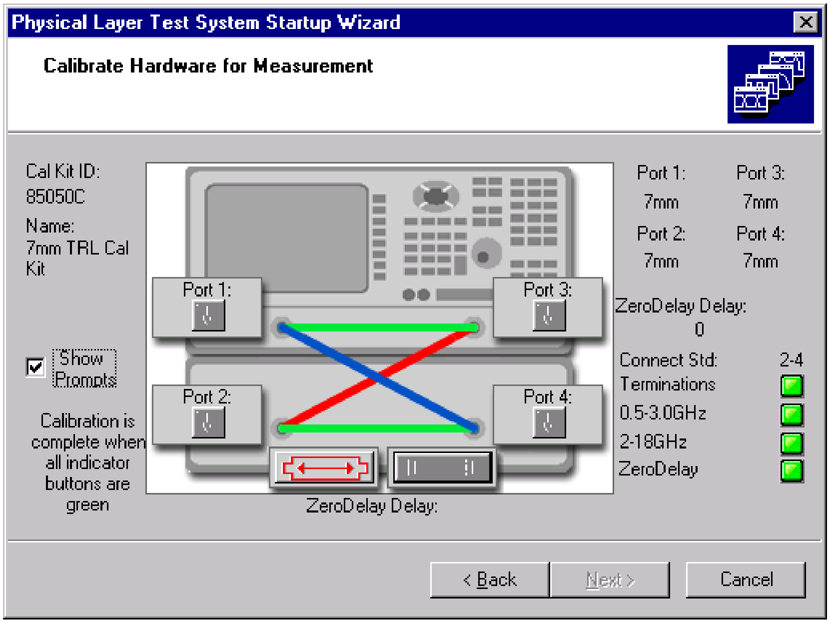
Figure 4-20 Port 1 - Port 3 Line Portion of Calibration Complete



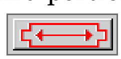
The color of the Line 1 (Terminations) indicator on the right edge of the display changes to blue indicating that this measurement is the next to be made. The remaining indicators are changed to red indicating they are not yet done for Port 2 - Port 4.

7. Repeat steps 4 through 6 for the Port 2 to Port 4 path.

Figure 4-21 Line Portion of Calibration Complete



8. Select the following icon to start the Thru portion of the calibration:



A prompt is displayed advising you to connect the Thru between Port 1 and Port 4.

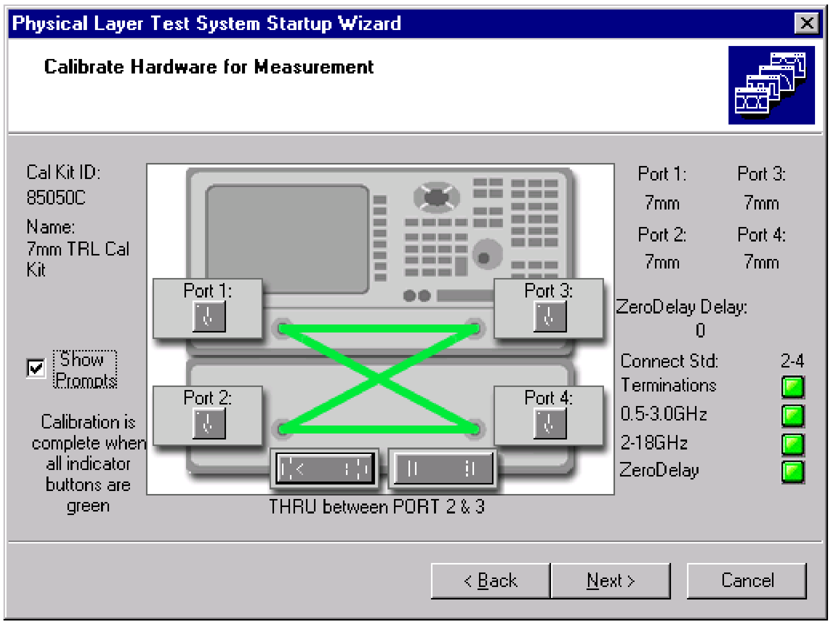
9. Click **OK** after the Thru is connected between ports 1 and 4.

10. After the Port 1 to Port 4 Thru calibration is made, repeat steps 8 and 9 to complete the Thru calibration between Port 2 and Port 3.

11. Once the Port 2 to Port 3 Thru calibration is made, the TRL calibration measurements are complete. Refer to Figure 4-22.

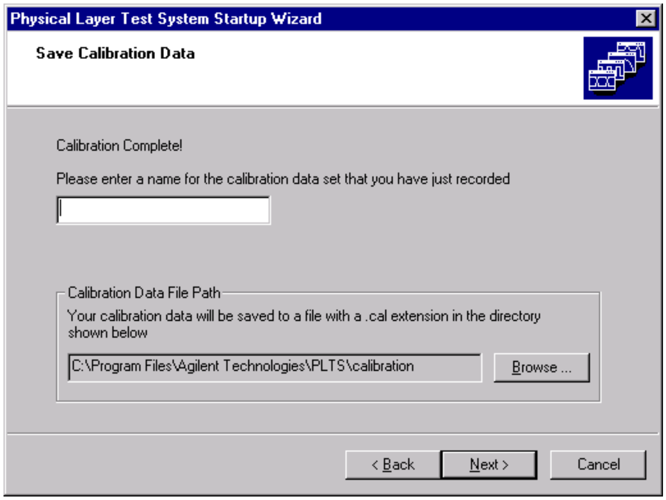
Continue at "To Save the TRL Calibration" on page 106.

Figure 4-22 TRL Calibration Complete



To Save the TRL Calibration Once you have completed the TRL calibration, the *Save Calibration Data* dialog box is displayed as shown in Figure 4-23.

Figure 4-23 Save Calibration Data Dialog Box



1. Enter a file name for the calibration data set.

   The calibration data file will be saved in the directory displayed in the **Calibration Data File Path** box. You may change the directory by entering the directory path in the box or selecting the **Browse**… button and navigating through your computer's directory structure to the desired directory. The calibration data is saved with a ".cal" file extension.

2. Save the calibration data by selecting the **Next >** button.

   When the calibration data is saved, the calibration is complete. A window is displayed showing how to make the connections to measure your DUT following the TRL calibration.

3. If you started the calibration:

   - As part of the example measurement of Chapter 3, return to "How to Make a Measurement" on page 70.
   - By entering the startup wizard at startup or by selecting **New** from the **File** menu, the software sends you to the Startup Wizard's *Setup & Calibration Complete!* window where you can make a measurement.
   - By selecting Calibration from the Utilities menu and then selecting Calibrate, the software returns to the main software window.

Characterizing Adapters

For non-insertable[1] calibrations, the thru adapter to be used must be characterized by itself so that its effects can later be removed from the calibration measurement results.

Several standard thru adapter characterization files have been provided with PLTS (see the ..\PLTS\adapters directory) and are automatically selected based on the calibration kit to be used. These files may be used with very good results, but for the very highest accuracy, it is recommended that you characterize your own adapters using the following procedure.

To perform the characterization, first, a short/open/load calibration is performed directly at the front panel of the system. Either one or two test ports will be used depending on the adapter category selected during the process. Then the adapter is inserted and the short/open/load calibration is repeated. The resulting adapter S-parameters are saved in Citifile format, which can later be de-embedded from the device measurement.

For adapters that will be used for broadband measurements, characterize the adapter over the entire frequency range of the instrument with as many points as possible. This allows for interpolation of adapter data if the frequency points used in a later DUT measurement are not exactly the same as the adapter frequency points.

Adapter characterization is performed directly at the instruments front panel (either Port 1 or Ports 1 and 4). If an additional adapter is needed between the front panel and the adapter to be characterized (for type or gender change), install the additional adapter first (metrology grade recommended), and perform all calibrations with it installed.

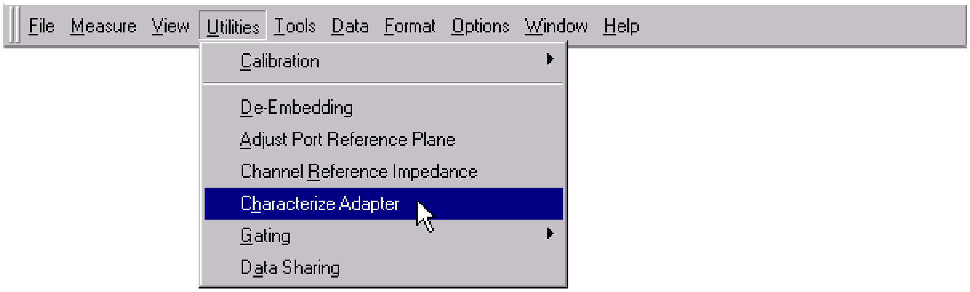
For purposes of characterization, your adapters must have an orientation. Mark the connectors on the adapter as ports 1 and 2, and treat them as such during the characterization procedure. Forward orientation has the lower-numbered adapter port connected to the test-set port.

Follow these steps to characterize your adapters:

1. Select **Characterize Adapter** from the **Utilities** menu to start the Custom Adapter Characterization Wizard.

1. Non-insertable calibrations are those in which the test port connectors are of the same gender (male-to-male or female-to-female).

Figure 4-24 Characterize Adapter Selection

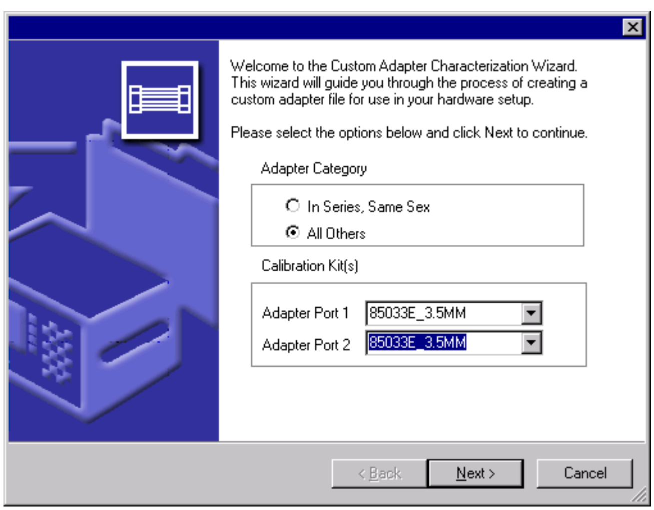


2. In the *Custom Adapter Characterization Wizard* dialog box, select the appropriate adapter category and the calibration kit to be used. See Figure 4-25. Press **Next >** to continue to the next window.

   The two adapter characterization categories are:

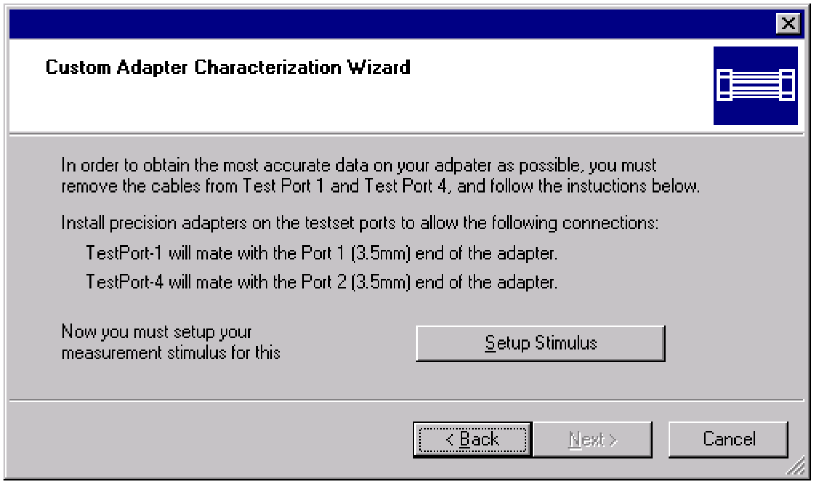
   - **"In-Series, Same-Sex"** uses a single port (Port 1) and applies only to adapters having the same type and gender on both ends (3.5 mm male-to-male, for example). Select the calibration kit to be used on Port 1 from the pull-down menu.
   - **"All Others"** uses two ports (Ports 1 and 2) and allows the adapter types to be specified independently. Select the calibration kits to be used on Port 1 and on Port 2 from the pull-down menus.

Figure 4-25 Custom Adapter Characterization Wizard



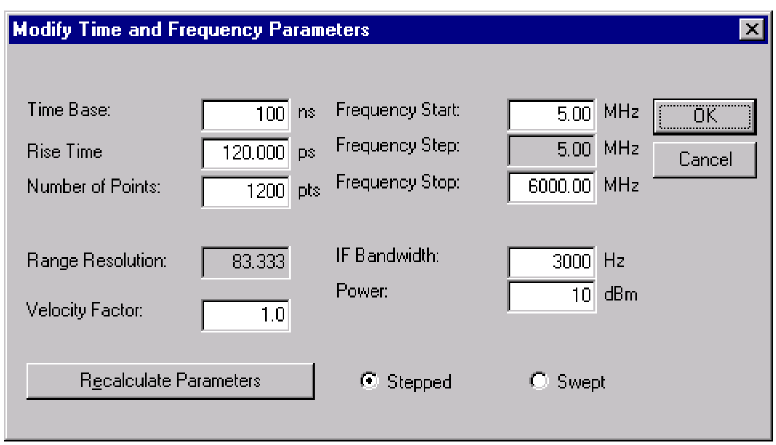
3. Make the connections listed on the Custom Adapter Characterization Wizard Setup Instructions window (Figure 4-26) and then click the **Setup Stimulus** button.

Figure 4-26 Custom Adapter Characterization Wizard Setup Instructions



4. Make any required changes to the stimulus to match your actual measurement conditions. When you make any change, click the **Recalculate Parameters** button to update all parameters. Refer to Figure 4-27. When you are satisfied with the parameters, click **OK**.

Figure 4-27 Stimulus Parameter Dialog Box



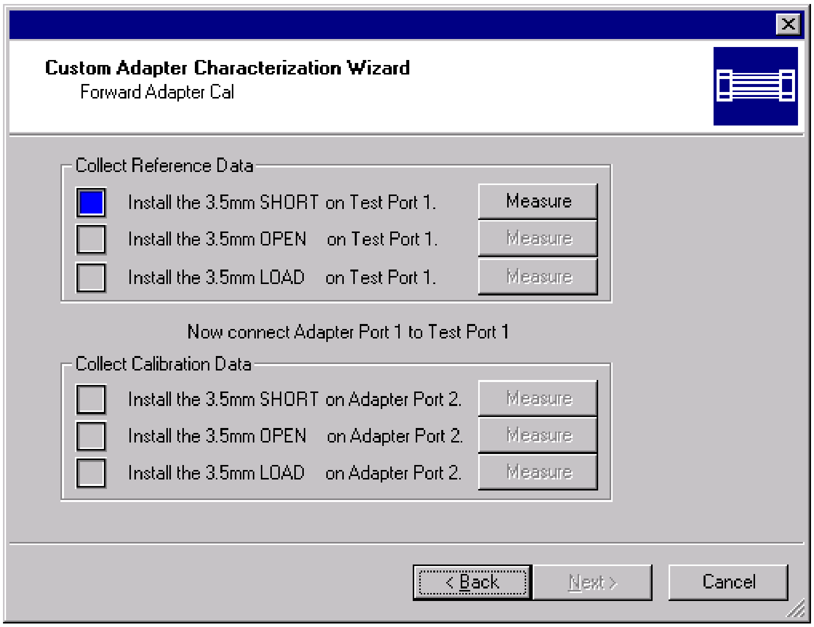
Refer to "Time and Frequency Parameter Descriptions" on page 68 for definitions of each

parameter.

5. Following the order shown on your *Forward Orientation Adapter Calibration* dialog box, install the calibration standards as listed and click the **Measure** button.

   Depending on your previous selections, your window may differ slightly from the window shown in Figure 4-28.

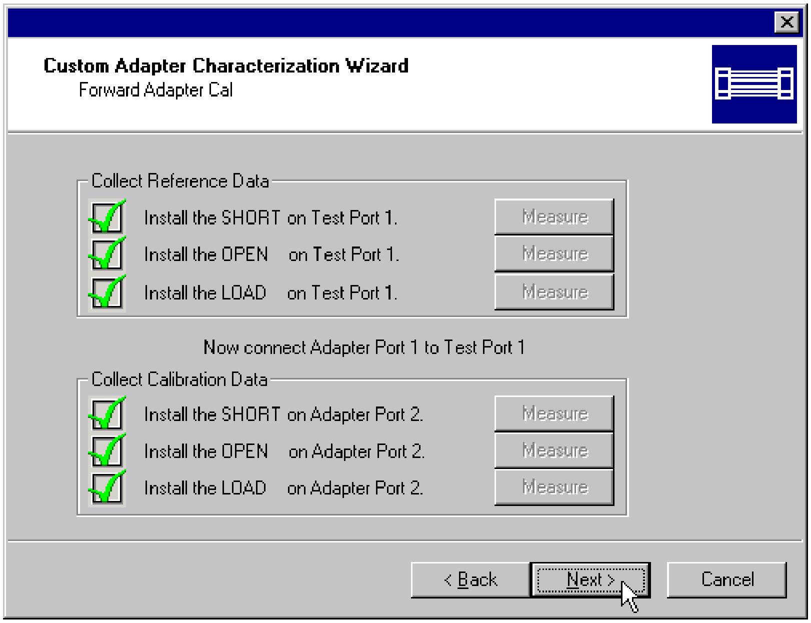
Figure 4-28 Forward Orientation Adapter Calibration Window



NOTE	The **Next >** button remains inactive until all data choices are measured.

6. As you make each measurement, a check mark is displayed in the check box to the left of the measurement. See Figure 4-29. Once all measurements are made, click **Next >** to continue.

Figure 4-29 Completed Forward Orientation Adapter Calibration Window

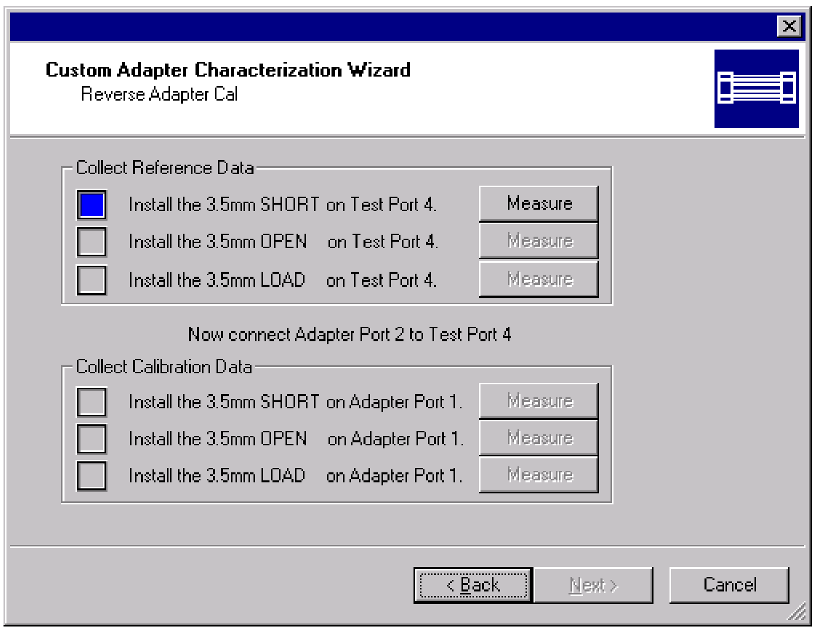


7. Following the order shown on your *Reverse Orientation Adapter Calibration* window, install the calibration standards as listed and click the **Measure** button. Depending on your previous selections, your window may differ slightly from the window shown in Figure 4-30.

   As you make each measurement, a check mark is displayed in the check box to the left of the measurement. Once all measurements are made, click **Next >** to continue.

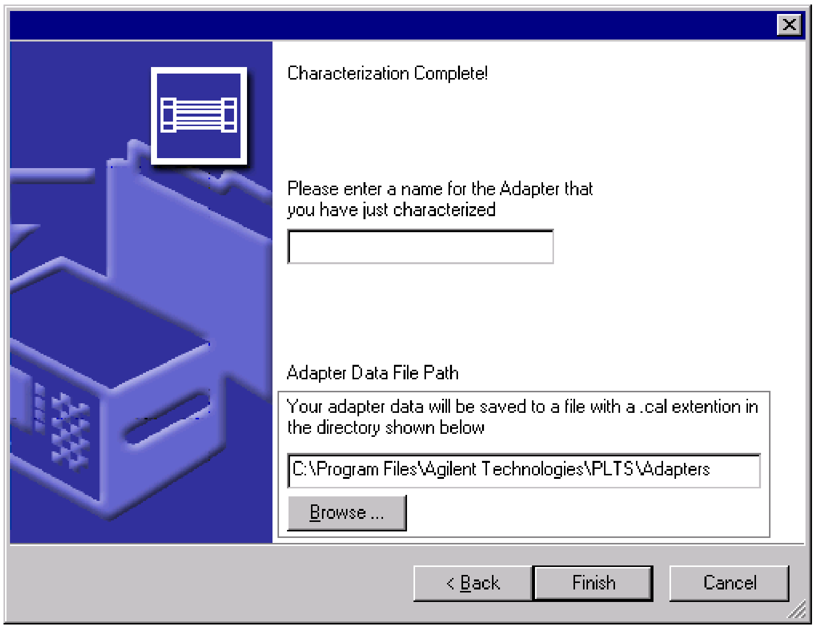
NOTE The **Next >** button remains inactive until all data choices are measured.

Figure 4-30 Reverse Orientation Adapter Calibration Window



8. When the characterization is complete, save the adapter file using the dialog box shown in Figure 4-31. Enter a file name for the adapter data and click **Finish**. The file is automatically saved as a ".txs" file. The default directory for saving adapter characterization information is C:\Program Files\Agilent Technologies\PLTS\Adapters, where C is the hard drive where the PLTS is stored.

Figure 4-31 Save Adapter Characterization File Dialog Box



Since the characterization file is in Citifile format, you can import the data and make a visual check of the quality of the characterization. Select **Import** from the **File** menu and then select **Citifile**. You may open and inspect the adapter characterization file.

5 Analyzing Data in the Frequency Domain

Physical layer test systems combine a vector network analyzer and a test set to make measurements by sweeping a signal in the frequency domain. The test system software can then mathematically transform these frequency domain measurements into other analysis types such as time domain, eye diagrams, and transmission line (RLCG). However, there is information to be gained from frequency domain measurements that these other analysis types do not provide.

Frequency measurements can help you verify and validate your modeling and simulation procedures by providing:

- vector error-corrected data which allows you to de-embed fixtures and signal launches.
- more accurate simulation for frequency dependent effects, such as bandwidth and impedance.
- insight into common analog problems, such as crosstalk, reflections, and loss.
- better information more efficiently when you are analyzing the effects of transmission lines, studying power/ground distribution, and investigating EMI effects as a function of frequency.
- S-parameter data which can be used over the widest range of applications and frequency bandwidths.

About S-Parameters

At high frequencies, S-parameters (scattering parameters) are commonly used to describe the performance of microwave and RF devices. These parameters can be used to completely describe the electrical behavior of the device (or network). For those not familiar with S-parameters, they are simply the energy that is reflected off of, or transmitted through, a device under test. While S-parameter data is formatted differently than TDR/TDT data, the underlying information is the same.

S-parameters relate to familiar measurements such as reflection coefficient (input/output match), and transmission coefficient (gain or loss, and isolation). They are the shared language between simulation and measurement and are easily imported into electronic-design automation (EDA) tools like HSPICE, ADS, and other simulators.

Conventional *single-ended* parameters describe the performance of a single-ended device when it is stimulated on a single port, and the corresponding responses are observed on all of the ports. For a detailed explanation, refer to "Single-Ended (Unbalanced) S-Parameters" on page 118. *Mixed-mode* (or *balanced*) S-parameters describe the performance of devices with balanced ports. For a detailed explanation, refer to "Mixed Mode (Balanced) S-Parameters" on page 120.

Common Frequency Measurements with S-Parameters

Reflection Measurements	Transmission Measurements
Return Loss	Insertion loss
Standing Wave Ratio (SWR)	Gain/loss
Reflection coefficient	Transmission coefficient
Impedance	Electrical delay
Sxx (x = stimulus port and response port)	Syz (z = stimulus port, y = response port)

How to Interpret S-Parameters

A multi-terminal device can be viewed in different ways, depending on how it is meant to be operated. For a device that is designed to be a single-ended four-port device, its conventional (single-ended) four-port S-parameters can be measured and displayed. In a balanced device, two terminals constitute a single balanced port. Each balanced port will support both a common-mode and a differential-mode signal. This performance is described using mixed-mode (balanced) S-parameters.

Single-Ended (Unbalanced) S-Parameters

Conventional single-ended S-parameters are defined as the ratio of two normalized power waves (response/stimulus), defined in terms of the voltages and current at each port of a device (see Figure 5-2).

S-parameter notation identifies these quantities using the following convention:

SAB

where:

The first number (represented by A) refers to the test-device port where the signal is received. This received signal is referred to as the *response*.
- and -
The second number (represented by B) refers to the test-device port where the signal is sourced. This signal is referred to as the *stimulus*.

Figure 5-1 S-Parameter Notation

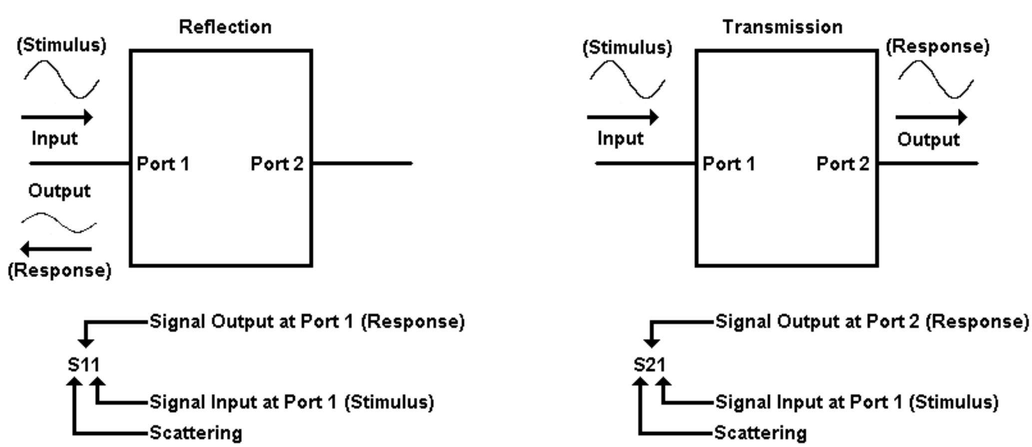
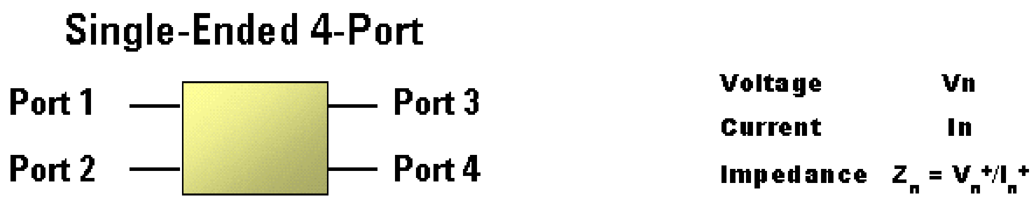


Figure 5-2 Single-Ended S-Parameter Review

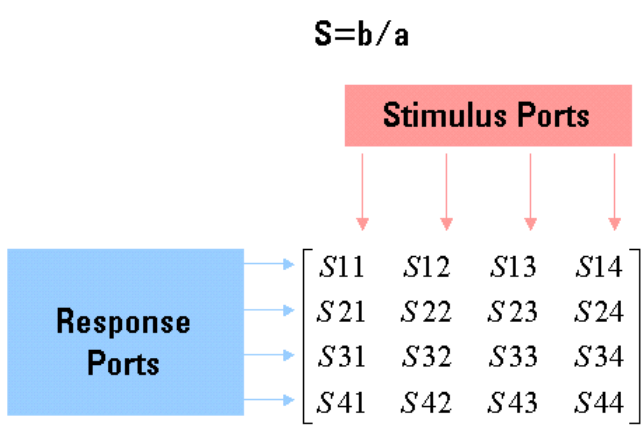


	Normalized Power Waves
Stimulus	$a_n = \frac{1}{2 \cdot \sqrt{Re(Zn)}}(Vn + In \cdot Zn)$
Response	$b_n = \frac{1}{2 \cdot \sqrt{Re(Zn)}}(Vn - In \cdot Zn)$

S = b/a

Figure 5-3 shows the naming convention for a single-ended 4-port S-matrix, showing the ratio of all possible combinations of response/stimulus.

Figure 5-3 Single-Ended S-Matrix



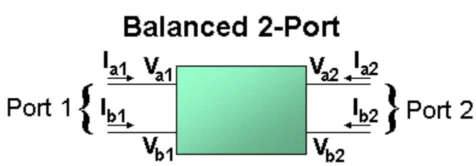
Mixed Mode (Balanced) S-Parameters

Mixed-mode S-parameters are used to describe the performance of balanced circuits by independently considering each mode of operation. The mixed-mode S-parameter concept is similar to conventional S-parameter definitions, except that instead of stimulating a single terminal of the DUT, we consider pairs of terminals to be stimulated in either a differential (anti-phase) or a common (in-phase) mode.

For a balanced device, we are not necessarily interested in voltages and current referenced to ground. Instead, we can define differential and common mode voltages and currents on each balanced port. Likewise, we can also define differential-mode and common-mode impedances.

We can define normalized power waves on the ports of a balanced device having the exact same form as the single-ended case. Only the definitions of “voltage” and “current” are changed. Both are defined as ratios of normalized power waves.

Figure 5-4 Mixed Mode S-Parameter Basics



	Differential	Common
Voltage	$V_{an} - V_{bn}$	$0.5 \times (V_{an} + V_{bn})$
Current	$0.5 \times (I_{an} - I_{bn})$	$I_{an} + I_{bn}$
Impedance	$Z_{Dn} = \frac{V_D+}{I_D+}$	$Z_{Cn} = \frac{V_C+}{I_C+}$

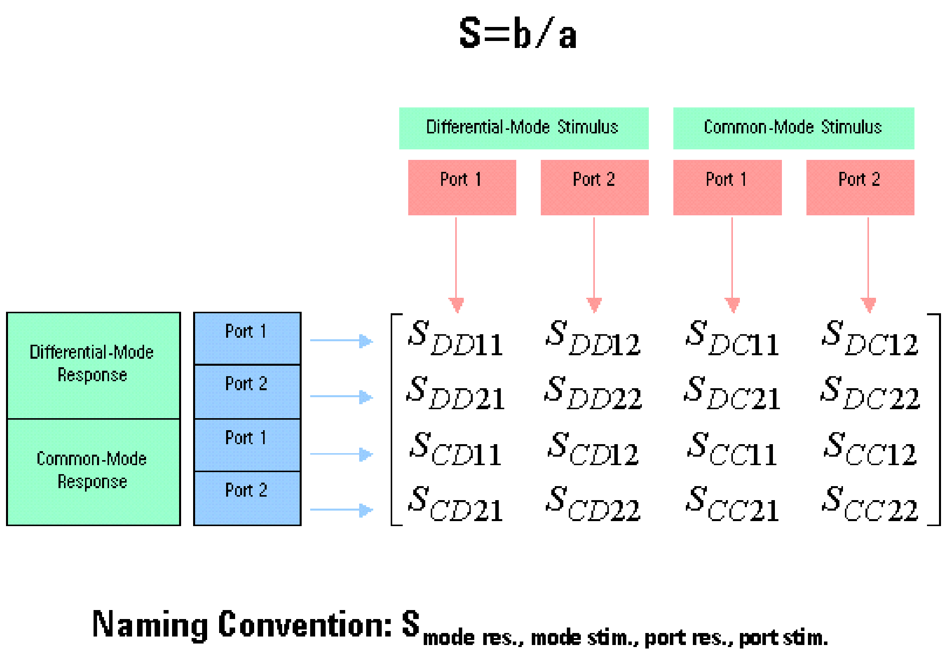
	Normalized Power Waves	
	Differential-Mode	**Common-Mode**
Stimulus	$b_{dn} = \frac{1}{2 \cdot \sqrt{Re(Zdn)}}(Vdn + Idn \cdot Zdn)$	$b_{cn} = \frac{1}{2 \cdot \sqrt{Re(Zcn)}}(Vcn + Icn \cdot Zcn)$
Response	$b_{dn} = \frac{1}{2 \cdot \sqrt{Re(Zdn)}}(Vdn - Idn \cdot Zdn)$	$b_{cn} = \frac{1}{2 \cdot \sqrt{Re(Zcn)}}(Vcn - Icn \cdot Zcn)$

S = b/a

The naming convention for mixed-mode S-parameters includes mode information as well as port information. Unlike the single-ended example, though, in the mixed-mode S-matrix, we are not only considering the port, but we are also considering the mode of the signal at each port. Therefore, the first two subscripts describe the mode of the response and stimulus, respectively, and the next two subscripts describe the ports of the response and stimulus.

Again we can take the ratio of all possible combinations of response over stimulus for the differential and common mode normalized power waves to calculate the mixed-mode S-parameters. The mixed-mode matrix fully describes the linear performance of a balanced two-port measurement. Figure 5-5 shows the naming convention for a mixed mode S-matrix, showing the ratio of all possible combinations of response/stimulus.

Figure 5-5 Mixed-Mode (Balanced) S-Matrix



Viewing Data in the Frequency Domain

This section guides you with opening measured data in the frequency domain and viewing the data in the way that best suits your requirements. As discussed earlier, there are 16 4-port S-parameters for both single-ended and balanced devices. See Figure 5-3 and Figure 5-5. You may elect to view any number of these S-parameters.

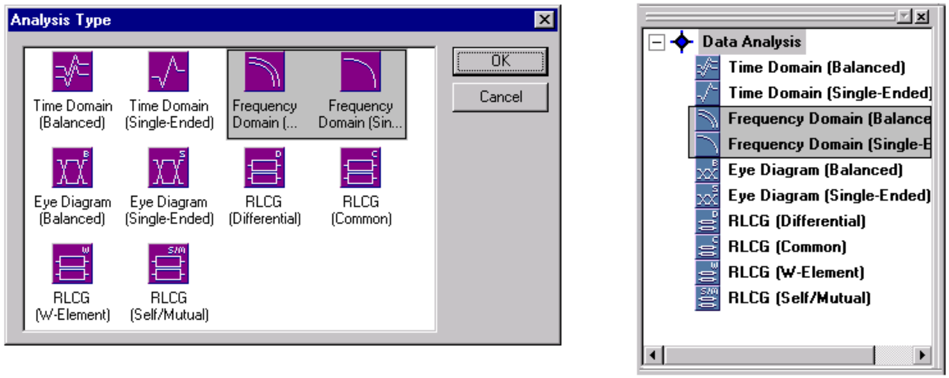
Opening a Frequency Domain Plot Window

The frequency domain may be viewed in either balanced or single-ended mode. You may open the frequency domain plot window in one of four ways.

- From the Startup Wizard immediately before selecting the **Measure** button where you must select the analysis type - see (A) of Figure 5-6
- From the Startup Wizard Welcome Screen by selecting **Load Measurement** where you must select the analysis type - see (A) of Figure 5-6
- From the **Open** selection in the **File** menu or the **Open** icon in the **Toolbar** where you must select the analysis type - see (A) of Figure 5-6
- From the **Browser** when data is already being viewed in another analysis type by selecting one of the Frequency Domain choices - see (B) of Figure 5-6

NOTE Using the **Browser** method to open a window requires that you select the parameters that you want to view from the **Parameter Bar** or the **Data** menu when the blank plot window is displayed.

Figure 5-6 Opening the Frequency Domain Plot Window



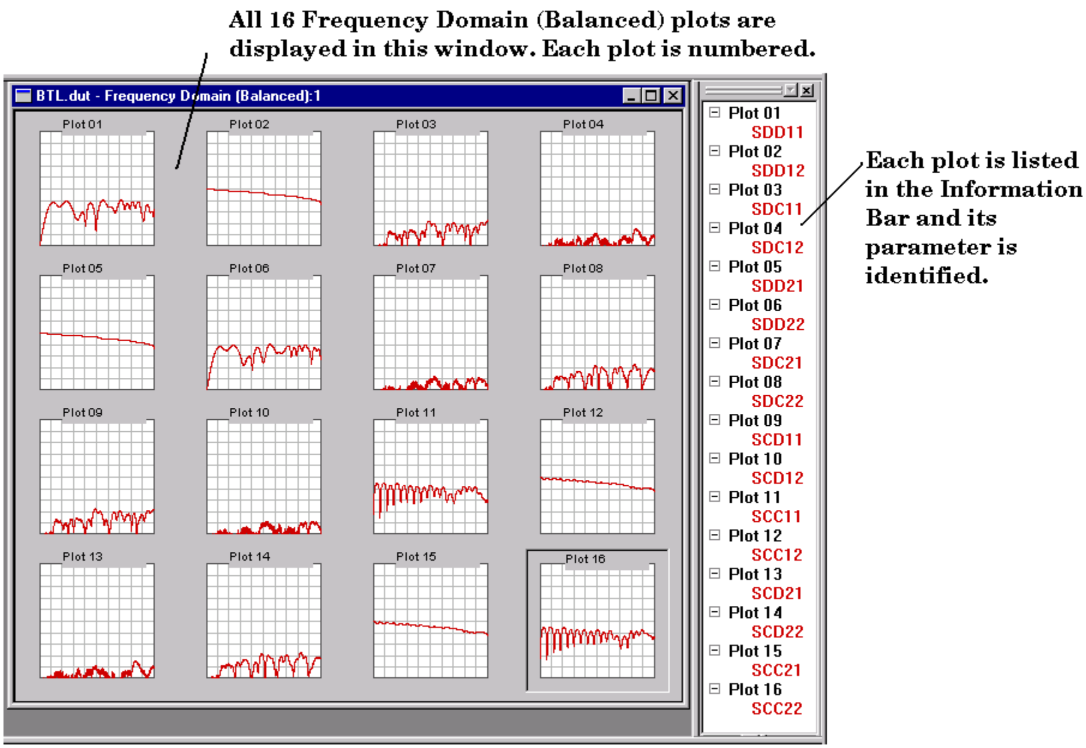
(A) **(B)**

Viewing All 16 S-Parameters

In all cases, except when you open the plot window using the **Browser**, all 16 frequency domain parameter plots are displayed. The parameter plots are displayed in the same orientation as shown in Figure 5-3 and Figure 5-5. Each of the plots are numbered. The **Information Bar** immediately to the right of the plots lists each plot by number and displays the associated parameter. See Figure 5-7.

As mentioned previously, when you open the plot window from the **Browser**, an empty plot window is displayed. View all 16 plots by selecting **All** from the **Parameter Bar** or from the **Data** menu with **New Plot** selected.

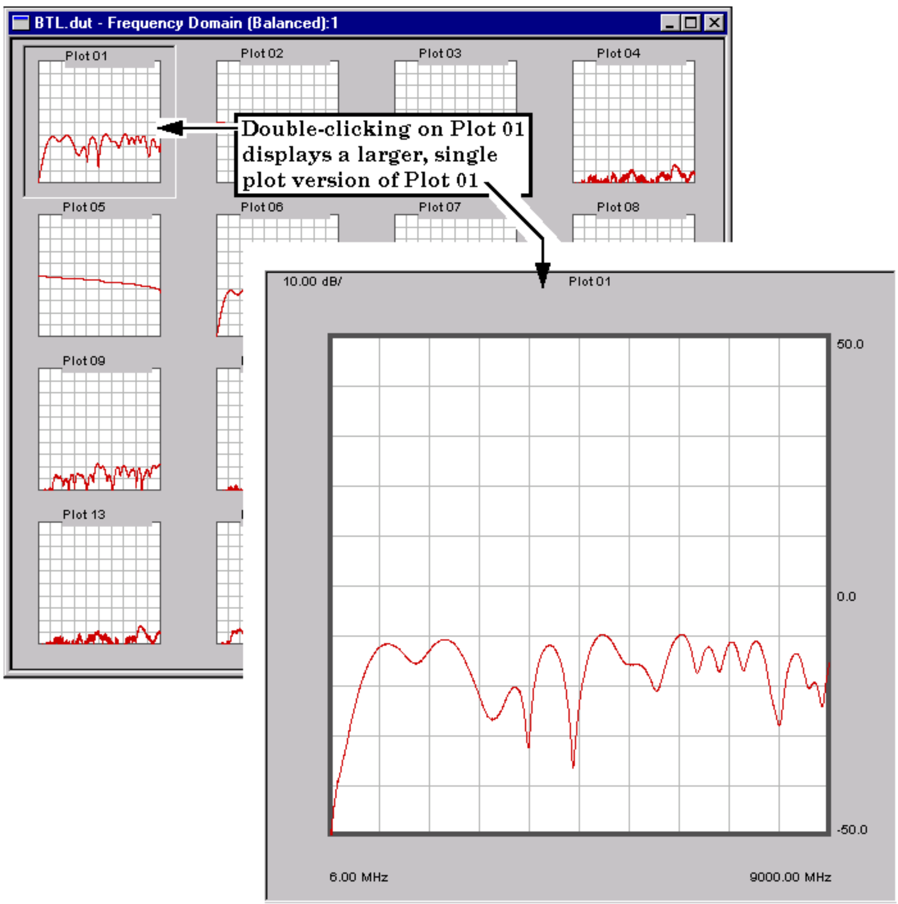
Figure 5-7 **Balanced Frequency Domain Plots with Information Bar**



Viewing a Single S-Parameter

Viewing a single plot gives better resolution. To display a single plot, from the window with all 16 plots (or with multiple plots if you have a custom plot window displayed), double-click on the plot that you would like to view. See Figure 5-8.

Figure 5-8 Opening a Single Plot

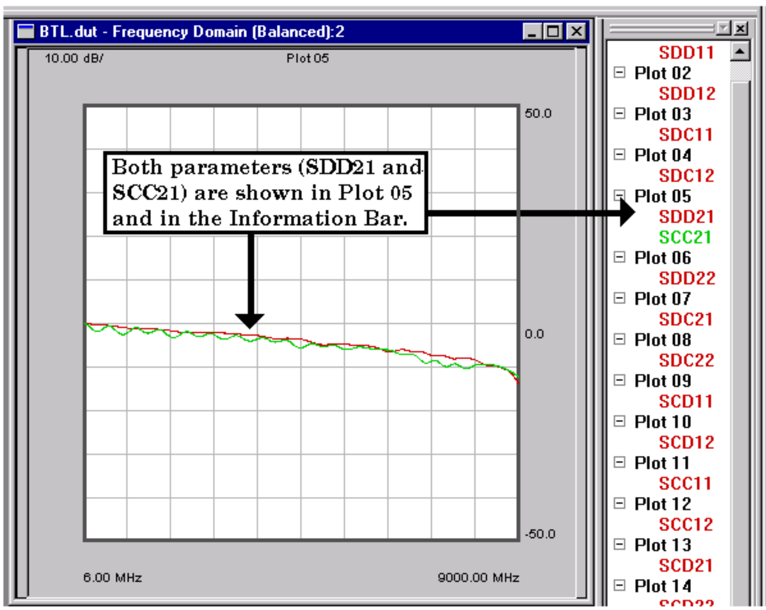


Double-click on the single plot to return to the original view with multiple plots.

View Multiple Traces on a Single Plot

This single plot may have just one parameter or if you choose, it could contain more. For example, you could show how SDD21 compares with SCC21. To do this double-click on the first plot so that is now displaying a single plot similar to Figure 5-8. For this example, Plot 05 (SDD21) was double-clicked and is displayed as a single plot. With **New Trace** selected in the **Parameter Bar** (or the **Data** menu), click the remaining parameters (SCC21 in this example).

Figure 5-9 A Single Plot with Multiple Traces

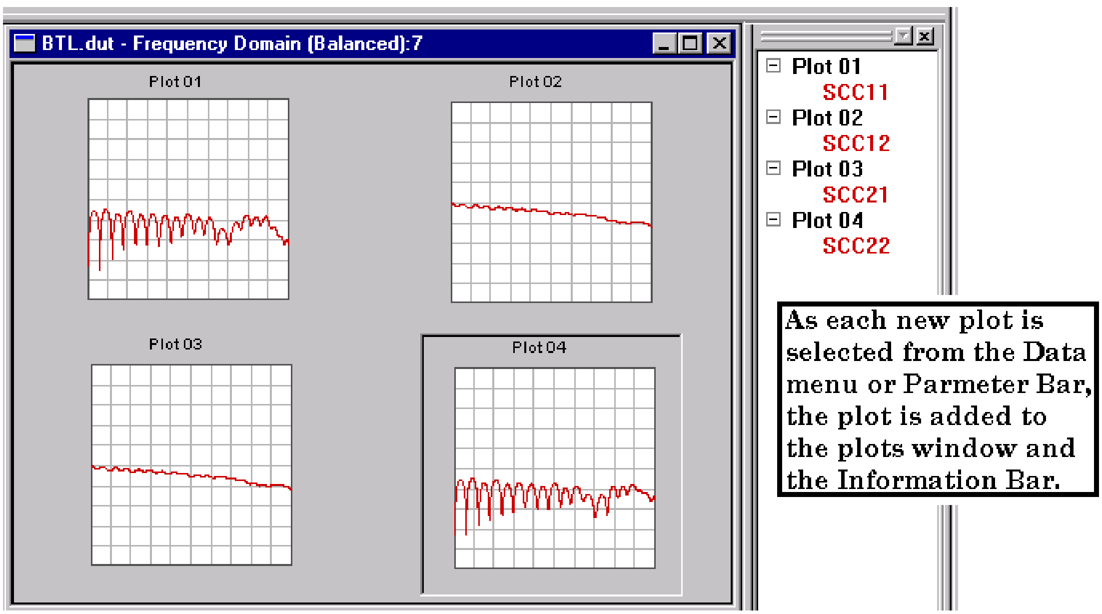


It could contain as many as all 16 of the parameters. However, this would be impractical because having 16 parameters on a single plot would be very hard to distinguish between the parameters and the vertical scale would have to be large to show all parameters.

Creating a Custom S-Parameter Plot Window

You can also create a plot window with just the plots you desire. For example, you may want your plot window to show just the four SCC*xx* plots. To create this custom window, open the measured data file in any analysis type. Then, in the **Browser**, select the data type that you want to display the plots. In this example, select **Frequency Domain (Balanced)**. A blank plots window is displayed. With **New Plot** selected in the **Parameter Bar** (or the **Data** menu), click the desired parameters (SCC11, SCC12, SCC21, and SCC22 in this example). As each parameter is selected, a new plot is added to the plots window. See Figure 5-10.

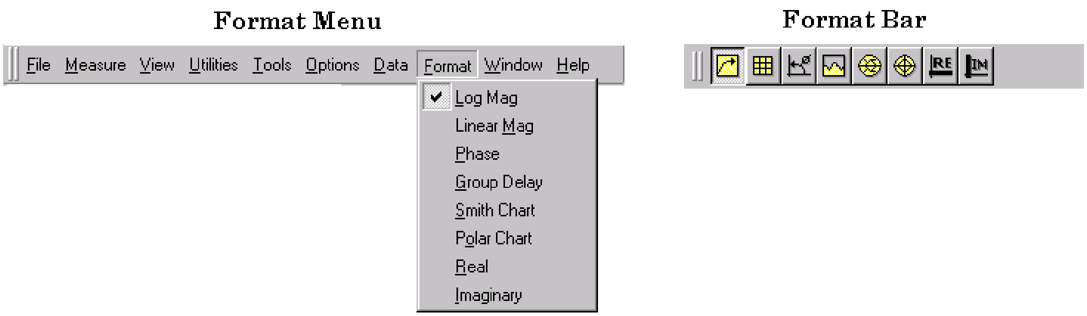
Figure 5-10 Custom S-Parameter Plots Window with Four Plots



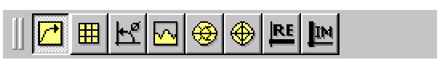
Selecting Frequency Domain Display Formats

A data format is the way the physical layer test system presents the measurement graphically. Select a data format appropriate to the information you want to learn about the device. You may use either the **Format Bar** or the **Format** menu to select the format.

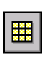
Figure 5-11 Format Menu and Format Bar for Frequency Domain



Frequency Domain Format Bar



 Log Mag — displays Cartesian logarithmic magnitude (no phase) in dB. Typical measurements are return loss and gain. This is the default format.

 Linear Mag — displays positive values only. Typical measurements are transmission, reflection coefficients, time domain transfer.

 Phase — displays phase (no magnitude).

 Group Delay — displays signal transmission (propagation) time through a device.

Frequency Domain Format Bar

Smith Chart

displays an impedance plane that is mapped onto the polar plane. Every point on the Smith Chart represents a complex impedance made up of a real resistance (r) and an imaginary reactance (r + jX). The dotted circles represent constant resistance. The horizontal line through the middle is purely resistive (no reactive component).

To the far right, the value is zero ohms (short). To the far left, the value is infinite ohms (open).

The dotted arcs represent constant reactance.

- The reactance arcs in the upper (positive) half of the circle represent inductive reactance.
- The reactance arcs in the lower (negative) half of the circle represent capacitive reactance.
- Typical measurements: Impedance profile

When in this format, the cursor bar allows you to choose the cursor value in either Mag + Phase or Inductance style. Refer to Using Cursors on page 135 for additional information.

Polar Chart

plots the measurement result in a vector representation.

The magnitude at any point is determined by its displacement from the center (or zero value). Magnitude is scaled linearly, with the value of the outer circle set to a ratio value of 1.

The radial lines scale the phase angle from 0 degrees to +180 degrees (counterclockwise) or –180 degrees (clockwise).

When in this format, the cursor bar allows you to choose the cursor value in either Mag + Phase or Inductance style. Refer to Using Cursors on page 135 for additional information.

Real

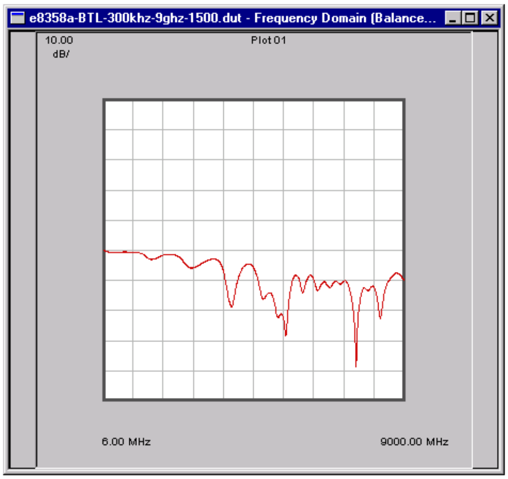
displays only the real (resistive) portion of the measured complex data. Can show both positive and negative values. Typical measurement: time domain

Imaginary

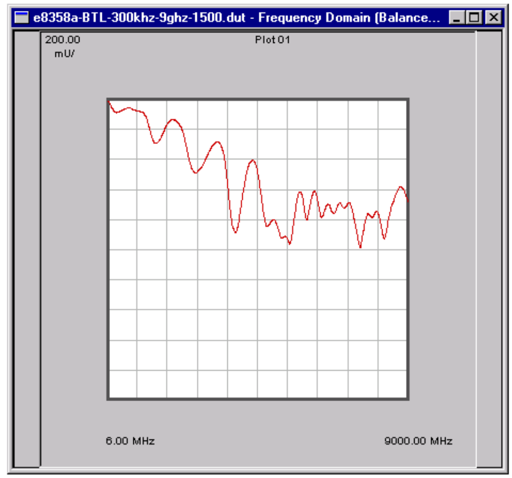
displays only the imaginary (reactive) portion of the measured complex data. Typical measurements are impedance for designing matching circuits.

Table 5-1 Frequency Domain Formats

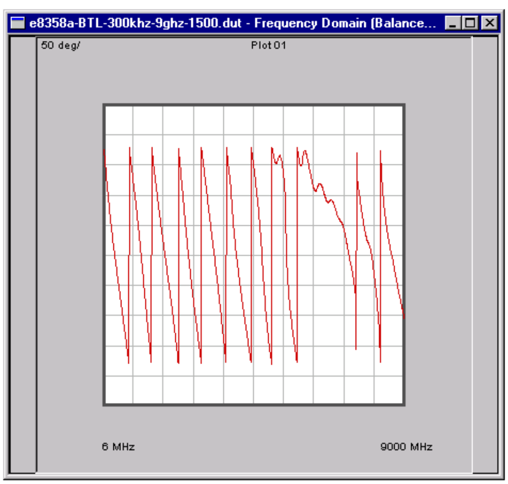
Log Mag



Linear Mag



Phase



Group Delay

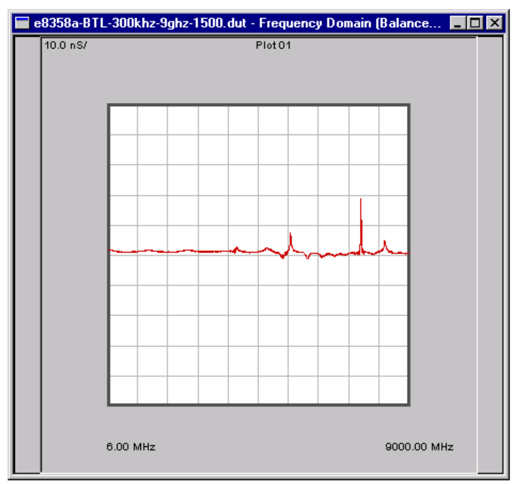
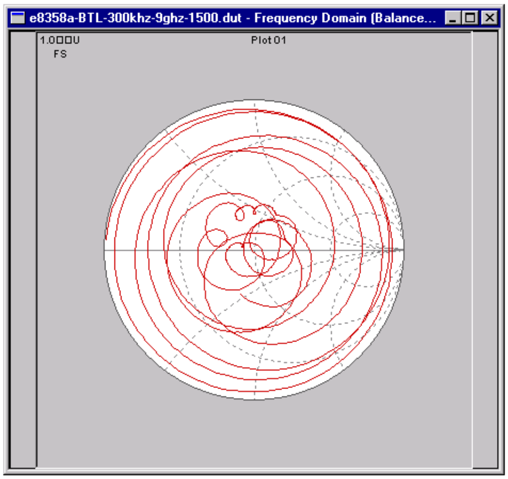
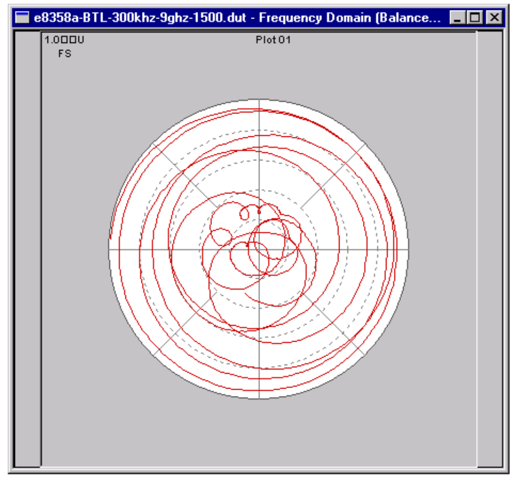


Table 5-1 Frequency Domain Formats

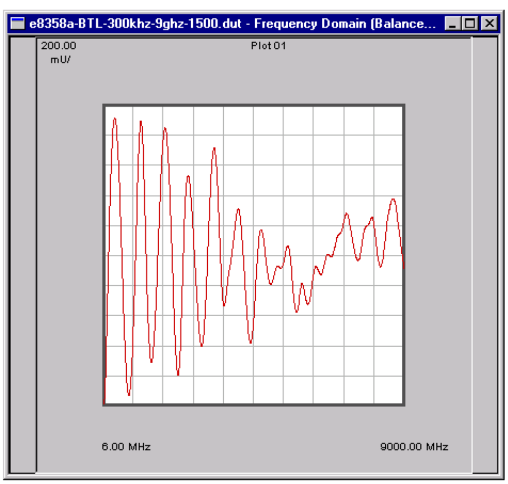
Smith Chart



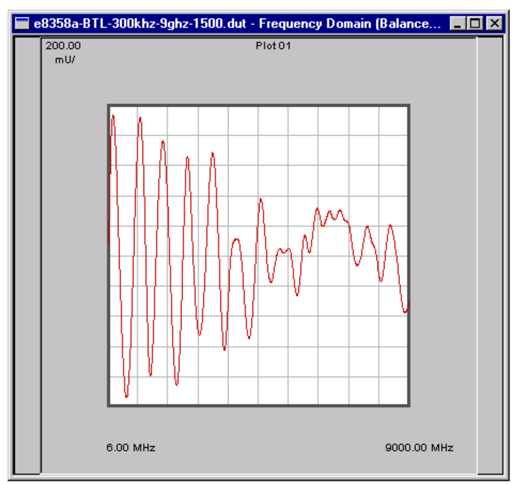
Polar Chart



Real



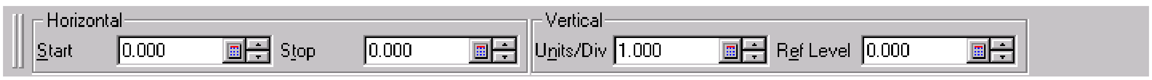
Imaginary



Setting the Scale

The PLTS software allows you to change the horizontal and vertical scale of the plots using the **Scaling Bar**.

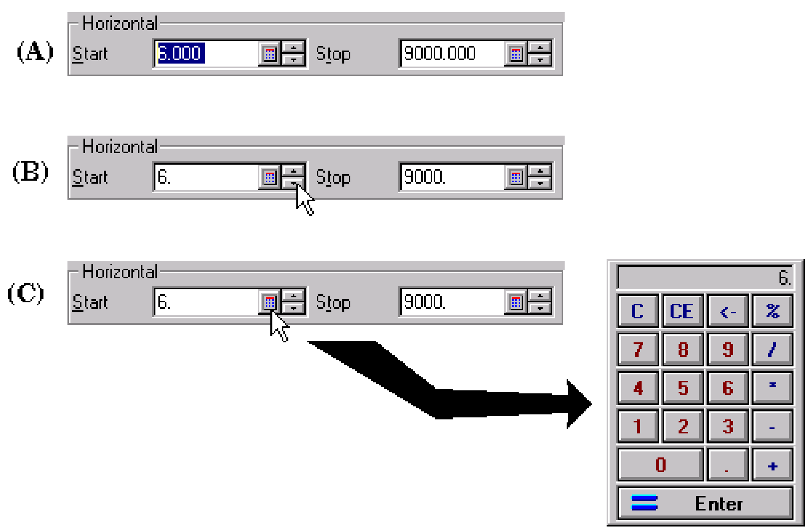
Figure 5-12 Scaling Bar



Change the Scaling Bar values by:

- Clicking and dragging within a scaling bar entry box to highlight the current value and then typing the new value. See (A) of Figure 5-13.
- Selecting the up/down arrow buttons to the right of each entry. See (B) of Figure 5-13.
- Selecting the calculator icon to the right of each entry to display a keypad. Click the keypad's numeric buttons to enter a new value and click the **Enter** button to save the new value. See (C) of Figure 5-13.

Figure 5-13 Entering a Scale Value



The horizontal scale is changed by changing the start and stop frequencies in megahertz (MHz). Note that you can not extend the start and stop frequencies beyond the start and stop frequencies used in the measurement. The horizontal scale may not be changed in Smith Chart and Polar formats.

The vertical scale units vary depending on the format.

Table 5-2

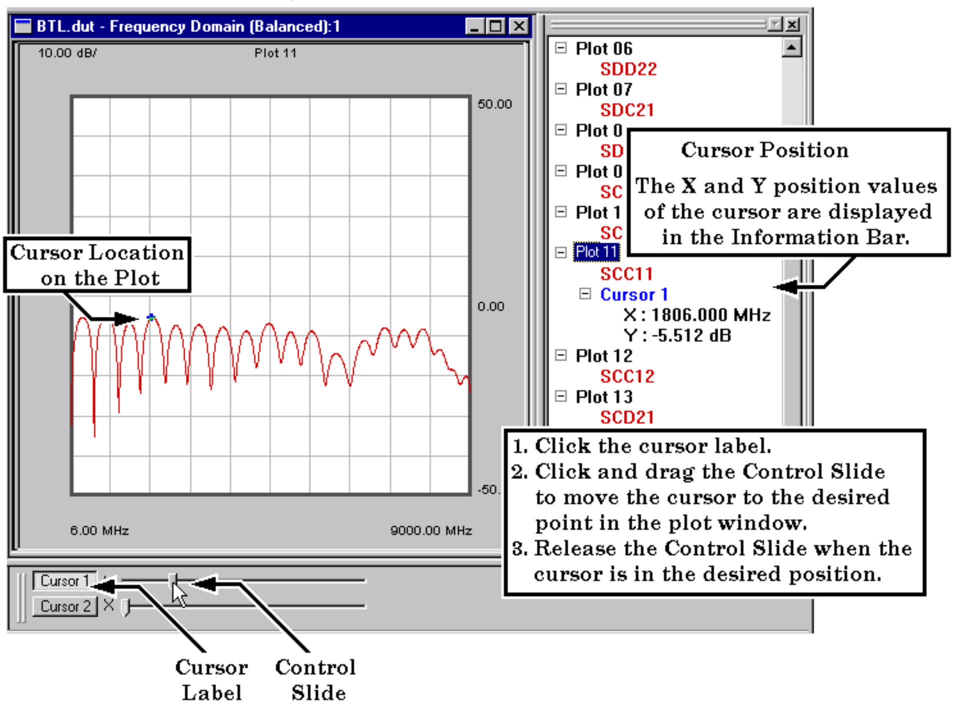
Format	**Vertical Scale Units**
Log Mag	decibels (dB)
Linear Mag	mU
Phase	degrees
Group Delay	nanoseconds (nS)
Smith Chart	Not Applicable
Polar	Not Applicable
Real	mU
Imaginary	mU

Using Cursors

Cursors may be used to find specific locations along the plot. When a cursor is activated, it's marker can be moved to any location along the plot trace. The horizontal and vertical values are displayed on the Information Bar. Two cursors are available.

To display a cursor, click the cursor label (either **Cursor 1** or **Cursor 2**) in the **Cursor Bar** and then click and drag its slide control. While dragging the control slide, watch the marker move along the trace in the active plot. Notice that the cursor values are displayed in the **Information Bar**.

Figure 5-14 Activating a Cursor

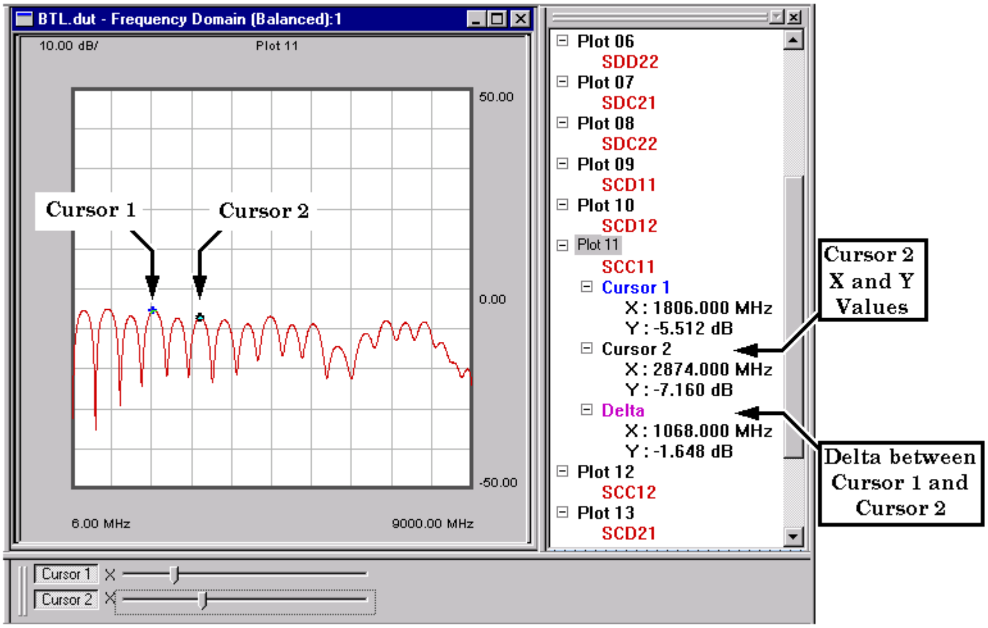


You can also change the cursor position, one point at a time, by pressing the left/right arrow keys on the keyboard.

Activate the second cursor as you did the first cursor. Notice that both cursor values along with the difference, the **Delta** (Δ), between the cursors are displayed in the **Information Bar**.

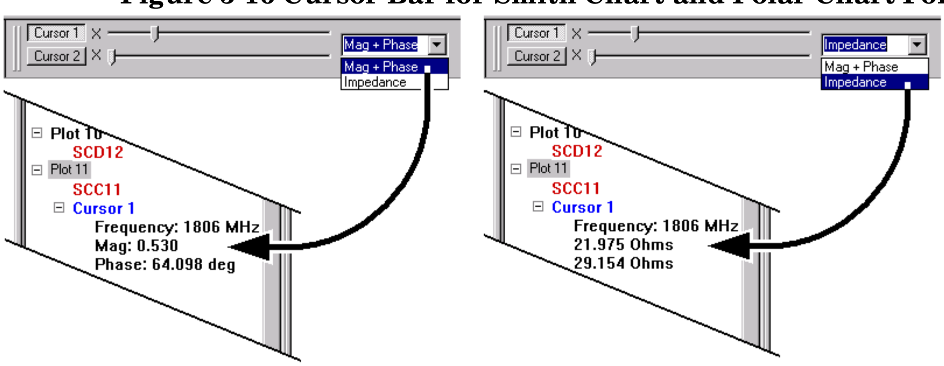
Delta = Value of Cursor 2 – Value of Cursor 1

Figure 5-15 Activating a Second Cursor



NOTE When the selected format is either **Smith Chart** or **Polar Chart**, the cursor bar also displays a list box containing two selections: **Mag + Angle** (magnitude and angle) and **Impedance**.

Figure 5-16 Cursor Bar for Smith Chart and Polar Chart Formats



Select the desired parameter to view the cursor values of that style in **Information Bar**. Selecting Impedance displays the real and imaginary components of the Smith Chart and Polar Chart cursor values.

6 Analyzing Data in the Time Domain

The Agilent physical layer test system or (PLTS) combined with Agilent's vector network analyzers and their companion multiport test sets perform measurements in the frequency domain by sweeping a RF signal and measuring the RF responses of a device under test or (DUT). The Agilent PLTS software can also mathematically transform these frequency domain data S parameters into their time domain counterparts and display them in either their step, impedance or their impulse/response modes.

In a linear network, the Fourier Transform describes the relationship between a frequency domain measurement and its corresponding time domain response in detail. Therefore, given the measured frequency domain response of a DUT, it is possible to determine its time domain response mathematically by performing an inverse Fourier Transform. And the PLTS software accomplishes it's frequency domain transformation to time domain by utilizing this inverse chirp Z Fourier transform[1].

The type of information that can be observed in time domain mode is quite different than the information that can be observed in frequency domain mode. If the network is thought of in terms of its equivalent circuit model, then the frequency domain response describes the composite behavior of all of the circuit elements at any given operating frequency.

By contrast, the time-domain response shows the contribution of each individual circuit element. Since there is a direct relationship between time and distance, this mode allows each element to be separated spatially. With an understanding of the unique signature characteristics of different circuit elements, this view of the DUT can provide considerable insight into the device.

An alternative method of obtaining time-domain characterization of a device is to make the measurement directly in the time domain by synthesizing a step waveform, applying it to the device, and observing the response on an oscilloscope. The advantages of using the PLTS measurement approach for TDR data are listed below.

While the traditional TDR measurement technique provides fast measurement speed, the measurement technique used by the physical layer test system provides:

- Superior accuracy
- Significantly better dynamic range (important for crosstalk and mode-conversion terms)
- Ability to de-embed fixtures and signal launchers
- Access to both frequency and time domain information (as vector quantities)
- Single setup for forward and reverse transmission and reflection, single-ended, differential-, and common-mode, and mode-conversion terms
- No need for DUT to have DC return path
- No large voltage steps applied to DUT

1. The advantage of the chirp z-transform is that it enables calculation of the sample of the z-transform equally spaced over an arc or a spiral contour with an arbitrary starting point and arbitrary frequency range. In contrast, the frequency range of the discrete Fourier Transform is strictly related to the sampling frequency.

TDR/TDT Mode

The time domain mode shows the contribution of each individual circuit element. Using time domain reflectance (TDR), you can measure the location, electrical length, nature of discontinuities (resistive, capacitive, inductive), and amount of reflection from discontinuities. Time domain transmission (TDT) response parameters typically measured are gain, propagation delay, and crosstalk between traces.

The physical layer test system can measure and display any of the single-ended (unbalanced) or mixed-mode S-parameters in the time domain and display the response of a device as if it were stimulated with either a step or an impulse waveform. For those not familiar with S-parameters, they are simply the energy that is reflected off of, or transmitted through, a device under test. S-parameters are defined as the ratio of two normalized power waves (response/stimulus), defined in terms of the voltages and current at each port of a device. For more information, see “How to Interpret S-Parameters” on page 118.

- In TDR/TDT mode, the horizontal axis displays:
  - — Reflection parameters showing the characteristics of the DUT at a certain time delay into the device.
  - — Transmission parameters showing the propagation delay through the device.
- The vertical axis displays:
  - — An impulse response that is a reflection or transmission coefficient on either a linear or logarithmic scale. This parameter can be displayed as an absolute number, or relative to a minimum or maximum value of the response.
  - — A step response on either a linear or a logarithmic scale. Alternatively, a reflection parameter can be displayed as impedance versus time rather than as a reflection coefficient.

The following table shows the relationship between frequency domain parameters to their time domain equivalents.

Table 6-1 Relationship of Frequency Domain Parameters to Time Domain Equivalents

Mode	Direction	Type	Parameter
Single-ended	N/A	TDR	S11
Single-ended	Reverse	TDT	S12
Single-ended	Reverse	TDT	S13

Table 6-1 Relationship of Frequency Domain Parameters to Time Domain Equivalents

Mode	Direction	Type	Parameter
Single-ended	Reverse	TDT	S14
Single-ended	Forward	TDT	S21
Single-ended	N/A	TDR	S22
Single-ended	Reverse	TDT	S23
Single-ended	Reverse	TDT	S24
Single-ended	Forward	TDT	S31
Single-ended	Forward	TDT	S32
Single-ended	N/A	TDR	S33
Single-ended	Reverse	TDT	S34
Single-ended	Forward	TDT	S41
Single-ended	Forward	TDT	S42
Single-ended	Forward	TDT	S43
Single-ended	N/A	TDR	S44
Differential	Forward	TDR	SDD11
Differential	Reverse	TDT	SDD12
Differential	Forward	TDT	SDD21
Differential	Reverse	TDR	SDD22
Common	Forward	TDR	SCC11
Common	Reverse	TDT	SCC12
Common	Forward	TDT	SCC21
Common	Reverse	TDR	SCC22
Differential-to-Common	Forward	TDR	SCD11
Differential-to-Common	Reverse	TDT	SCD12

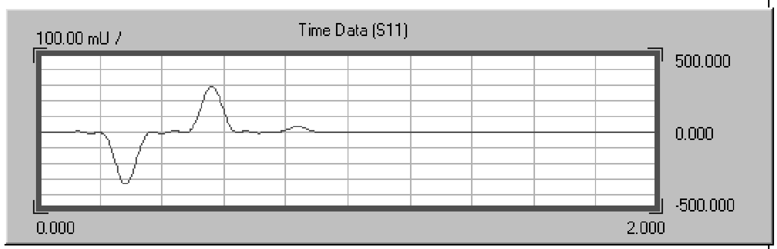
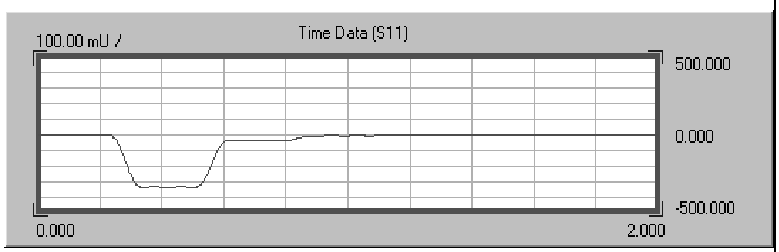
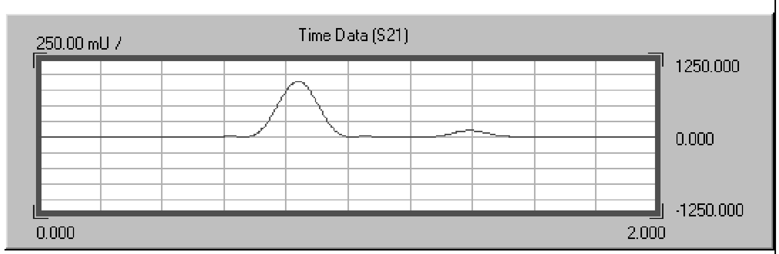
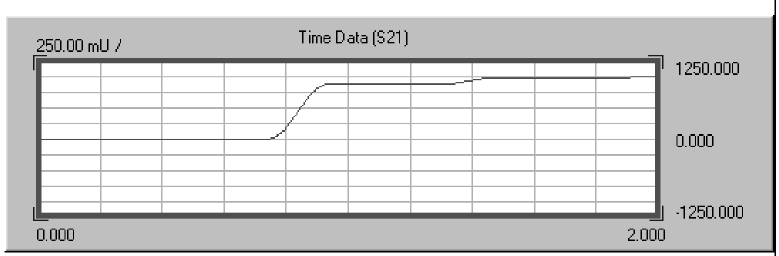
Table 6-1 Relationship of Frequency Domain Parameters to Time Domain Equivalents

Mode	Direction	Type	Parameter
Differential-to-Common	Forward	TDT	SCD21
Differential-to-Common	Reverse	TDR	SCD22
Common-to-Differential	Forward	TDR	SDC11
Common-to-Differential	Reverse	TDT	SDC12
Common-to-Differential	Forward	TDT	SDC21
Common-to-Differential	Reverse	TDR	SDC22
Differential-to-Single-ended	Reverse	TDT	SSD12
Differential-to-Single-ended	Reverse	TDT	SSD13
Single-ended-to-Differential	Forward	TDT	SDS21
Single-ended-to-Differential	Forward	TDT	SDS31
Common-to-Single-ended	Reverse	TDT	SSC12
Common-to-Single-ended	Reverse	TDT	SSC13
Single-ended-to-Common	Forward	TDT	SCS21
Single-ended-to-Common	Forward	TDT	SCS31

Analyzing Time-Domain Signatures

The time-domain response of a device, its signature, provides specific circuit detail. The shape of the response indicates the element type and configuration (series or shunt). Its value and location can be determined from the size of the reflection and its time delay. In general, a wider measurement bandwidth will provide finer response resolution. Table 6-2 shows various circuit elements and associated time-domain signatures.

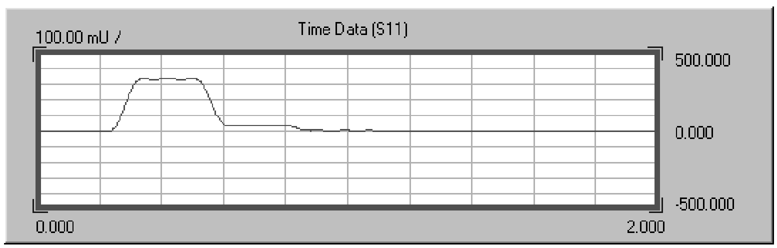
Table 6-2 **Time Domain Signatures**

Transmission Line: ZC < Z0	
Impulse Reflection	
Step Reflection	
Impulse Transmission	
Step Transmission	

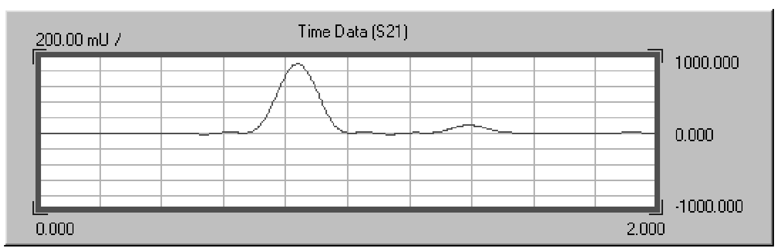
Transmission Line: ZC > Z0

Impulse
Reflection

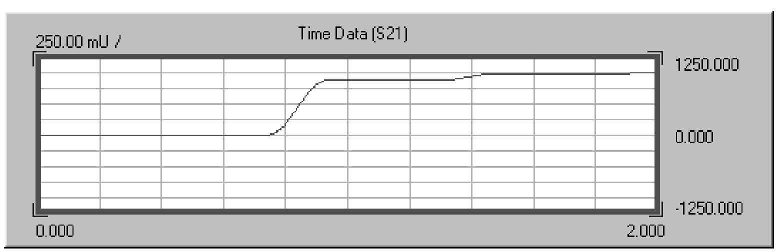
Step
Reflection



Impulse
Transmission

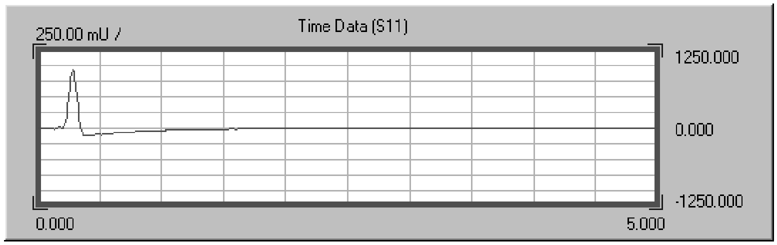


Step
Transmission

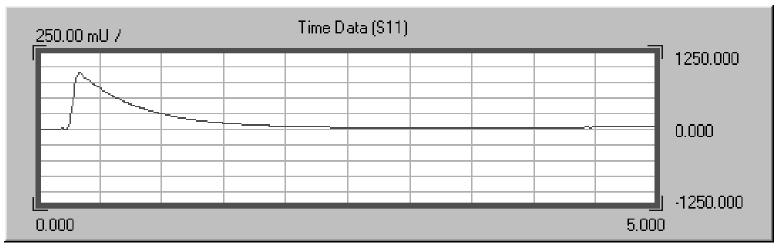


Series Inductor

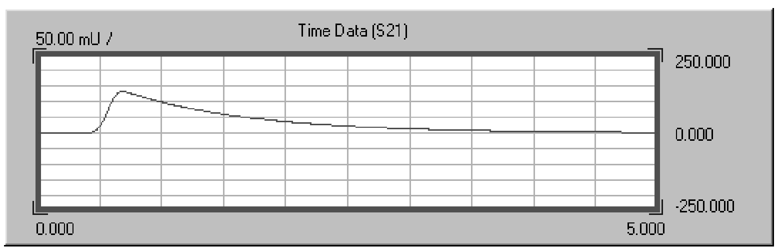
Impulse Reflection



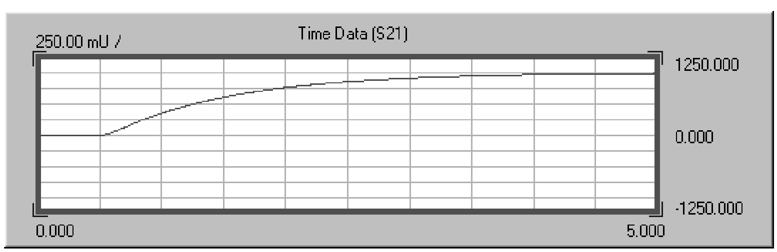
Step Reflection



Impulse Transmission

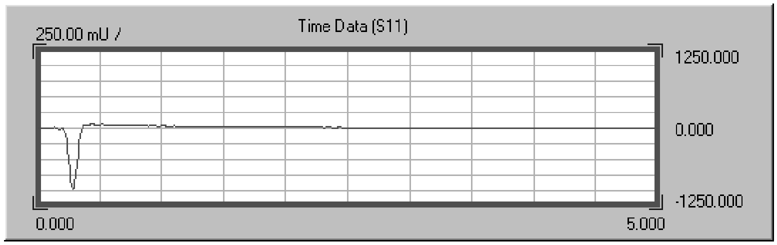


Step Transmission

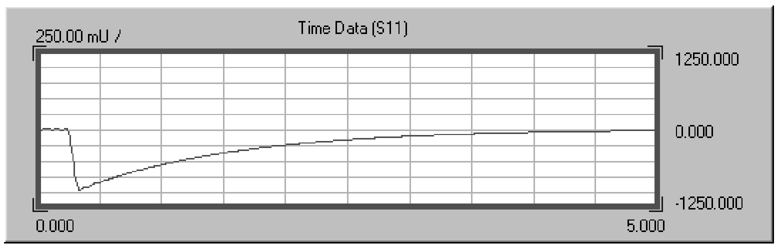


Shunt Capacitor

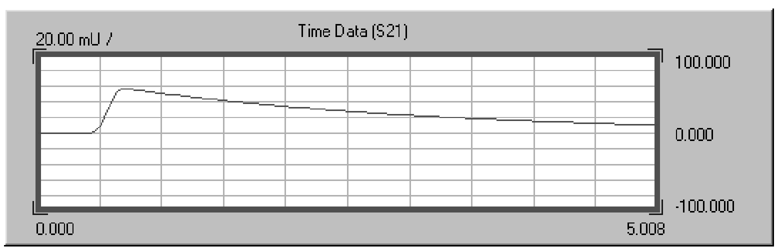
Impulse Reflection



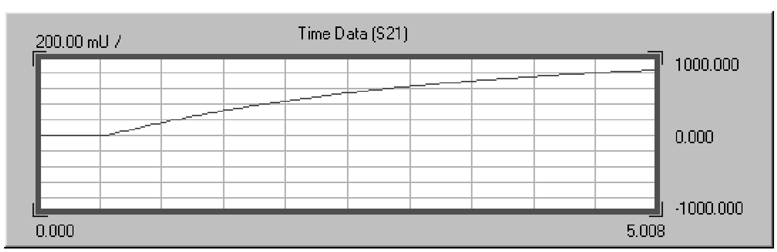
Step Reflection



Impulse Transmission



Step Transmission



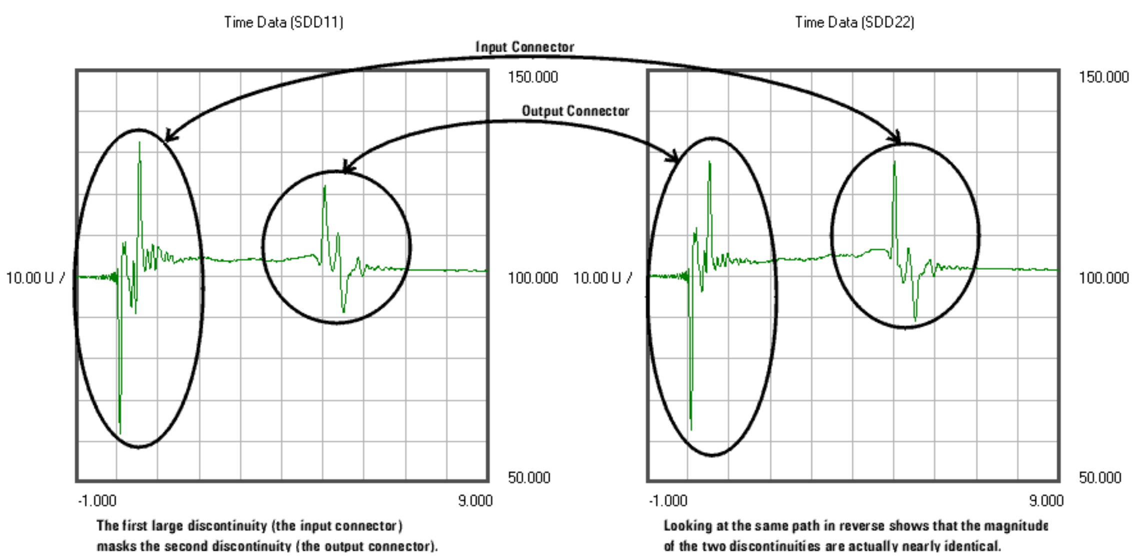
Practical Considerations

In general, better accuracy of the measured frequency domain data will provide for better accuracy of the time domain data. Using the step mode rather than the sweep mode provides additional frequency stability of the source which can greatly improve the time domain data. The following are several other important considerations.

Masking

Time domain responses are most accurate closest to the location of the source. A discontinuity in the DUT will reflect some power back to the source, meaning less power is transmitted to the rest of the DUT. This loss of power going away from the source is referred to as masking, and allows the true impedance of the next discontinuity to be misrepresented.

Figure 6-1 Masking Effects



Masking effects can be seen in Figure 6-1. The plot on the left shows the differential-mode input reflection of a device (SDD11). The first large discontinuity is the input connector; the second is the output connector. Because these connectors are physically identical, the apparent impedance difference between the two can be attributed to masking. The power level at the output connector has been decreased (masked) by the input connector. The plot on the right, output reflection (SDD22), proves this. Looking backwards into the device, the output

connector now exhibits the greater apparent impedance. Were it not for masking, these two plots, and the measured impedance of the input and output connectors, would be identical.

The high dynamic range of the PLTS system extends the ability of the instrument to accurately characterize devices that have several discontinuities or high loss.

Time Domain Windowing

The PLTS software has a feature called *Time Domain Windowing* that is designed to enhance Time Domain measurements. The need for windowing is due to the abrupt transitions in the Frequency Domain measurement at the Start and Stop frequencies. This band limiting of the frequency domain response causes overshoot and ringing in the Time Domain response. It causes the un-Windowed Impulse stimulus to have a sin(kt)/kt shape (k=π/frequency span), which has two effects that limit the usefulness of the Time Domain measurement:

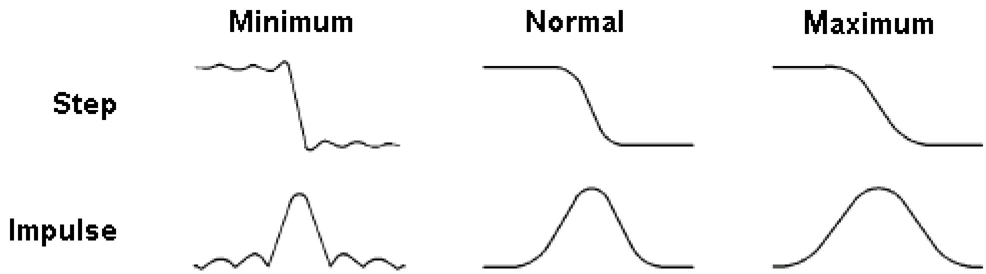
- Finite Impulse Width limits the ability to resolve between two closely-spaced responses. The effects of the finite impulse width cannot be improved with increasing the frequency span of the measurement.
- Impulse Sidelobes limit the dynamic range of the Time Domain measurement by hiding low level response within the sidelobes of the higher level responses. The effects of sidelobes can be improved by windowing.

Windowing improves the dynamic range of the Time Domain measurement by modifying (filtering) the Frequency Domain data prior to conversion to the Time Domain to produce an impulse stimulus with lower sidelobes. This greatly enhances the effectiveness in viewing Time Domain responses that are very different in magnitude. The sidelobe reduction is achieved, however, as the tradeoff with increased impulse width. The effect of Windowing on the STEP stimulus is a reduction of overshoot and ringing a the tradeoff with increased rise time.

Three windows are available: **Minimum**, **Normal**, and **Maximum**. The sidelobe levels of the Time Domain stimulus depend only on the Window that is selected. See Figure 6-3.

The purpose of windowing is to make the Time Domain response more useful in isolating and identifying individual responses. The window does not affect the displayed Frequency Domain response. It is turned on only when the Time Domain response is viewed. Figure 6-2 shows typical effects of windowing on the Time Domain response of the reflection measurement of a short circuit.

Figure 6-2 Effect of Windowing on Time Domain Responses of a Short Circuit

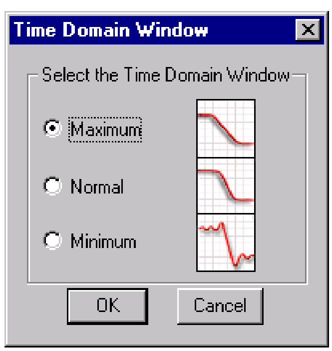


The physical layer test system uses a default filter coefficient value of 0.375, and provides equivalent rise times of T=0.72/F (where T is the effective step rise time or impulse width in picoseconds, and F is the frequency span in gigahertz). For example, a 20 GHz measurement on the N4418A provides an equivalent time of 36 pS and a dynamic range of 110 dB.

By increasing or decreasing the filter value above or below the default, a trade-off can be made between pulse width (rise time) and side-lobe level (dynamic range). The key is to pay attention to the calculated frequency-domain response versus the original data when changing the filter value.

When **Time Domain Window**… is selected from the **Tool** menu, the *Time Domain Window* dialog box is displayed allowing a choice of the three Time Domain Window settings.

Figure 6-3 Time Domain Window Dialog Box



- **Maximum** gives the minimum sidelobes and this provides the greatest dynamic range. The filter coefficient value is 0.375. This is the default setting.
- **Normal** gives reduced sidelobes and is normally the most useful. The filter coefficient value is 0.475.

- **Minimum** is essentially no window and therefore give the highest sidelobes. The filter coefficient value is 0.500.

NOTE When you open measurement data in time domain format, the previously selected windowing is used. To change the windowing selection, select **Time Domain Window**… is selected from the **Tool** menu to display the *Time Domain Window* dialog box. Make your windowing selection from the dialog box, and click **OK**. Then, delete the current plot window and reopen a new plot window using the same data. The new windowing choice is then applied to the data.

Response Resolution

The response resolution describes how close in time two responses can be distinguished. This depends on the width of the impulse response, which is inversely related to the measurement bandwidth. The relationship between the three is approximately R = T = 1.25/BW; where R is the response resolution in picoseconds, T is the effective impulse width in picoseconds, and BW is the frequency span in GHz.

Range Resolution

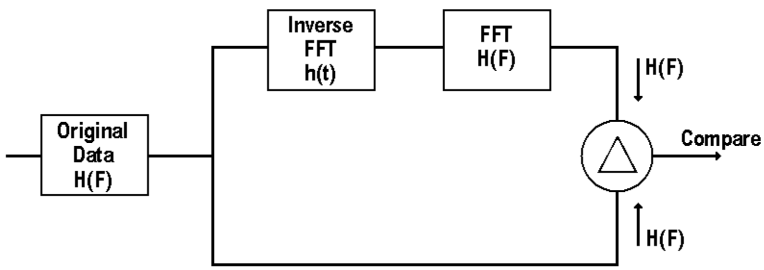
As described previously in "Analyzing Time-Domain Signatures" on page 141, the TDR signature provides specific circuit detail. Range resolution (TD span/Number of points, or Stop-Start/Number of points) will define how accurately the signature of a response can be identified. In general, a wider measurement bandwidth will provide finer spatial resolution.

To improve range resolution, zoom in on the section of interest and adjust the start- and stop-points to be as narrow as possible without compromising the agreement in the frequency domain.

Checking the Validity of a Time-Domain Calculation

There are a number of practical considerations in examining time domain data, as described previously. Therefore, it is very important to have a method of validating the data. This can be accomplished by comparing the original frequency domain data to the data after it is inverse Fourier transformed into the time domain, and then Fourier transformed back into the frequency domain, as shown in Figure 6-4. Ideally, these data should be identical. Changing the time domain start- and stop-points, the filter value, and the value of the DC parameter may improve the agreement.

Figure 6-4 Time Domain Data Validation Model



Viewing Data in the Time Domain

This section guides you with opening measured data in the time domain and viewing the data in the way that best suits your requirements. There are 16 parameter plots for both single-ended and balanced devices. You may elect to view any number of these plots.

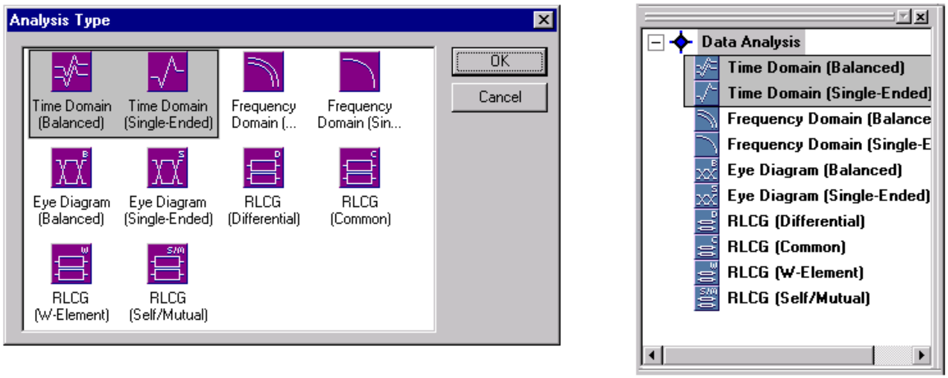
Opening a Time Domain Plot Window

The time domain may be viewed in either balanced or single-ended mode. You may open the time domain plot window in one of four ways.

- From the Startup Wizard immediately before selecting the **Measure** button where you must select the analysis type - see (A) of Figure 6-5
- From the Startup Wizard Welcome Screen by selecting **Load Measurement** where you must select the analysis type - see (A) of Figure 6-5
- From the **Open** selection in the **File** menu or the **Open** icon in the **Toolbar** where you must select the analysis type - see (A) of Figure 6-5
- From the **Browser** when data is already being viewed in another analysis type by selecting one of the Time Domain choices - see (B) of Figure 6-5

NOTE Using the **Browser** method to open a window requires that you select the parameters that you want to view from the **Parameter Bar** or the **Data** menu when the blank plot window is displayed.

Figure 6-5 Opening the Time Domain Plot Window



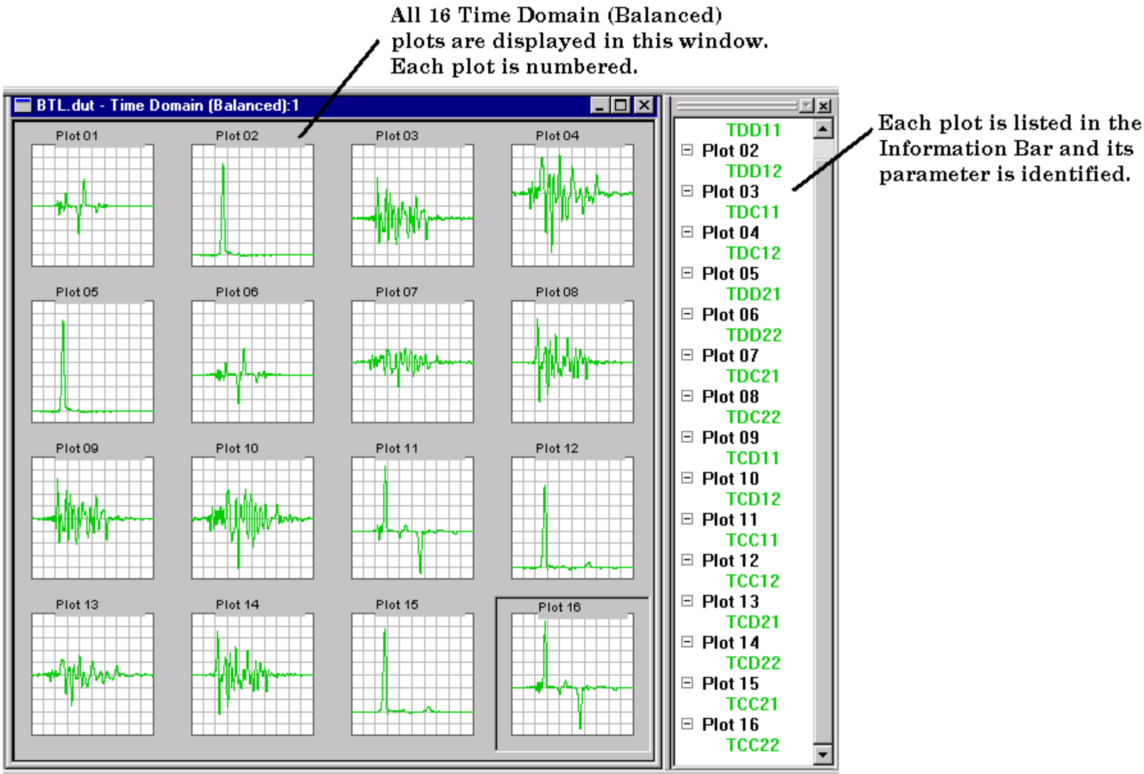
(A) (B)

Viewing All 16 Parameters

In all cases, except when you open the plot window using the **Browser**, all 16 time domain parameter plots are displayed. Each of the plots are numbered. The **Information Bar** immediately to the right of the plots lists each plot by number and displays the associated parameter. See Figure 6-6.

As mentioned previously, when you open the plot window from the **Browser**, an empty plot window is displayed. View all 16 plots by selecting **All** from the **Parameter Bar** or from the **Data** menu with **New Plot** selected.

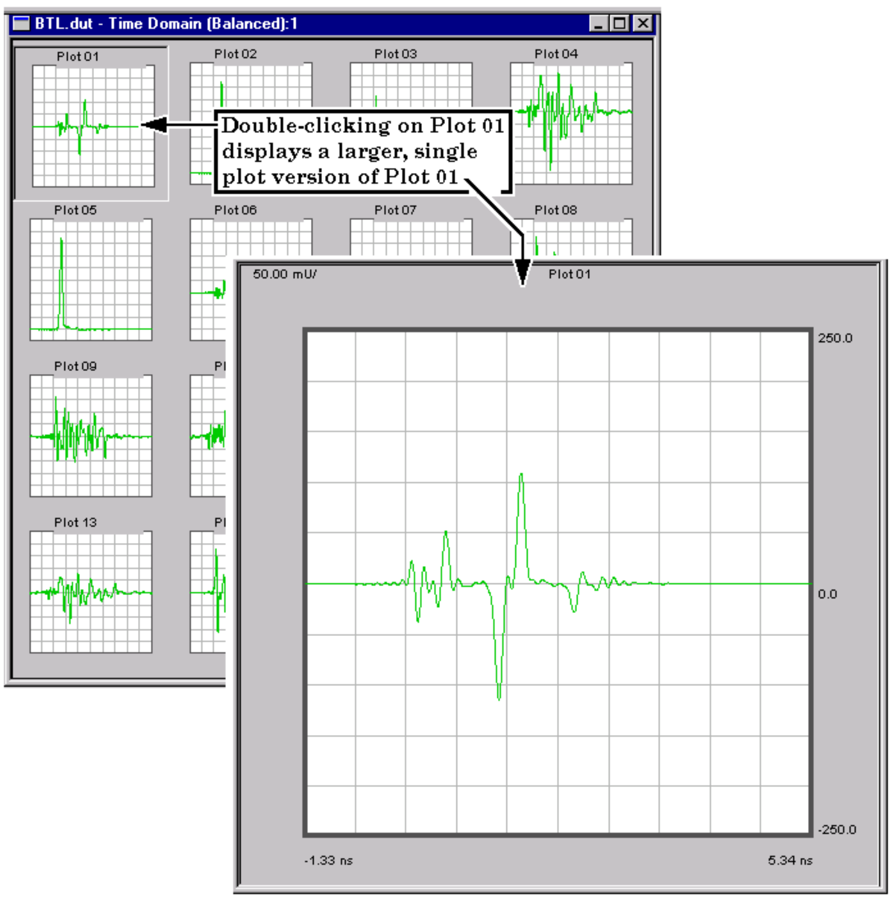
Figure 6-6 Balanced Time Domain Plots with Information Bar



Viewing a Single Parameter

Viewing a single plot gives better resolution. To display a single plot, from the window with all 16 plots (or with multiple plots if you have a custom plot window displayed), double-click on the plot that you would like to view. See Figure 6-7.

Figure 6-7 Opening a Single Plot

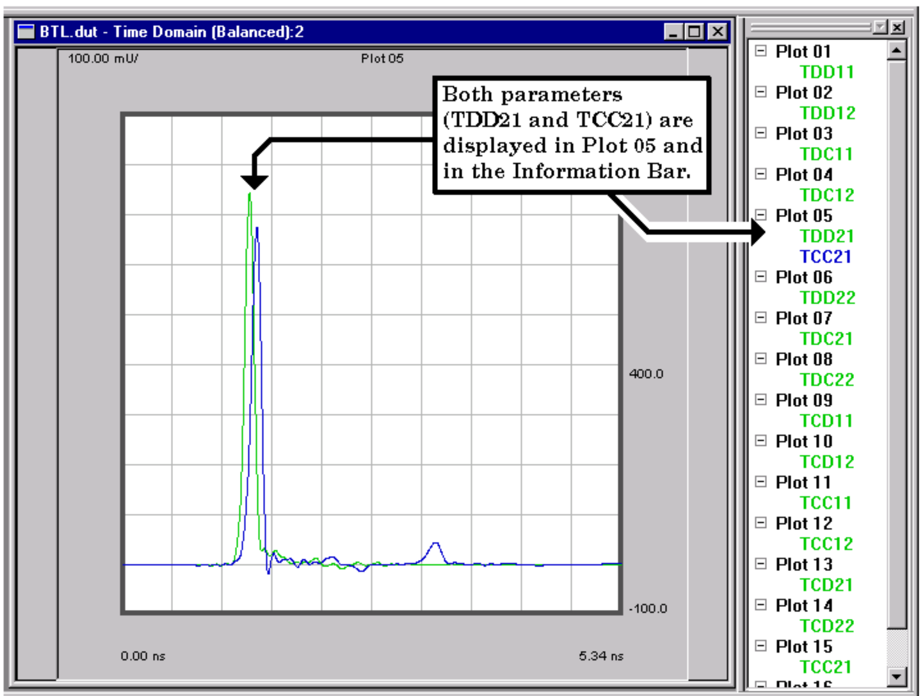


Double-click on the single plot to return to the original view with multiple plots.

View Multiple Traces on a Single Plot

This single plot may have just one parameter or if you choose, it could contain more. For example, you could show how TDD21 compares with TCC21. To do this double-click on the first plot so that is now displaying a single plot similar to Figure 6-7. For this example, Plot 05 (TDD21) was double-clicked and is displayed as a single plot. With **New Trace** selected in the **Parameter Bar** (or the **Data** menu), click the remaining parameters (TCC21 in this example).

Figure 6-8 A Single Plot with Multiple Traces

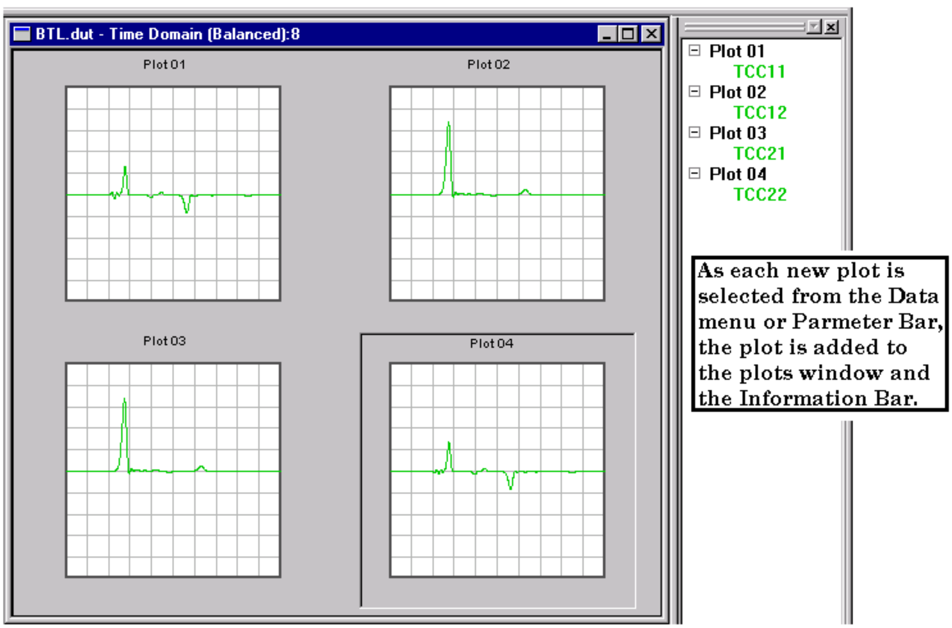


It could contain as many as all 16 of the parameters. However, this would be impractical because having 16 parameters on a single plot would be very hard to distinguish between the parameters and the vertical scale would have to be large to show all parameters.

Creating a Custom Time Domain Plots Window

You can also create a plot window with just the plots you desire. For example, you may want your plot window to show just the four TCC*xx* plots. To create this custom window, open the measured data file in any analysis type. Then, in the **Browser**, select the data type that you want to display the plots. In this example, select **Time Domain (Balanced)**. A blank plots window is displayed. With **New Plot** selected in the **Parameter Bar** (or the **Data** menu), click the desired parameters (TCC11, TCC12, TCC21, and TCC22 in this example). As each parameter is selected, a new plot is added to the plots window. See Figure 6-9.

Figure 6-9 Custom Time Domain Plots Window with Four Plots

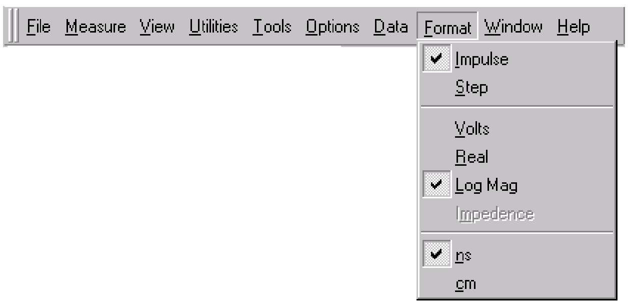


Selecting Time Domain Display Formats

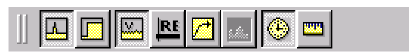
A data format is the way the physical layer test system presents the measurement graphically. Select a data format appropriate to the information you want to learn about the device. You may use either the **Format Bar** or the **Format** menu to select the format.

Figure 6-10 Format Menu and Format Bar for Time Domain

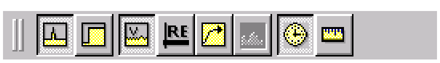
Format Menu



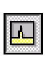
Format Bar



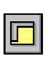
Time Domain Format Bar



Stimulus - Type of the input to the DUT



Impulse inputs an impulse waveform as the stimulus. This is the default format.



Step inputs a step waveform as the stimulus.

Vertical Format - Units used on the vertical axis

Volts selects volts as the vertical unit of measure.

Real displays only the real (resistive) portion of the measured complex data. Real can show both positive and negative values. This is the default format.

Log Mag displays Cartesian logarithmic magnitude (no phase) in dB. Typical measurements are return loss and gain.

Impedance selects ohms as the vertical unit of measure. This choice is active only for reflection plots with a Step stimulus.

Time Domain Format Bar

Horizontal Format - Units used on the horizontal axis

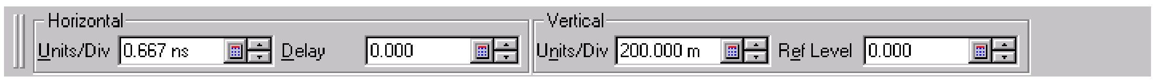
 **ns** selects time units (in nanoseconds) for the horizontal format. This is the default format.

 **cm** selects distance units (in centimeters) for the horizontal format.

Setting the Scale

The PLTS software allows you to change the horizontal and vertical scale of the plots using the **Scaling Bar**.

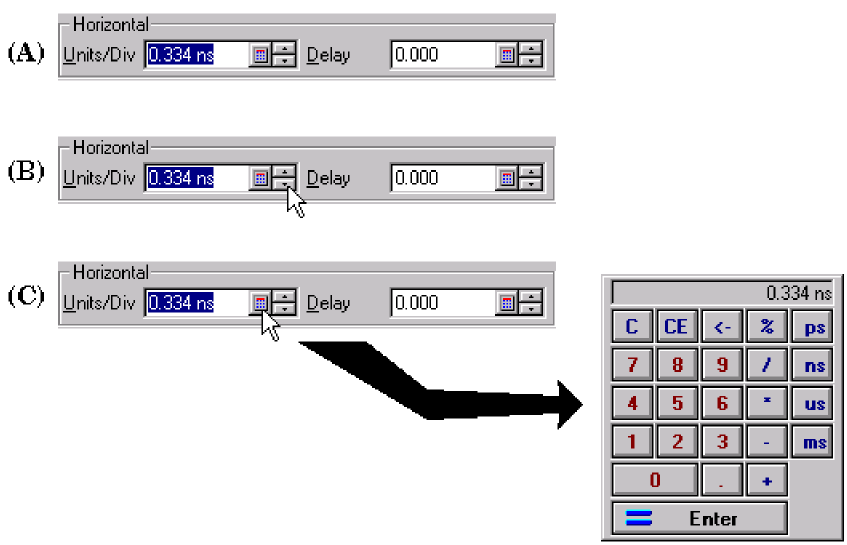
Figure 6-11 Time Domain Scaling Bar



Change the **Scaling Bar** values by:

- Clicking and dragging within a scaling bar entry box to highlight the current value and then typing the new value. See (A) of Figure 6-12.
- Selecting the up/down arrow buttons to the right of each entry. See (B) of Figure 6-12.
- Selecting the calculator icon to the right of each entry to display a keypad. Click the keypad's numeric buttons to enter a new value and click the **Enter** button to save the new value. See (C) of Figure 6-12. The scaling calculator icon varies slightly between scaling entries meet the requirements of the specific entry.

Figure 6-12 Entering a Scale Value



The horizontal scale is changed by changing the start and stop frequencies in megahertz (MHz). Note that you can not extend the start and stop frequencies beyond the start and stop frequencies used in the measurement.

The horizontal scale units are either nanoseconds (ns) or centimeters (cm) depending on the **Format Bar** or **Format** menu selection.

The vertical scale is either volts, units, ohms, or decibels depending on the **Format Bar** or **Format** menu selection. The vertical scale selections are:

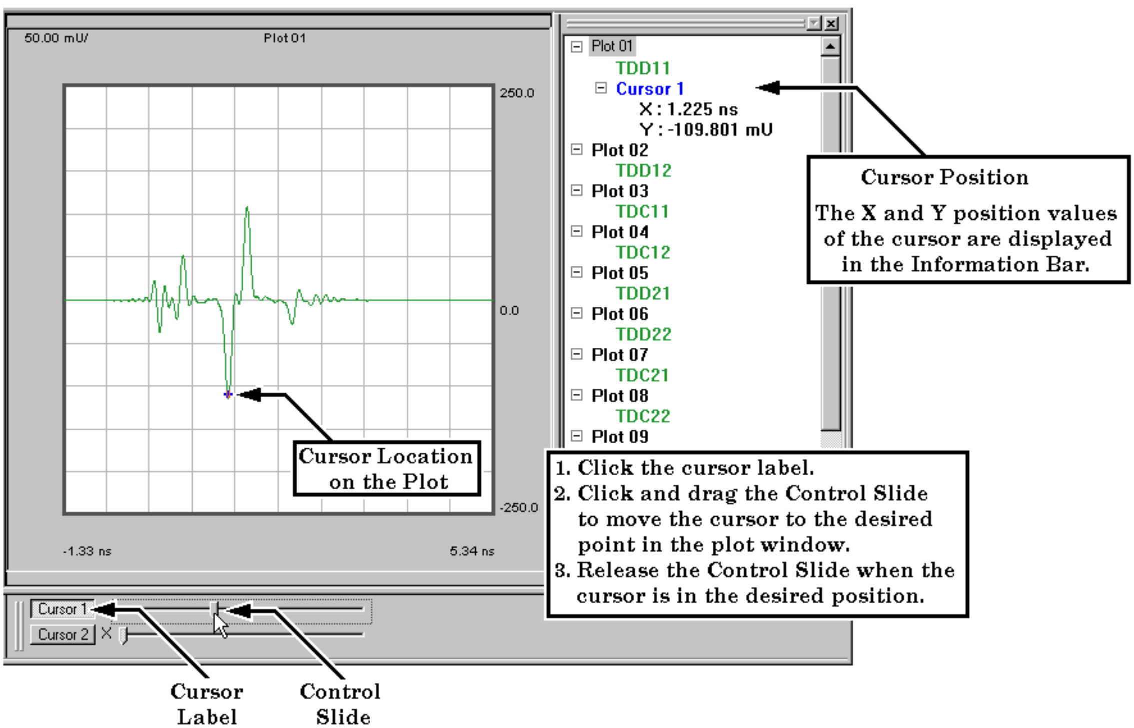
Volts	selects volts as the vertical unit of measure.
Real	displays only the real (resistive) portion of the measured complex data. Real can show both positive and negative values. This is the default format.
Log Mag	displays Cartesian logarithmic magnitude (no phase) in dB. Typical measurements are return loss and gain.
Impedance	selects ohms as the vertical unit of measure. This choice is active only for reflection plots with a Step stimulus.

Using Cursors

Cursors may be used to find specific locations along the plot. When a cursor is activated, it's marker can be moved to any location along the plot trace. The horizontal and vertical values are displayed on the **Information Bar**. Two cursors are available.

To display a cursor, click the cursor label (either **Cursor 1** or **Cursor 2**) in the **Cursor Bar** and then click and drag its slide control. While dragging the control slide, watch the marker move along the trace in the active plot. Notice that the cursor values are displayed in the **Information Bar**.

Figure 6-13 Activating a Cursor

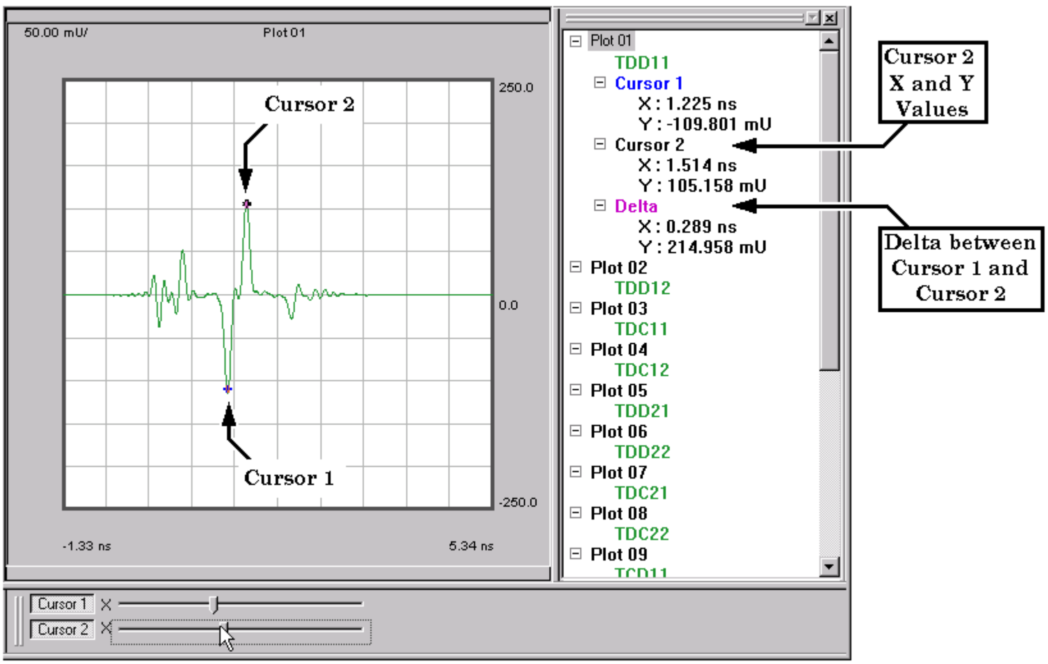


You can also change the cursor position, one point at a time, by using the left/right arrow keys on the keyboard.

Activate the second cursor as you did the first cursor. Notice that both cursor values along with the difference, the **Delta** (Δ), between the cursors are displayed in the **Information Bar**.

Delta = Value of Cursor 2 – Value of Cursor 2

Figure 6-14 Activating a Second Cursor



Gating

Gating provides the ability to remove the effect of a particular circuit element mathematically from time-domain plots. The gated section removes a section of the plot that you define, replacing it with an ideal transmission line having the same electrical delay as the removed section. By observing the original frequency domain response and the transformed frequency domain response, the effect of the gating operation on the S-parameter data can be seen. For detailed information on gating, refer to "Gating" on page 211.

7 Analyzing Data using Eye Diagrams

The physical layer test system software generates eye patterns or diagrams by convolving the time domain impulse response with a user-specified bit sequence. The eye diagram is derived from the passive parts of the circuit, not from the active parts.

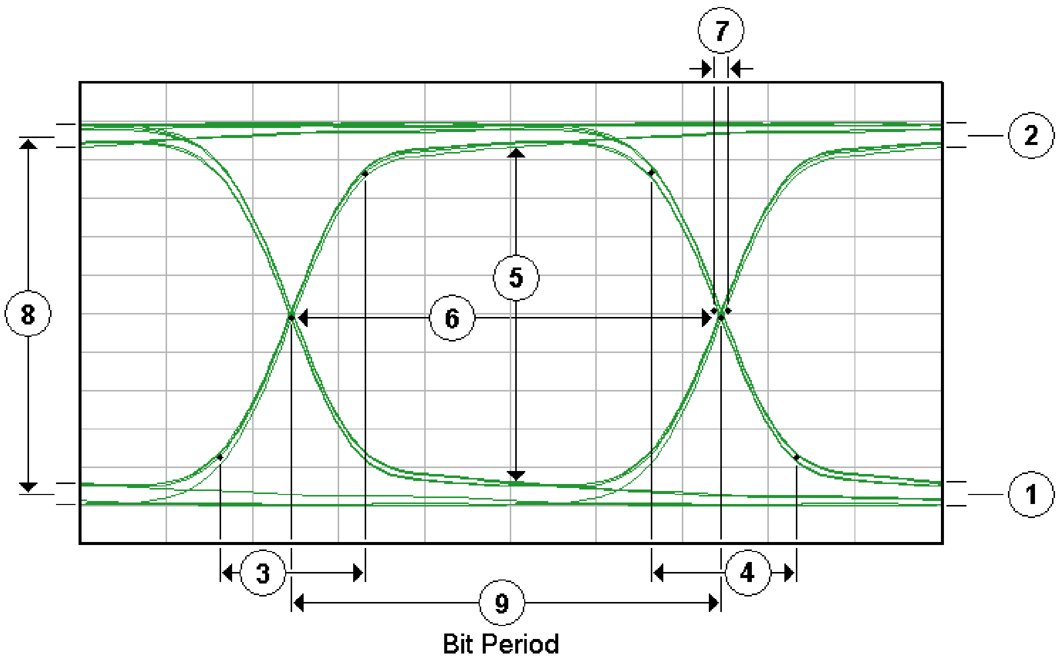
With eye diagrams you can see signal quality with one display, you can diagnose and locate any problems, such as attenuation, noise, jitter, and dispersion that arise or characterize specific parts of the system.

The software allows you to specify a bit sequence of between 8 and 32 bits to be used in generating the eye diagram. You may select a pre-defined bit pattern, a bit pattern that you have defined, or an arbitrary bit stream.

The Eye Diagram

The eye diagram shown in Figure 7-1 identifies key eye diagram definitions. These definitions are listed below this illustration. The eye diagram shown in Figure 7-1 was created using the BTL.dut file located in the PLTS data folder. The bit pattern used is the K28.5 with 80 ps rise/fall time, 2.5 Gb/s data rate, and a 32-bit pattern length.

Figure 7-1 **The Eye Diagram**



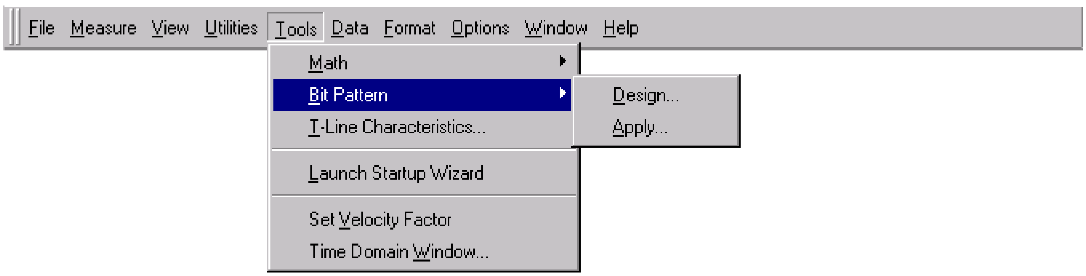
1	**Zero Level**	Zero Level is a measure of the mean value of the logical 0 of an eye diagram.
2	**One Level**	One Level is a measure of the mean value of the logical 1 of an eye diagram.
3	**Rise Time**	Rise time is a measure of the transition time of the data from the 10% level to the 90% level on the upward slope of an eye diagram.

4	**Fall Time**	Fall time is a measure of the transition time of the data from the 90% level to the 10% level on the downward slope of an eye diagram.
5	**Eye Height**	Eye height is a measure of the vertical opening of an eye diagram. An ideal eye opening would be measured from the one level to the zero level. However, noise on the eye will cause the eye to close. The eye height measurement determines eye closure due to noise.
6	**Eye Width**	Eye width is a measure of the horizontal opening of an eye diagram. Ideally, the eye width would be measured between the crossing points of the eye. However, jitter may appear on the waveform and influence the eye opening.
7	**Deterministic Jitter**	Deterministic jitter is the deviation of a transition from its ideal time caused by reflections relative to other transitions.
8	**Eye Amplitude**	Eye amplitude is the difference between the logic 1 level and the logic 0 level histogram mean values of an eye diagram.
9	**Bit Rate**	Bit rate (data rate) is the inverse of bit period (1 / bit period). The bit period is a measure of the horizontal opening of an eye diagram at the crossing points of the eye.

Designing a Bit Pattern for Eye Diagrams

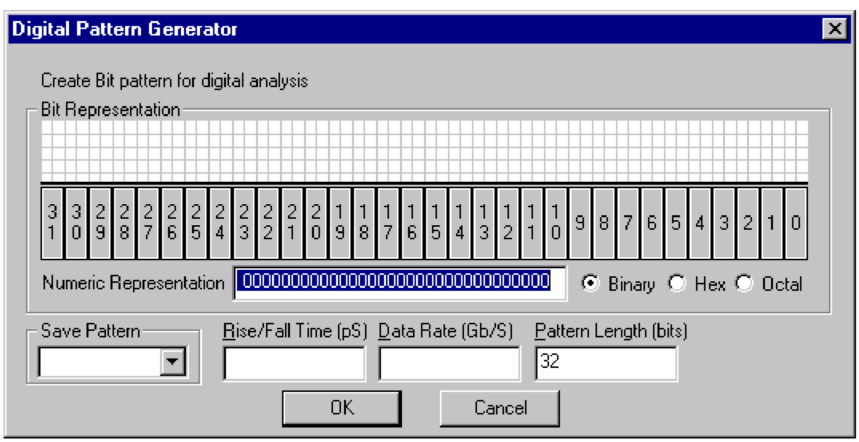
The **Bit Pattern** feature in the **Tools** menu allows you to design a digital bit pattern and to apply a bit pattern that has been saved to eye diagram plots. Only the industry standard K 28.5 bit pattern has been created and included in the software. However, the PLTS software allows you to create bit patterns, from 8 to 32 bits very easily.

Figure 7-2 Tools Menu with Bit Pattern Expanded



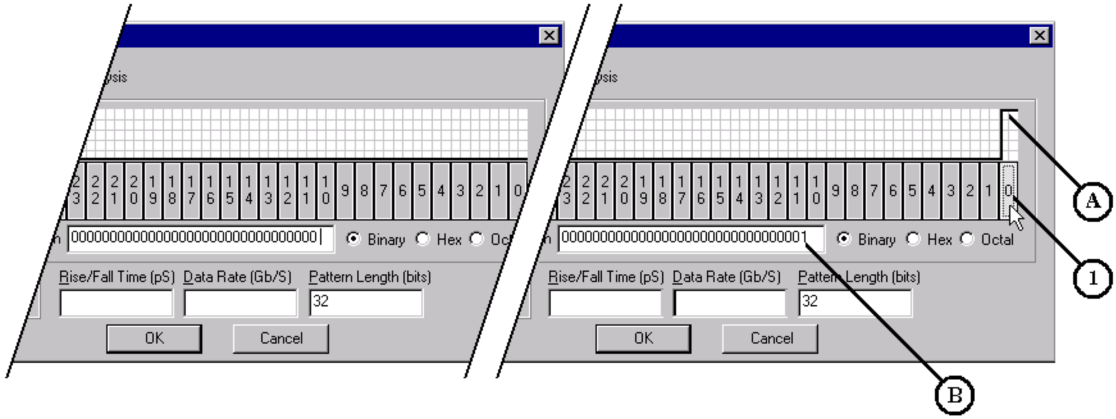
1. Select **Bit Pattern** then **Design**… from the **Tools** menu to open the *Digital Pattern Generator* dialog box shown in Figure 7-3.

Figure 7-3 Digital Pattern Generator



2. Click on the “**0**” key as shown in Figure 7-4.

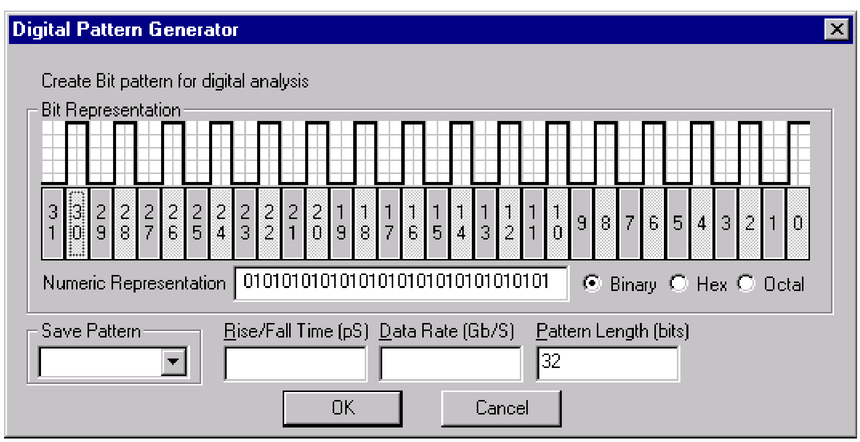
Figure 7-4 Selecting the “0” Piano Key



1. **Selecting the “0” key (piano key) in the Bit Representation area:**
   - **A.** Causes Bit 0 to go high (turn on)
   - **B.** Generates a “0” in the first digit of the binary numeric representation

3. Select the remaining even-numbered *piano* keys so that you have a series of alternating bits as shown in Figure 7-5.

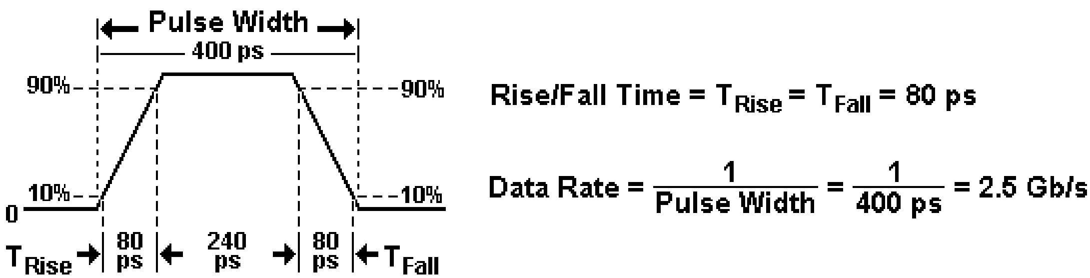
Figure 7-5 Digital Pattern Generator with a 32-Bit Pattern



Note the alternating bits going high (turning on) and the alternating 1’s and 0’s in the **Numeric Representation** area.

4. Enter values in the **Rise/Fall Time** and the **Data Rate** boxes. **Rise/Fall Time** is entered in picoseconds (ps) and **Data Rate** is entered in Gigabits per second (Gb/s). See Figure 7-6 and Figure 7-7.

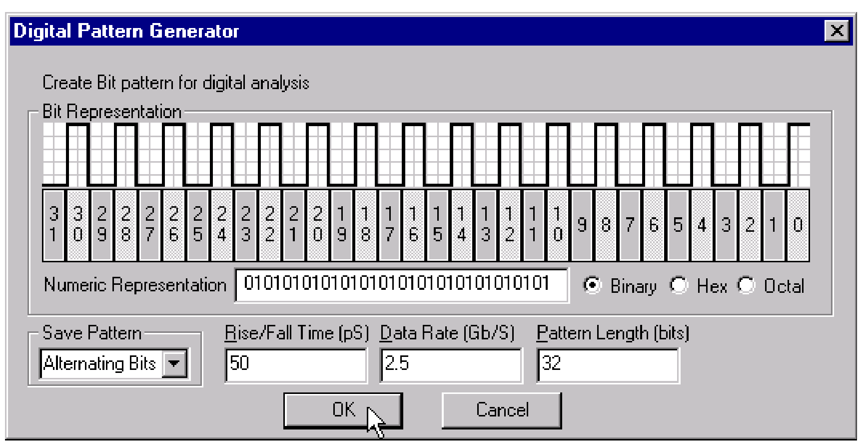
Figure 7-6 Rise/Fall Time and Data Rate



5. Check the value in the **Pattern Length (bits)** box. The default value is 32. The allowable range is between 8 and 32 bits. You may change this if your pattern contains fewer bits. If this value is changed to a value less than 32, any remaining bits are ignored. For example if you enter 10 as the pattern length value, then bits 0 through 9 are used and bits 10 through 31 are ignored.

6. Enter a name for the digital pattern in the **Save Pattern** box. In this example, `Alternating Bits` is entered. Click the **OK** button to save the pattern to be used later. See Figure 7-7.

Figure 7-7 Save the Digital Pattern



Viewing Data using Eye Diagrams

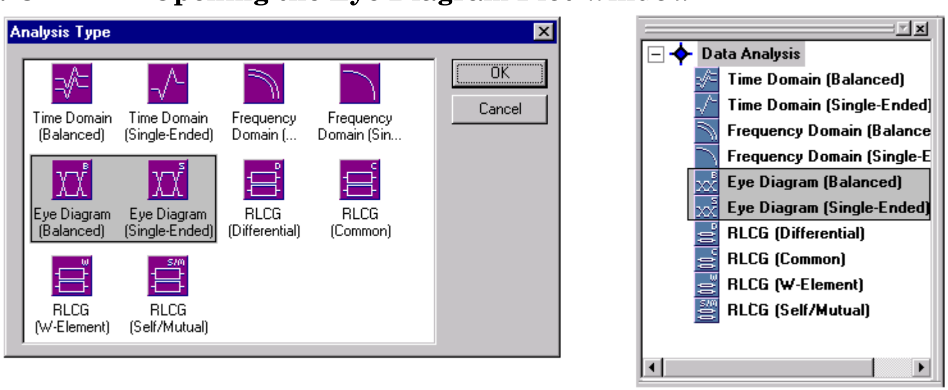
This section guides you with opening measured data in the eye diagram plot mode and viewing the data in the way that best suits your requirements. There are 8 output plots for balanced mode and 12 output plots for single-ended mode. Only transmission paths are displayed; no reflection paths are displayed.

Opening a Eye Diagram Plot Window

The eye diagram may be viewed in either balanced or single-ended mode. You may open the eye diagram plot window in one of four ways.

- From the Startup Wizard immediately before selecting the **Measure** button where you must select the analysis type - see (A) of Figure 7-8
- From the Startup Wizard Welcome Screen by selecting **Load Measurement** where you must select the analysis type - see (A) of Figure 7-8
- From the **Open** selection in the **File** menu or the **Open** icon in the **Toolbar** where you must select the analysis type - see (A) of Figure 7-8
- From the **Browser** when data is already being viewed in another analysis type by selecting one of the Eye Diagram choices - see (B) of Figure 7-8

Figure 7-8 Opening the Eye Diagram Plot Window

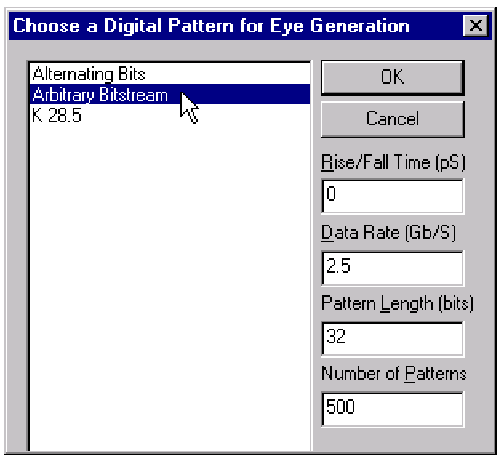


(A) (B)

NOTE When using the **Browser** method to open a window, first select the bit pattern to use with the data (described in the rest of this section), then select the parameters that you want to view from the **Parameter Bar** or the **Data** menu once the blank plot window is displayed.

The *Choose a Digital Pattern for Eye Generation* dialog box is then displayed (see Figure 7-9). You may select a digital pattern to apply from the list of digital patterns. The software is shipped with the **K 28.5** selection (an industry standard) and the **Arbitrary Bitstream** selection (a *random-like* bit stream). Any bit patterns that you have created and saved using the process described in Designing a Bit Pattern for Eye Diagrams beginning on page 169 are also displayed in the *Choose a Digital Pattern for Eye Generation* dialog box.

Figure 7-9 Choose a Digital Pattern Dialog Box



NOTE If the bit pattern has already been selected for the data, the *Choose a Digital Pattern for Eye Generation* dialog box is not displayed and the data will is displayed using that bit pattern information. To change the bit pattern, select **Bit Pattern** then **Apply**… from the **Tools** menu to display the dialog box shown in Figure 7-9. Then, select the desired bit pattern from the list on the left, enter the desired information (Rise/Fall Time, Data Rate, Pattern Length, and Number of Patterns) as described below, and click **OK**. Then, delete the current plot window and reopen a new plot window using the same data. The new bit pattern is then applied.

After clicking a digital pattern in the *Choose a Digital Pattern for Eye Generation* dialog box list, review the digital pattern parameter entries on the right side of the dialog box and enter the desired parameter values.

- **Rise/Fall Time (pS)** is the time that it takes a signal to transition from a low to a high (10% to 90%) condition (or the time that it takes a signal to transition from a high to a low (90% to 10%) condition).
- **Data Rate (Gb/S)** is the speed that data is transferred over a circuit or a communications line.
- **Pattern Length (bits)** is the number of bits in the digital pattern used to create the eye diagram. This value is the limiting factor in creating unique digital patterns. The number of bits allowed is between 8 and 32. Where **B** is the number of bits entered, the number of unique bit patterns is: $2^B - 2$. If B = 32 (the maximum number of allowable bits), the then 4.29×10^9 unique bit patterns are generated.
- **Number of samples** (active only when **Arbitrary Bitstream** is selected) is used to indicate the number of unique bit patterns to use in creating the eye diagram. This value must be equal or less than the number of unique bit patterns determined by the number of bits entry.

Then, click **OK** to view the eye diagram in the plot window. **Cancel** closes the dialog box without making any changes.

IMPORTANT **Arbitrary Bitstream**

Arbitrary Bitstream (ABS) is random-like bit stream used to generate eye diagrams. The number of bits and the number of samples is used to create the ABS. As explained earlier, the number of bits is used to identify how many unique bit patterns are available. The number of samples is used to identify how many of the available bit patterns will be used to create the eye diagram.

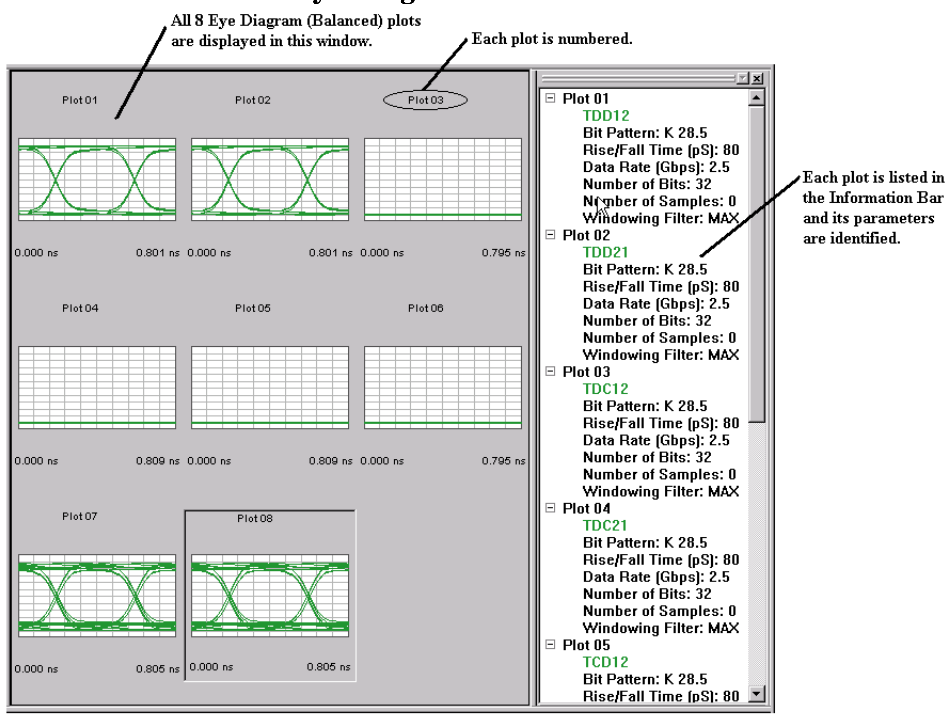
Using both of these values, a random number generator selects unique bit patterns until the appropriate number of samples are identified. Each of these unique bit patterns are then used to create the eye diagram, one bit pattern at a time. Using this procedure, the arbitrary bit stream is reproduced when the number of bits and the number of samples are the same values. As the number of samples becomes larger, the time to complete this process also increases.

Viewing All Parameters

In all cases, except when you open the plot window using the **Browser**, all eye diagram parameter plots are displayed. There are eight parameter plots for balanced devices and 12 parameter plots for single-ended devices. Each of the plots are numbered. The **Information Bar** immediately to the right of the plots lists each plot by number and displays the associated parameter. See Figure 7-10.

As noted above, when you open the plot window from the Browser, an empty plot window is displayed. View all plots by selecting **All** from the **Parameter Bar** or from the **Data** menu.

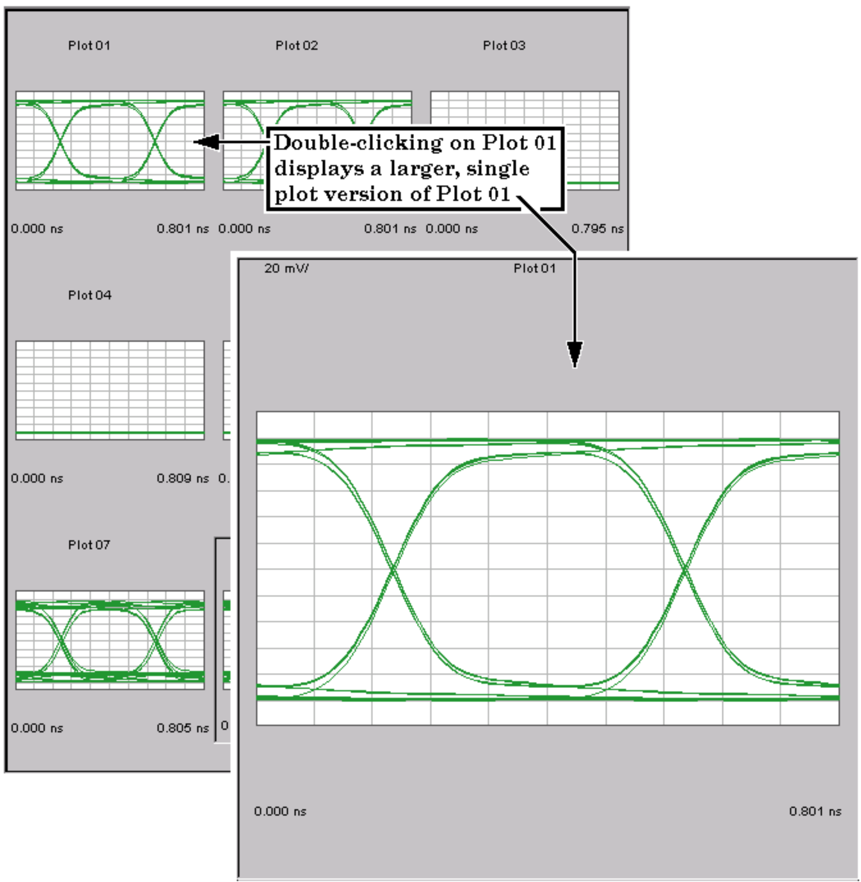
Figure 7-10 Balanced Eye Diagram Plots with Information Bar



Viewing a Single Eye Diagram

Viewing a single plot gives better resolution. To display a single plot, from the window with all plots (or with multiple plots if you have a custom plot window displayed), double-click on the plot that you would like to view. See Figure 7-11.

Figure 7-11 Opening a Single Plot

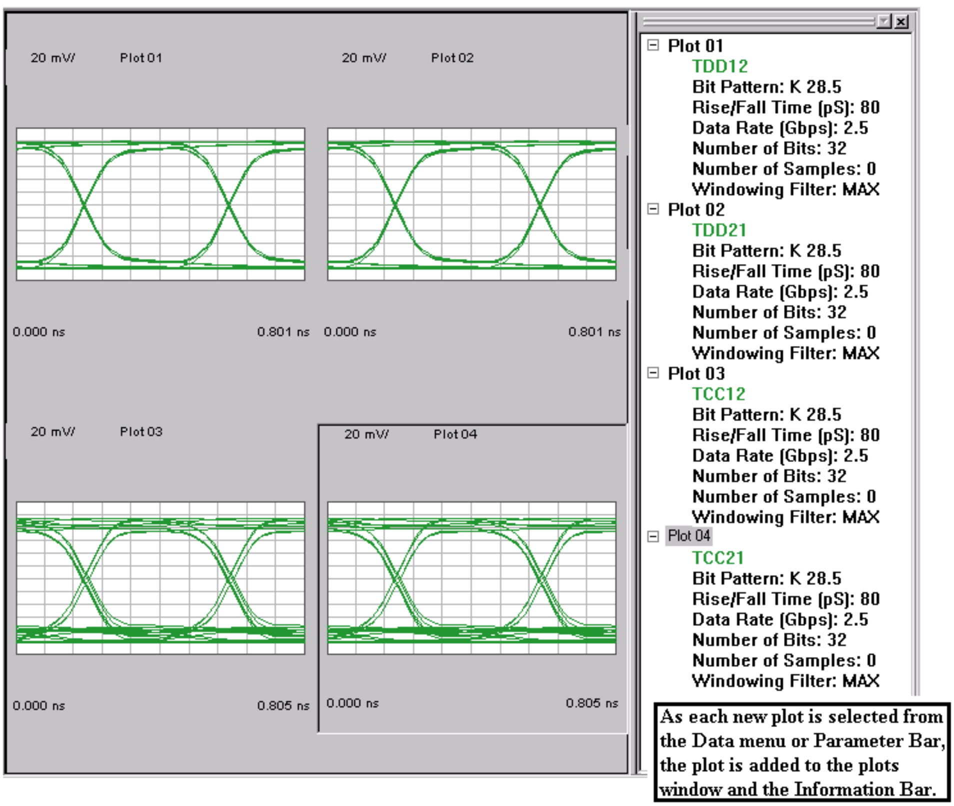


Double-click on the single plot to return to the original view with multiple plots.

Creating a Custom Eye Diagram Plot Window

You can also create a plot window with just the plots you desire. For example, you may want your plot window to show just the two TDDxx plots and the two TCCxx plots. To create this custom window, open the measured data file in any analysis type. Then, in the **Browser**, select the data type that you want to display the plots. In this example, select **Eye Diagram (Balanced)**. A blank plots window is displayed. From the **Parameter Bar**, click the desired parameters (TDD12, TDD21, TCC12, and TCC21 in this example). As each parameter is selected, a new plot is added to the plots window. See Figure 7-12.

Figure 7-12 Custom Eye Diagram Plots Window with Four Plots

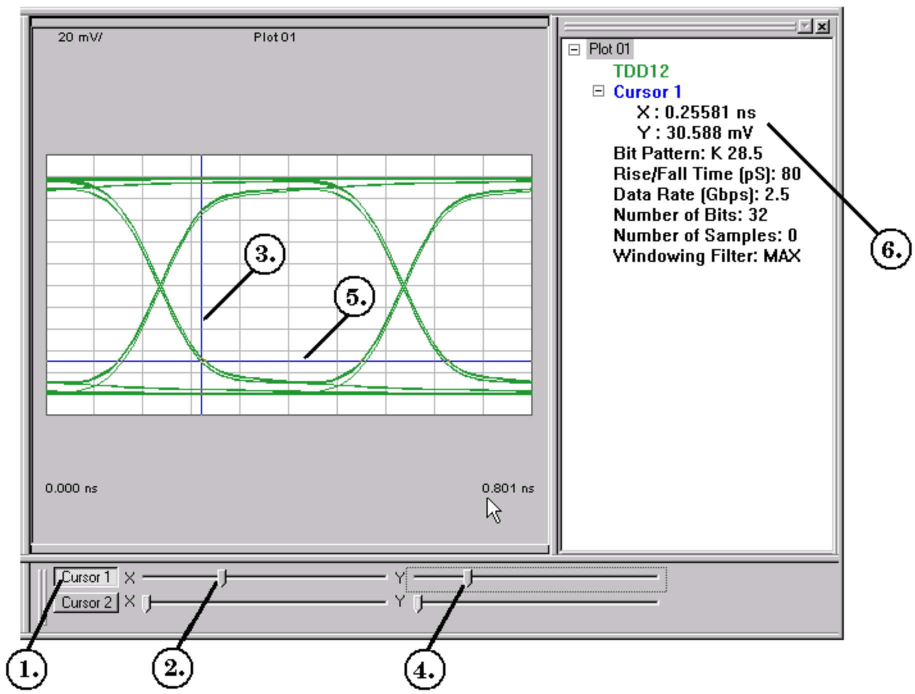


Using Cursors

Cursors are used to find specific locations on an eye diagram. Eye diagram plot windows have two cursors. Each cursor has both a horizontal (X) and a vertical (Y) indicators which are controlled separately. The horizontal indicator displays a thin line in the X-axis from one side of the plot to the other. The vertical indicator displays a thin line in the Y-axis from the top of the display to the bottom. The horizontal and vertical indicator values are displayed on the **Information Bar**.

Follow the steps listed below and in Figure 7-13 to display a cursor:

Figure 7-13 Steps to Display the Cursor



1. Select the cursor label (either **Cursor 1** or **Cursor 2**) in the **Cursor Bar**.
2. Click and drag the X-axis slide control.
3. While dragging the X-axis control slide, watch the X-axis indicator line move across the active plot from left to right.
4. Click and drag the Y-axis control slide.
5. While dragging the Y-axis control slide, watch the Y-axis indicator line move up the active plot from the bottom toward the top.
6. Note the positions of the X-axis and Y-axis indicators on the **Information Bar**.

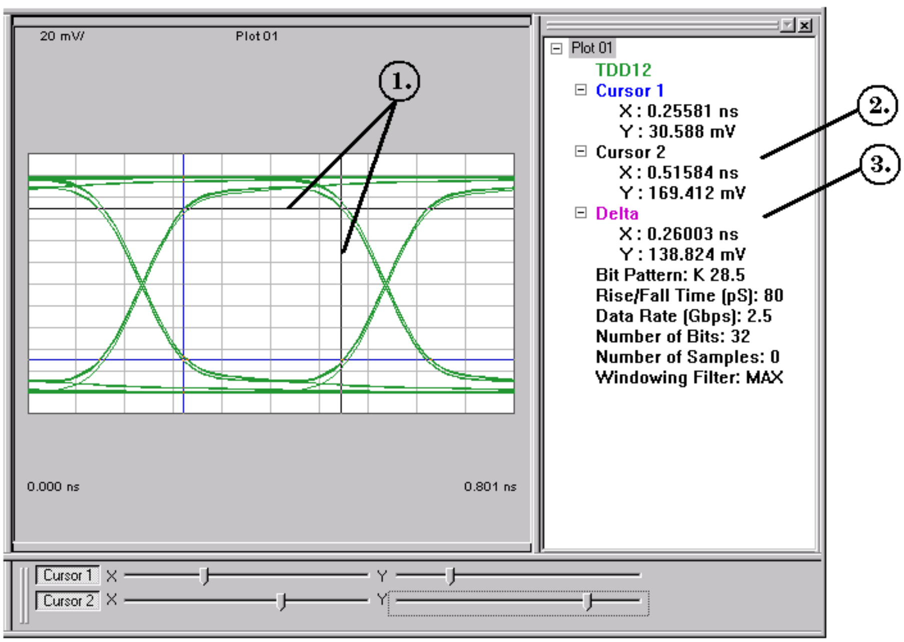
Display the second cursor as you did the first cursor.

Note the following in Figure 7-14:

1. The second pair of indicator lines in the plot window.
2. The positions of the X-axis and Y-axis indicators for Cursor 2.
3. The difference, the **Delta** (Δ), between the cursors for both the X-axis and Y-axis indicators.

   Delta = Value of Cursor 2 – Value of Cursor 1

Figure 7-14 Activating a Second Cursor



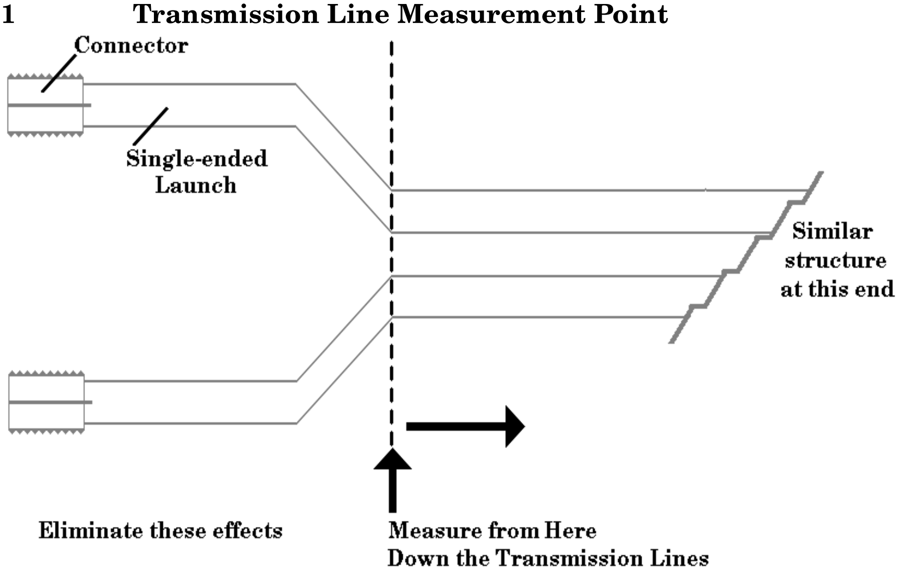
8 Extracting Transmission Line (RLCG) Parameters

The physical layer test system makes 4-port scattering parameter measurements. This data is transformed into frequency domain mixed-mode S-parameters in order to view the transmission lines as balanced pairs. From the mixed-mode frequency domain data, the physical layer test system software extracts the parameters R, L, G, and C and calculates the complex propagation constant and complex characteristic impedance. These generated transmission line parameters provide the standard transmission line model parameters of your device under test for importing into a simulator, such as HSPICE or ADS.

Characteristic impedance and time delay, or series inductance and shunt capacitance, completely specify the electrical properties of a lossless transmission line. Propagation velocity and length are also required in order to completely specify a physical cable or PC board trace. There are times when it is beneficial to think of a transmission line in terms of Z_o and t_d and likewise, there are times when thinking in terms of C_{total} and L_{total} is best. While the transmission line model used in HSPICE and many other time domain simulators is defined by characteristic impedance and time delay, the best way to model a transmission line is by using an RLCG type of mode. This method is what the PLTS system offers.

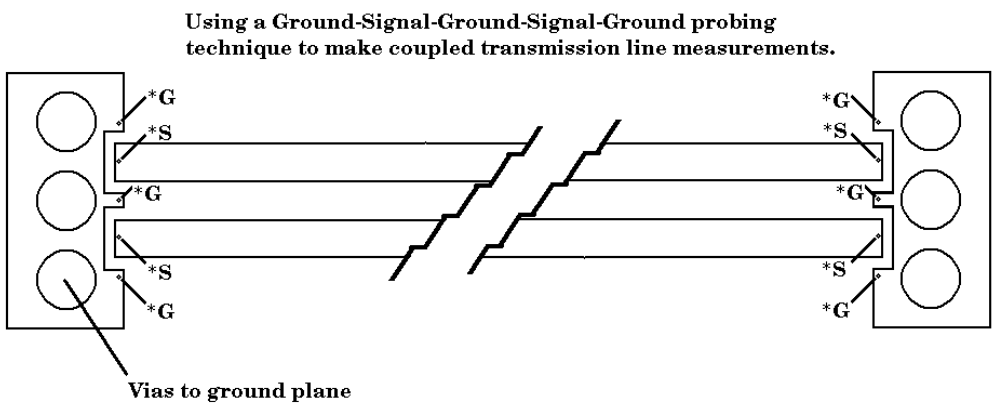
The physical layer test system currently only generates models for two-coupled transmission lines (differential transmission lines). When measuring transmission lines, it is important to measure just the differential transmission line. This measurement should *not* include discontinuities, such as variations in the width or the thickness, vias, bends in the line, etc. Any single-ended launch effects, such as connectors or single ended launches (transmission lines), need to be removed (de-embedded) before computing RLCG model parameters. This is a more difficult task. Refer to Figure 8-1.

Figure 8-1 Transmission Line Measurement Point



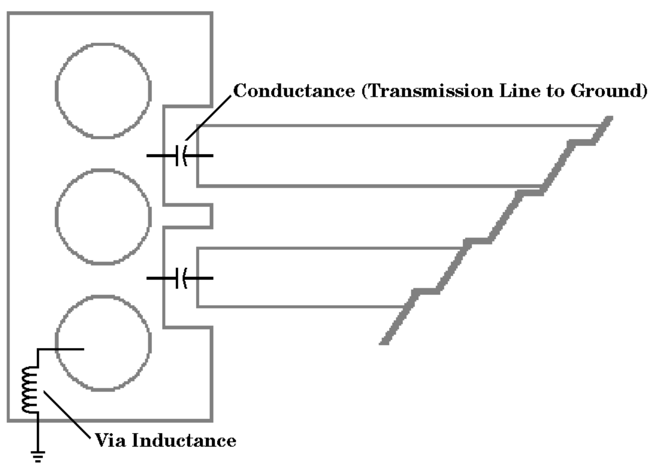
It is easier to probe the transmission line to be characterized, thus minimizing the “launch” effects, assuming that calibration is performed at the probe tips. Ground-Signal-Ground-Signal-Ground (GSGSG) probes have given the best results so far. The middle ground probe helps to isolate coupling between the two signal probe tips. Refer to Figure 8-2 for an example of probing coupled transmission lines using GSGSG probes.

Figure 8-2 Probing Coupled Transmission Lines Using G-S-G-S-G Probes



The remaining parasitic effects are small and can be ignored (except at higher frequencies). Typically, capacitance from each line to the ground block and a small inductance for the vias in the ground block as shown in Figure 8-3.

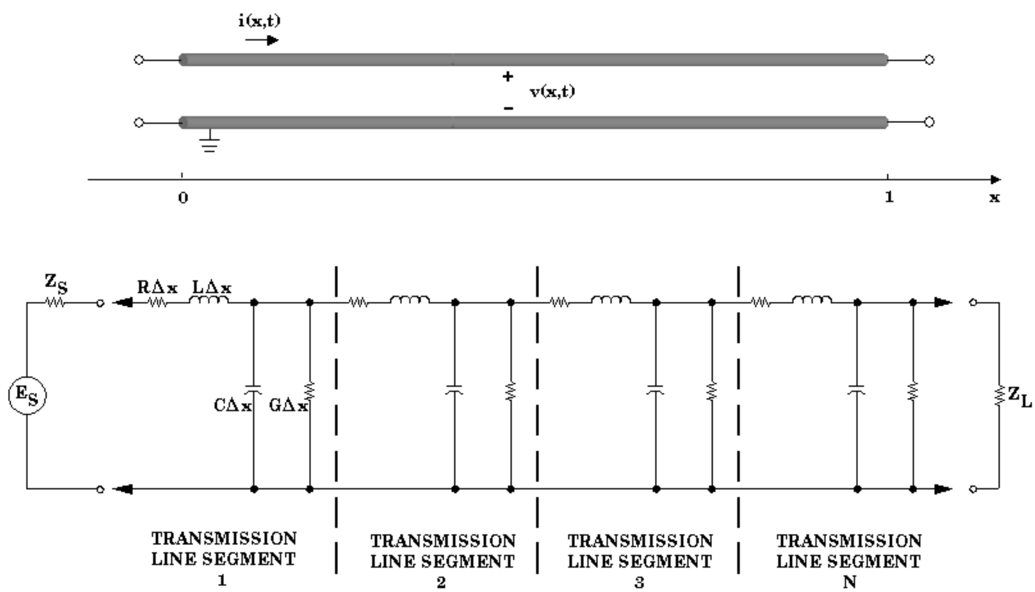
Figure 8-3 Transmission Line Parasitic Capacitances and Inductances



Propagation on a Transmission Line

RLCG type models are commonly used in the industry to describe the electrical behavior of passive transmission lines. This model is a distributed network of a series resistance and inductance with parallel capacitance and conductance (see Figure 8-4). The classical transmission line is assumed to consist of a continuous structure of resistors (R), inductors (L), capacitors (C), and conductances (G). By studying this equivalent circuit, several characteristics of the transmission line can be determined.

Figure 8-4 Lumped Equivalent Model of a Distributed Transmission Line



The different terms included in the model describe the following physical phenomena where x is distance and t is time:

R Conductor resistive loss (skin effect + DC loss)

L Inductive part of the circuit resulting from the layout of the conductors and the physical properties of the materials.

C Capacitive part of the circuit resulting from the layout of the conductors and the physical properties of the materials.

G Dielectric loss

If the line is infinitely long and R, L, G, and C are defined per unit length, then

$$Z_{in} = Z_o = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

where Z_o is the characteristic impedance of the line. A voltage introduced at the generator will require a finite time to travel down the line to a point x. The phase of the voltage moving down the line will lag behind the voltage introduced at the generator by an amount β per unit length. Furthermore, the voltage will be attenuated by an amount α per unit length by the series resistance and shunt capacitance of the line. The phase shift and attenuation are defined by the propagation constant γ,

where

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)}$$

α = attenuation in nepers per unit length
β = phase shift in radians per unit length

The velocity at which the voltage travels down the line can be defined in terms of β where:

$$v_p = \frac{\omega}{\beta} \text{ unit length per second}$$

The velocity of propagation approaches the speed of light, v_c, for transmission lines with air dielectric. For the general case where ε_r is the dielectric constant.

$$v_p = \frac{v_c}{\sqrt{\varepsilon_r}}$$

The propagation constant γ can be used to define the voltage and the current at any distance x down an infinitely long line by the relations:

$$E_x = E_{in} e^{-\Upsilon x}$$

$$I_x = I_{in} e^{-\Upsilon x}$$

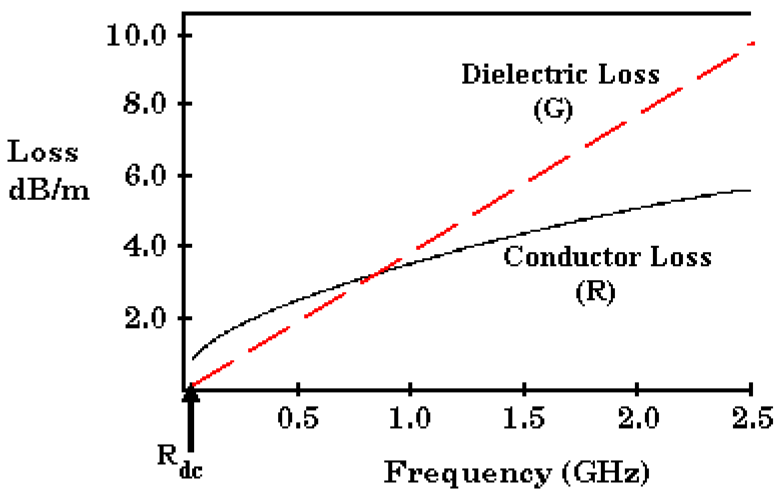
Since the voltage and the current are related at any point by the characteristic impedance of the line:

$$Z_o = \frac{E_{in} e^{-\Upsilon x}}{I_{in} e^{-\Upsilon x}} = \frac{E_{in}}{I_{in}} = Z_{in}$$

When the transmission line is finite in length and is terminated in a load whose impedance matches the characteristic impedance of the line, the voltage and current relationships are satisfied by the preceding equations.

RLCG models are frequency-based models (refer to Figure 8-5). Equation set 1 describes the most adopted frequency dependencies of RLCG parameters.

Figure 8-5 **Loss as a Function of Frequency**



Equation set 1

$$
\begin{aligned}
R &= R_{DC} + R_{SKIN}\sqrt{f} \\
L &= Constant \\
G &= G_{DC} + G_{AC} \cdot f \\
C &= Constant
\end{aligned}
$$

These parameters are called fitted parameters.

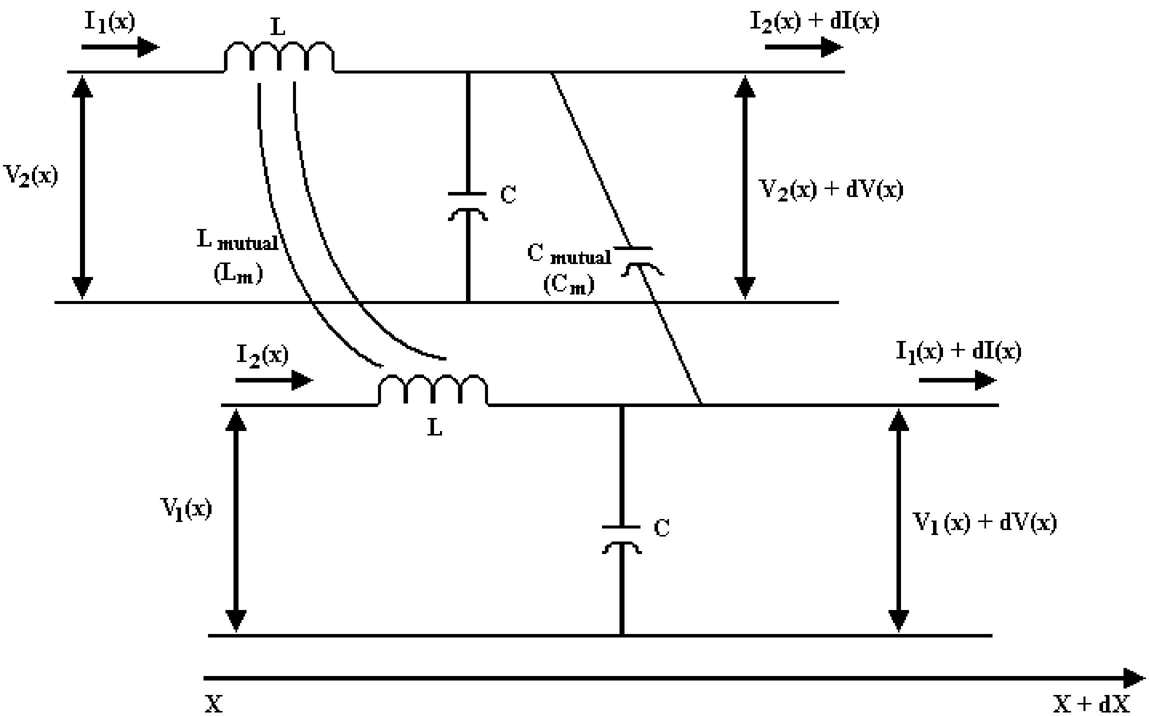
In the case of a pair of coupled transmission lines, each RLCG parameter is actually a 2×2 matrix. For symmetrical uniform coupled transmission lines, the matrices are real and symmetrical.

Understanding How RLCG Parameters Are Extracted

Coupled-Transmission Line (CPTL) Models

Start with an ideal lossless symmetrical CPTL as shown in Figure 8-6.

Figure 8-6 Lossless Symmetrical Coupled Transmission Line



The Telegraphers set of equations are described in equation sets 2 and 3.

Equation set 2

$$-\frac{\partial V_1}{\partial x} = L\frac{\partial I_1}{\partial t} + L_m\frac{\partial I_2}{\partial t}$$

$$-\frac{\partial V_2}{\partial x} = L_m\frac{\partial I_1}{\partial t} + L\frac{\partial I_2}{\partial t}$$

Equation set 3

$$-\frac{\partial I_1}{\partial x} = C\frac{\partial V_1}{\partial t} + C_m\frac{\partial (V_1 - V_2)}{\partial t}$$

$$-\frac{\partial I_2}{\partial x} = C_m\frac{\partial (V_2 - V_1)}{\partial t} + C\frac{\partial V_2}{\partial t}$$

These equations represent the closest form to the physical behavior of CPTL, since they describe each line by its own self parameters (L,C) and the mutual couplings (Lm and Cm). Refer to Figure 8-6. Obviously, these equations can be extended for the lossy case, where the conductor and dielectric losses would be taken into account.

These parameters will be called self-parameters

By rearranging equation sets 2 and 3, we can define a second set of parameters:

Equation set 4

$$-\frac{\partial V_1}{\partial x} = L_{11}\frac{\partial I_1}{\partial t} + L_{12}\frac{\partial I_2}{\partial t}$$

$$-\frac{\partial V_2}{\partial x} = L_{21}\frac{\partial I_1}{\partial t} + L_{22}\frac{\partial I_2}{\partial t}$$

Equation set 5

$$-\frac{\partial I_1}{\partial x} = C_{11}\frac{\partial V_1}{\partial t} + C_{12}\frac{\partial V_2}{\partial t}$$

$$-\frac{\partial I_2}{\partial x} = C_{21}\frac{\partial V_1}{\partial t} + C_{22}\frac{\partial V_2}{\partial t}$$

In the general case, RLCG parameters are grouped in 2x2 real matrices, each term being frequency-dependent. In the case of symmetrical coupled-lines, these matrices are symmetrical:

Equation set 6

$$R = \begin{pmatrix} R_{11} & R_{12} \\ R_{12} & R_{11} \end{pmatrix} \qquad G = \begin{pmatrix} G_{11} & G_{12} \\ G_{12} & G_{11} \end{pmatrix}$$

$$L = \begin{pmatrix} L_{11} & L_{12} \\ L_{12} & L_{11} \end{pmatrix} \qquad C = \begin{pmatrix} C_{11} & C_{12} \\ C_{12} & C_{11} \end{pmatrix}$$

These parameters are called SPICE-parameters.

Most SPICE-type simulators use this type of model description with different variations in the implementation. This aspect is described in more detail in "Exporting Transmission Line Data" on page 205.

The third model representation is called Differential-Common Modes Equivalent Model. The main reason this model was created is because the current RLCG extraction algorithm deals only with single-ended transmission lines (SETL). This model treats each quadrant from the mixed-mode S-parameters, in particular the Diff-Diff and Com-Com, as two separate SETL, with predefined normalized impedance.

The new set of RLCG parameters extracted for the differential and common modes, can be represented in a frequency-dependent matrix format, as shown in Equation set 7.

Equation set 7

$$R = \begin{pmatrix} R_{dd} & 0 \\ 0 & R_{cc} \end{pmatrix} \qquad G = \begin{pmatrix} G_{dd} & 0 \\ 0 & G_{cc} \end{pmatrix}$$

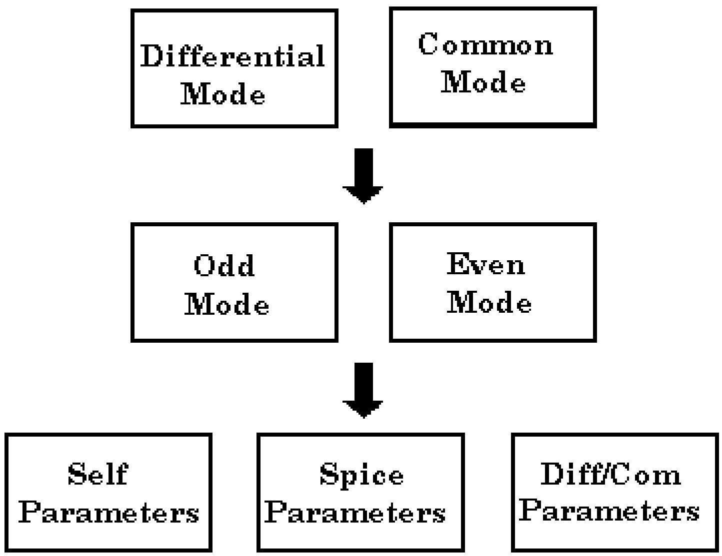
$$L = \begin{pmatrix} L_{dd} & 0 \\ 0 & L_{cc} \end{pmatrix} \qquad C = \begin{pmatrix} C_{dd} & 0 \\ 0 & C_{cc} \end{pmatrix}$$

These parameters are called Diff/Com parameters.

CPTL RLCG Extraction Procedure

The algorithm starts by extracting the RLCG parameters for each of these two modes: Diff-Diff and Com-Com. In the case of symmetrical CPTL, mode-conversion should be negligible. The Odd Mode and Even Mode, although not displayed, are calculated as interim step in extracting the three parameters sets from the Differential and Common modes. Refer to Figure 8-7.

Figure 8-7 Extraction Procedure



The following describes the formulas for the different transformations. Equation sets 8 and 9, relate the Odd and Even modes to the Differential and Common modes of propagation.

Equation set 8

$$Z_{cc} = \frac{Z_e}{2}$$

$$\gamma_{cc} = \gamma_e$$

Equation set 9

$$Z_{dd} = 2\,Z_o$$

$$\gamma_{dd} = \gamma_o$$

Using the propagation constant and the characteristic impedance for the Odd/Even modes, the SPICE-parameters can be derived as shown in equation sets 10 through 13.

Equation set 10

$$R_{11} = \mathrm{Re}\{\gamma_e Z_e + \gamma_o Z_o\}$$
$$R_{12} = \mathrm{Re}\{\gamma_e Z_e - \gamma_o Z_o\}$$
$$L_{11} = \mathrm{Im}\{\gamma_e Z_e + \gamma_o Z_o\}/\omega$$
$$L_{12} = \mathrm{Im}\{\gamma_e Z_e - \gamma_o Z_o\}/\omega$$

Equation set 11

$$G_{11} = \mathrm{Re}\{\gamma_e / Z_e + \gamma_o / Z_o\}$$
$$G_{12} = \mathrm{Re}\{\gamma_e / Z_e - \gamma_o / Z_o\}$$
$$C_{11} = \mathrm{Im}\{\gamma_e / Z_e + \gamma_o / Z_o\}/\omega$$
$$C_{12} = \mathrm{Im}\{\gamma_e / Z_e - \gamma_o / Z_o\}/\omega$$

Equation set 12

$$R_S = R_{11}$$
$$R_m = R_{12}$$
$$L_S = L_{11}$$
$$L_m = L_{12}$$

Equation set 13

$$G_S = G_{11} + G_{12}$$
$$G_m = -G_{12}$$
$$C_S = C_{11} + C_{12}$$
$$C_m = -C_{12}$$

RLCG Output Plots

The following individual plots show the extracted RLCG parameters. See Figure 8-8.

Figure 8-8 **Extracted RLCG Parameters**

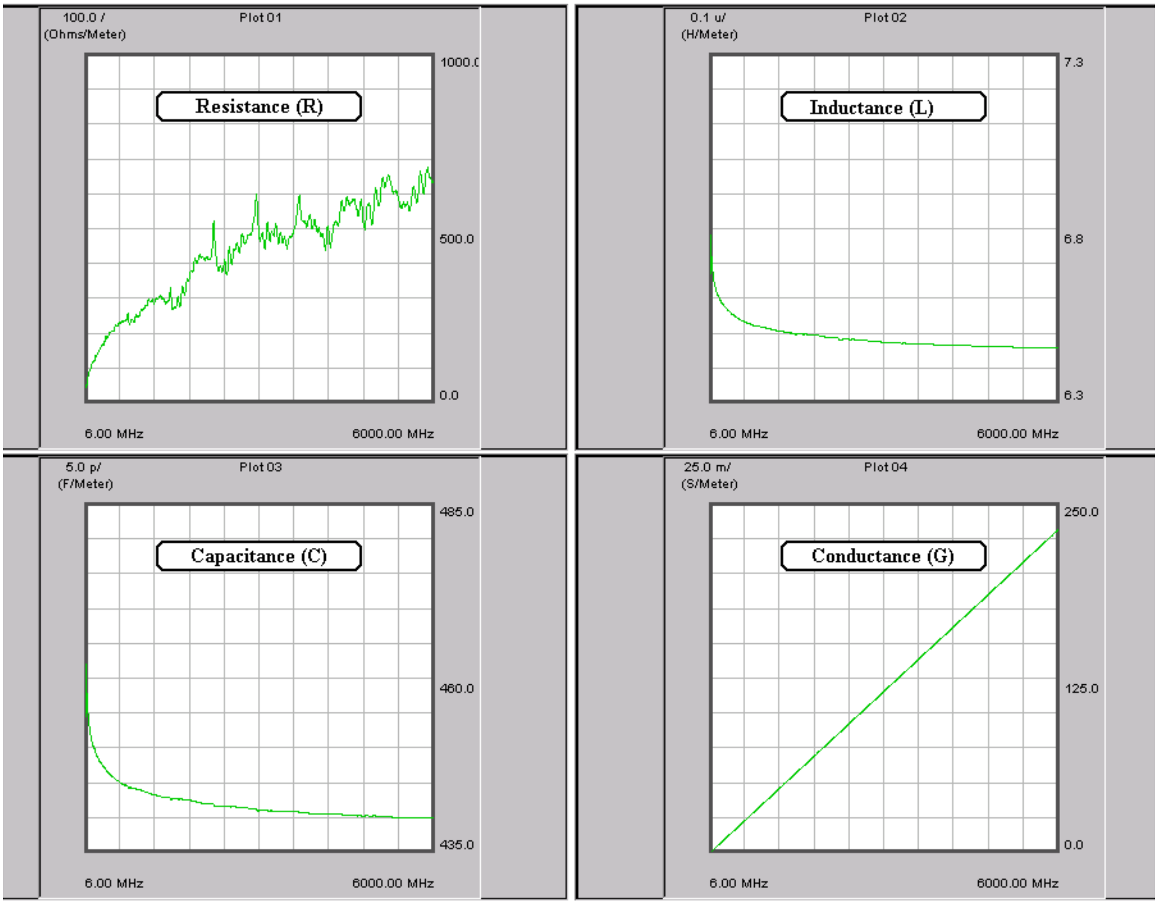


Figure 8-9 illustrates the propagation constant and Figure 8-10 illustrates the characteristic impedance in real-imaginary format.

Figure 8-9 Propagation Constant (Unwrapped)

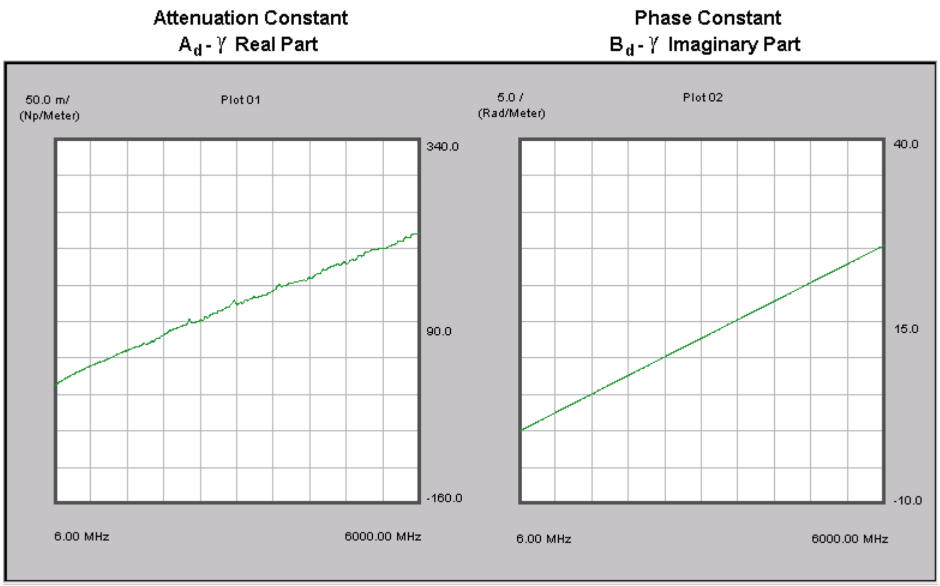
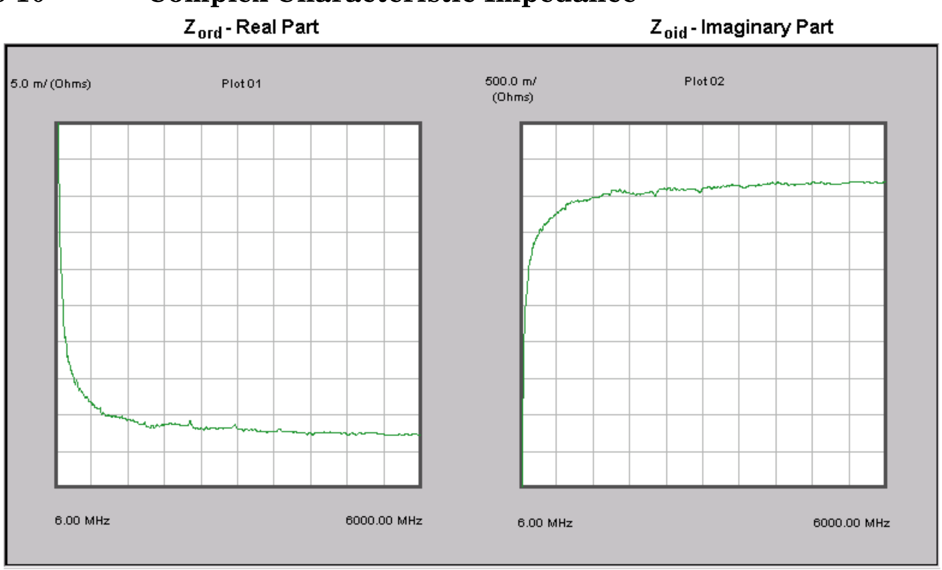


Figure 8-10 Complex Characteristic Impedance



Viewing Transmission Line Data

This section guides you with opening measured data and viewing the data using transmission line (RLCG) parameter extraction. There are eight transmission line parameters for each transmission line format. You may elect to view any number of these parameters.

Opening a Transmission Line Plot Window

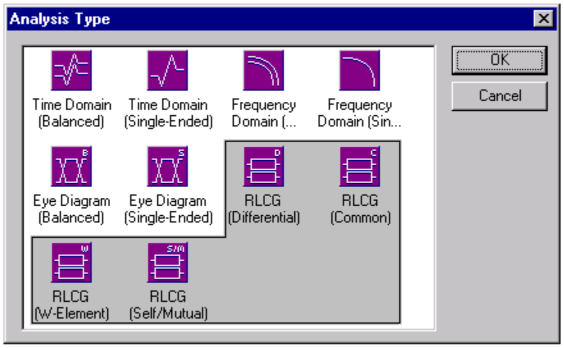
The transmission line parameters may be viewed in any of four formats (differential, common, W-Element, and self/mutual).

You may open the transmission line plot window in one of four ways.

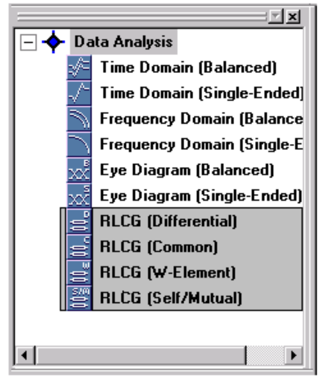
- From the Startup Wizard immediately before selecting the **Measure** button where you must select the analysis type - see (A) of Figure 8-11
- From the Startup Wizard Welcome Screen by selecting **Load Measurement** where you must select the analysis type - see (A) of Figure 8-11
- From the **Open** selection in the **File** menu or the **Open** icon in the **Toolbar** where you must select the analysis type - see (A) of Figure 8-11
- From the **Browser** when data is already being viewed in another analysis type by selecting one of the RLCG choices - see (B) of Figure 8-11

NOTE Using the **Browser** method to open a window requires that you select the parameters that you want to view from the **Parameter Bar** or the **RLCG** menu once the blank plot window is displayed after the T-Line parameters are defined in the next step.

Figure 8-11 Opening the Transmission Line Plot Window



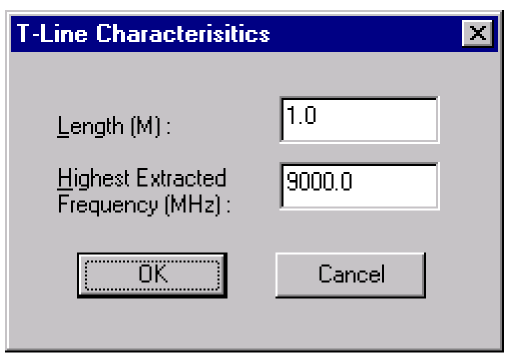
(A)



(B)

The *T-Line Characteristics* dialog box (Figure 8-12) is then displayed. Enter the length of the transmission line (in meters) and the highest measured frequency (in megahertz) and then click **OK**.

Figure 8-12 T-Line Characteristics Dialog Box



Length (M) can be used to scale extracted values in units/meter.

Highest Extracted Frequency (MHz) defaults to the stop frequency. However, this can be set at a lower frequency to better fit your parameters.

The individual parameter selections are based on the specific RLCG data analysis type. The following lists each data analysis type and its associated parameters.

RLCG (Differential):	Rd, Ld, Cd, Gd, Zor, Zoi, Ad, Bd
RLCG (Common):	Rc, Lc, Cc, Gc, Zor, Zoi, Ac, Bc
RLCG (W-Element):	R11, L11, C11, G11, R12, L12, C12, G12
RLCG (Self/Mutual):	Rs, Ls, Cs, Gs, Rm, Lm, Cm, Gm

where,

A represents the Attenuation Constant (α)

B represents the Phase Constant (β)

C represents Capacitance

G represents Conductance

L represents Inductance

R represents Resistance

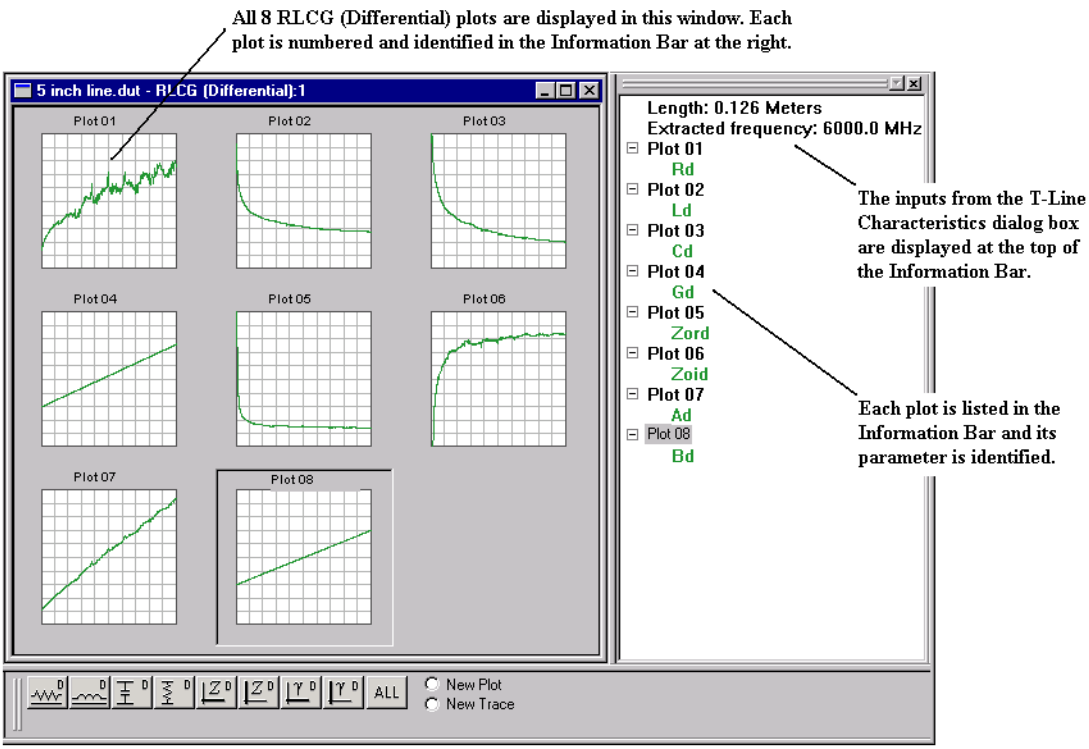
Z represents Impedance

Viewing All Parameters

In all cases, except when you open the plot window using the **Browser**, all eight of the RLCG parameter plots are displayed. Each of the plots are numbered. The **Information Bar** immediately to the right of the plots lists each plot by number and displays the associated parameter. See Figure 8-13.

As mentioned previously, when you open the plot window from the **Browser**, an empty plot window is displayed. View all eight plots by selecting **All** from the **Parameter Bar** or from the **RLCG** menu with **New Plot** selected.

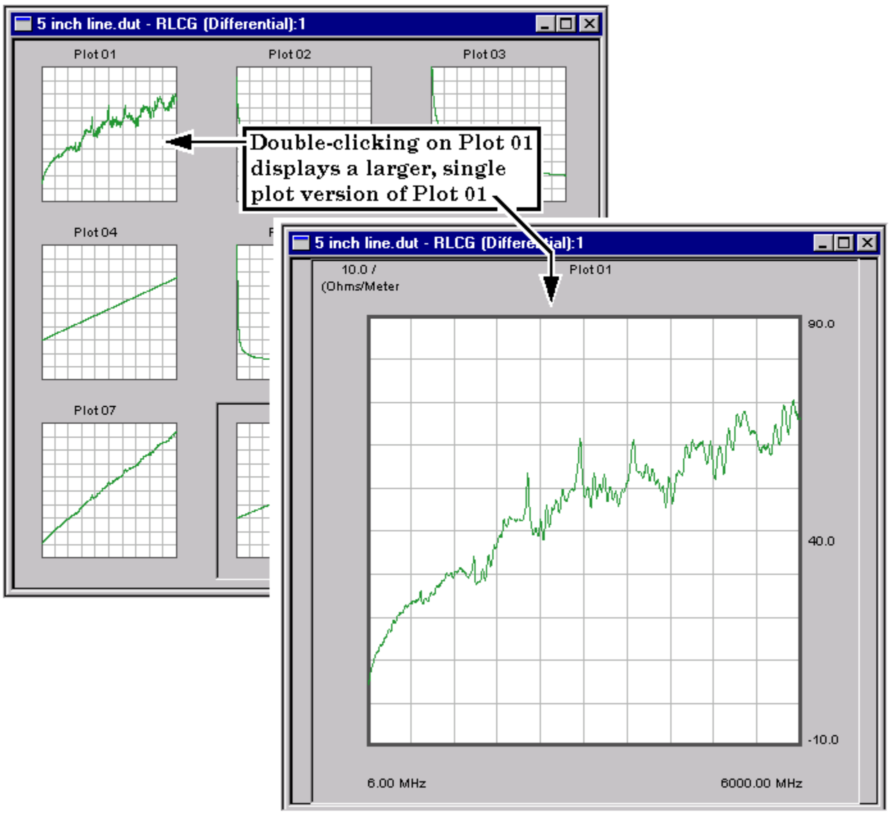
Figure 8-13 Balanced Frequency Domain Plots with Information Bar



Viewing a Single RLCG Parameter

Viewing a single plot gives better resolution. To display a single plot, from the window with all eight plots (or with multiple plots if you have a custom plot window displayed), double-click on the plot that you would like to view. See Figure 8-14.

Figure 8-14 Opening a Single Plot

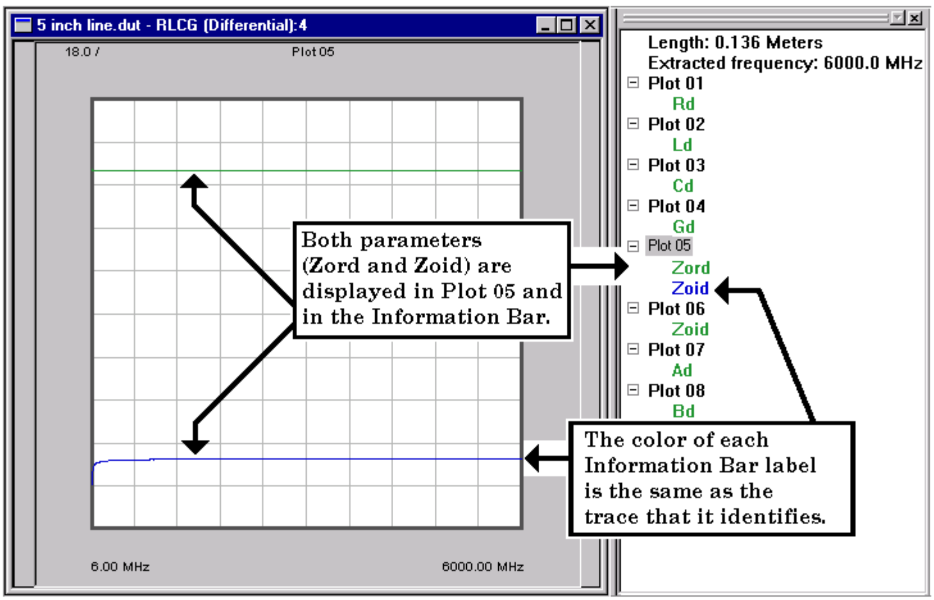


Double-click on the single plot to return to the original view with multiple plots.

View Multiple Traces on a Single Plot

This single plot may have just one parameter or if you choose, it could contain more. For example, you could show how Zord compares with Zoid. To do this double-click on the first plot so that is now displaying a single plot similar to Figure 8-14. For this example, Plot 05 (**Zord**) was double-clicked and is displayed as a single plot. With **New Trace** selected in the **Parameter Bar** (or the **RLCG** menu), click the remaining parameters (**Zoid** in this example).

Figure 8-15 A Single Plot with Multiple Traces

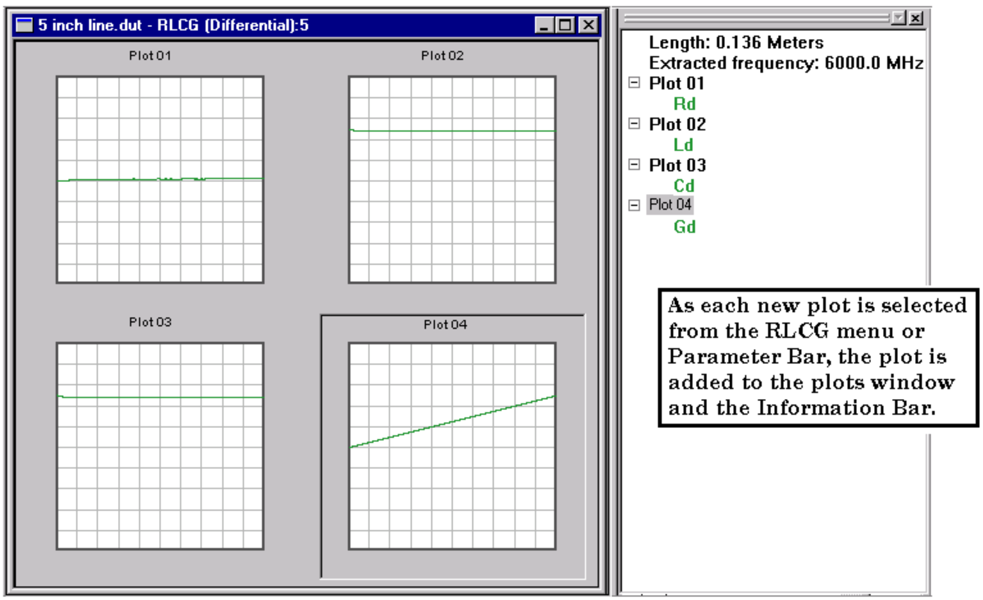


It could contain as many as all eight of the parameters. However, this would be impractical because having eight parameters on a single plot would be very hard to distinguish between the parameters and the vertical scale would have to be large to show all parameters.

Creating a Custom RLCG Plot Window

You can also create a plot window with just the plots you desire. For example, you may want your plot window to show just the four RLCG plots of RLCG (Differential). To create this custom window, open the measured data file in any analysis type. Then, in the **Browser**, select the data type that you want to display the plots. In this example, select **RLCG (Differential)**. A blank plots window is displayed. With **New Plot** selected in the **Parameter Bar** (or the **RLCG** menu), click the desired parameters (R, L, C, and G in this example). As each parameter is selected, a new plot is added to the plots window. See Figure 8-16.

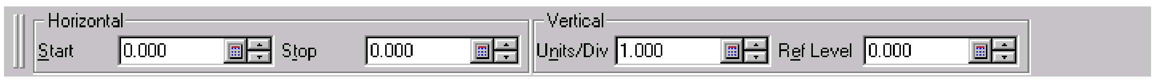
Figure 8-16 Custom S-Parameter Plots Window with Four Plots



Setting the Scale

The PLTS software allows you to change the horizontal and vertical scale of the plots using the **Scaling Bar**.

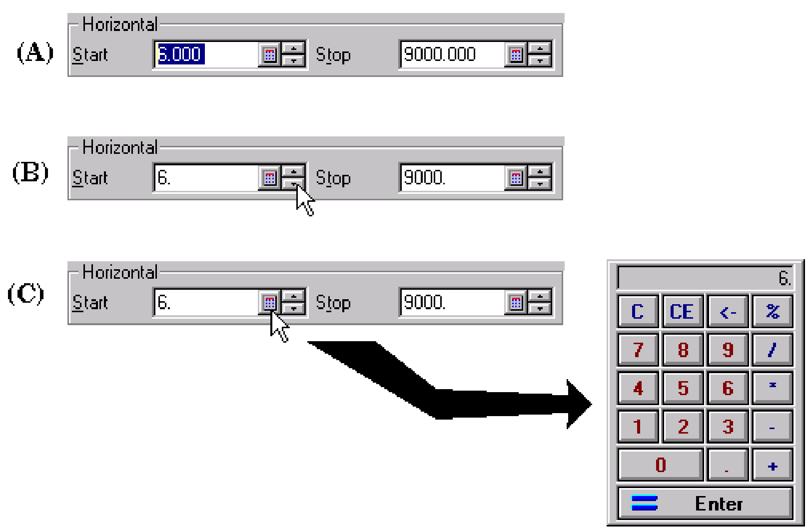
Figure 8-17 Scaling Bar



Change the **Scaling Bar** values by:

- Clicking and dragging within a scaling bar entry box to highlight the current value and then typing the new value. See (A) of Figure 8-18.
- Selecting the up/down arrow buttons to the right of each entry. See (B) of Figure 8-18.
- Selecting the calculator icon to the right of each entry to display a keypad. Click the keypad's numeric buttons to enter a new value and click the **Enter** button to save the new value. See (C) of Figure 8-18. The scaling calculator icon varies slightly between scaling entries meet the requirements of the specific entry.

Figure 8-18 Entering a Scale Value



The horizontal scale is changed by changing the start and stop frequencies in megahertz (MHz). Note that you can not extend the start and stop frequencies beyond the start and stop frequencies used in the measurement.

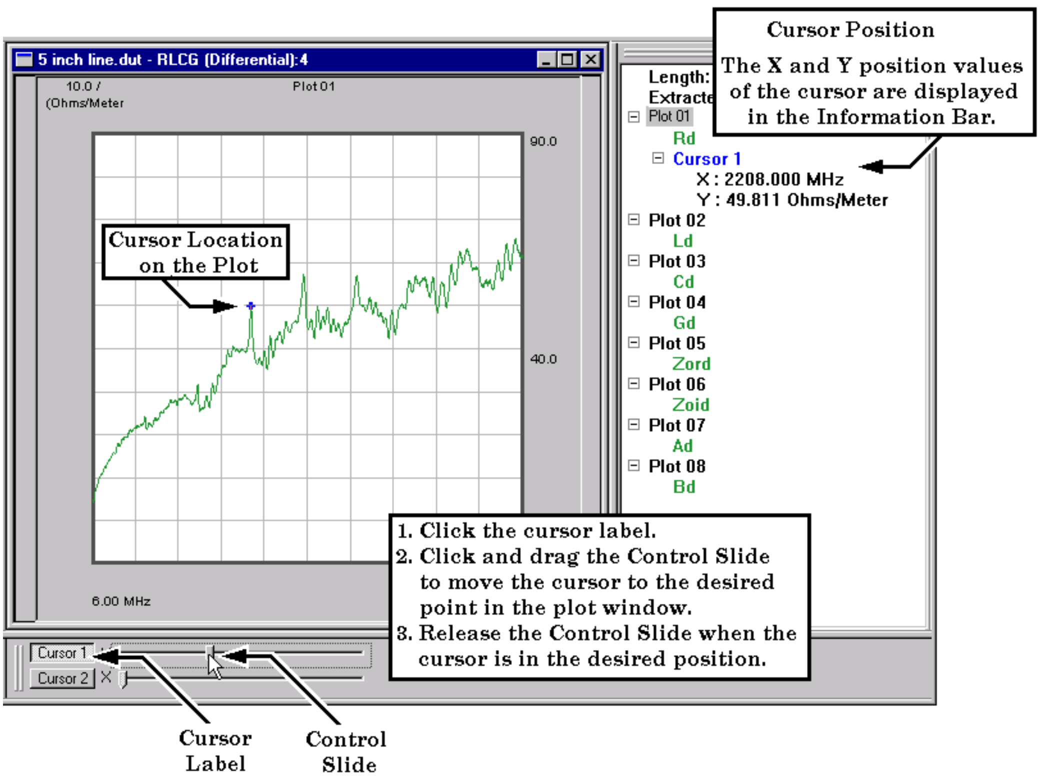
The vertical scale units are changed using the same method as used for the horizontal units. The units vary to be appropriate for each plot. For example, when the plot is inductance, the units are in Henrys while when a resistive plots is displayed, the units are ohms.

Using Cursors

Cursors may be used to find specific locations along the plot. When a cursor is activated, it's marker can be moved to any location along the plot trace. The horizontal and vertical values are displayed on the **Information Bar**. Two cursors are available.

To display a cursor, click the cursor label (either **Cursor 1** or **Cursor 2**) in the **Cursor Bar** and then click and drag its slide control. While dragging the control slide, watch the marker move along the trace in the active plot. Notice that the cursor values are displayed in the **Information Bar**.

Figure 8-19 Activating a Cursor

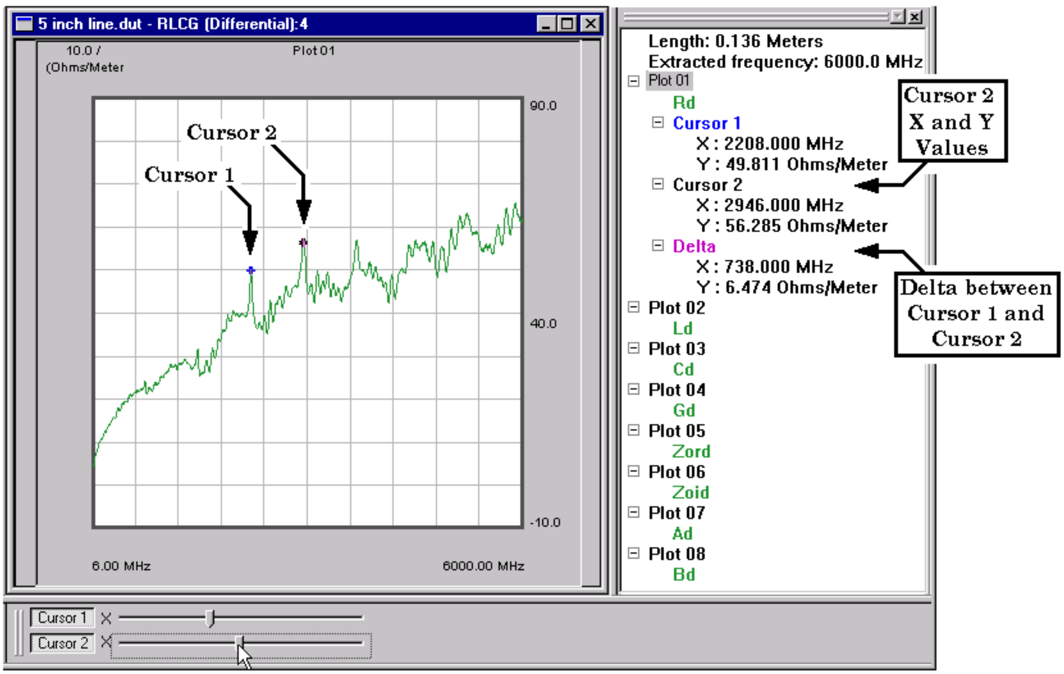


You can also change the cursor position, one point at a time, by using the left/right arrow keys on the keyboard.

Activate the second cursor as you did the first cursor. Notice that both cursor values along with the difference, the **Delta** (Δ), between the cursors are displayed in the **Information Bar**.

Delta = Value of Cursor 2 – Value of Cursor 1

Figure 8-20 Activating a Second Cursor



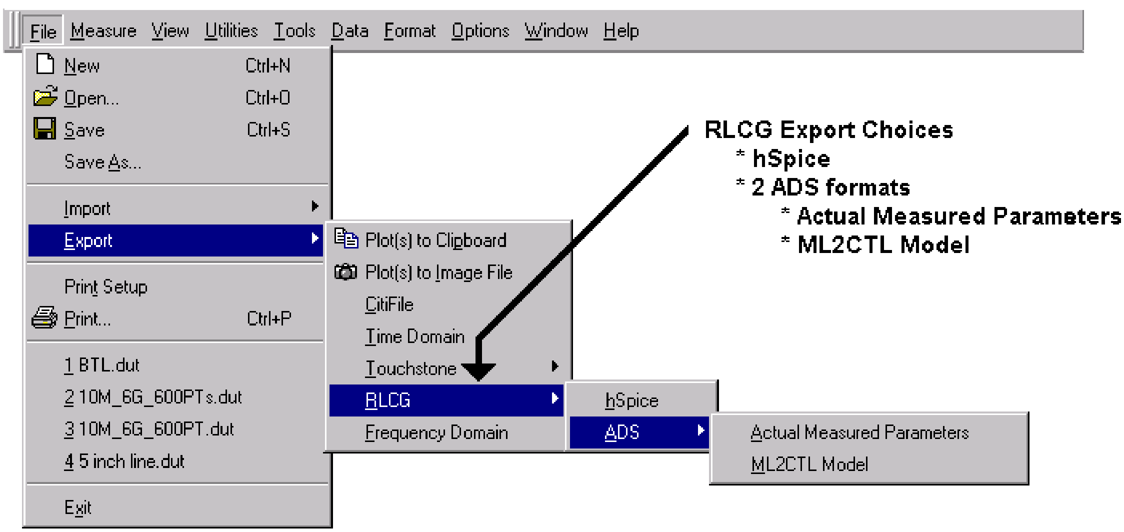
Exporting Transmission Line Data

The PLTS can export the transmission line data to the main electronic design automation (EDA) software tools used by R&D engineers in the field of signal integrity. These EDA simulators are:

- HSPICE
- ADS (Advanced Design System - Integrated Design Software and Test Instrumentation solution from Agilent Technologies)

Selecting the **Export** in the **File** menu to access the three RLCG export menu selections. A brief description and the syntax of each selection is listed in this section.

Figure 8-21 RLCG Export Menu



hSpice

The **hSpice** selection in Figure 8-21 exports the transmission line data to HSPICE as fitted parameters in an ASCII file to be used with the W-element Transmission Line model, a format available in HSPICE. The syntax is listed below:

File name: Ext_Model.rlc

```
* RLGC parameters for a 2-conductor lossy
* frequency-dependent lines
* N (number of signal conductors
*********************************
2
* L
*********************************
2.311e-6
4.14e-7   2.311e-6
* C
*********************************
2.392e-11
-5.41e-12   2.392e-11
* R_DC
*********************************
42.5
0    42.5
* G_DC
*********************************
0.000609
-0.0001419    0.000609
* R_AC
*********************************
0.001303
0         0.001303
* G_AC
*********************************
5.242e-13
-1.221e-13   5.242e-13
```

ADS Actual Measured Parameters

The second format, **Actual Measured Parameters**, exports extracted parameters versus frequency in an ASCII file for ADS. The format of this file is the ADS discrete file format. The syntax is listed below:

```
BEGIN DSCRDATA
%INDEX Freqs  Rdd  Ldd  Cdd  Gdd
1, 5, 5.074784114, 5.42871376384E-7, 6.28220297914E-11,2.36737159369E-6
2, 10, 5.64906645339, 5.40149885542E-7, 6.25070940881E-11,3.73474318738E-6
3, 15, 6.07688409858, 5.39555482061E-7, 6.24383086726E-11,5.10211478107E-6
END
```

ADS ML2CTL Model

The last format, **ML2CTL Model**, exports fitted parameters in an ASCII file (also the discrete file format) to be used with the MultiLayer 2 Coupled Transmission Lines (ML2CTL) model. The syntax is listed below:

```
BEGIN DSCR(RLGC)
! C[i][j]/eps0  L[i][j]/mu0  Rdc[i][j]  Rhf[i][j]/sqrt(f_GHz)
G[i][j]/omega*eps0
% C(real)  L(real)  Rdc(real)  Rhf(real) G(real)
10.1504 0.330146 0 0 0
-1.97204 0.0928309 0 0 0
-1.97204 0.0928309 0 0 0
10.1504 0.330146 0 0 0
END
```

Where, eps0 (epsilon) equals the dielectric constant of air,
mu0 equals the permittivity constant of air,
omega equals $2\pi \times$ frequency,
C equals the capacitance,
L equals the inductance,
Rdc equals the DC resistance,
Rhf equals the high frequency resistance, and
G equals the conductance

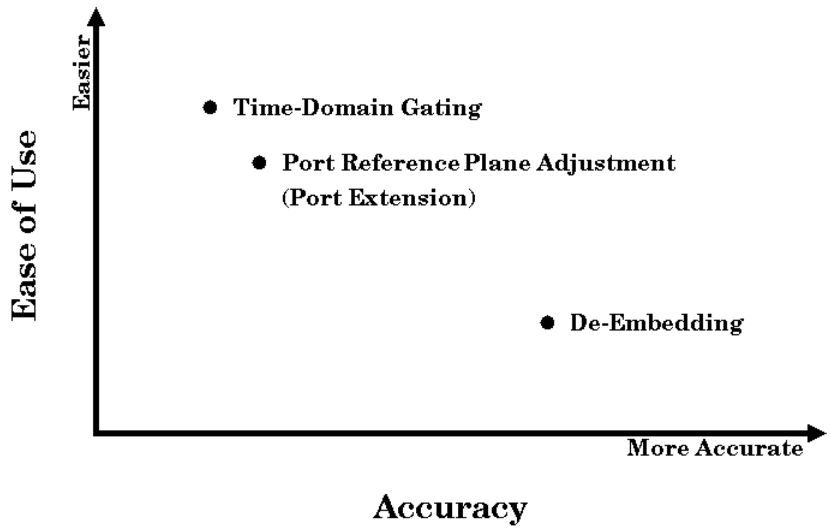
NOTE You can also use exported measurements in ADS using either CitiFile or Touchstone formats.

---

9 Removing Unwanted Effects from the Measurement

To reduce your measurement, analysis, and redesign cycles, the physical layer test system offers three techniques to help you define/redefine your device under test (DUT).

Figure 9-1 Ease Versus Accuracy of Removing Unwanted Effects



- **Gating** provides the ability to remove the effect of a particular circuit element mathematically from time-domain plots. The gated section removes a section of the plot that you define, replacing it with an ideal transmission line having the same electrical delay as the removed section. By observing the original frequency domain response and the transformed frequency domain response, the effect of the gating operation on the S-parameter data can be seen.
- **Port Reference Plane Adjustment** (or port reference plane rotation) mathematically extends the measurement plane to the DUT, but assumes the fixture looks like a perfect transmission line: a flat magnitude response, a linear phase response, and constant impedance. Port reference plane adjustments are usually done after a coaxial calibration has been performed at the end of the test cables. If the fixture is very well designed, this technique may be sufficient.
- **De-embedding** affords a very accurate technique that removes the effect of added loss, phase shift, and mismatch due to adding adapters, probes, and fixtures to your DUT. It combines the errors determined from a coaxial calibration with the errors in the fixture to obtain a single error coefficient array that corrects for everything up to the measurement plane of the DUT. Deembedding uses an accurate linear model of the fixture, or measured S-parameter data of the fixture. This modeled or measured data is then mathematically removed from the DUT measurement data in post-processing.

Gating

The controls for gating the time domain response provide the ability to remove the effect of a particular circuit element mathematically. You define the start- and stop-points of the gate. An 'Ideal' gate replaces the gated section with an ideal transmission line having the same electrical delay as the section that it replaced.

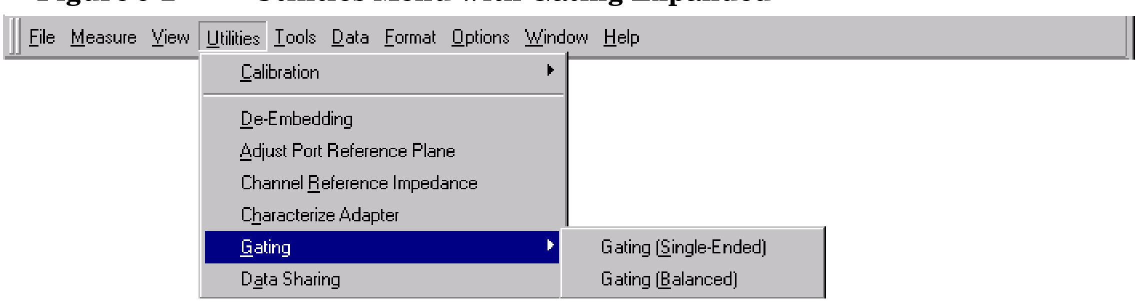
Up to 10 gates can be added. The gates are numbered sequentially from the left edge of the plot to the right edge. For example, the first gate (Gate 1) was added. Then a second gate is added to the left of the Gate 1. The gates are then renumbered such that the gate on the left (the second gate that was added) becomes Gate 1, and the original gate is changed to Gate 2. Either deleting or moving a gate can cause the gates to be renumbered.

By observing the original frequency domain response and the transformed frequency domain response, the effect of the gating operation on the S-parameter data can be seen.

To Add a Gate

1. Click **Gating** from the **Utilities** menu. Then click either **Gating (Single Ended)** or **Gating (Balanced)** depending on whether your Time Domain plot is single-ended or balanced.

Figure 9-2 Utilities Menu with Gating Expanded



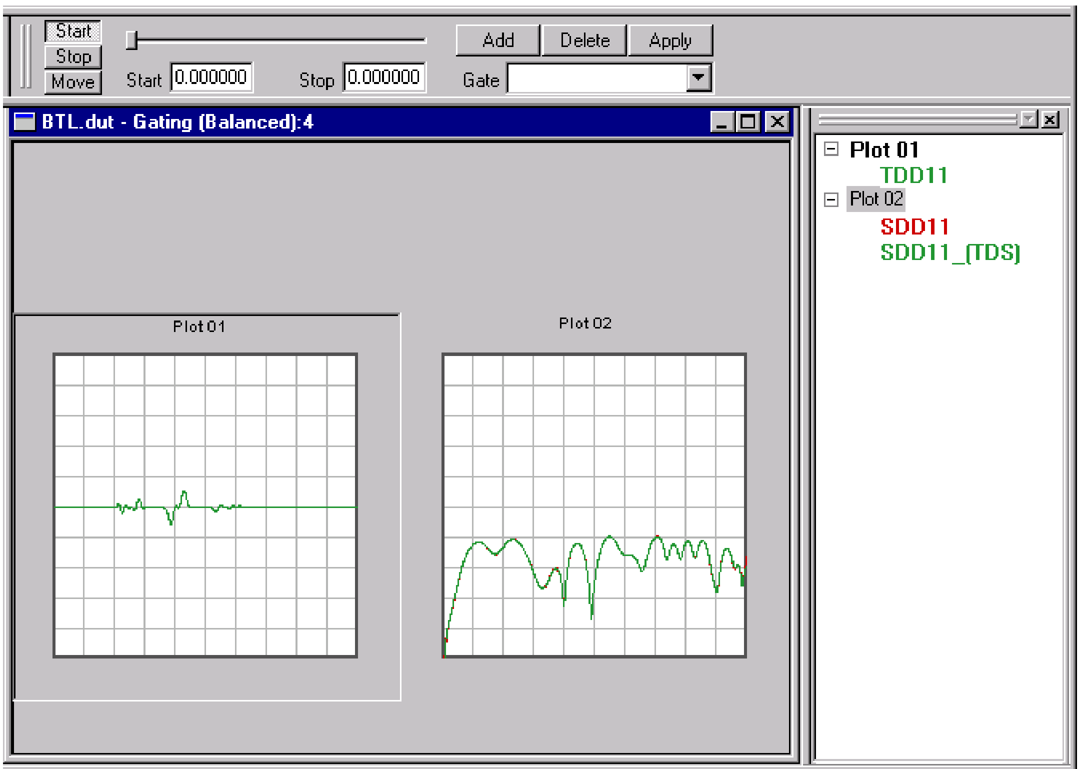
The **Gating Bar** (shown in Figure 9-3) and an empty plot window are displayed when gating is selected from the **Utilities** menu.

Figure 9-3 Gating Bar

2. From the **Parameter Bar** (or from the **Data** menu), select the parameter that will have gates added to them.

   When you select the parameter, two plots are displayed in the plots window. Plot 01 is the parameter you selected displayed in Time Domain mode. Plot 02 is that same parameter displayed in Frequency Domain Mode. See Figure 9-4. When adding a gate to the trace in Plot 01, you will also be able to see how adding the gate affects the parameter in the Frequency Domain by watching Plot 02.

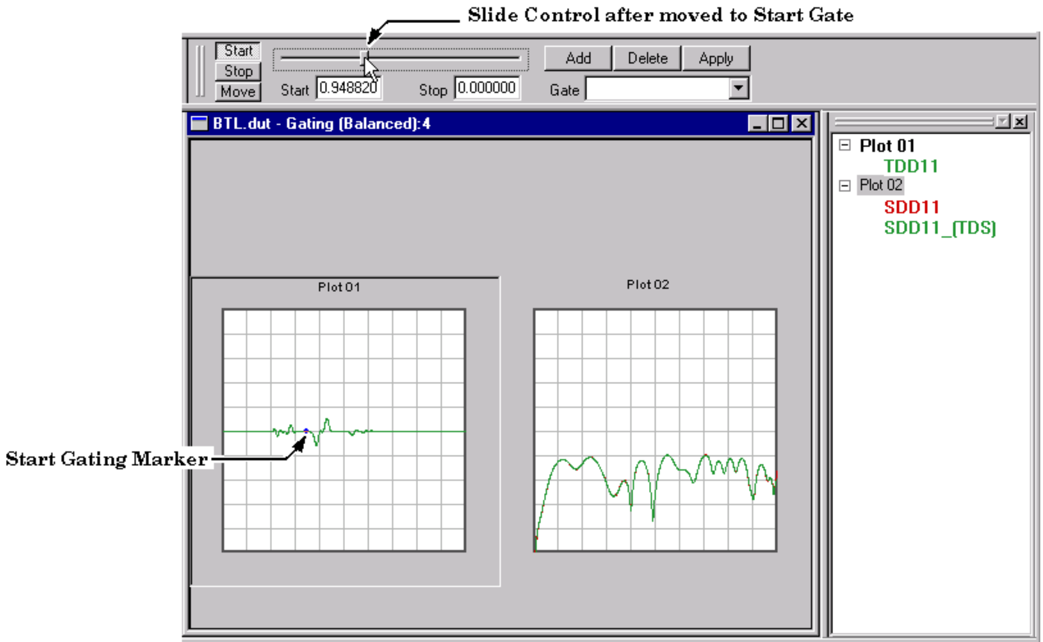
Figure 9-4 Gating Display: Plot 01 Time Domain, Plot 02 Frequency Domain



3. Click the **Start** button.

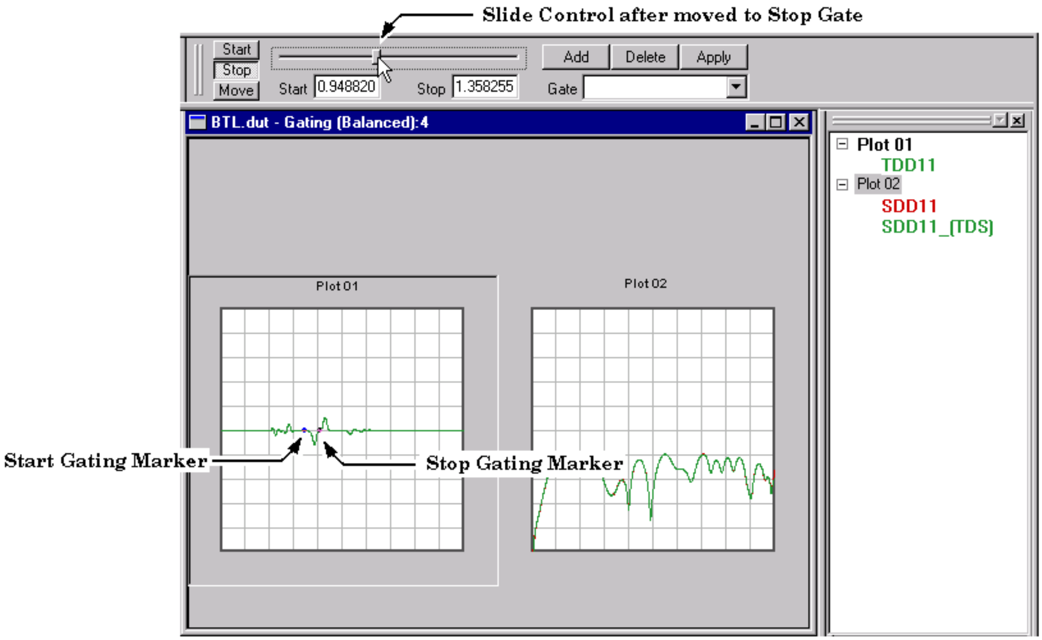
4. While watching the start gating marker on your time domain plot (Plot 01), move the slide control to the right to set the start position of the gate. As the slide control is positioned, the time (or distance) of the start gating marker is displayed in the **Start** box. See Figure 9-5.

Figure 9-5 Setting the Gating Start Position



5. Click **Stop** button.
6. While watching the gating indicator on your time domain plot (Plot 01), move the slide control to the right to set the stop position of the gate.

Figure 9-6 Setting the Gating Stop Position

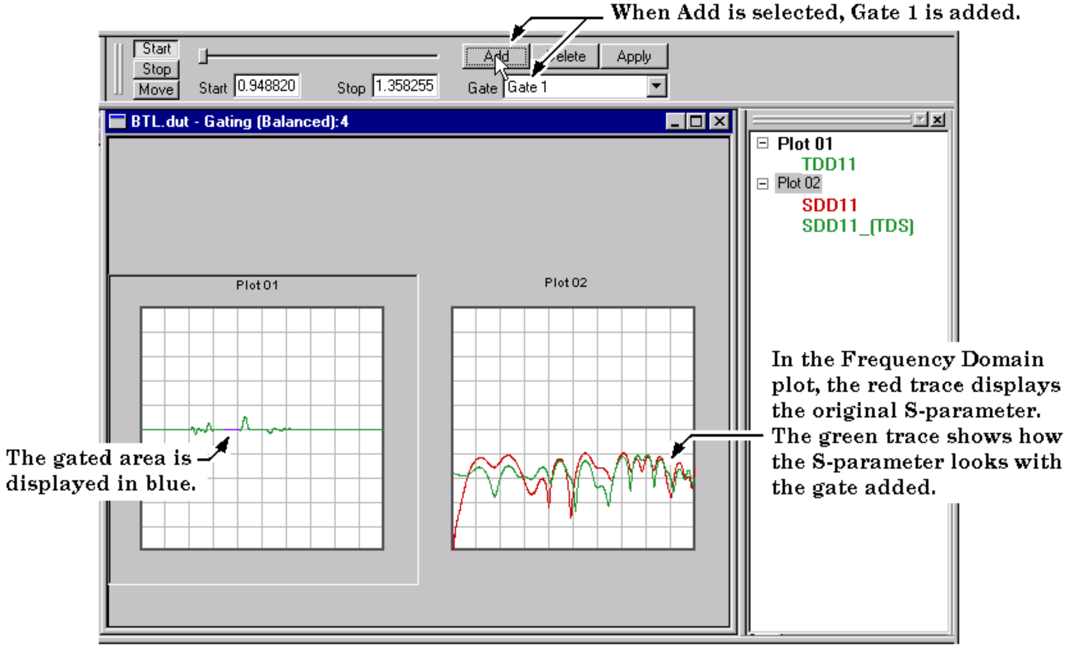


7. Click the **Add** button to add the gate.

   When **Add** is selected:

   - A gate identifier is added to the **Gate** box to identify the number of the gate that was just added. See Figure 9-7.
   - In the Time Domain plot (Plot 01), a straight blue line is added between the start and stop points to reflect that the measured data is being replaced mathematically with an *ideal* transmission line.
   - In the Frequency Domain plot (Plot 02), the red trace shows how the original S-parameter looks. The green trace shows how the S-parameter looks when the effects of the gate are taken into account.

Figure 9-7 The Effects of Adding a Gate



8. Repeat Steps 3 through 7 to add additional gates.

   The maximum number of gates that can be added is 10.

To Move a Gate

A gate can be moved by selecting the gate from the **Gate** list and clicking the **Move** button, and moving the slide control left or right to the desired location. Then select the **Apply** button to have the move take affect. The range between the start and stop values of the gate remains the same, just the start and stop values are changed.

To Delete a Gate

A gate can be deleted by selecting the gate from the **Gate** list and clicking the **Delete** button. The gate numbers are moved down in number when a gate is deleted. For example, when Gate 4 is deleted, Gate 5 becomes Gate 4, and Gate 6 becomes Gate 5, and so on.

To Change the Displayed Gating Plot

The automatically calculated start and stop time values and the DC level (normally approximated from the measured data) can be changed. Enter the value change in the **Start** and **Stop** fields for a change in the start and stop time or in the **DC** field for a change in the DC level and click **Apply**. The gating plot is then displayed using these changes. To return the plot back to it's original values, click **Default**.

Figure 9-8 Position Bar for Gating Plots

Port Reference Plane Adjustment

Adding adapters, fixtures, and probes introduces additional loss, phase shift, and mismatch that can add error to the measurement of your DUT. The port reference plane adjustment feature allows you to move the calibrated reference plane from the end of the test cable toward the DUT in an attempt to eliminate the effects of phase shift introduced by the addition of adapters, fixtures, and probes. Port reference plane adjustment does not correct for additional loss and mismatch introduced by these items.

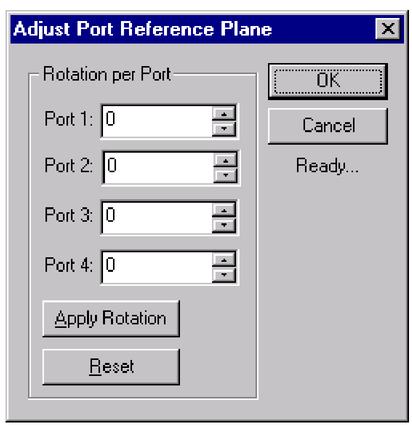
Port reference plane adjustment can be adjusted using either of the two methods described in this section. Refer to To Adjust Port Reference Plane located below or "To Rotate the Reference Plane Using the De-Embedding Dialog Box" on page 218.

To Adjust Port Reference Plane

The easiest way to adjust the port reference plane is by using the following method:

1. Select **Adjust Port Reference Plane** from the **Utilities** menu to open the *Adjust Port Reference Plane* dialog box where you can change the reference plane rotation settings and recalculate the displayed data.

Figure 9-9 Adjust Phase Skew Dialog Box



2. Enter the new reference plane values for the desired ports by using the arrows or entering the values in the port box directly.

   A positive value rotates the phase towards the DUT (effectively removing a length of 50Ω line) and a negative number rotates the phase away from the DUT (effectively adding a length of 50Ω line).

3. Click **Apply Rotation** to recalculate the data and display the new plots.

   Note that when reference plane rotation is applied, the **De-Embedding** indicator color changes to a bright color. See Figure 9-11 on page 219.

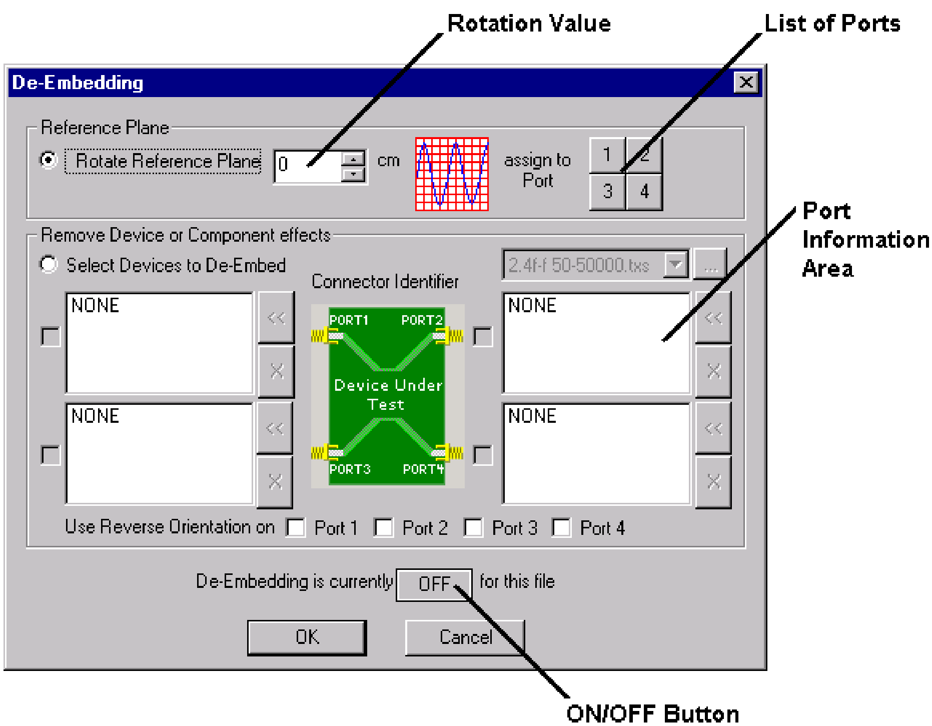
   Reset returns the values to zero, recalculates the data, and displays original plots.

To Rotate the Reference Plane Using the De-Embedding Dialog Box

1. Select **De-Embedding** from the **Utilities** menu to open the *De-Embedding* dialog box.

   Use the *De-Embedding* dialog box to configure DUT reference planes by de-embedding probes, fixtures, or adapters from the measured data.

Figure 9-10 De-Embedding Dialog Box



2. In the **Reference Plane** area, click **Rotate Reference Plane**.

3. Enter a reference plane rotation value (in centimeters-in-air).

   You can use the spinner or click in the **cm** box and enter a value directly.

   A positive value rotates the phase towards the DUT (effectively removing a length of 50Ω line) and a negative number rotates the phase away from the DUT (effectively adding a length of 50Ω line).

4. Select the port to assign the rotation value to a port by selecting from the port numbers.

   As you select a port, that rotation value is shown below in the information area for that port.

5. Repeat steps 3 and 4 until you have assigned rotation values to all appropriate ports.

6. Turn the port reference plane adjustment on by clicking the **ON/OFF** button (shown in Figure 9-10) until the label reads: **De-embedding is currently ON for this file**

7. Click **OK** to accept the configuration and exit the dialog box.

   Cancel ignores any changes and exits the dialog box.

The **De-Embedding** indicator on status bar means that De-embedding is being applied. See Figure 9-11.

Figure 9-11 De-Embedding Indicator on the Status Bar

De-Embedding

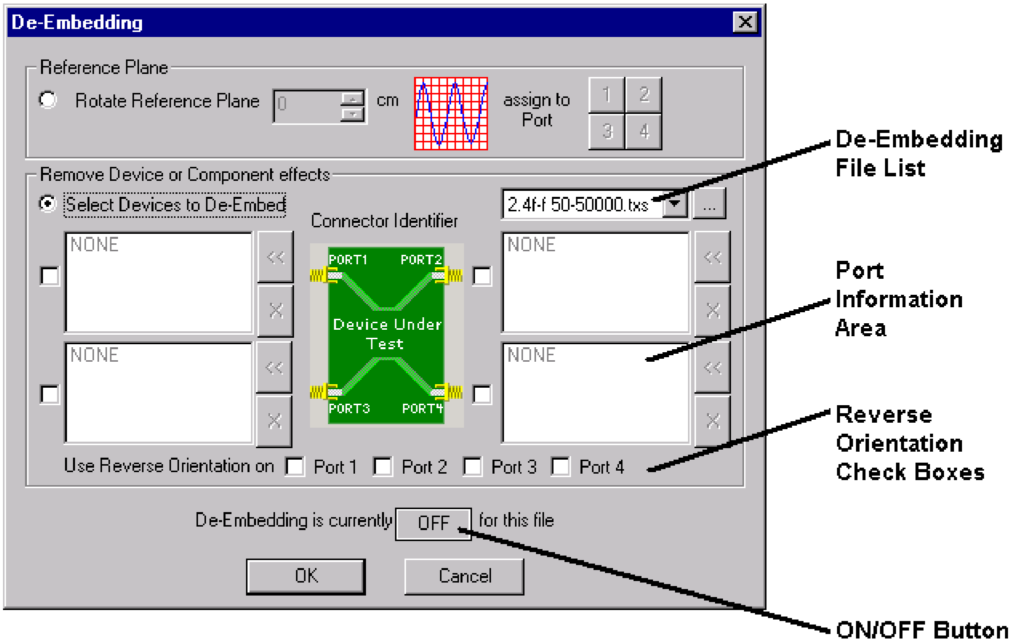
Adapters, test fixtures, or other non-DUT structures introduce unwanted effects and error into measurement results. These unwanted effects typically include additional loss, phase shift, mismatch, discontinuities, and time delay. De-embedding is the process of mathematically removing previously characterized performance of the non-DUT structure from the measurement in post-processing.

NOTE De-embedding is a powerful utility, but requires advanced S-parameter characterization of the non-DUT structure through measurement or modeling. While measuring the structure can provide the most accurate characterization, it may be difficult or impossible to perform the measurement due to connectivity issues. In these cases, S-parameter models may offer the best alternative.

After an S-parameter file of the non-DUT structure is created in CitiFile format, it is user-modified and saved as an adapter characterization file (with a ".txs" filename extension). See "Converting a CitiFile to a PLTS Adapter File" on page 380. At that point, it is ready to be used by following the instructions below.

1. Select **De-Embedding** from the **Utilities** menu to open the *De-Embedding* dialog box.

Figure 9-12 De-Embedding Dialog Box



2. Click **Select Device to De-Embed**.
3. Select a de-embedding file (.txs) that you want to use from the de-embedding file list.
4. Select the check box associated with the port to which the file applies.
5. Click the associated **<<** button to add the file to the port. (Clicking the ✕ button will remove the file from the port.)
6. Repeat steps 3 through 5 until you have assigned de-embedding files to all appropriate ports.
7. Select all ports that use reverse adapter orientation.

   Reverse orientation is noted by check marks for each port specified in the **Use Reverse Orientation** check boxes. Reverse orientation refers to when port 1 of the adapter is connected to the DUT. Refer to "Characterizing Adapters" on page 107 for further information and instructions on performing adapter characterization.
8. Turn the de-embedding on by clicking the **ON/OFF** button (shown in Figure 9-12) until the label reads: **De-embedding is currently ON for this file**

9. Click **OK** to accept the configuration and exit the dialog box.

   Cancel ignores any changes and exits the dialog box.

The **De-Embedding** indicator on status bar means that de-embedding is being applied. See Figure 9-13.

Figure 9-13 De-Embedding Indicator on the Status Bar

III Reference

Part III provides reference information related to operating the physical layer test system.

Chapter 10, “Menu Reference”	Provides you with descriptions of each menu bar selection in the test system software.
Chapter 11, “Specifications and Characteristics”	Provides you with the specifications and characteristics of the physical layer test system.
Chapter 12, “Test Set Front Panel and Rear Panel”	Provides you with specific information regarding each test set front panel and rear panel connector, switch, fuse, and LED indicator.
Chapter 13, “Troubleshooting and Maintenance”	Provides you with information about troubleshooting the test system, contacting Agilent for assistance, care of test cables and coaxial connectors, and electrostatic discharge.
Chapter 14, “Safety and Regulatory Information”	Provides you with information that will allow you to operate the test system safely. This chapter also lists the appropriate information required by regulatory agencies.

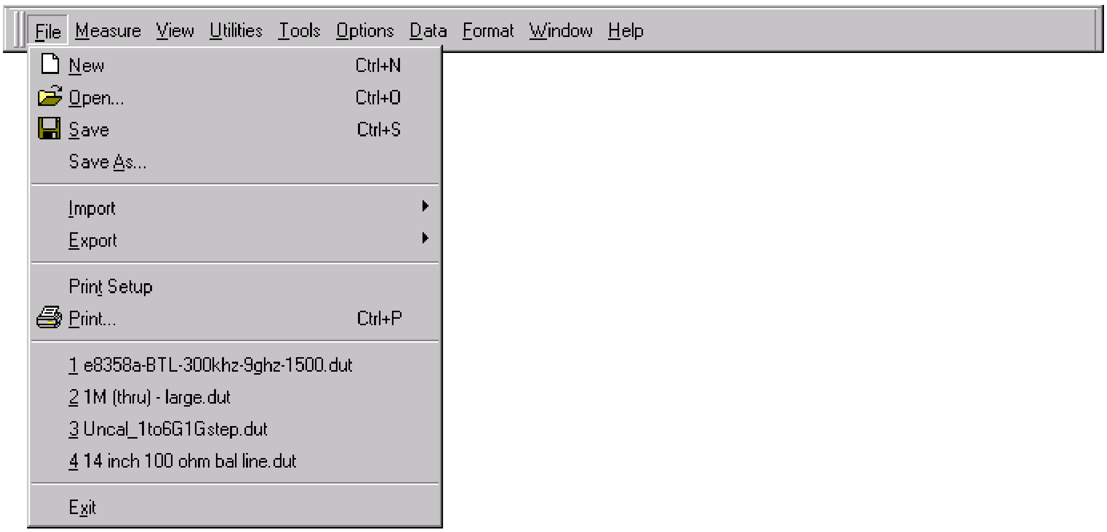
10 Menu Reference

The following menus and each of their selections are described in detail in this chapter. Many of these menus are displayed only under specific measurement conditions. Refer to each specific menu on the pages listed for selections and conditions.

File Menu

The **File** menu provides access to many standard software functions such as creating, opening, and saving data, importing and exporting files, printing, and exiting the software.

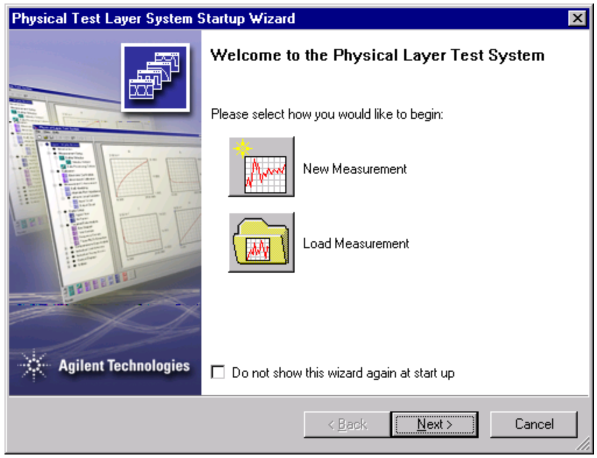
Figure 10-1 File Menu



New

Select **New** from the **File** menu to start a new measurement process and open the Startup Wizard window.

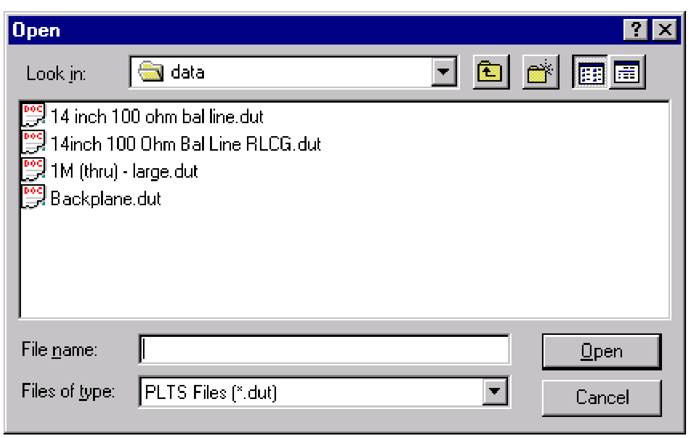
Figure 10-2 Startup Wizard Window



Open

Select **Open** from the **File** menu to load a previously saved file.

Figure 10-3 Open Dialog Box

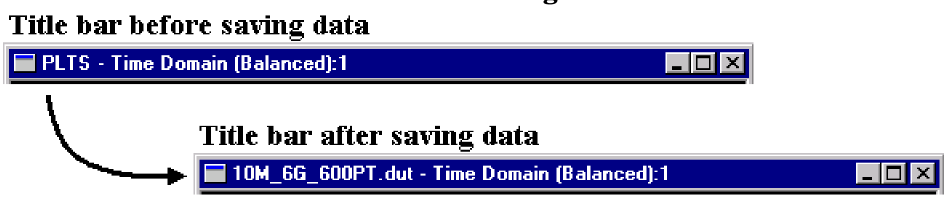


Save

Select **Save** from the **File** menu to save the current measurement or calibration data. New data or imported data may be saved.

Until measurement data is saved, the plot window title bar is labeled PLTS along with the analysis type of the plot window and the sequential plow window number. Once the data is saved, the PLTS label is replaced with the name of the saved file. Figure 10-4 shows the plot window title bar before the data was saved and how it changes to match the file name (10M 6G 600PT.dut) after it is saved.

Figure 10-4 Plot Window Title Bar Changes After Data is Saved

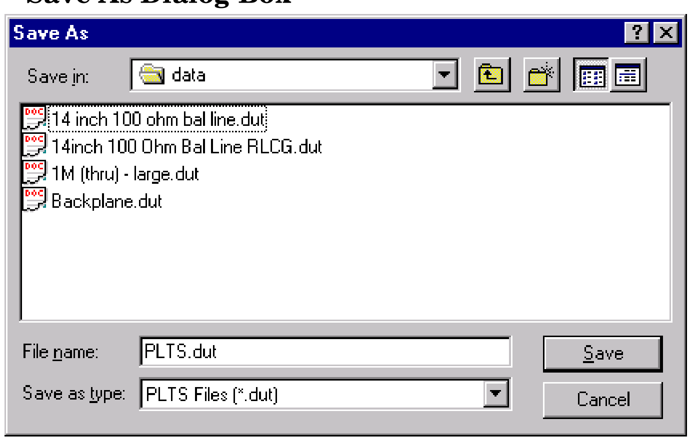


Only one unsaved plot window may be open at a time. If you have one unsaved plot window, you must either save the data or delete the window before you can open another plot window with unsaved data.

Save As…

Select **Save As**… from the **File** menu to save new measurement or calibration data or existing data as a new file.

Figure 10-5 Save As Dialog Box



Import

Select **Import** from the **File** menu to import a single-ended measurement data file. Then select either **CitiFile** to import a file in CitiFile format or **Touchstone** to import a file in Touchstone format. Then select from one of the port selections (either **Balanced 1324** or **Balanced 1234**) based on the calibration type used with the original measurement.

Figure 10-6 File Menu with Import and CitiFile Expanded

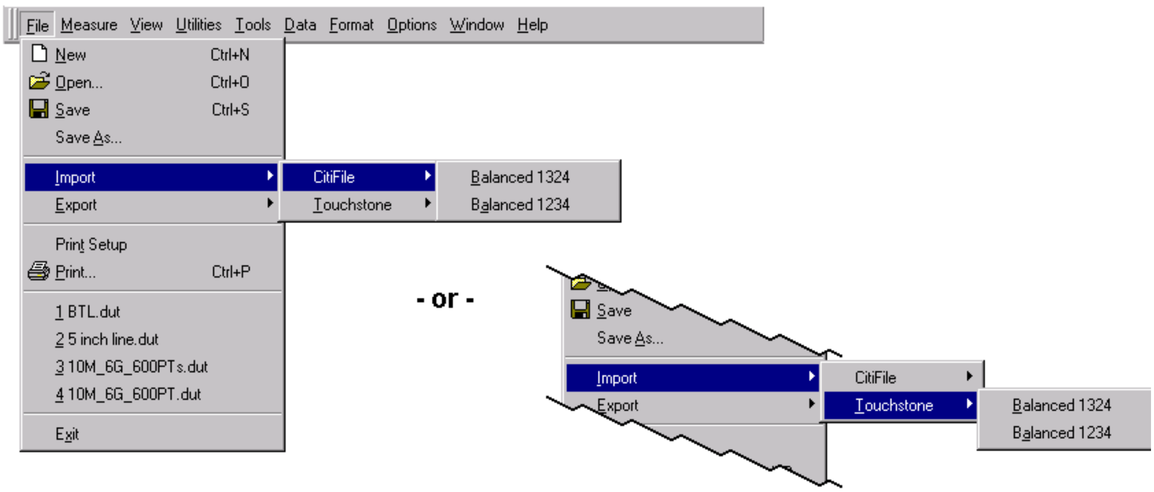
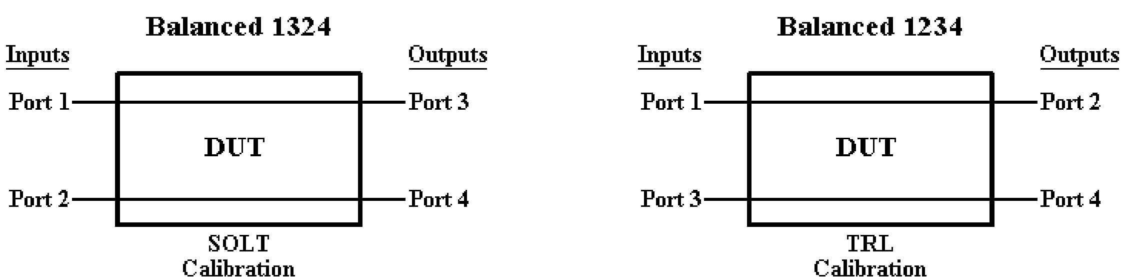


Figure 10-7 Balanced Transform Port Configuration Diagram



CitiFile

CitiFile imports data previously saved in CitiFile (*.cit) format. CitiFiles imported in this fashion can be used for comparison with other data sets using trace memory and math functions. Refer to Figure 10-7 and choose from one of the following port selections.

Balanced 1324 is used to import single-ended measurement data that has taken with the system calibrated using the SOLT calibration.

Balanced 1234 is used to import single-ended measurement data that has taken with the system calibrated using the TRL calibration.

Touchstone

Touchstone imports data previously saved in Touchstone (*.S4P) format. Refer to Figure 10-7 and choose from one of the following port selections.

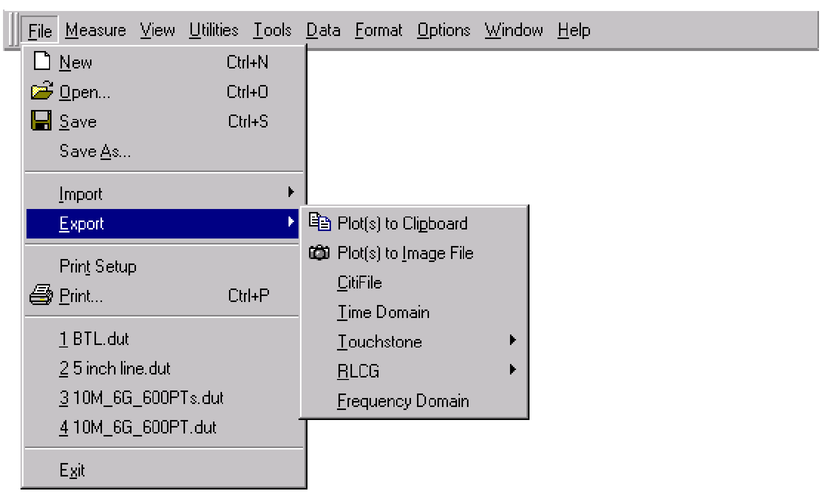
Balanced 1324 is used to import single-ended measurement data that has taken with the system calibrated using the SOLT calibration.

Balanced 1234 is used to import single-ended measurement data that has taken with the system calibrated using the TRL calibration.

Export

Select **Export** from the **File** menu to export a file. Then select from the following choices to select a specific format: **Plots to Clipboard**, **Plots to Image File**, **CitiFile**, **Time Domain**, **Touchstone**, **RLCG**, and **Frequency Domain**.

Figure 10-8 File Menu with Export Expanded



Plots to Clipboard exports the contents of the current plot window to the Windows clipboard.

Plots to Image File exports the contents of the current plot window as an image file. When you export it, you may choose from Windows Bitmap (*.BMP), JPEG Bitmap (*.JPG), Targa Bitmap (*.TGA), or PaintBrush (*.PCX) formats.

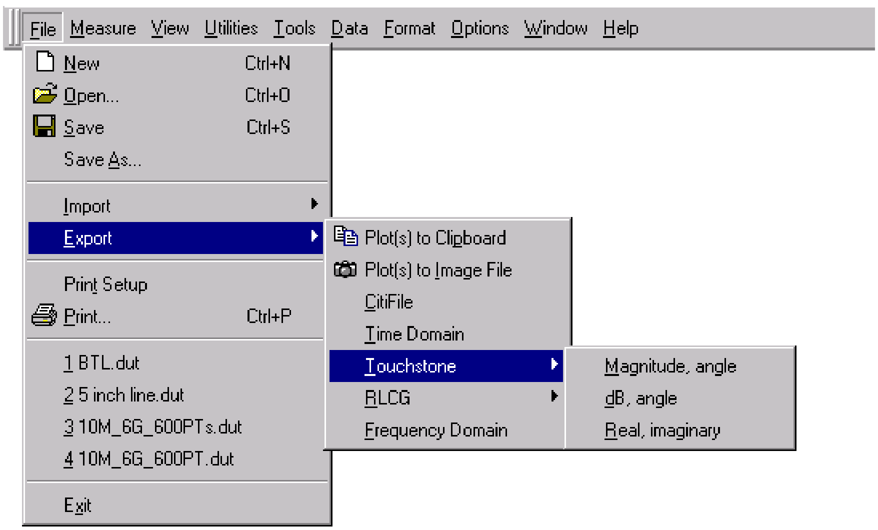
CitiFile exports the current data in CitiFile format (*.cit).

Time Domain exports the current time domain data in text format (*.txt). It saves a name, the parameter and format information in a header. In the body, each X and Y measurement coordinate is displayed separated by a comma. These coordinates are bounded by a BEGIN and END message.

Touchstone exports the current data in the S4P format which also has the following data format choices in which the data may be saved:

- **Magnitude, angle**
- **dB, angle** (power, angle)
- **Real, imaginary**

Figure 10-9 File Menu with Export and Touchstone Expanded

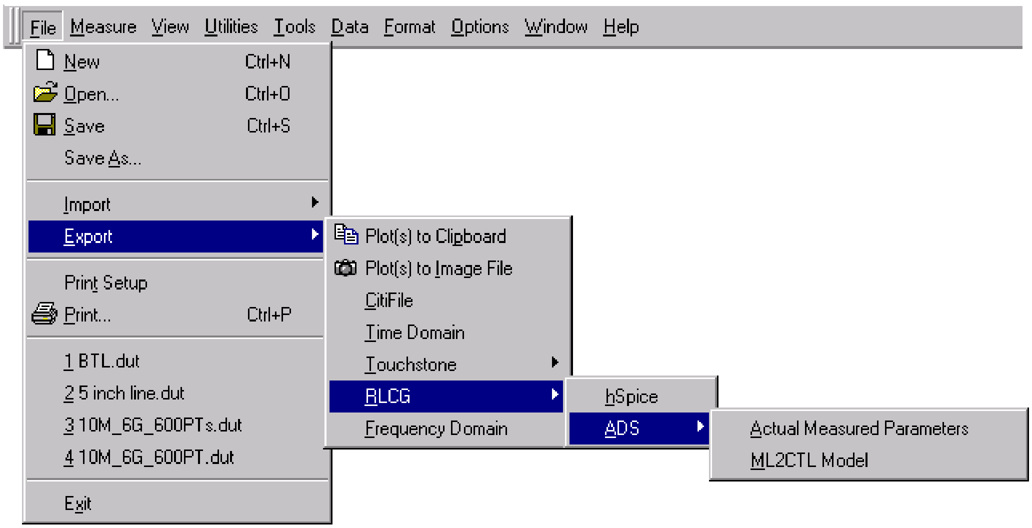


RLCG exports the current data in one of two RLCG formats:

- **hSpice** exports the RLCG data in a format compatible with HSPICE (a Simulation Program with Integrated Circuit Emphasis) software. Refer to "hSpice" on page 206.
- **ADS** exports the RLCG data in a format compatible with the Agilent Advanced Design System (ADS) software format which also has the two following data format choices in which the data may be saved:
    - ❑ **Actual Measured Parameters** exports extracted parameters versus frequency in an ASCII file for ADS. Refer to "ADS Actual Measured Parameters" on page 207.

- ❑ **ML2CTL** exports fitted parameters in an ASCII file to be used with the ADS MultiLayer 2 Coupled Transmission Lines (ML2CTL) model. Refer to “ADS ML2CTL Model” on page 207.

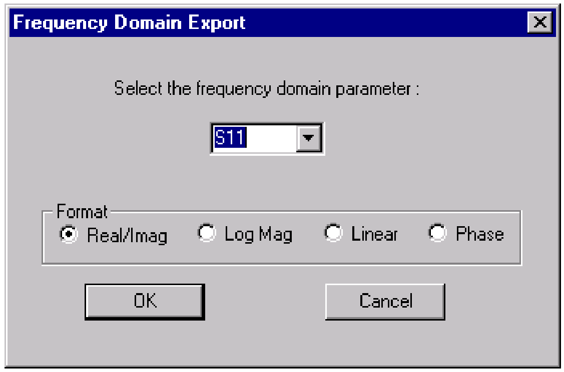
Figure 10-10 File Menu with Export, RLCG, and ADS Expanded



Frequency Domain exports the data of a single S-parameter (either single-ended or balanced) in one of four frequency domain formats: Real/Imaginary, Log Magnitude, Linear Magnitude, or Phase. All four formats are exported in tabular format as a text file, each with a header. The measured data is bounded by a `BEGIN` and an `END` message. The Real/Imaginary data of each measured point is exported as comma-separated values.

Use the *Frequency Domain Export* dialog box shown in to select the S-parameter (all single-ended and balanced S-parameters are listed). Then select the desired format and click **OK** to export the data.

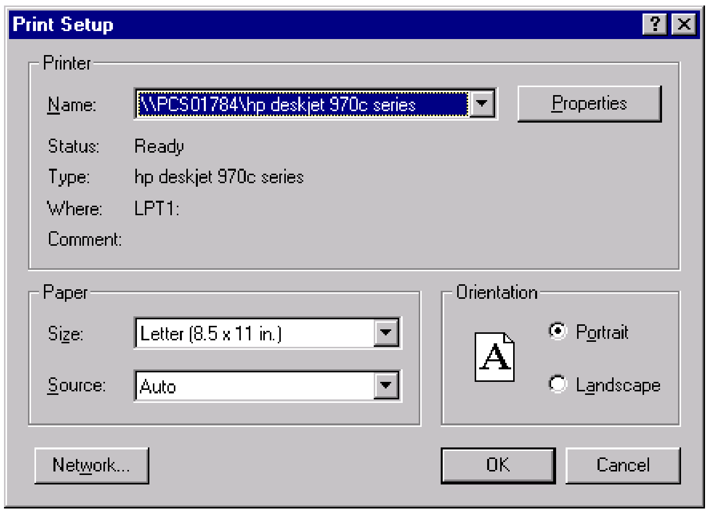
Figure 10-11 Frequency Domain Export Dialog Box



Print Setup…

Click the **File** menu and then click **Print Setup** to review the printer settings. The *Print Setup* dialog box is displayed. The *Print Setup* dialog box allows you to select the destination printer and its properties, the paper size and printer paper source, additional network printers, and choose the orientation of the paper when printed.

Figure 10-12 Print Setup Dialog Box



If you are connected to other networks, click **Network...** to find additional printers.

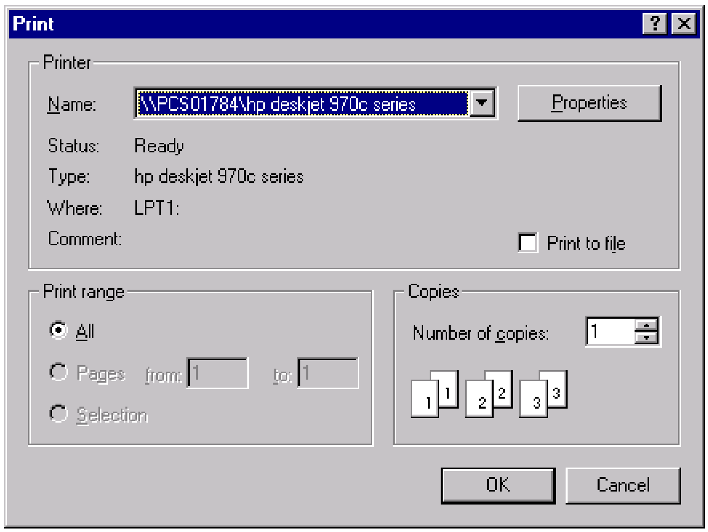
Click **OK** to print the selected plots and return to the program.

Click **Cancel** to close the dialog box and return to the program without printing.

Print

Click **Print** from the **File** menu to print the selected plots and display the *Print* dialog box. The *Print* dialog box allows you to select the destination printer and its properties, the range of pages to be printed, and the number of copies you wish to print.

Figure 10-13 Print Dialog Box



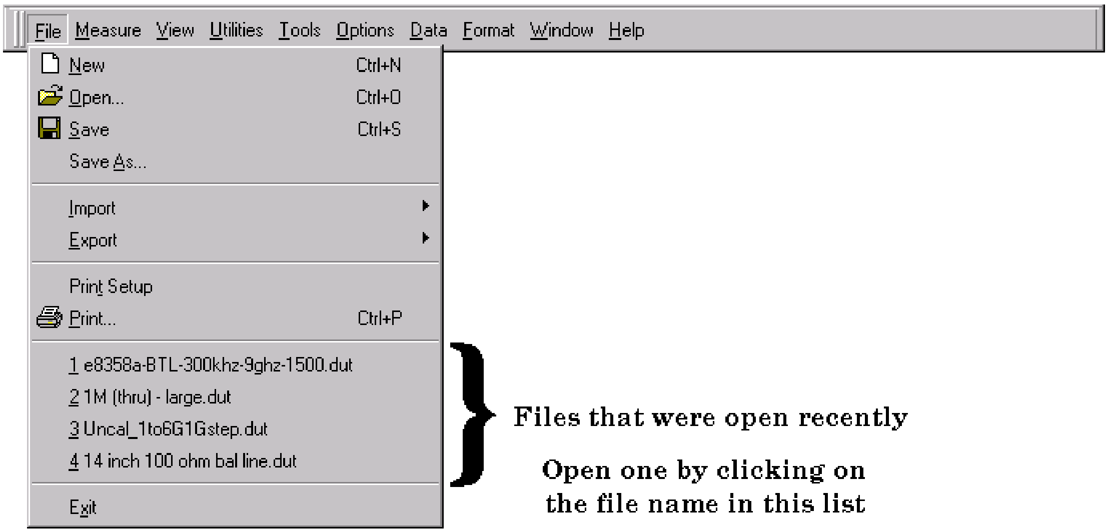
Click **OK** to print the selected plots and return to the program.

Click **Cancel** to close the dialog box and return to the program without printing.

Recent Files

Open any of the four most recently accessed files by clicking the name of the file from this list. Only the four most recently accessed files are displayed.

Figure 10-14 Opening Recently Accessed Files



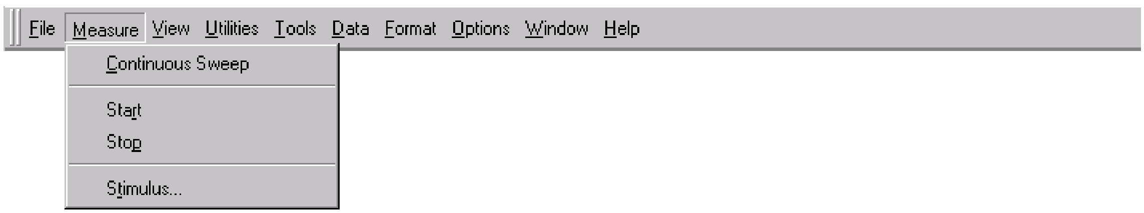
Exit

Click **Exit** from the **File** menu to quit this program.

Measure Menu

The Measure menu allows you to start a measurement, start and stop a continuous sweep measurement, and change the stimulus.

Figure 10-15 Measure Menu



Continuous Sweep

Continuous Sweep sets the system to make measurements as the selected frequency span is swept continuously. After each measurement, the displayed data is updated.

To perform a continuous sweep measurement, select **Continuous Sweep** so that it has a check mark on its left side on the Measure menu. With **Continuous Sweep** active, the **Start** and **Stop** menu selections control continuous sweep. Select **Start** to begin a continuous measurement and select **Stop** to stop the measurement.

The **Continuous sweep** indicator on status bar means that system is currently in the continuous sweep mode. See Figure 10-16.

Figure 10-16 Continuous Sweep Indicator on the Status Bar

Start

Start begins a measurement when it is selected. When **Continuous Sweep** has a check mark, **Start** begins a continuous sweep measurement; otherwise it begins a single sweep measurement.

Stop

Stop stops a continuous sweep measurement.

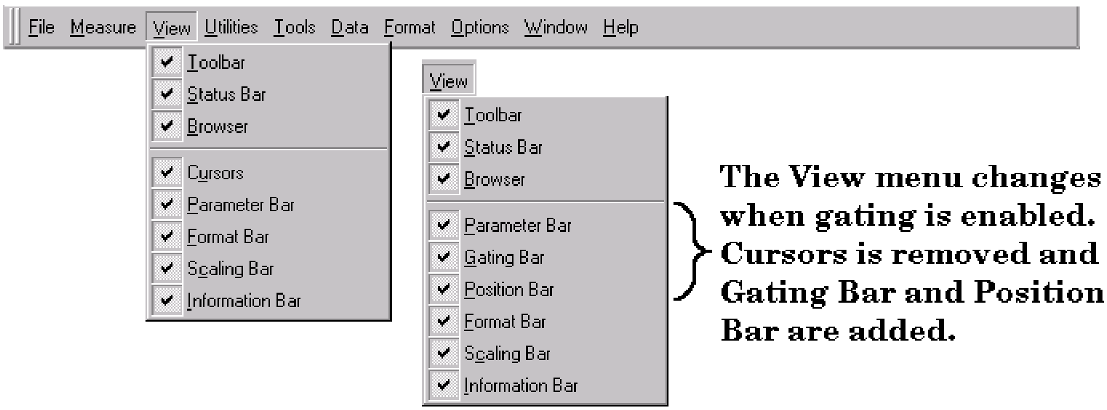
Stimulus…

Stimulus… opens the *Modify Time and Frequency Parameters* dialog box so that you can change the parameters. Refer to the stimulus information on “Setting Up the Calibrate and Measure Parameters” on page 67 for detailed information regarding changing the stimulus parameters.

View Menu

The **View** menu opens and closes the various tool bars.

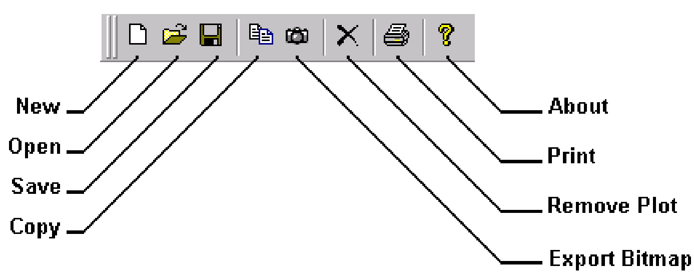
Figure 10-17 View Menu



Toolbar

The **Toolbar** provides quick access to several File menu features as well as two others. The features that are available on the **Toolbar** are **New**, **Open**, **Save**, **Copy**, **Export Bitmap**, **Remove Plot**, **Print**, and **About**.

Figure 10-18 Toolbar



Status Bar

The **Status Bar** provides a graphic display of when several features are active. Each feature has a label on the left and an indicator just to the right side of the label. When a feature is active, the indicator is changed to a bright color. When the feature in not active, the indicator is gray.

In addition, the impedance of each test system channel is displayed at the right side of this bar.

Figure 10-19 Status Bar

Measurement is bright when a measurement is being performed.
Continuous sweep is bright when a continuous sweep measurement is being performed.
De-Embedding is bright when de-embedding is applied to the data.
Ref-Z is bright when channel reference impedance is applied to the data.
Hardware is bright when the software recognizes the GPIB-connected hardware.

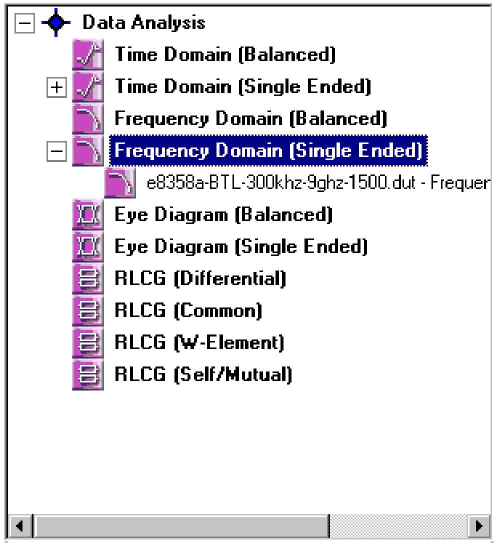
Browser

The **Browser** allows selection of data analysis type and the selection of plots to view. Selecting a data analysis type (a bold selection) opens a blank plot window for that analysis type. Selecting an existing plot (a non-bold selection) makes that plot active and displays it in the front of the plot window.

Data analysis types that have a plot opened have either a “+” or a “-” to the left of the label.

Select the + to display all plots of that type.
Select the – to collapse and hide all plots of that type.

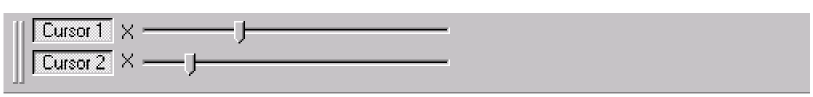
Figure 10-20 Browser



Cursors

The **Cursors** bar allows you to add up to 2 cursors to a plot. Simply select the plot, select the cursor button, and click and drag the horizontal scroll bar in the window to move the cursor in the plot. The cursor values are displayed on the information bar. See "Information Bar" on page 246. The frequency domain Smith Chart and Polar Chart formats allow you to choose between magnitude/phase and impedance styles (see "Using Cursors" on page 134). This is not available when time domain Gating is enabled.

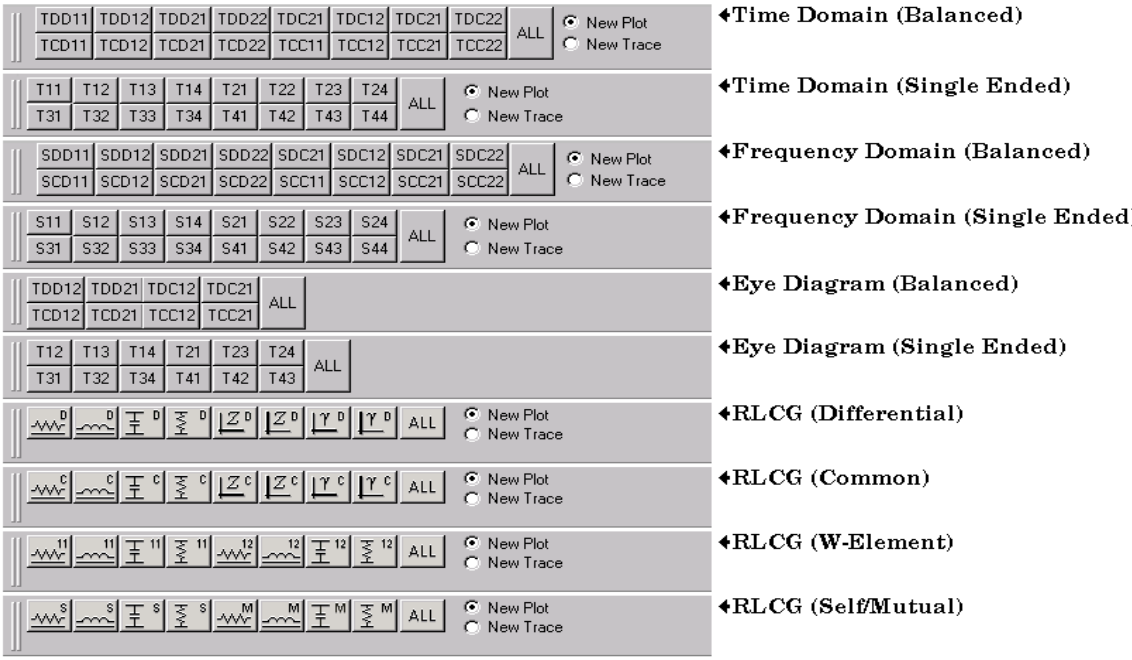
Figure 10-21 Cursors Bar



Parameter Bar

The **Parameter Bar** displays each individual parameter for each specific data analysis type as well as the capability to display all of the parameters. The time domain, frequency domain, and RLCG data analysis types also have the option to allow you to display multiple plots on the same plot or separate plots. For Time Domain, Frequency Domain, and Eye Diagram, refer to "Data Menu" on page 266 for detailed information. For RLCG, refer to "RLCG Menu" on page 271 for detailed information.

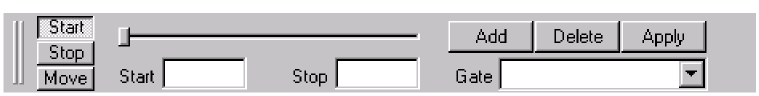
Figure 10-22 Parameter Bars for Each Data Analysis Type



Gating Bar

The **Gating Bar** allows you to add up to 10 gates to a time domain plot. Select **Gating** from the **Utilities** menu to display this bar. After the time domain plot is displayed, slide the horizontal control to set the gate's stop and start position and then press **Add** to add the gate to the plot. Gates may also be deleted and moved from this window. See "Gating" on page 211. This is only available when time domain Gating is enabled.

Figure 10-23 Gating Bar

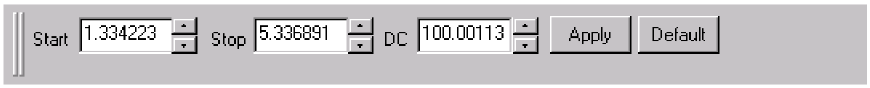


Position Bar

The **Position Bar** allows you to change the calculated start and stop time values and the DC level. Enter the value change in the **Start** and **Stop** fields for a change in the start and stop time or in the **DC** field for a change in the DC level and click **Apply**. The gating plot is then

displayed using these changes. To return the plot back to it's original values, click **Default**. See "To Change the Displayed Gating Plot" on page 216. This is only available when time domain Gating is enabled.

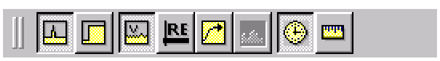
Figure 10-24 Position Bar



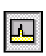
Format Bar

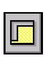
The **Format Bar** displays the plot using the format selected from the bar. **Format Bar** is only available for Time Domain and Frequency Domain plots. As shown below, the Time Domain Format Bar differs from the Frequency Domain Format Bar. Refer to "Format Menu" on page 269 for a detailed description of each format item.

Time Domain Format Bar



For detailed information about each of the selections, refer to "Selecting Time Domain Display Formats" on page 157.

 Impulse

 Step

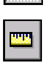
 Volts

 Real

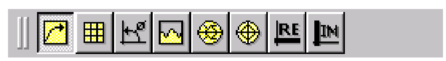
 Log Mag

 Impedance

 ns (nanoseconds)

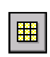
 cm (centimeters)

Frequency Domain Format Bar



For detailed information about each of the selections, refer to "Selecting Frequency Domain Display Formats" on page 128.

 Log Mag

 Linear Mag

 Phase

 Group Delay

 Smith Chart

 Polar Chart

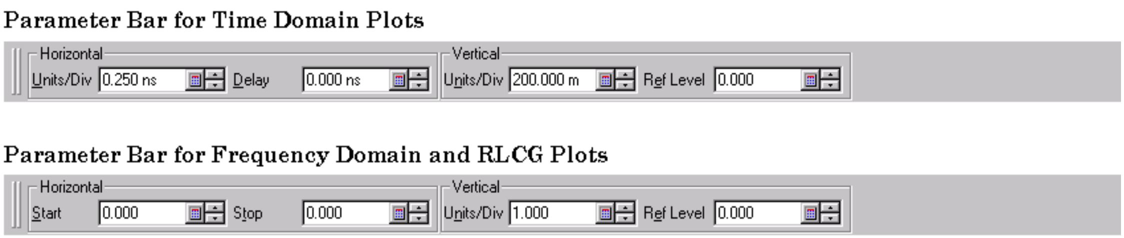
 Real

 Imaginary

Scaling Bar

Scaling Bar allows you to change the scale of the active plot. There are two different scaling bars available. The analysis type determines the scaling bar that is displayed. Eye Diagrams do not have an associated scaling bar

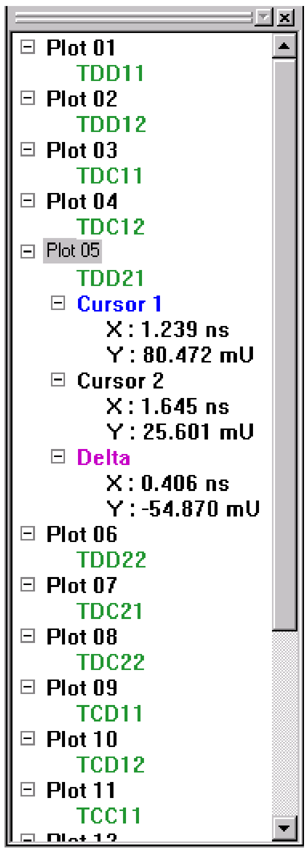
Figure 10-25 Scaling Bar



Information Bar

Information Bar displays a listing of each plot window along with the associated parameters for each. If a plot window has multiple traces, all associated parameters are listed. In addition, any cursor information is displayed in this area.

Figure 10-26 Information Bar



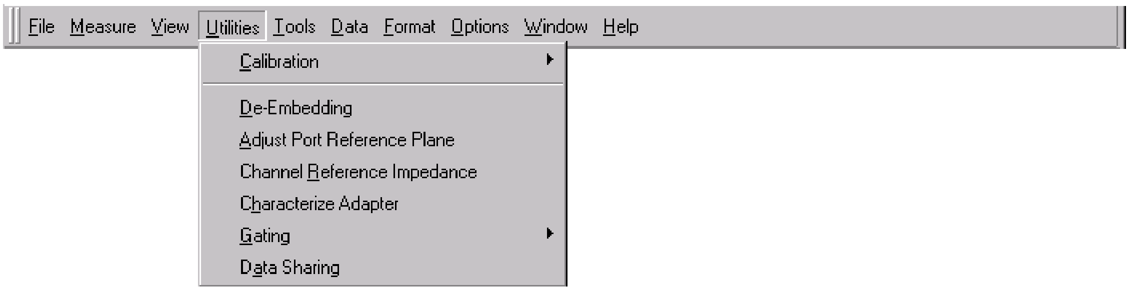
Each plot window has either a "+" or a "–" to the left of the label. A long list of information may be displayed for each window.

Select the + to display all plot information.
Select the – to collapse and hide all plot information.

Utilities Menu

The **Utilities** menu provides access to calibration resources and several enhancement tools that you can use to provide a realistic analysis result.

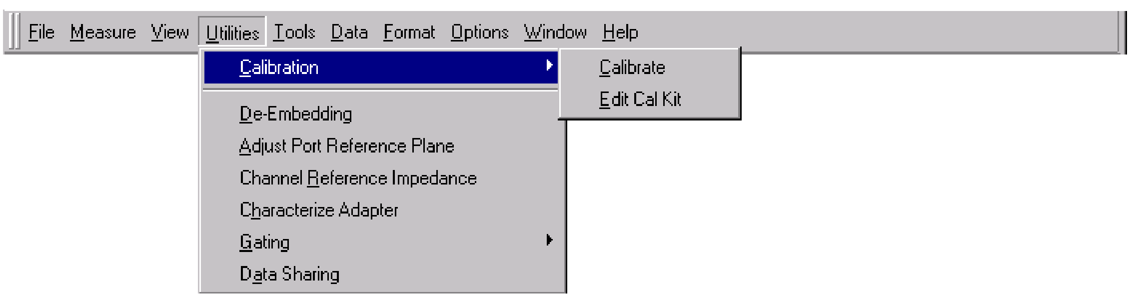
Figure 10-27 Utilities Menu



Calibration

The **Calibration** selection allows you to either start a calibration or edit the definition of mechanical calibration kits.

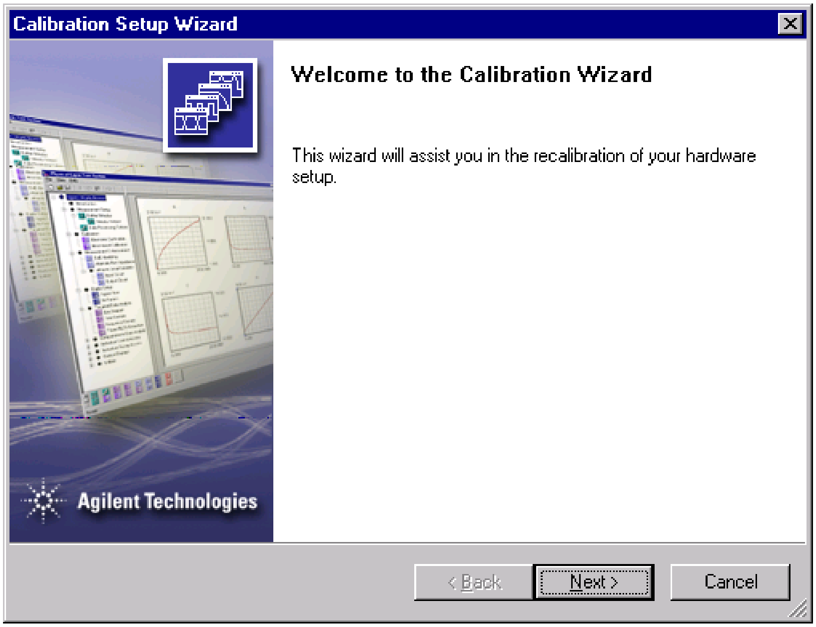
Figure 10-28 Utilities Menu with Calibration Expanded



Calibrate

Selecting **Calibrate** opens the wizard so that you may begin your calibration. Refer to Chapter 4, “Calibrating for Measurement Accuracy,” for detailed calibration information.

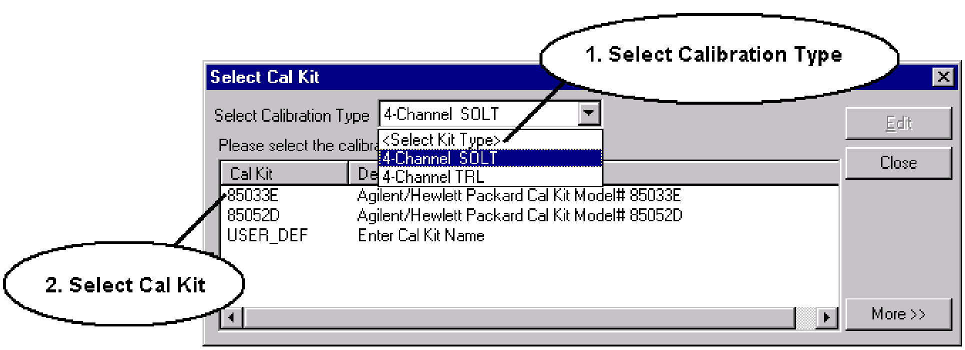
Figure 10-29 Calibration Wizard



Edit Cal Kit

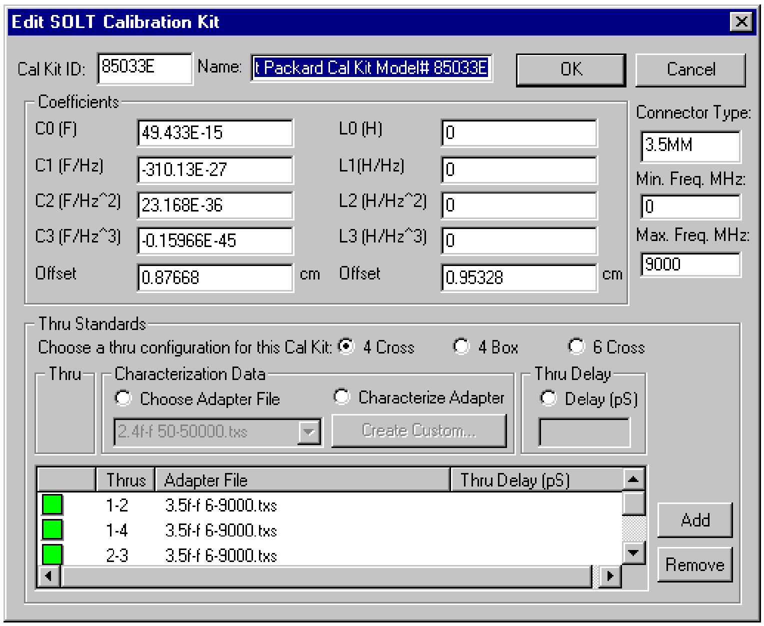
The **Edit Cal Kit** feature gives you flexibility to make changes to your calibration kit definition or to add new calibration kits. First, select the calibration type from the **Select Calibration Type** list. Then, from the **Cal Kit** column, select your calibration kit model number to edit an existing kit or select **USER_DEF** to define a new calibration kit.

Figure 10-30 Select Cal Kit Dialog Box



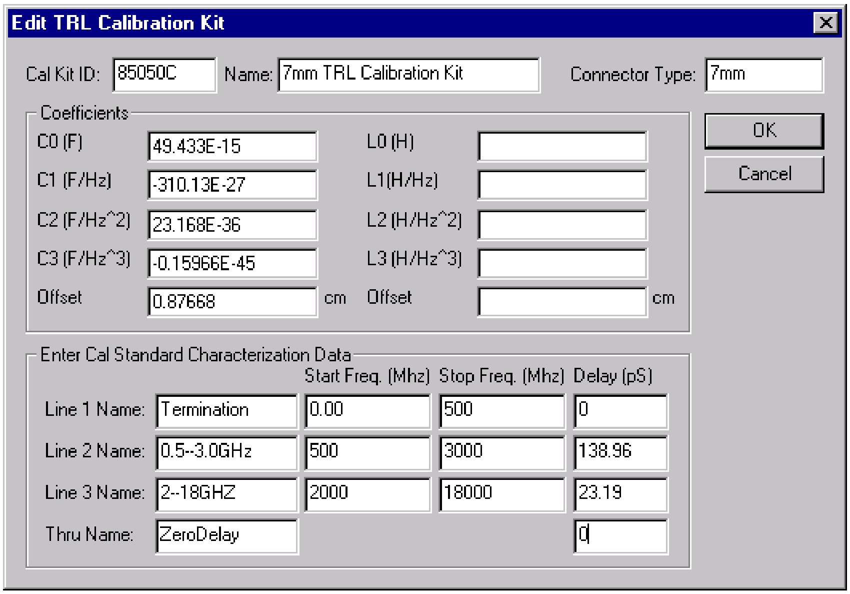
The *Edit Calibration Kit* dialog box allows you to change the calibration kit parameters. The **USER_DEF** selection provides a blank dialog box that you can enter new parameter values. Refer to Figure 10-31, "Edit SOLT Calibration Kit Dialog Box" and Figure 10-32, "Edit TRL Calibration Kit Dialog Box."

Figure 10-31 Edit SOLT Calibration Kit Dialog Box



Refer to "Defining a TRL Calibration Kit" on page 96 for information on defining a TRL calibration kit.

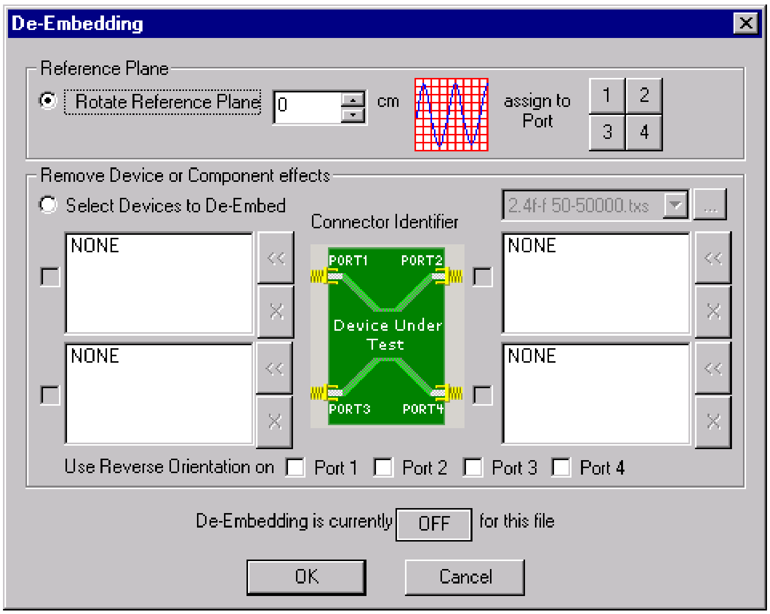
Figure 10-32 Edit TRL Calibration Kit Dialog Box



De-Embedding

Select **De-Embedding** from the **Utilities** menu to open the *De-Embedding* dialog box. Use the *De-Embedding* dialog box to configure DUT reference planes by de-embedding probes, fixtures, or adapters from the measured data.

Figure 10-33 De-Embedding Dialog Box



Select the reference plane rotation using one of the following methods:

- **Reference Plane**

  You can use the **Adjust Port Reference Plane** selection in the **Utilities** menu (see "Adjust Port Reference Plane" on page 253) or you can use this method of adjusting the reference plane.

  1. Click **Rotate Reference Plane**.
  2. Enter a reference plane rotation value (in centimeters-in-air).

     A positive value rotates the phase towards the DUT (effectively removing a length of 50Ω line) and a negative number rotates the phase away from the DUT (effectively adding a length of 50Ω line).

  3. Select the port to assign the rotation value.

4. Repeat steps 2 and 3 until you have assigned rotation values to all appropriate ports.
5. Make sure that De-embedding is on. If the **OFF** button is displayed, click it to turn de-embedding on.

- **Remove Device or Component Effects**

1. Click **Select Device to De-Embed**.
2. Select a de-embedding file (.txs) that you want to use from the drop-down box.
3. Select the check box associated with the port to which the file applies.
4. Click the associated **<<** button to add the file to the port. (Clicking the ✕ button will remove the file from the port.)
5. Repeat steps 2 through 4 until you have assigned de-embedding files to all appropriate ports.
6. Select all ports that use reverse orientation.

   Reverse orientation is noted by check marks for each port specified in the **Use Reverse Orientation** check boxes.
7. Make sure that de-embedding is on. If the **OFF** button is displayed, click it to turn de-embedding on.

Click **OK** to accept the configuration and exit the dialog box or **Cancel** to ignore any changes and exit the dialog box.

De-embedding files hold information about the ports on the fixture that you are de-embedding, and match the connectors during de-embed setup. If you try to specify a fixture connection that cannot be made, the software warns you.

NOTE Port connectors are defined by the cal kits assigned to them in the *Calibration Kit Selection* dialog box.

The **De-Embedding** indicator on status bar means that is being applied. See Figure 10-34.

Figure 10-34 De-Embedding Indicator on the Status Bar

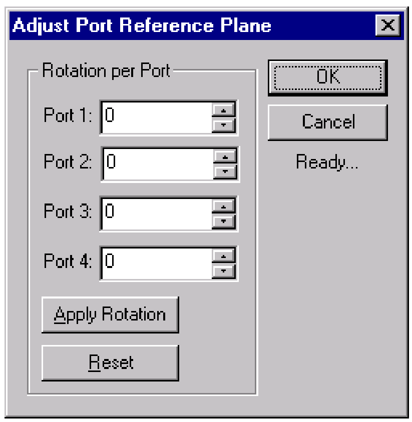
Adjust Port Reference Plane

Select **Adjust Port Reference Plane** from the **Utilities** menu to open the *Adjust Port Reference Plane* dialog box where you can change the reference plane rotation settings and recalculate the displayed data.

Enter the new reference plane rotation values for the desired ports by using the arrows or entering the values in the port box directly. A positive value rotates the phase towards the DUT (effectively removing a length of 50Ω line) and a negative number rotates the phase away from the DUT (effectively adding a length of 50Ω line).

Click **Apply Rotation** to recalculate the data and display the new plots. **Reset** returns the values to zero, recalculates the data, and displays original plots.

Figure 10-35 Adjust Port Reference Plane Dialog Box

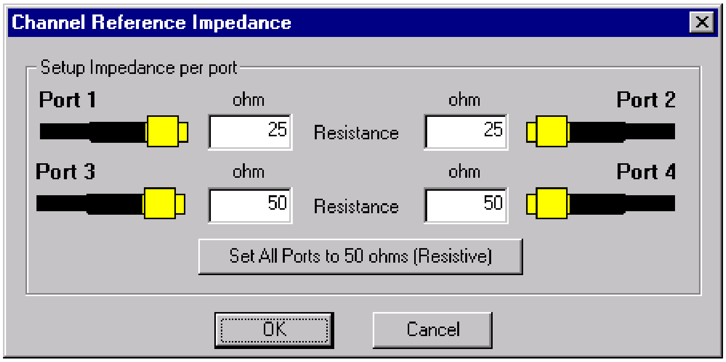


Note that when reference plane is applied, the **De-Embedding** indicator color changes to a bright color. See Figure 10-34.

Channel Reference Impedance

Select **Channel Reference Impedance** from the **Utilities** menu to open the *Channel Reference Impedance* dialog box. By default, all four ports are set to a resistive 50Ω impedance. Enter new reference impedances in the port boxes as desired.

Figure 10-36 Channel Reference Impedance Dialog Box



This feature does not affect the impedance presented to the DUT by the system hardware. Rather, it mathematically transforms the measured data to show how the performance of a linear device would change in a non-50Ω measurement system. Impedance transforms can be specified either before or after measurement. Only the current data set is affected.

The reference impedance can only be specified as a resistive circuit.

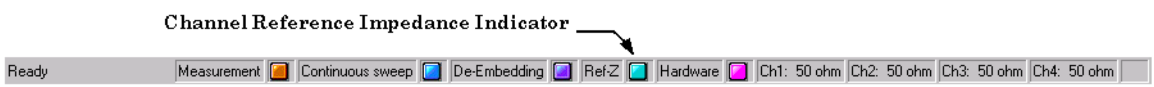
Differential reference impedances are additive. For example, specifying a reference impedance of 125Ω on port 1 and 125Ω on port 3 corresponds to a differential-mode reference impedance of 250Ω on balanced port one. Likewise, the common-mode reference impedances are the parallel equivalent impedance.

Click **Set All Ports to 50 ohms (Resistive)** to return to the default configuration.

Click **OK** to accept the configuration and exit the dialog box or **Cancel** to ignore any changes and exit the dialog box.

The **Ref-Z** indicator on status bar means that the current data has been modified for a non-50Ω reference impedance for at least one port. See Figure 10-37.

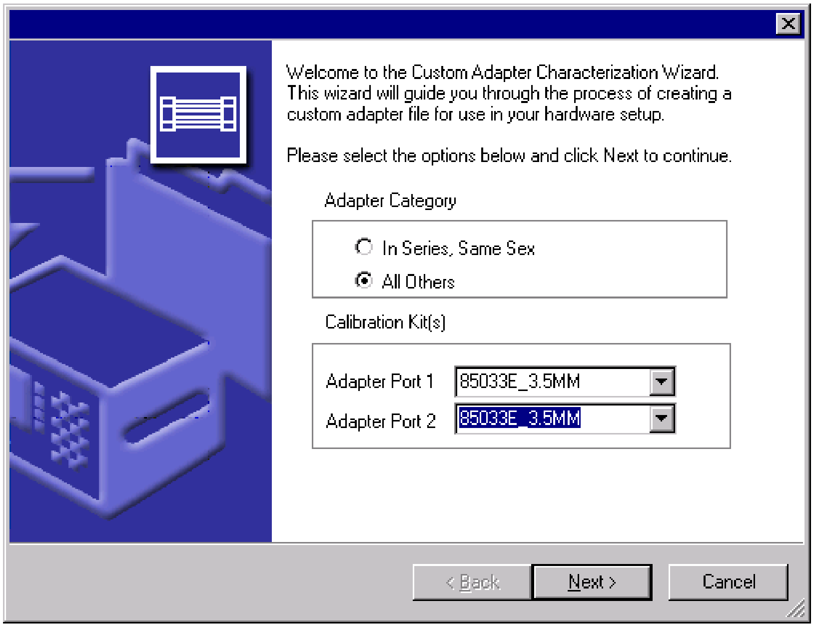
Figure 10-37 Channel Reference Impedance (Ref-Z) Indicator on the Status Bar



Characterize Adapter

Adapters used in measurements and calibration must be characterized to ensure accurate results. The Physical Layer Test System software has a wizard that steps you through this adapter characterization process. Select **Characterize Adapter** from the **Utilities** menu to start the *Custom Adapter Characterization Wizard*.

Figure 10-38 Custom Adapter Characterization Wizard



A short/open/load calibration is performed directly at the network analyzer front panel test port with out any cables. Then the calibration is repeated with the adapter inserted. The resulting adapter S-parameters are saved in Citifile format, which can later be de-embedded from the device measurement.

To allow for best interpolation of adapters used in broadband measurements, characterize the adapter over the entire frequency range of the system with as many points as possible.

Your adapters must have an orientation, forward and reverse directions. Mark the connectors on the adapter as ports 1 and 2. Forward orientation has the lower-numbered adapter port connected to the test-set port.

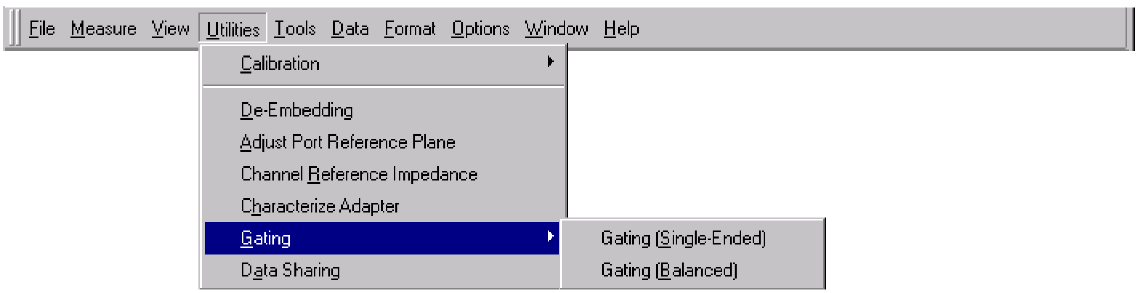
Refer to "Characterizing Adapters" on page 107 for detailed instructions on performing adapter characterization.

Gating

Gating the time domain response provides the ability to mathematically remove the effect of a particular circuit element. By observing the original frequency domain response and the transformed frequency domain response, the effect of the gating operation on the S-parameter data can be seen. Refer to "Gating" on page 211 for additional information.

Click **Gating** from the **Utilities** menu. Then click either **Gating (Single Ended)** or **Gating (Balanced)** depending on whether your Time Domain plot is single-ended or balanced.

Figure 10-39 Utilities Menu with Gating Expanded



Gating (Single Ended)

Select **Gating (Single Ended)** when you are planning to gate a single-ended Time Domain plot.

Gating (Balanced)

Select **Gating (Balanced)** when you are planning to gate a balanced Time Domain plot.

Data Sharing

Data Sharing is used to overlay the plot of one measurement over the plot of another so that differences and similarities between the two plots can easily be viewed.

The plots must have the same number of points to be shared.

The plot in Figure 10-40 shows a TDD21 plot in the time domain mode. The same plot with de-embedding and channel reference impedance applied will be data shared with this plot.

Figure 10-40 A Plot Before Data Sharing is Used

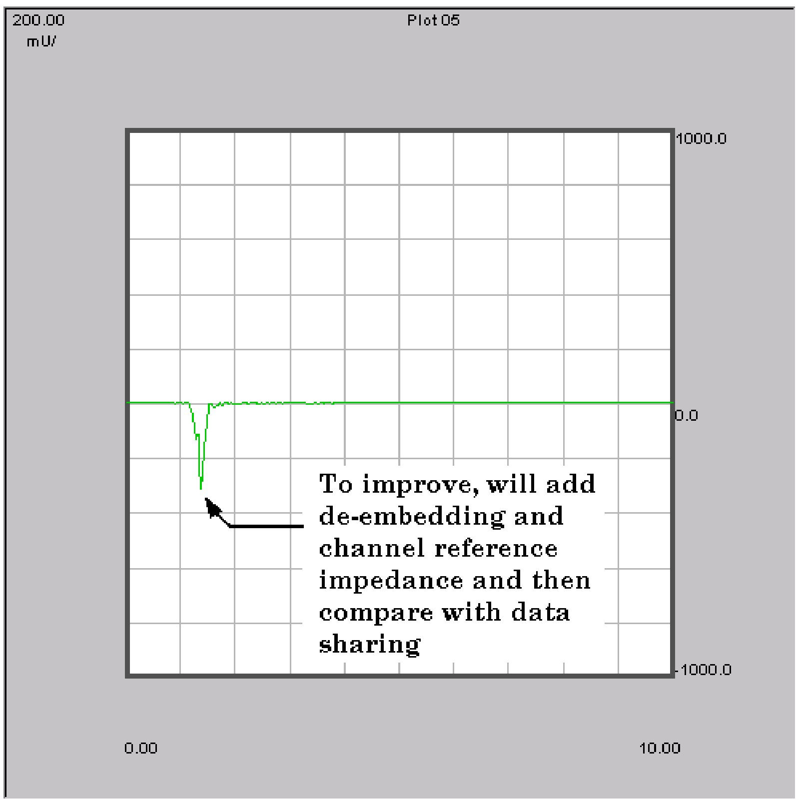
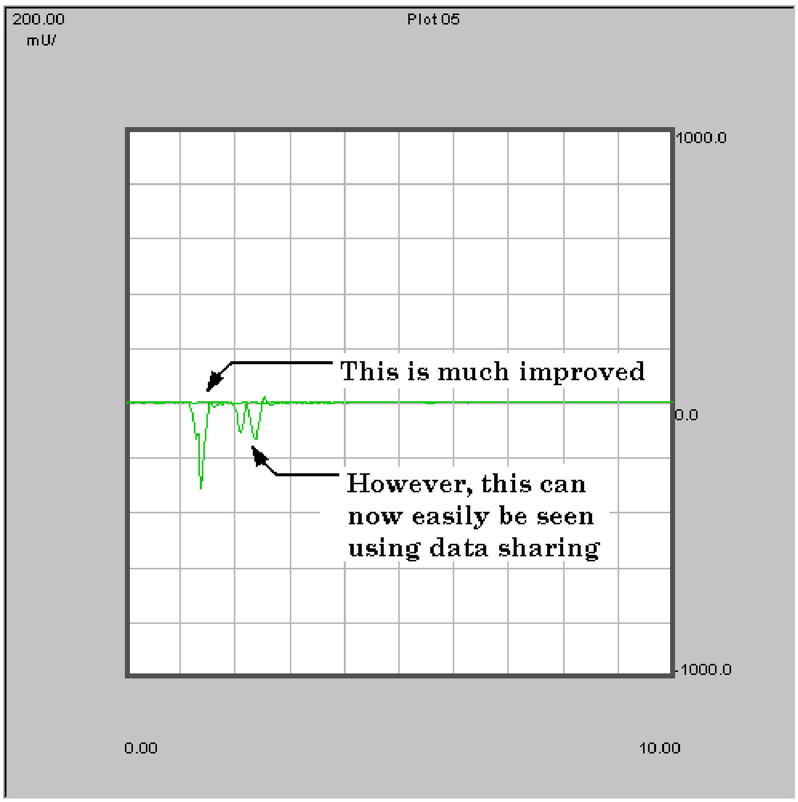


Figure 10-41 shows the file with de-embedding and channel reference impedance applied being selected from the list of open files. The TDD21 parameter is also selected from the **Parameter** list.

Figure 10-41 Data Sharing

When the **Show** button on the **Data Sharing** bar is clicked, the new files TDD21 plot is overlaid on the original plot where it is very easy to see differences.

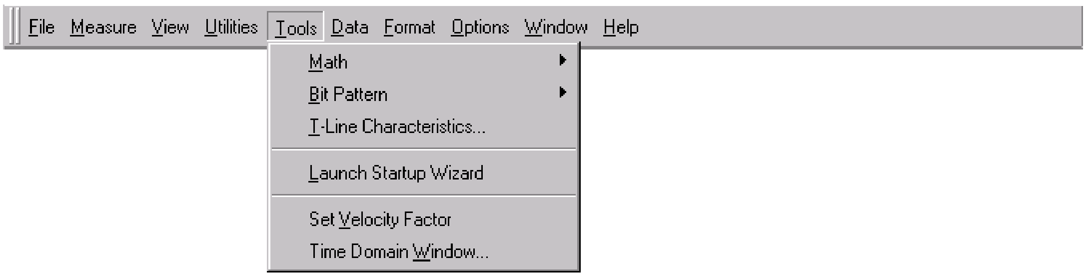
Figure 10-42 Two Plots Compared with Data Sharing



Tools Menu

The **Tools** menu allows access to the Math, Bit Pattern, and T-Line Characteristics features. It also allows you to launch the startup wizard.

Figure 10-43 Tools Menu



Math

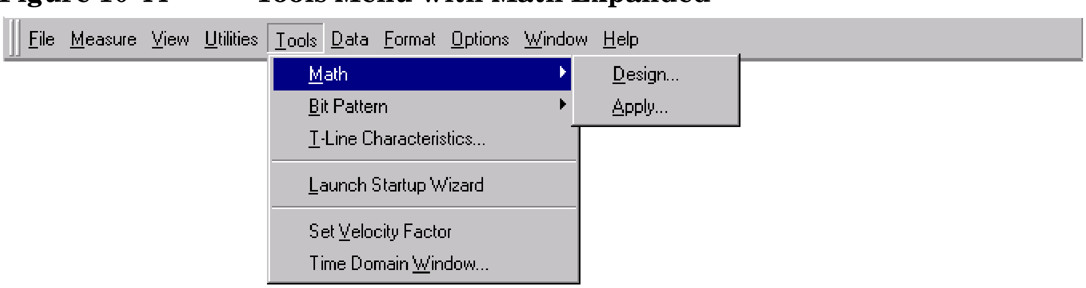
The **Math** feature allows you to design and save a mathematical formula and to apply that formula to compare measured parameters. For example, you could use the math feature to determine noise immunity on a balanced line by calculating the common mode rejection ratio (CMRR) using the following equation:

$$CMRR = (SDD21)/(SCC21)$$

You could also characterize the loss of a single-ended frequency domain measurement using the following equation:

$$Loss = \frac{1}{\sqrt{2}}(S21 + jS31)$$

Figure 10-44 Tools Menu with Math Expanded

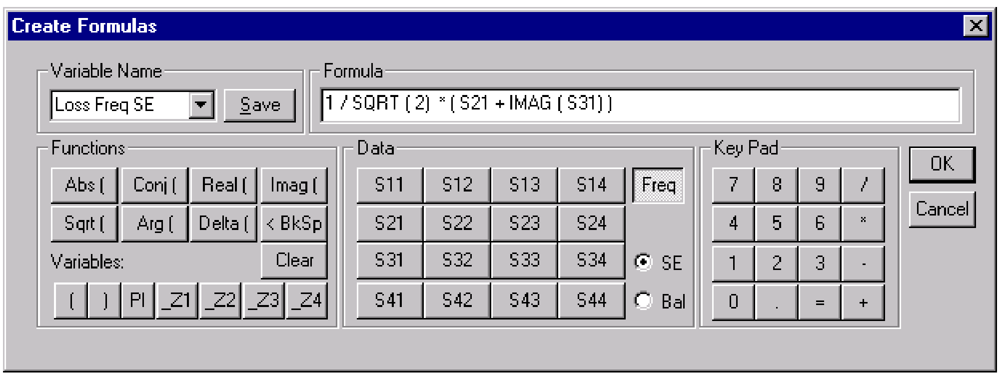


Design

To create a formula for use with the measured data, select **Design** from the **Math** choice of the **Tools** menu. Select either **SE** (single-ended) or **Bal** (balanced) in the **Data** area. Click the **Formula** box to begin entering the equation. Then using the buttons in the **Functions**, **Data**, and **Key Pad** areas, enter your equation from left to right. When you have finished entering the equation, enter a name in the **Variable Name** box and click the **Save** button. When you have finished inputting equations, click the **OK** button.

The **Functions** area contains mathematical functions, terms, and operators. The **Data** area contains the applicable parameters for the analysis type. The **Key Pad** area contains numerals and simple operators (numbers 0-9 and symbols for decimal, equals, addition, subtraction, multiplication, and division).

Figure 10-45 Create Formulas Dialog Box

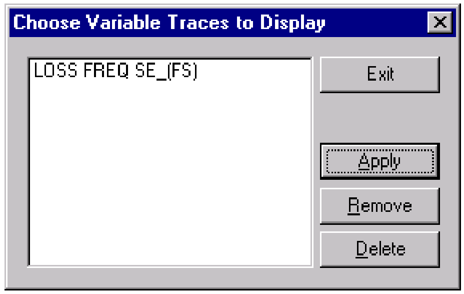


Apply

To apply a formula to the active data, display the *Choose Variable Traces to Display* dialog box by selecting **Apply** from the **Math** choice of the **Tools** menu. Then select the formula name from those displayed in the list. Click the **Apply** button to apply the formula to the active data and display a trace showing the data with the formula applied.

Remove removes the selected formula from the active data and removes the trace shown when **Apply** was clicked. **Delete** removes the selected variable from the list in the dialog box. **Exit** closes the dialog box.

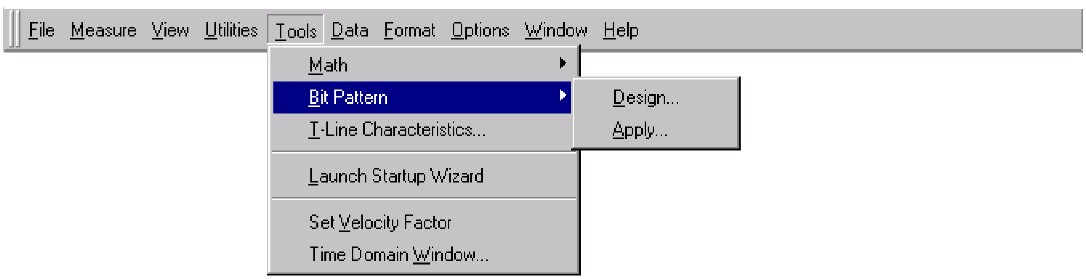
Figure 10-46 Choose Variable Traces to Display Dialog Box



Bit Pattern

The **Bit Pattern** feature allows you to design a digital pattern and save the pattern. Then you can apply the digital pattern to eye diagram plots.

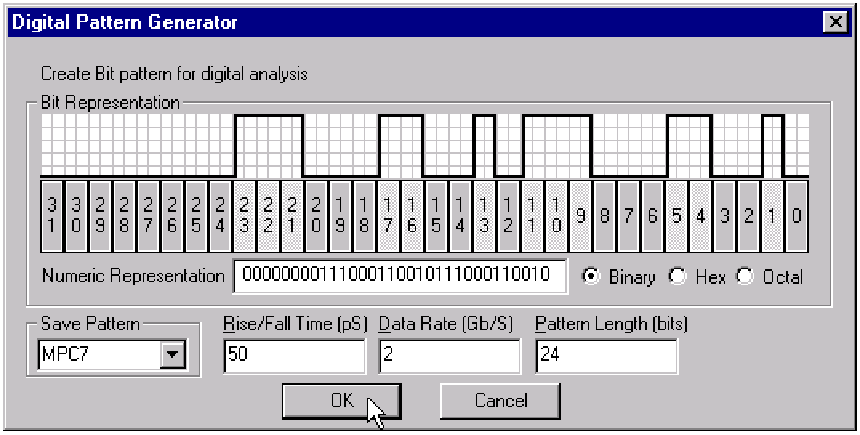
Figure 10-47 Tools Menu with Bit Pattern Expanded



Design

Select **Design** from the **Bit Pattern** choice in the **Tools** menu to design a digital pattern using the *Digital Pattern Generator*. The *Digital Pattern Generator* allows you to create a pattern of between 8 and 32 bits. You may create the pattern in one of two ways, either clicking the numbered keys (0 to 31) or by typing the numeric value in either Binary (base 2), Octal (base 8), or Hexadecimal (base 16) formats. As you enter the pattern inputs, the pattern is displayed in the upper portion of the **Bit Representation** area.

Figure 10-48 Digital Pattern Generator

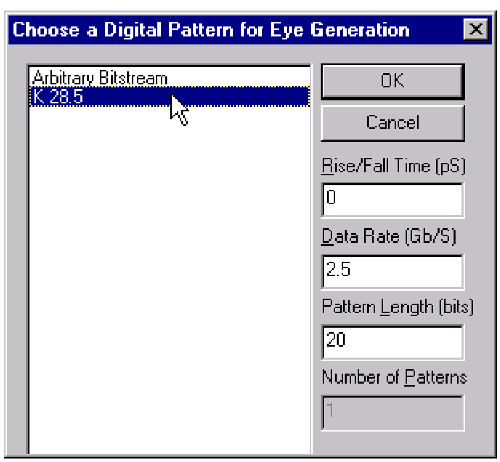


After the pattern has been created and is displayed correctly, save the pattern by entering a pattern name in the **Save Pattern** box and values in the **Rise/Fall Time (pS)**, **Data Rate (Gb/s)**, and **Pattern Length** boxes. Then select **OK** to save the digital pattern.

Apply

Apply a digital pattern to an eye diagram using the *Choose a Digital Pattern for Eye Generation* dialog box. This dialog box also allows you to change the values for the rise/fall time, data rate, pattern length, and number of patterns (arbitrary bitstream only). A digital pattern must be applied to view data using the eye diagram data analysis type.

Figure 10-49 Choose a Digital Pattern for Eye Generation Dialog Box



After clicking a digital pattern in the *Choose a Digital Pattern for Eye Generation* dialog box list, review the digital pattern parameter entries on the right side of the dialog box and enter the desired parameter values.

- **Rise/Fall Time (pS)** is the time that it takes a signal to transition from a low to a high condition (or the time that it takes a signal to transition from a high to a low condition). Refer to Figure 7-6 on page 171 for additional information regarding transition time.
- **Data Rate (Gb/s)** is the speed that data is transferred over a circuit or a communications line. Refer to Figure 7-6 on page 171 for additional information regarding data rate.
- **Pattern Length (bits)** is the number of bits in the digital pattern used to create the eye diagram. This value is the limiting factor in creating unique digital patterns. The number of bits allowed between 8 and 32. Where **B** is the number of bits entered, the number of unique bit patterns is: $2^B - 2$. If B = 32 (the maximum number of allowable bits), the then 4.29×10^9 unique bit patterns are generated.
- **Number of Patterns** (active only when **Arbitrary Bitstream** is selected) is used to indicate the number of unique bit patterns to use in creating the eye diagram. This value must be equal or less than the number of unique bit patterns determined by the pattern length entry.

Then, click **OK** to view the eye diagram in the plot window. **Cancel** closes the dialog box without making any changes.

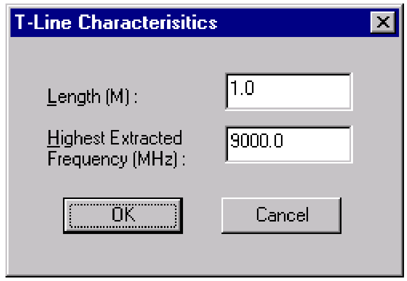
For additional information regarding Arbitrary Bitstream, refer to "Arbitrary Bitstream" on page 174.

NOTE You may change the digital pattern using the dialog box shown in Figure 10-49 by selecting **Bit Pattern** then **Apply**… from the **Tools** menu.

T-Line Characteristics

T-Line Characteristics displays the RLCG data analysis *T-Line Characteristics* dialog box. This is the same dialog box that is displayed when any RLCG analysis is selected. Enter the length of the transmission line (in meters) and the highest frequency (in megahertz) in this dialog box to change the existing transmission line characteristics.

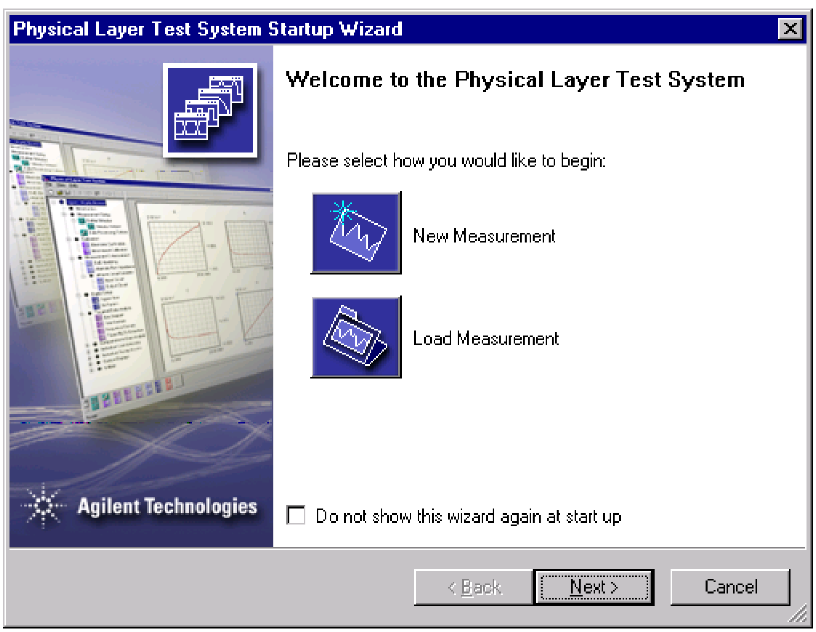
Figure 10-50 T-Line Characteristics



Launch Startup Wizard

When **Launch Startup Wizard** is selected, this menu choice starts the **Physical Layer Test System Startup Wizard**. See Figure 10-51.

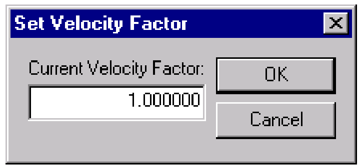
Figure 10-51 Startup Wizard



Set Velocity Factor

When **Set Velocity Factor** is selected from the **Tools** menu, the dialog box shown in Figure 10-52 is displayed. Enter the new velocity factor in the **Current Velocity Factor** box and click **OK**. The maximum allowable value is 1.000000.

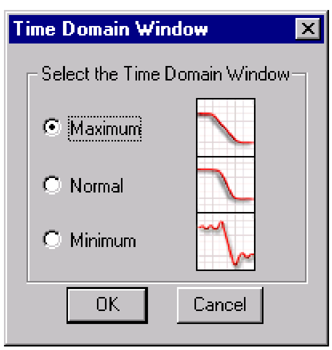
Figure 10-52 Set Velocity Factor Dialog Box



Time Domain Window…

When **Time Domain Window**… is selected from the **Tool** menu, the *Time Domain Window* dialog box is displayed (see Figure 10-53). This dialog box allows you to set the Time Domain Window setting to one of three levels, **Maximum** (the default value), **Normal**, and **Minimum**. See "Time Domain Windowing" on page 147 for additional information.

Figure 10-53 Time Domain Window Dialog Box



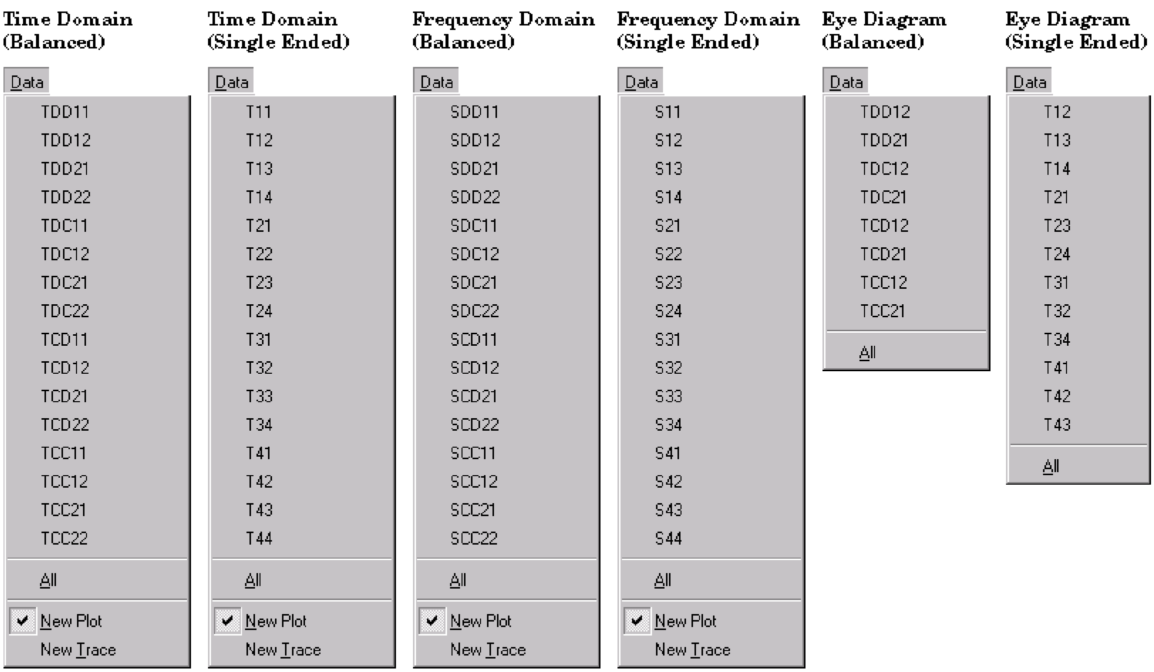
- **Maximum** gives the minimum sidelobes and this provides the greatest dynamic range. This is the default setting.
- **Normal** gives reduced sidelobes and is normally the most useful.
- **Minimum** is essentially no window and therefore give the highest sidelobes.

OK closes the dialog box. **Cancel** closes the dialog box without making changes.

Data Menu

The **Data** menu displays each individual parameter for each specific data analysis type as well as the capability to display all of the parameters. The time domain and frequency domain data analysis types also have the option to allow you to display multiple plots on the same plot or separate plots. Figure 10-54 shows each of the data menus and their selections. See also "Parameter Bar" on page 242.

Figure 10-54 Data Menu



Individual Parameter Selections

The individual parameter selections are based on the specific data analysis type. The following lists each data analysis type and its associated parameters:

- **Time Domain (Balanced)**

  TDD11, TDD12, TDD21, TDD22, TDC11, TDC12, TDC21, TDC22, TCD11, TCD12, TCD21, TCD22, TCC11, TCC12, TCC21, TCC22

- **Time Domain (Single Ended)**

  T11, T12, T13, T14, T21, T22, T23, T24, T31, T32, T33, T34, T41, T42, T43, T44

- **Frequency Domain (Balanced)**

  SDD11, SDD12, SDD21, SDD22, SDC11, SDC12, SDC21, SDC22,
  SCD11, SCD12, SCD21, SCD22, SCC11, SCC12, SCC21, SCC22

- **Frequency Domain (Single Ended)**

  S11, S12, S13, S14, S21, S22, S23, S24, S31, S32, S33, S34, S41, S42, S43, S44

- **Eye Diagram (Balanced)**

  TDD12, TDD21, TDC12, TDC21, TCD12, TCD21, TCC12, TCC21

- **Eye Diagram (Single Ended)**

  T12, T13, T14, T21, T23, T24, T31, T32, T34, T41, T42, T43

All

Selecting **All** displays:

- All 16 of the time domain parameters if the active plot window is a time domain window.
  - If **New Plot** is chosen, selecting **All** displays all 16 of the parameters on individual plots in one window.
  - If **New Trace** is chosen, selecting **All** displays all 16 of the parameters on a single plot.
- All 16 of the frequency domain parameters if the active plot window is a frequency domain window.
  - If **New Plot** is chosen, selecting **All** displays all 16 of the parameters on individual plots in one window.
  - If **New Trace** is chosen, selecting **All** displays all 16 of the parameters on a single plot.
- All 8 of the eye diagram parameters if the active plot window is a balanced eye diagram window.
- All 12 of the eye diagram parameters if the active plot window is a single-ended eye diagram window.

New Plot

When **New Plot** is chosen, selecting any of the time or frequency domain parameters will display a new plot with that parameter within the active plots window. If **New Plot** is chosen, selecting **All** displays all 16 of the time or frequency domain parameters on individual plots in one window.

New Trace

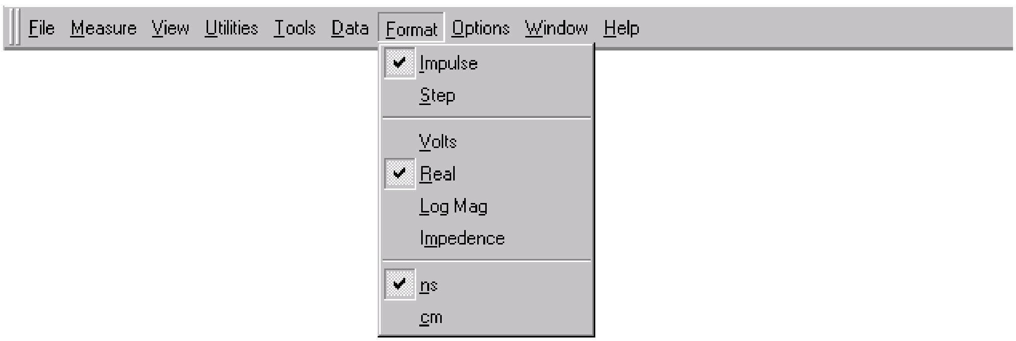
When **New Trace** is chosen, selecting any of the time or frequency domain parameters will display a new trace within the active plot. If **New Trace** is chosen, selecting **All** displays all 16 of the time or frequency domain parameters on a single plot.

Format Menu

There are two versions of the **Format** menu, one for active displays in the time domain and another for active displays in the frequency mode. The **Format** menu is not displayed for displays in other modes. See also "Format Bar" on page 244.

Time Domain Format Menu

Figure 10-55 Format Menu for Time Domain Measurements

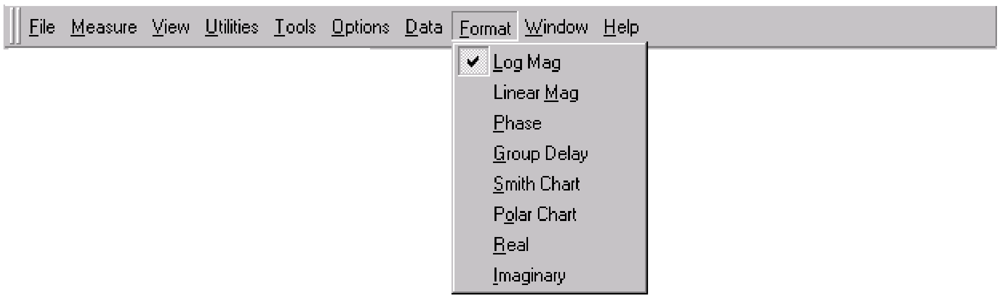


Impulse	Sets the active time domain plot to show the response with an impulse stimulus. This is the default setting.
Step	Sets the active time domain plot to show the response with a step-voltage stimulus.
Volts	Sets the active time domain plot's vertical axis to Volts mode.
Real	Sets the active time domain plot's vertical axis to Real mode. This is the default setting.
Log Mag	Sets the active time domain plot's vertical axis to Log Mag mode.
Impedance	Sets the active time domain plot's vertical axis to impedance mode. Active only for reflection plots with a step stimulus.
ns	Sets the active time domain plot's horizontal axis to nanoseconds (ns). This is the default setting.
cm	Sets the active time domain plot's horizontal axis to centimeters (cm).

Refer to "Selecting Time Domain Display Formats" on page 157 for more information.

Frequency Domain Format Menu

Figure 10-56 Format Menu for Frequency Domain Measurements



Log Mag Displays the active frequency domain plot in Log Magnitude format. This is the default setting.

Linear Mag Displays the active frequency domain plot in Linear Magnitude format.

Phase Displays the active frequency domain plot in Phase format.

Group Delay Displays the active frequency domain plot in Group Delay format.

Smith Chart Displays the active frequency domain plot in Smith Chart format.

Polar Chart Displays the active frequency domain plot in Polar Chart format.

Real Displays the active frequency domain plot in Real format.

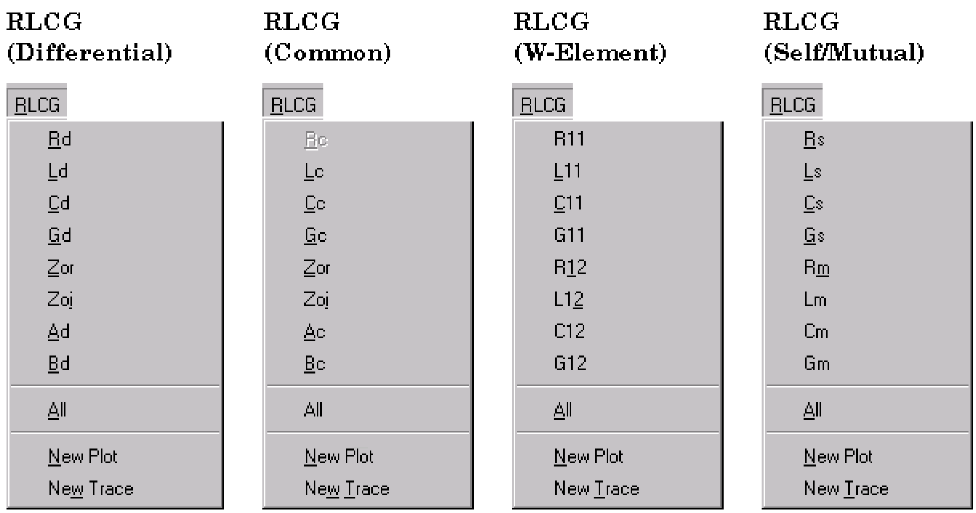
Imaginary Displays the active frequency domain plot in Imaginary format.

Refer to "Selecting Frequency Domain Display Formats" on page 128 for more information.

RLCG Menu

When any of the RLCG data analysis types are selected, the **RLCG** menu is displayed. Each of the four RLCG data analysis types has its own menu. Refer to Figure 10-57.

Figure 10-57 RLCG Menus



Individual Parameter Selections

The individual parameter selections are based on the specific RLCG data analysis type. The following lists each data analysis type and its associated parameters.

RLCG (Differential):	Rd, Ld, Cd, Gd, Zor, Zoi, Ad, Bd
RLCG (Common):	Rc, Lc, Cc, Gc, Zor, Zoi, Ac, Bc
RLCG (W-Element):	R11, L11, C11, G11, R12, L12, C12, G12
RLCG (Self/Mutual):	Rs, Ls, Cs, Gs, Rm, Lm, Cm, Gm

where, **A** represents the Attenuation Constant (α) **B** represents the Phase Constant (β)

C represents Capacitance **G** represents Conductance

L represents Inductance **R** represents Resistance

Z represents Impedance

All

If **New Plot** is chosen, selecting **All** displays all eight parameters on individual plots in one window. If **New Trace** is chosen, selecting **All** displays all eight parameters on a single plot.

New Plot

When **New Plot** is chosen, selecting any of the RLCG parameters will display a new plot with that parameter within the active plots window. If **New Plot** is chosen, selecting **All** displays all eight parameters on individual plots in one window.

New Trace

When **New Trace** is chosen, selecting any of the RLCG parameters will display a new trace within the active plot. If **New Trace** is chosen, selecting **All** displays all eight parameters on a single plot.

Options Menu

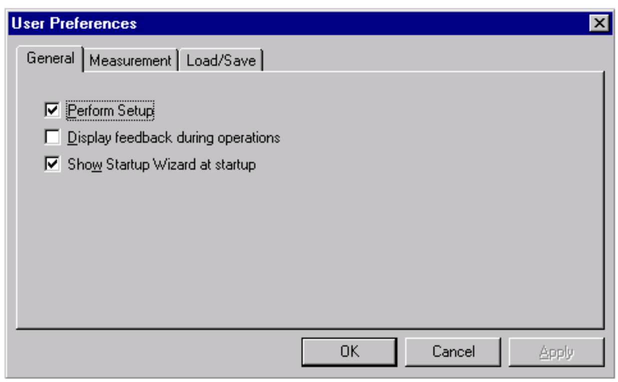
The **Options** menu provides access to the *User Preferences* dialog box

Figure 10-58 Options Menu

User Preferences

The *User Preferences* dialog box allows you to customize your Physical Layer Test System software. This dialog box has the following three tabs to choose from: **General**, **Measurement**, and **Load/Save**.

Figure 10-59 User Preferences Dialog Box



General

The **General** tab (see Figure 10-59) has the following choices:

- **Perform Setup -** when selected, the PLTS software, when it is next started, will operate as if it has just been installed and go through a complete setup routine. At the conclusion of this routine, the **Perform Setup** option is automatically turned off.
- **Display feedback during operations -** controls the display of informational and progress windows for various operations, such as the file conversion summary window and the measurement post-processing progress window. When selected, these windows are displayed; otherwise, these windows are hidden. This option's default setting is ON.

- **Show Startup Wizard at startup** - when selected, the startup wizard is displayed each time the software is started. This option's default setting is ON.

Measurement

The **Measurement** tab (see Figure 10-59) has the following choices:

- **Beep when measurement is complete** - when checked, the PC emits a beep to indicate that the measurement is complete.
- **Show warning before uncalibrated measurements** - when checked, a message is displayed confirming that you are making an uncalibrated measurement.

Load/Save

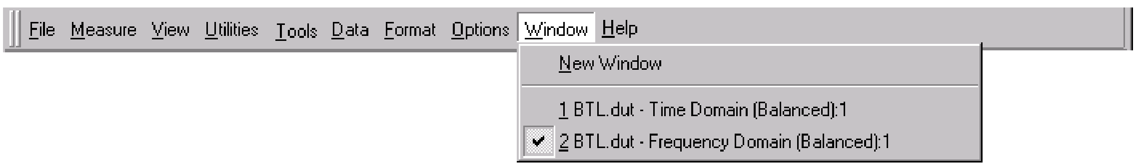
The **Load/Save** tab (see Figure 10-59) has the following choices:

- **Save data in BMS Format** - when checked, data is saved in Balanced Measurement System format.

Window Menu

The **Window** menu provides an efficient method of working with analysis windows. It gives you the ability to add new analysis windows, arrange open analysis windows for optimum viewing, arrange the minimized analysis window icons, and select/display individual analysis windows.

Figure 10-60 Window Menu



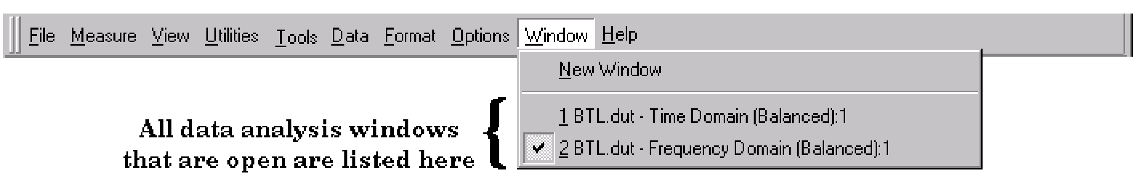
New Window

New Window adds a new analysis window to the display area. The new window will display the analysis type that is currently selected.

List of Open Analysis Windows

The **Window** menu also lists the open analysis windows below the standard **Window** menu selections. Each open analysis window is listed in the order they were opened with the most recent window listed at the bottom. The active analysis window is shown with a check mark displayed at its left side. Selecting a window from the list displays the window in the display area.

Figure 10-61 List of Open Data Analysis Windows



Help Menu

The **Help** menu provides access to information about the software.

Figure 10-62 Help Menu

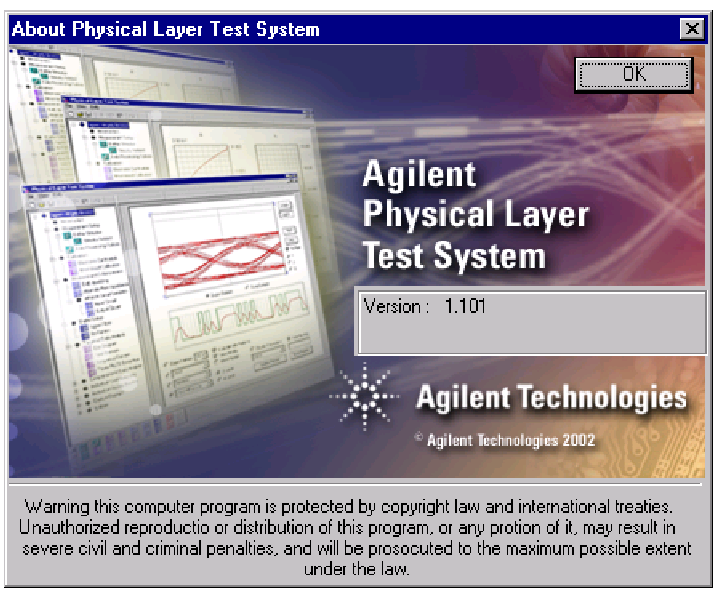
Help…

The **Help**… selection displays the user's guide (this manual) in pdf format.

About PLTS…

The *About PLTS*… window displays the software version information.

Figure 10-63 About PLTS… Window



11 Specifications and Characteristics

Definitions

All specifications and characteristics apply over a 25 °C ±5 °C range (unless otherwise stated) and 90 minutes after the instrument has been turned on.

Specification (spec.)	Warranted performance. Specifications include guard bands to account for the expected statistical performance distribution, measurement uncertainties, and changes in performance due to environmental conditions.
Characteristic (char.)	A performance parameter that the product is expected to meet before it leaves the factory, but that is not verified in the field and is not covered by the product warranty. A characteristic includes the same guard bands as a specification.
Typical (typ.)	Expected performance of an average unit which does not include guard bands. It is not covered by the product warranty.
Nominal (nom.)	A general, descriptive term that does not imply a level of performance. It is not covered by the product warranty.
Calibration	The process of measuring known standards to characterize the system's systematic (repeatable) errors.
Corrected (residual)	Indicates performance after error correction (calibration). It is determined by the quality of calibration standards and how well “known” they are, plus system repeatability, stability, and noise.
Uncorrected (raw)	Indicates instrument performance without error correction. The uncorrected performance affects the stability of a calibration.

N1947A and N1948A Electrical Specifications and Characteristics

The following specifications are applicable for a system in the following configurations:

Network Analyzer:	Agilent E8803A Option 014 (N1947A System)
	Agilent E8358A Option 015 (N1948A System)
Test Set:	Agilent N4417A Option 103 (N1947A System)
	Agilent N4417A Option 104 (N1948A System)
Calibration Kit:	Agilent 85052C Precision 3.5 mm
Test Port Cables:	Agilent N4417A Option B20
Calibration Technique:	Four-Port SOLT

System Dynamic Range

The test port transmission measurements are valid at 10 Hz IF bandwidth with four-port error correction and +10 dBm maximum output power. The dynamic range is the difference between the rms noise floor and the maximum output power.

Table 11-1 System Dynamic Range

Frequency Range	Specification
300 kHz to 1.3 GHz	120 dB[a]
1.3 GHz to 3.0 GHz	120 dB
3.0 GHz to 6.0 GHz	108 dB
6.0 GHz to 9.0 GHz	103 dB

a. May be limited to 100 dB at particular frequencies below 750 MHz due to spurious receiver residuals.

Measurement Port

Residual uncertainties for corrected data using four-port error correction. These apply for 25 °C with less than 1 °C variation from calibration.

Table 11-2 Measurement Port Characteristics

Description	Characteristic			
	300 kHz to 1.3 GHz	1.3 GHz to 3.0 GHz	3.0 GHz to 6.0 GHz	6.0 GHz to 9.0 GHz
Directivity	50 dB	47 dB	42 dB	40 dB
Source Match	42 dB	42 dB	38 dB	35 dB
Load Match	50 dB	47 dB	42 dB	40 dB
Reflection Tracking	± 0.006 dB	± 0.007 dB	± 0.009 dB	± 0.015 dB
Transmission Tracking	± 0.012 dB	± 0.015 dB	± 0.040 dB	± 0.060 dB

Measurement Uncertainties

The following graphics show the worst case transmission and reflection magnitude and phase uncertainty for the N1947A and N1948A systems.

Figure 11-1 3.5 mm Transmission Magnitude and Phase Uncertainty

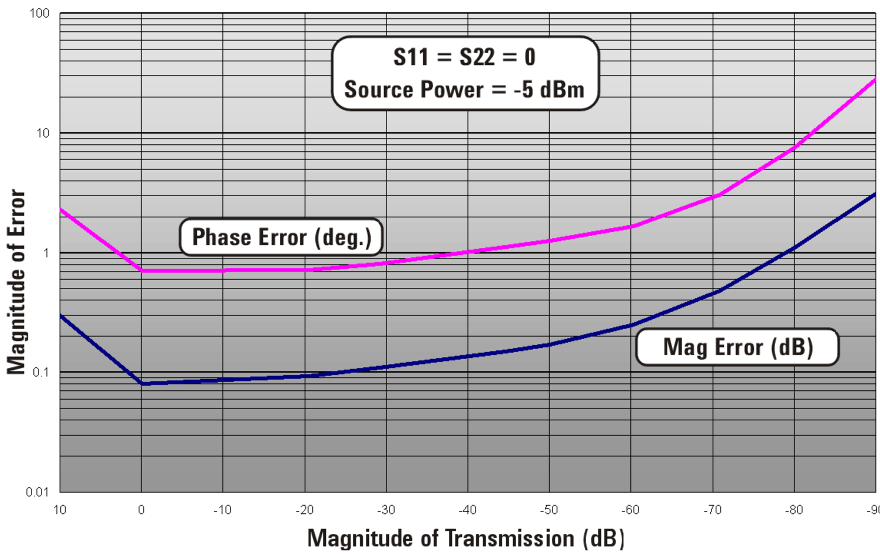
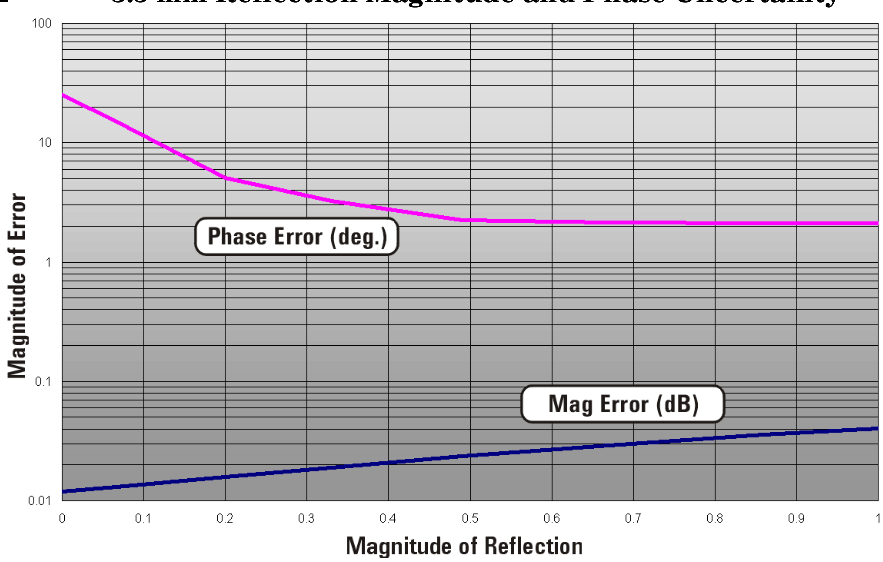


Figure 11-2 3.5 mm Reflection Magnitude and Phase Uncertainty



Test Set Performance

Table 11-3 Test Set Performance

Description	Specification	Supplemental Information
Frequency Range	300 kHz to 9.0 GHz	
Impedance		50 Ohms (nom.)
Insertion Loss		
Source Out to Coupler In	4.5 dB maximum	
Port 2 to A In and Port 4 to B In	8.5 dB maximum	
A In to A Out and B In to B Out	8.0 dB maximum	
Isolation (port to port and A to B)	≥ 105 dB	
Maximum Operating Level	+20 dBm	
Damage Level		+30 dBm (typ.)
Test Port Connectors		50-ohm Type-N Connectors (nom.)

Power Supply

The power supply requirements for the test sets are listed below.

Table 11-4 Test Set Power Supply Specifications

Description	Specification
Input Voltage Range	100 to 120 Volts 220 to 250 Volts
Frequency Range	47 to 62 Hertz
Power	40 VA

N1951A Electrical Specifications and Characteristics

The following specifications are applicable for a system in the following configurations:

Network Analyzer:	Agilent 8720ES Option H32
Test Set:	Agilent N4418A
Calibration Kit:	Agilent 85052C Precision 3.5 mm
Test Port Cables:	Agilent N4418A Option B20
Calibration Technique:	Four-Port SOLT

System Dynamic Range

The test port transmission measurements are valid at 10 Hz IF bandwidth with four-port error correction and +5 dBm maximum output power. The dynamic range is the difference between the rms noise floor and the maximum output power.

Table 11-5 System Dynamic Range

Frequency Range	Specification
50 MHz to 840 MHz	77 dB
840 MHz to 20.0 GHz	90 dB

Measurement Port

Residual uncertainties for corrected data using four-port error correction. These apply for 25 °C with less than 1 °C variation from calibration.

Table 11-6 Measurement Port Characteristics

Description	Characteristic		
	50 MHz to 2.0 GHz	2.0 GHz to 8.0 GHz	8.0 GHz to 20.0 GHz
Directivity	48 dB	48 dB	43 dB
Source Match	41 dB	41 dB	38 dB
Load Match	48 dB	48 dB	43 dB
Reflection Tracking	± 0.005 dB	± 0.005 dB	± 0.008 dB
Transmission Tracking	± 0.014 dB	± 0.014 dB	± 0.035 dB

Measurement Uncertainties

The following graphics show the worst case transmission and reflection magnitude and phase uncertainty for the N1951A system.

Figure 11-3 3.5 mm Transmission Magnitude and Phase Uncertainty

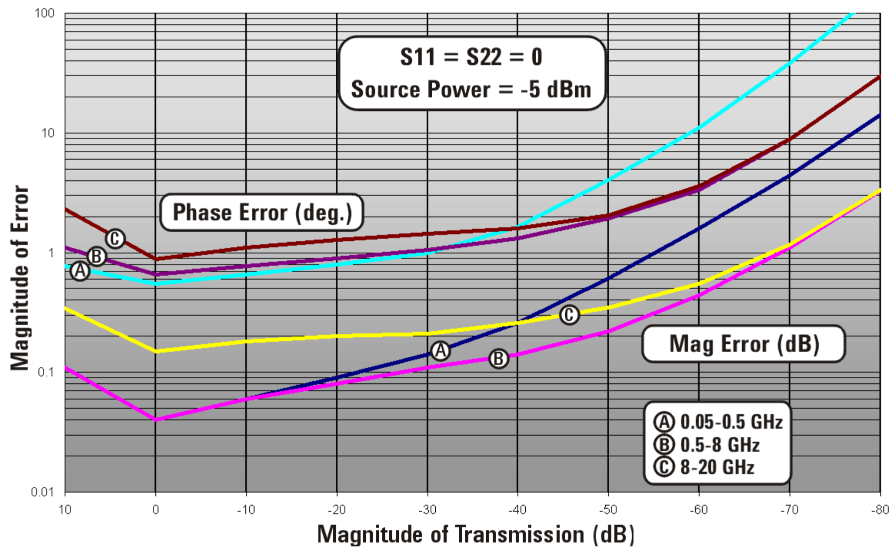
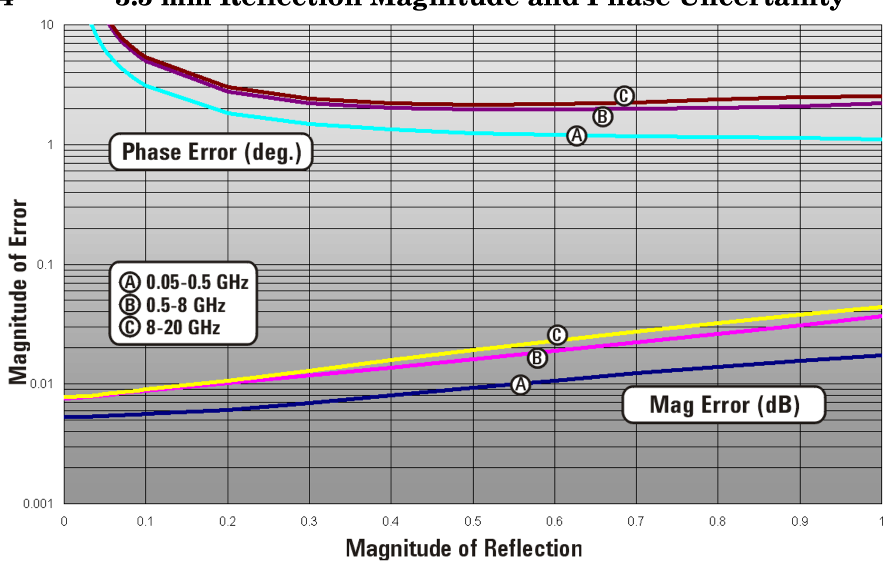


Figure 11-4 3.5 mm Reflection Magnitude and Phase Uncertainty



Test Set Performance

Table 11-7 Test Set Performance

Description	Specification	Supplemental Information
Frequency Range	50 MHz to 20.0 GHz	
Impedance		50 Ohms (nom.)
Insertion Loss	8 to 10 dB	
Isolation (port to port)	≥ 85 dB	
Maximum Operating Level	+20 dBm	
Damage Level		+30 dBm (typ.)
DC Bias Range (Option UNK only)		40 VDC, 500 mA
Test Port Connectors		3.5 mm (m) Connectors

Power Supply

The power supply requirements for the test sets are listed below.

Table 11-8 Test Set Power Supply Specifications

Description	Specification
Input Voltage Range	100 to 120 Volts 220 to 250 Volts
Frequency Range	47 to 62 Hertz
Power	40 VA

N1953A Electrical Specifications and Characteristics

The following specifications are applicable for a system in the following configurations:

Network Analyzer:	Agilent E8362A Option 014 UNL
Test Set:	Agilent N4419A
Calibration Kit:	Agilent 85052D 3.5 mm
Test Port Cables:	Agilent N4419A Option B20
Calibration Technique:	Four-Port SOLT

System Dynamic Range

The test port transmission measurements are valid at 10 Hz IF bandwidth with four-port error correction and –5 dBm default maximum output power. The dynamic range is the difference between rms noise floor and the output power.

Table 11-9 System Dynamic Range

Frequency Range	Specification
45 MHz to 500 MHz	70 dB
500 MHz to 2.0 GHz	100 dB
2.0 GHz to 10.0 GHz	100 dB
10.0 GHz to 20.0 GHz	85 dB

Measurement Port

Residual uncertainties for corrected data using four-port error correction. These apply for 25 °C with less than 1 °C variation from calibration.

Table 11-10 Measurement Port Characteristics

Description	Characteristic		
	45 MHz to 2.0 GHz	**2.0 GHz to 10.0 GHz**	**10.0 GHz to 20.0 GHz**
Directivity	56 dB	42 dB	40 dB
Source Match	42 dB	36 dB	33 dB
Load Match	56 dB	42 dB	40 dB
Reflection Tracking	± 0.0015 dB	± 0.009 dB	± 0.013 dB
Transmission Tracking	± 0.020 dB	± 0.032 dB	± 0.050 dB

Measurement Uncertainties

The following graphics show the worst case transmission and reflection magnitude and phase uncertainty for the N1953A system.

Figure 11-5 3.5 mm Transmission Magnitude and Phase Uncertainty

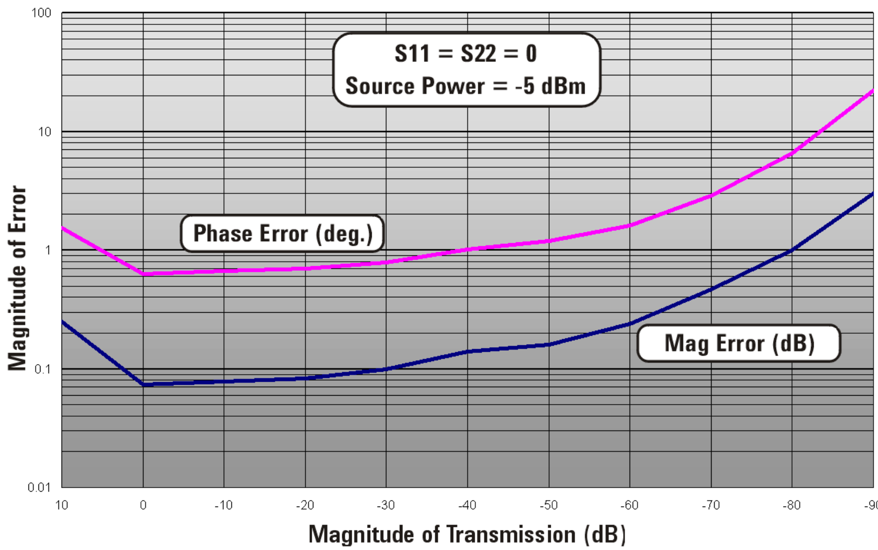
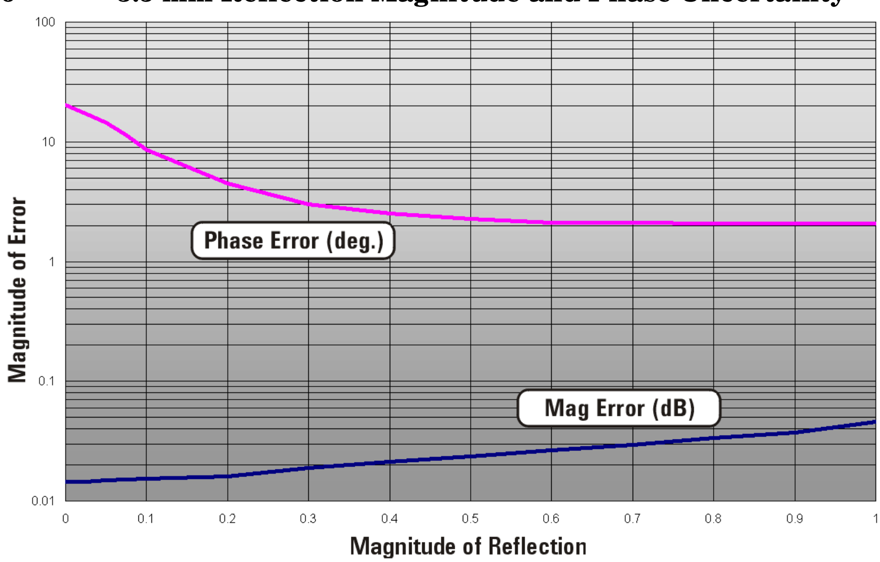


Figure 11-6 3.5 mm Reflection Magnitude and Phase Uncertainty



Test Set Performance

Table 11-11 Test Set Performance

Description	Characteristics	Supplemental Information
Frequency Range	45 MHz to 20.0 GHz	
Impedance		50 Ohms (nom.)
Insertion Loss		
Source Out to Coupler Thru	5.0 dB maximum	
Port 2 to Rcvr A In and Port 4 to Rcvr B In		
45 MHz to 1.0 GHz		18 to 45 dB (typical)
1.0 GHz to 20.0 GHz		18 to 25 dB (typical)
Rcvr A In to Cplr Arm and Rcvr B In to Cplr Arm	8.0 dB maximum	
Isolation (port to port)		
45 MHz to 200 MHz	≥ 70 dB	
200 MHz to 20 GHz	≥ 90 dB	
Maximum Operating Level	+20 dBm	
Damage Level		+30 dBm (typical)
Test Port Connectors		50-ohm 3.5 mm Connectors (nom.)

Power Supply

The power supply requirements for the test sets are listed below.

Table 11-12 Test Set Power Supply Specifications

Description	Specification
Input Voltage Range	100 to 240 Volts
Frequency Range	47 to 63 Hertz
Power	40 VA

N1957A Electrical Specifications and Characteristics

The following specifications are applicable for a system in the following configurations:

Network Analyzer:	Agilent E8364B Options 014 and 711
Test Set:	Agilent N4421A
Calibration Kit:	Agilent 85056A 2.4 mm
Test Cables:	Agilent N4421A-B20
Calibration Technique:	Four-Port SOLT

System Dynamic Range

The test port transmission measurements are valid at 10 Hz IF bandwidth with four-port error correction and –17 dBm default maximum output power. The dynamic range is the difference between rms noise floor and the output power.

Table 11-13 System Dynamic Range

Frequency Range	Specification
45 MHz to 500 MHz	55 dB
500 MHz to 10.0 GHz	70 dB
10.0 GHz to 20.0 GHz	70 dB
20.0 GHz to 50.0 GHz	55 dB

Measurement Port

Residual uncertainties for corrected data using four-port error correction. These apply for 25 °C with less than 1 °C variation from calibration.

Table 11-14 Measurement Port Characteristics

Description	Characteristic			
	45 MHz to 0.5 GHz	0.5 GHz to 10.0 GHz	10.0 GHz to 20.0 GHz	20.0 GHz to 50.0 GHz
Directivity	43 dB	39.5 dB	39 dB	33 dB
Source Match	38 dB	34 dB	34 dB	27 dB
Load Match	43 dB	39.5 dB	39 dB	33 dB
Reflection Tracking	± 0.001 dB	± 0.002 dB	± 0.008 dB	± 0.026 dB
Transmission Tracking	± 0.015 dB	± 0.020 dB	± 0.040 dB	± 0.20 dB

Measurement Uncertainties

The following graphics show the worst case transmission and reflection magnitude and phase uncertainty for the N1957A system.

Figure 11-7 2.4 mm Transmission Magnitude and Phase Uncertainty

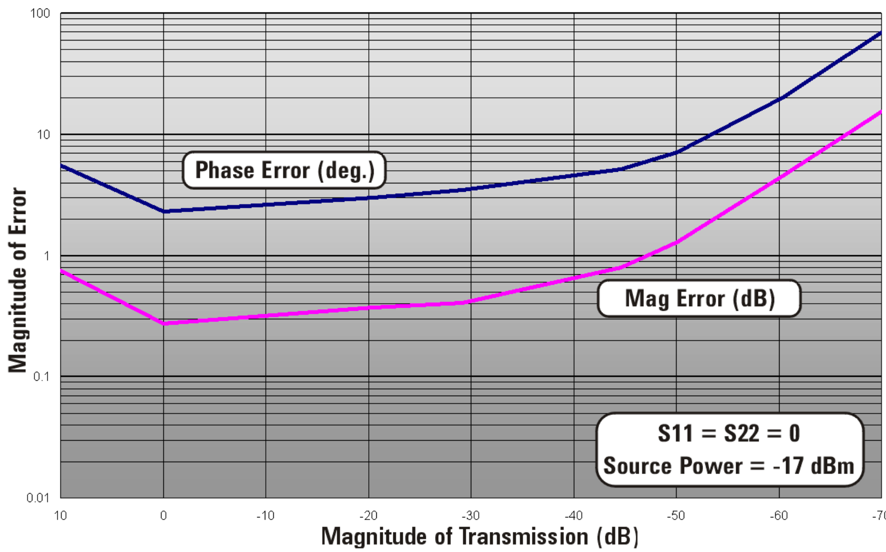
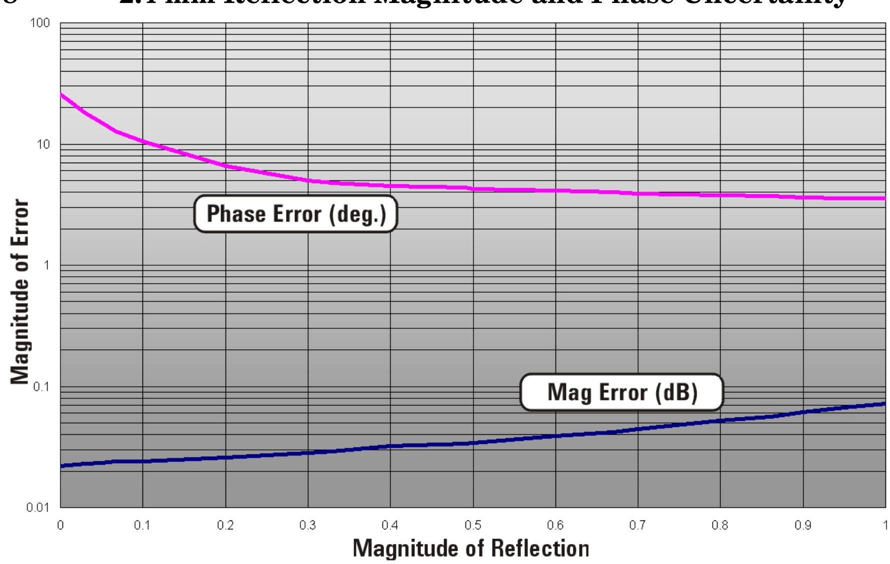


Figure 11-8 2.4 mm Reflection Magnitude and Phase Uncertainty



Test Set Performance

Table 11-15 Test Set Performance

Description	Characteristics	Supplemental Information
Frequency Range	45 MHz to 50.0 GHz	
Transition Time (10 to 90%, TR=.72/BW)	14 ps	
Impedance		50 Ohms (nom.)
Insertion Loss		
Source Out to Coupler Thru	12.0 dB maximum	
Port 2 to Rcvr A In and Port 4 to Rcvr B In		
45 MHz to 1.0 GHz		18 to 45 dB (typical)
1.0 GHz to 50.0 GHz		16 to 26 dB (typical)
Rcvr A In to Cplr Arm and Rcvr B In to Cplr Arm	15.0 dB maximum	
Isolation (port to port)		
45 MHz to 200 MHz	≥ 70 dB	
200 MHz to 50 GHz	≥ 90 dB	
Maximum Operating Level	+20 dBm	
Damage Level		+30 dBm (typical)
Test Port Connectors		50-ohm 2.4 mm (m) Connectors (nom.)

Power Supply

The power supply requirements for the test sets are listed below.

Table 11-16 Test Set Power Supply Specifications

Description	Specification
Input Voltage Range	100 to 240 Volts
Frequency Range	47 to 63 Hertz
Power	40 VA

General Characteristics

The test set environmental operating conditions and physical characteristics are displayed on the following pages.

Environmental Operating Conditions

The environmental operating conditions for the test set are listed below.

Table 11-17 Test Set Environmental Operating Conditions

Description	Conditions
Operating Environment	Indoor use
Altitude	
Operating:	0 to 2.0 km (6,560 ft)
Storage:	0 to 15.24 km (50,000 ft)
Temperature	0 °C to 40 °C
Maximum Relative Humidity	80% for temperatures up to 31 °C decreasing linearly to 50% for a temperature of 40 °C

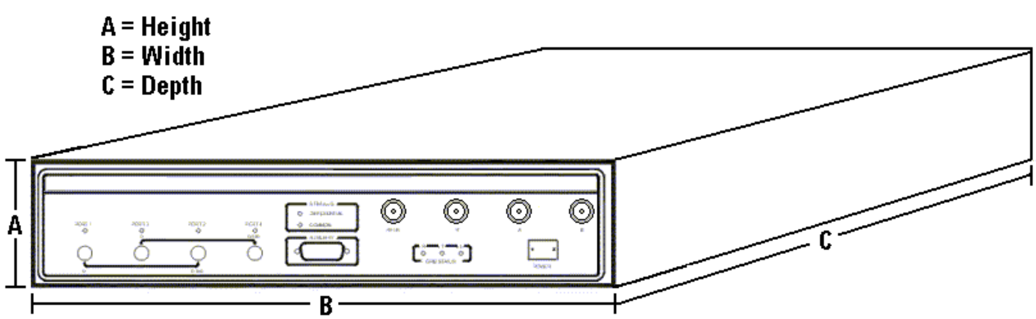
This product is designed for use in INSTALLATION CATEGORY II and POLLUTION DEGREE 2, per IED 61010-1 and 664, respectively.

Physical Characteristics

The weight and dimensions for the test sets are listed below.

Weight and Dimensions

Table 11-18 Test Set Weight and Dimensions



Model Number	Weight	Dimensions		
		Height (A)	**Width (B)**	**Depth (C)**
N4415A, N4416A, N4417A, N4418A, and N4419A	9.0 kilograms (19.9 pounds)	3.0 in (7.62 cm)	16.75 in (42.55 cm)	19.25 in (48.90 cm)
N4421A	9.0 kilograms (19.9 pounds)	5.5 in (13.97 cm)	16.75 in (42.55 cm)	16.75 in (42.55 cm)

12 Test Set Front Panel and Rear Panel

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This chapter provides a graphical overview of the test sets used as part of the physical layer test system. This chapter also illustrates the front and rear panels of the S-parameter test sets separately. The features of each front and rear panel (such as connectors, switches, LEDs, and fuses) are identified and briefly described.

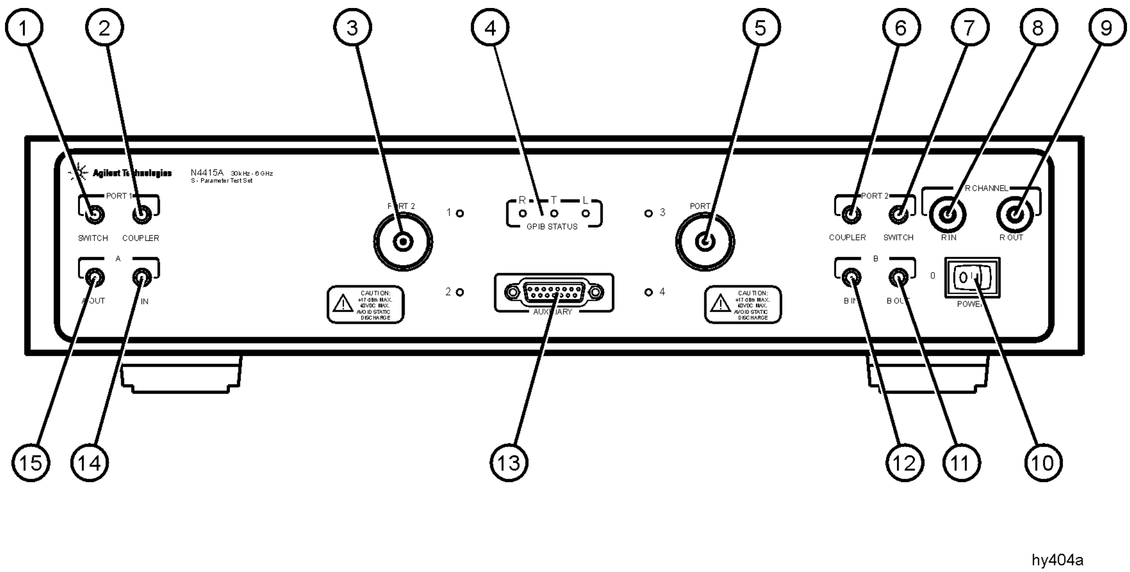
The individual network analyzer features are described in the network analyzer documentation. They are not be described in this document!

The front and rear panel of each S-parameter test set model is illustrated and described. Refer to the page number listed below for your test set model number.

For Model Number:	Refer to:
N4415A	page 302
N4416A	page 306
N4417A	page 310
N4418A	page 314
N4419A	page 318
N4421A	page 322

N4415A

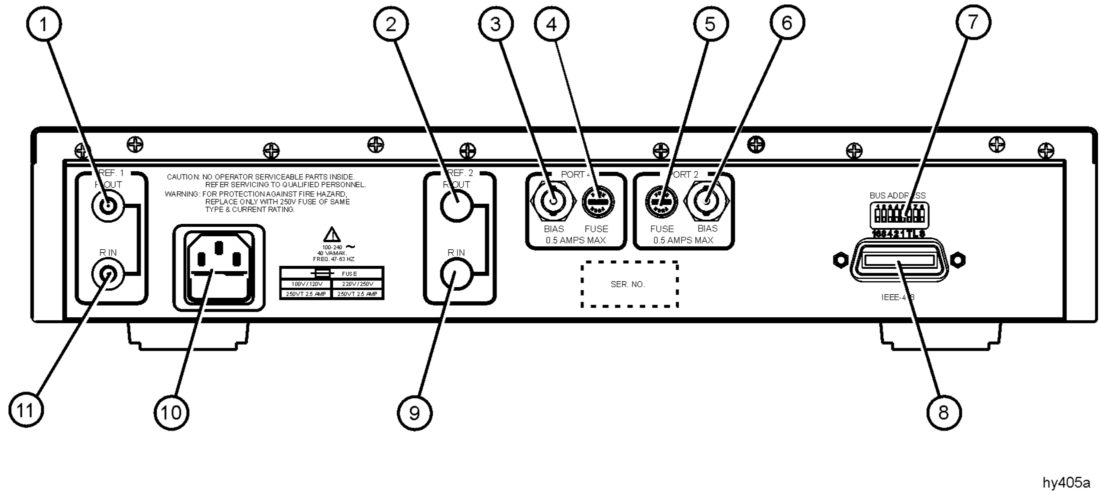
N4415A Front Panel



ID Number	Front Panel Feature	Feature Description
1	SWITCH	SMA (f) connector that is connected to the network analyzer PORT 1 SWITCH connector using a semirigid cable.
2	COUPLER	SMA (f) connector that is connected to the network analyzer PORT 1 COUPLER connector using a semirigid cable.
3	PORT 2	APC-7 connector that is connected to the DUT or fixture. (+17 dBm maximum operating level)
4	GPIB STATUS	Three LEDs (R, T, and L) that display the GPIB status of the test set when it is communicating with the network analyzer. R = Remote Operation, T = Talk mode, L = Listen mode.
5	PORT 4	APC-7 connector that is connected to the DUT or fixture. (+17 dBm maximum operating level)

ID Number	Front Panel Feature	Feature Description
6	COUPLER	SMA (f) connector that is connected to the network analyzer PORT 2 COUPLER connector using a semirigid cable.
7	SWITCH	SMA (f) connector that is connected to the network analyzer PORT 2 SWITCH connector using a semirigid cable.
8	R IN	SMA (f) connector that is connected to the network analyzer R Channel IN connector using a semirigid cable.
9	R OUT	SMA (f) connector that is connected to the network analyzer R Channel OUT connector using a semirigid cable.
10	POWER	ON/OFF switch that disconnects the mains circuits from the mains supply before other parts of the test set. The front panel POWER switch disconnects the mains circuits from the mains supply after the EMC filters and before other parts of the instrument.
11	B OUT	SMA (f) connector that is connected to the network analyzer B OUT connector using a semirigid cable.
12	B IN	SMA (f) connector that is connected to the network analyzer B IN connector using a semirigid cable.
13	AUXILIARY	15-pin ribbon (f) connector that may be connected to the Agilent N4430A/B ECal module to provide ECal capability.
14	A IN	SMA (f) connector that is connected to the network analyzer A IN connector using a semirigid cable.
15	A OUT	SMA (f) connector that is connected to the network analyzer A OUT connector using a semirigid cable.

N4415A Rear Panel

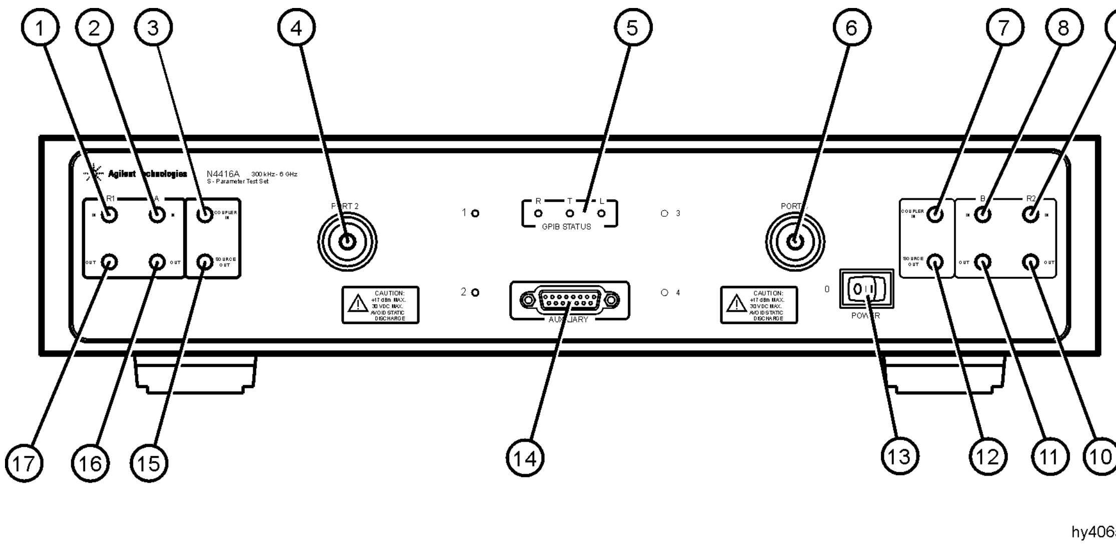


ID Number	Rear Panel Feature	Feature Description
1	REF 1 R OUT	SMA (f) connector, used as an output reference signal
2	REF 2 R OUT	Not Used
3	PORT 4 BIAS	BNC (f) connector. The bias port is used to supply a dc voltage to an active DUT, such as an amplifier or a transistor.
4	PORT 4 FUSE	Bias Fuse, 0.5 A, 250 V (Agilent part number 2110-0012)
5	PORT 2 FUSE	Bias Fuse, 0.5 A, 250 V (Agilent part number 2110-0012)
6	PORT 2 BIAS	BNC (f) connector. The bias port is used to supply a dc voltage to an active DUT, such as an amplifier or a transistor.
7	BUS ADDRESS	Switch that is used to set the GPIB address. Refer to "Step 7. Set Up the General Purpose Interface Bus (GPIB)" on page 21 for further information.
8	IEEE-488	24-pin IEEE-488/PCB (f) connector. The GPIB is the communication bus with the PC and the network analyzer.
9	REF 2 R IN	Not Used

ID Number	**Rear Panel Feature**	**Feature Description**
10	Power Cord Connector	Connector, 100-120 Vac or 220-250Vac input and Fuse, T 2.5 A 250 V (Agilent part number 2110-0681)
11	REF 1 R IN	SMA (f) connector, used as an input reference signal

N4416A

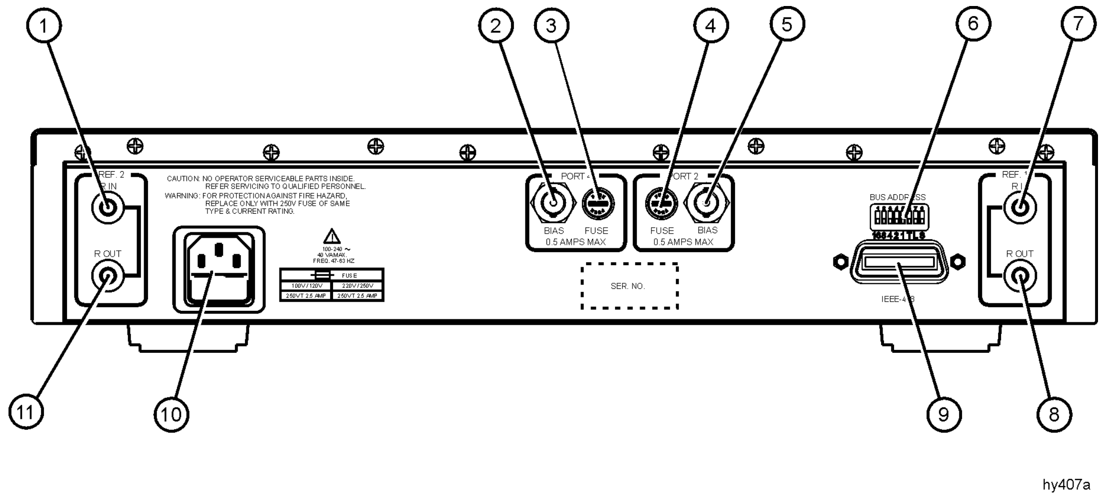
N4416A Front Panel



ID Number	Front Panel Feature	Feature Description
1	R1 IN	SMA (f) connector that is connected to the network analyzer R1 IN connector using a semirigid cable.
2	A IN	SMA (f) connector that is connected to the network analyzer A IN connector using a semirigid cable.
3	COUPLER IN	SMA (f) connector that is connected to the network analyzer COUPLER IN connector using a semirigid cable.
4	PORT 2	APC-7 connector that is connected to the DUT or fixture. (+17 dBm maximum operating level)
5	GPIB STATUS	Three LEDs (R, T, and L) that display the GPIB status of the test set when it is communicating with the network analyzer. R = Remote Operation, T = Talk mode, L = Listen mode.

ID Number	Front Panel Feature	Feature Description
6	PORT 4	APC-7 connector that is connected to the DUT or fixture. (+17 dBm maximum operating level)
7	COUPLER IN	SMA (f) connector that is connected to the network analyzer COUPLER IN connector using a semirigid cable.
8	B IN	SMA (f) connector that is connected to the network analyzer B IN connector using a semirigid cable.
9	R2 IN	SMA (f) connector that is connected to the network analyzer R2 IN connector using a semirigid cable.
10	R2 OUT	SMA (f) connector that is connected to the network analyzer R2 OUT connector using a semirigid cable.
11	B OUT	SMA (f) connector that is connected to the network analyzer B OUT connector using a semirigid cable.
12	SOURCE OUT	SMA (f) connector that is connected to the network analyzer SOURCE OUT connector using a semirigid cable.
13	POWER	ON/OFF switch that disconnects the mains circuits from the mains supply before other parts of the test set. The front panel POWER switch disconnects the mains circuits from the mains supply after the EMC filters and before other parts of the instrument.
14	AUXILIARY	15-pin ribbon (f) connector that may be connected to the Agilent N4430A/B ECal module to provide ECal capability.
15	SOURCE OUT	SMA (f) connector that is connected to the network analyzer SOURCE OUT connector using a semirigid cable.
16	A OUT	SMA (f) connector that is connected to the network analyzer A OUT connector using a semirigid cable.
17	R1 OUT	SMA (f) connector that is connected to the network analyzer R1 OUT connector using a semirigid cable.

N4416A Rear Panel

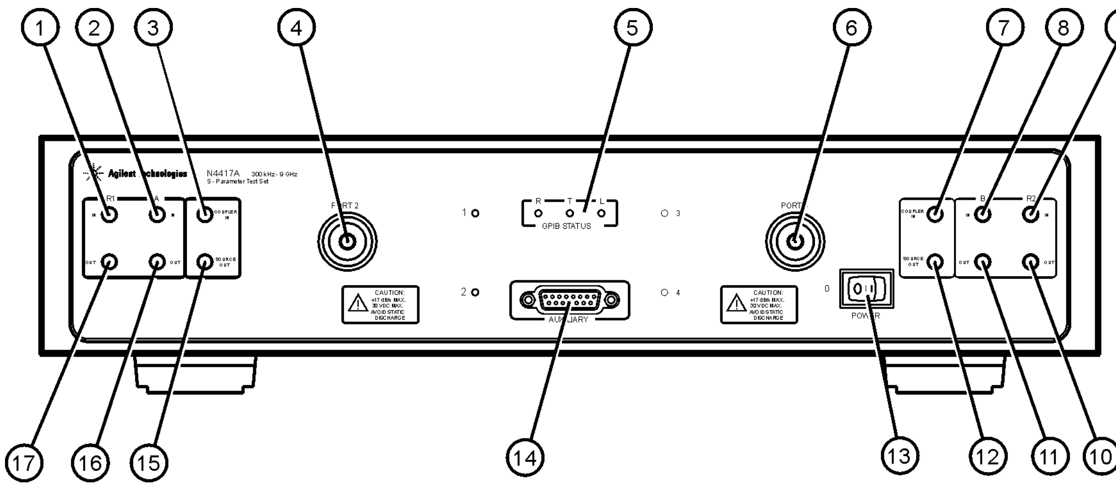


ID Number	Rear Panel Feature	Feature Description
1	REF 2 R IN	SMA (f) connector, used as an input reference signal
2	PORT 4 BIAS	BNC (f) connector. The bias port is used to supply a dc voltage to an active DUT, such as an amplifier or a transistor.
3	PORT 4 FUSE	Bias Fuse, 0.5 A, 250 V (Agilent part number 2110-0012)
4	PORT 2 FUSE	Bias Fuse, 0.5 A, 250 V (Agilent part number 2110-0012)
5	PORT 2 BIAS	BNC (f) connector. The bias port is used to supply a dc voltage to an active DUT, such as an amplifier or a transistor.
6	BUS ADDRESS	Switch that is used to set the GPIB address. Refer to “Step 7. Set Up the General Purpose Interface Bus (GPIB)” on page 21 for further information.
7	REF 1 R IN	SMA (f) connector, used as an input reference signal
8	REF 1 R OUT	SMA (f) connector, used as an output reference signal
9	IEEE-488	24-pin IEEE-488/PCB (f) connector. The GPIB is the communication bus with the PC and the network analyzer.

ID Number	Rear Panel Feature	Feature Description
10	Power Cord Connector	Connector, 100-120 Vac or 220-250Vac input and Fuse, T 2.5 A 250 V (Agilent part number 2110-0681)
11	REF 2 R OUT	SMA (f) connector, used as an output reference signal

N4417A

N4417A Front Panel

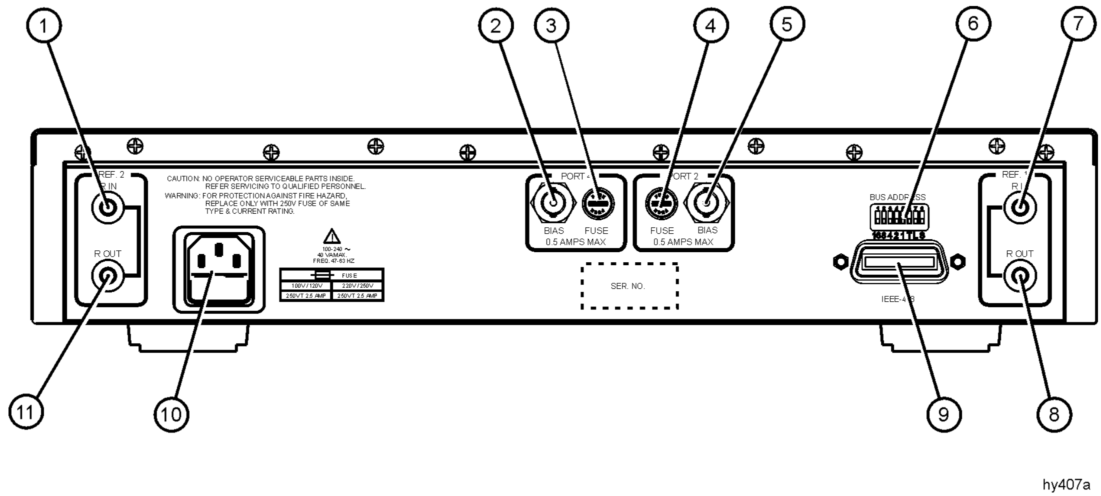


4417_frtpnl

ID Number	Front Panel Feature	Feature Description
1	R1 IN	SMA (f) connector that is connected to the network analyzer R1 IN connector using a semirigid cable.
2	A IN	SMA (f) connector that is connected to the network analyzer A IN connector using a semirigid cable.
3	COUPLER IN	SMA (f) connector that is connected to the network analyzer COUPLER IN connector using a semirigid cable.
4	PORT 2	APC-7 connector that is connected to the DUT or fixture. (+17 dBm maximum operating level)
5	GPIB STATUS	Three LEDs (R, T, and L) that display the GPIB status of the test set when it is communicating with the network analyzer. R = Remote Operation, T = Talk mode, L = Listen mode.

ID Number	Front Panel Feature	Feature Description
6	PORT 4	APC-7 connector that is connected to the DUT or fixture. (+17 dBm maximum operating level)
7	COUPLER IN	SMA (f) connector that is connected to the network analyzer COUPLER IN connector using a semirigid cable.
8	B IN	SMA (f) connector that is connected to the network analyzer B IN connector using a semirigid cable.
9	R2 IN	SMA (f) connector that is connected to the network analyzer R2 IN connector using a semirigid cable. This connector is installed on Option 104 only. It is not installed on Option 103.
10	R2 OUT	SMA (f) connector that is connected to the network analyzer R2 OUT connector using a semirigid cable. This connector is installed on Option 104 only. It is not installed on Option 103.
11	B OUT	SMA (f) connector that is connected to the network analyzer B OUT connector using a semirigid cable.
12	SOURCE OUT	SMA (f) connector that is connected to the network analyzer SOURCE OUT connector using a semirigid cable.
13	POWER	ON/OFF switch that disconnects the mains circuits from the mains supply before other parts of the test set. The front panel POWER switch disconnects the mains circuits from the mains supply after the EMC filters and before other parts of the instrument.
14	AUXILIARY	15-pin ribbon (f) connector that may be connected to the Agilent N4430A/B ECal module to provide ECal capability.
15	SOURCE OUT	SMA (f) connector that is connected to the network analyzer SOURCE OUT connector using a semirigid cable.
16	A OUT	SMA (f) connector that is connected to the network analyzer A OUT connector using a semirigid cable.
17	R1 OUT	SMA (f) connector that is connected to the network analyzer R1 OUT connector using a semirigid cable.

N4417A Rear Panel

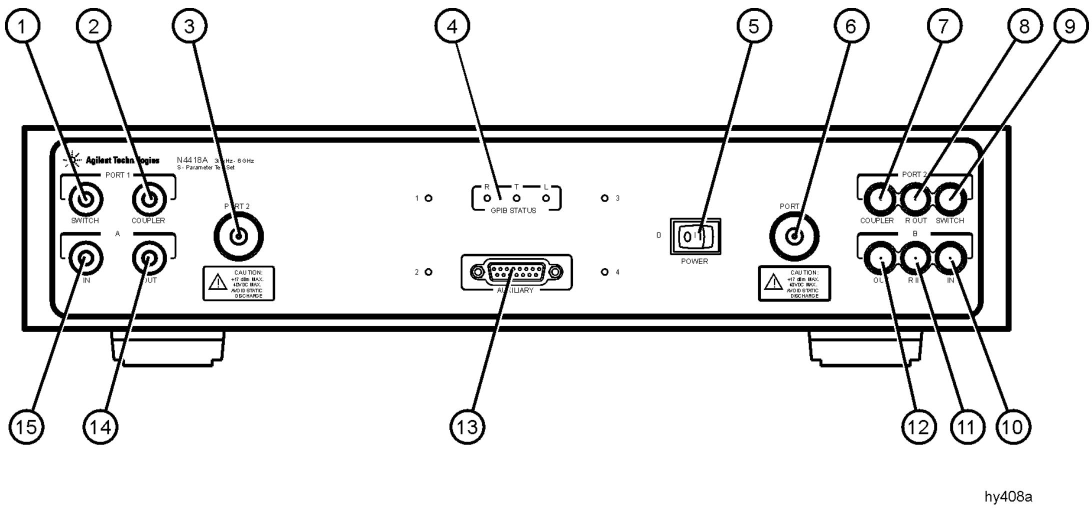


ID Number	Rear Panel Feature	Feature Description
1	REF 2 R IN	SMA (f) connector, used as an input reference signal. This connector is installed on Option 104 only. It is not installed on Option 103.
2	PORT 4 BIAS	BNC (f) connector. The bias port is used to supply a dc voltage to an active DUT, such as an amplifier or a transistor.
3	PORT 4 FUSE	Bias Fuse, 0.5 A, 250 V (Agilent part number 2110-0012)
4	PORT 2 FUSE	Bias Fuse, 0.5 A, 250 V (Agilent part number 2110-0012)
5	PORT 2 BIAS	BNC (f) connector. The bias port is used to supply a dc voltage to an active DUT, such as an amplifier or a transistor.
6	BUS ADDRESS	Switch that is used to set the GPIB address. Refer to “Step 7. Set Up the General Purpose Interface Bus (GPIB)” on page 21 for further information.
7	REF 1 R IN	SMA (f) connector, used as an input reference signal
8	REF 1 R OUT	SMA (f) connector, used as an output reference signal

ID Number	Rear Panel Feature	Feature Description
9	IEEE-488	24-pin IEEE-488/PCB (f) connector. The GPIB is the communication bus with the PC and the network analyzer.
10	Power Cord Connector	Connector, 100-120 Vac or 220-250Vac input and Fuse, T 2.5 A 250 V (Agilent part number 2110-0681)
11	REF 2 R OUT	SMA (f) connector, used as an output reference signal. This connector is installed on Option 104 only. It is not installed on Option 103.

N4418A

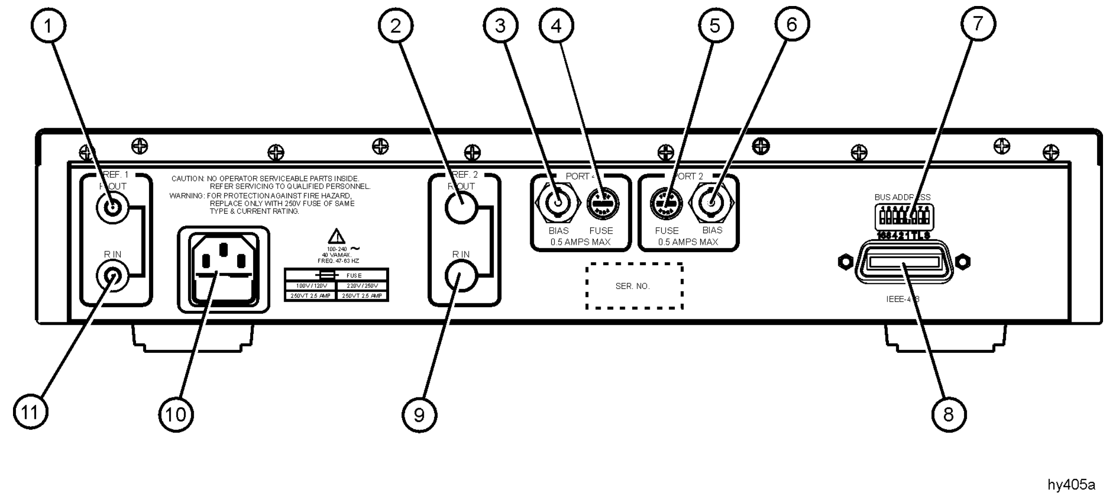
N4418A Front Panel



ID Number	Front Panel Feature	Feature Description
1	SWITCH	SMA (f) connector that is connected to the network analyzer PORT 1 SWITCH connector using a semirigid cable.
2	COUPLER	SMA (f) connector that is connected to the network analyzer PORT 1 BIAS TEE connector using a semirigid cable.
3	PORT 2	APC-3.5 (m) connector with 20 mm nut that is connected to the DUT or fixture. (+17 dBm maximum operating level)
4	GPIB STATUS	Three LEDs (R, T, and L) that display the GPIB status of the test set when it is communicating with the network analyzer. R = Remote Operation, T = Talk mode, L = Listen mode.

ID Number	Front Panel Feature	Feature Description
5	POWER	ON/OFF switch that disconnects the mains circuits from the mains supply before other parts of the test set. The front panel POWER switch disconnects the mains circuits from the mains supply after the EMC filters and before other parts of the instrument.
6	PORT 4	APC-3.5 (m) connector with 20 mm nut that is connected to the DUT or fixture. (+17 dBm maximum operating level)
7	COUPLER	SMA (f) connector that is connected to the network analyzer PORT 2 BIAS TEE connector using a semirigid cable.
8	R OUT	SMA (f) connector that is connected to the network analyzer R CHANNEL OUT connector using a semirigid cable.
9	SWITCH	SMA (f) connector that is connected to the network analyzer PORT 2 SWITCH connector using a semirigid cable.
10	IN	SMA (f) connector that is connected to the network analyzer B IN connector using a semirigid cable.
11	R IN	SMA (f) connector that is connected to the network analyzer R CHANNEL IN connector using a semirigid cable.
12	OUT	SMA (f) connector that is connected to the network analyzer B OUT connector using a semirigid cable.
13	AUXILIARY	15-pin ribbon (f) connector that may be connected to the Agilent N4430A/B ECal module to provide ECal capability.
14	OUT	SMA (f) connector that is connected to the network analyzer A OUT connector using a semirigid cable.
15	IN	SMA (f) connector that is connected to the network analyzer A IN connector using a semirigid cable.

N4418A Rear Panel

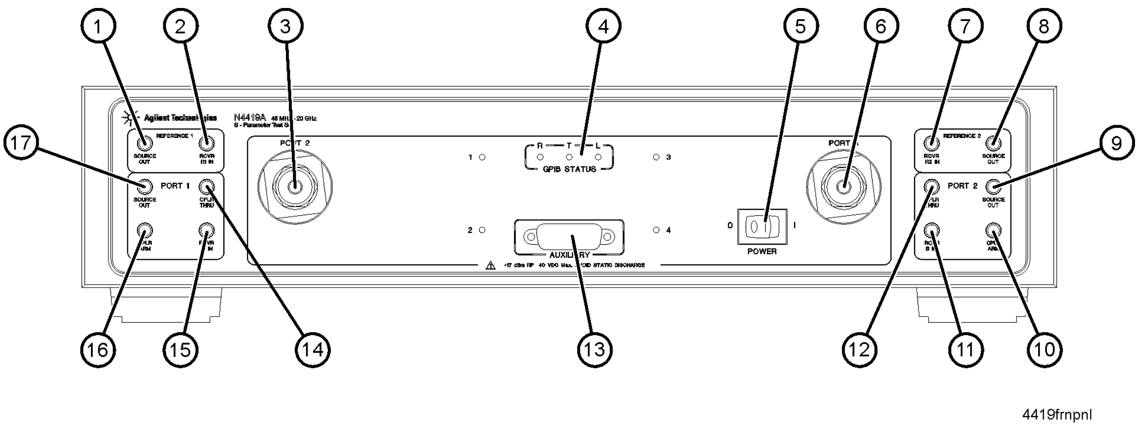


ID Number	Rear Panel Feature	Feature Description
1	REF 1 R OUT	SMA (f) connector, used as an output reference signal
2	REF 2 R OUT	SMA (f) connector, used as an output reference signal
3	PORT 4 BIAS	BNC (f) connector. The bias port is used to supply a dc voltage to an active DUT, such as an amplifier or a transistor.
4	PORT 4 FUSE	Bias Fuse, 0.5 A, 250 V (Agilent part number 2110-0012)
5	PORT 2 FUSE	Bias Fuse, 0.5 A, 250 V (Agilent part number 2110-0012)
6	PORT 2 BIAS	BNC (f) connector. The bias port is used to supply a dc voltage to an active DUT, such as an amplifier or a transistor.
7	BUS ADDRESS	Switch that is used to set the GPIB address. Refer to “Step 7. Set Up the General Purpose Interface Bus (GPIB)” on page 21 for further information.
8	IEEE-488	24-pin IEEE-488/PCB (f) connector. The GPIB is the communication bus with the PC and the network analyzer.
9	REF 2 R IN	SMA (f) connector, used as an input reference signal.

ID Number	Rear Panel Feature	Feature Description
10	Power Cord Connector	Connector, 100-120 Vac or 220-250Vac input and Fuse, T 2.5 A 250 V (Agilent part number 2110-0681)
11	REF 1 R IN	SMA (f) connector, used as an input reference signal

N4419A

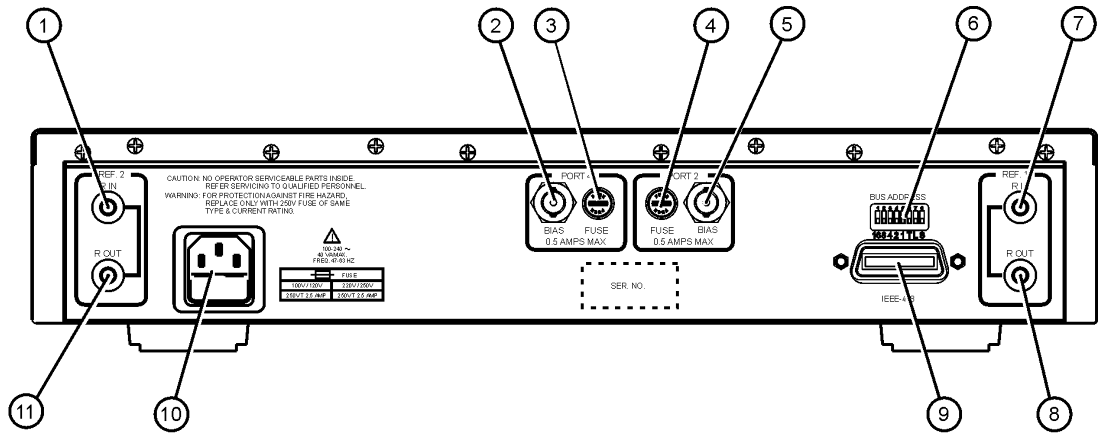
N4419A Front Panels



ID Number	Front Panel Feature	Feature Description
1	REFERENCE 1 SOURCE OUT	SMA (f) connector that is connected to the network analyzer REFERENCE 1 SOURCE OUT connector using a semirigid cable.
2	REFERENCE 1 RCVR R1 IN	SMA (f) connector that is connected to the network analyzer REFERENCE 1 RCVR R1 IN connector using a semirigid cable.
3	PORT 2	*PORT 2 - APC-3.5 (m) connector with 20 mm nut that is connected to the DUT or fixture. (+17 dBm maximum operating level)*
4	GPIB STATUS	Three LEDs (R, T, and L) that display the GPIB status of the test set when it is communicating with the network analyzer. R = Remote Operation, T = Talk mode, L = Listen mode.
5	POWER	ON/OFF switch that disconnects the mains circuits from the mains supply before other parts of the test set. The front panel POWER switch disconnects the mains circuits from the mains supply after the EMC filters and before other parts of the instrument.
6	PORT 4	*PORT 4 - APC-3.5 (m) connector with 20 mm nut that is connected to the DUT or fixture. (+17 dBm maximum operating level)*

ID Number	Front Panel Feature	Feature Description
7	REFERENCE 2 RCVR R2 IN	SMA (f) connector that is connected to the network analyzer REFERENCE 2 RCVR R2 IN connector using a semirigid cable.
8	REFERENCE 2 SOURCE OUT	SMA (f) connector that is connected to the network analyzer REFERENCE 2 SOURCE OUT connector using a semirigid cable.
9	PORT 2 SOURCE OUT	SMA (f) connector that is connected to the network analyzer PORT 2 SOURCE OUT connector using a semirigid cable.
10	PORT 2 CPLR ARM	SMA (f) connector that is connected to the network analyzer PORT 2 CPLR ARM connector using a semirigid cable.
11	PORT 2 RCVR B IN	SMA (f) connector that is connected to the network analyzer PORT 2 RCVR B IN connector using a semirigid cable.
12	PORT 2 CPLR THRU	SMA (f) connector that is connected to the network analyzer PORT 2 CPLR THRU connector using a semirigid cable.
13	AUXILIARY	15-pin ribbon (f) connector that may be connected to the Agilent N4430A/B ECal module to provide ECal capability.
14	PORT 1 CPLR THRU	SMA (f) connector that is connected to the network analyzer PORT 1 CPLR THRU connector using a semirigid cable.
15	PORT 1 RCVR A IN	SMA (f) connector that is connected to the network analyzer PORT 1 RCVR A IN connector using a semirigid cable.
16	PORT 1 CPLR ARM	SMA (f) connector that is connected to the network analyzer PORT 1 CPLR ARM connector using a semirigid cable.
17	PORT 1 SOURCE OUT	SMA (f) connector that is connected to the network analyzer PORT 1 SOURCE OUT connector using a semirigid cable.

N4419A Rear Panel



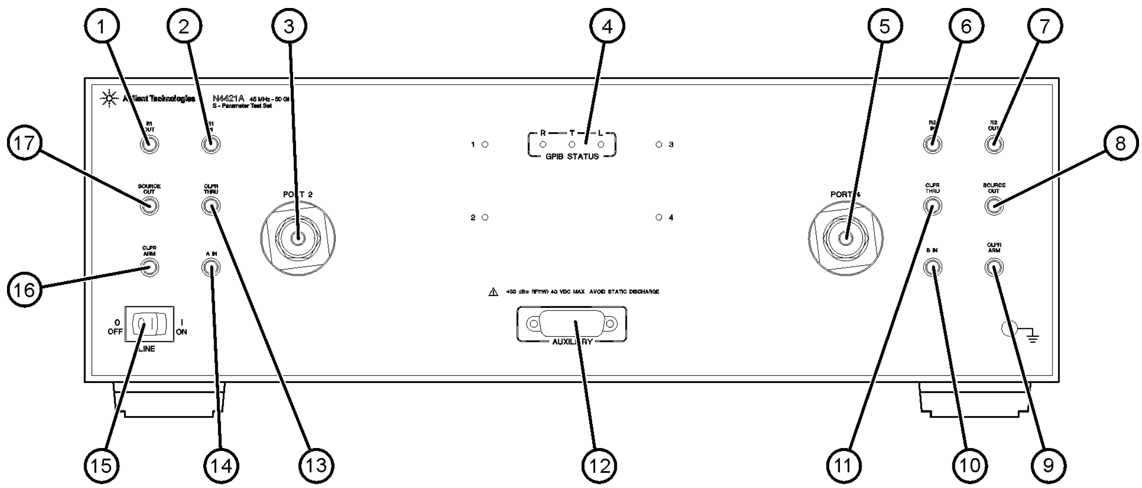
hy407a

ID Number	Rear Panel Feature	Feature Description
1	REF 2 R IN	SMA (f) connector, used as an input reference signal
2	PORT 4 BIAS	BNC (f) connector. The bias port is used to supply a dc voltage to an active DUT, such as an amplifier or a transistor.
3	PORT 4 FUSE	Bias Fuse, 0.5 A, 250 V (Agilent part number 2110-0012)
4	PORT 2 FUSE	Bias Fuse, 0.5 A, 250 V (Agilent part number 2110-0012)
5	PORT 2 BIAS	BNC (f) connector. The bias port is used to supply a dc voltage to an active DUT, such as an amplifier or a transistor.
6	BUS ADDRESS	Switch that is used to set the GPIB address. Refer to "Step 7. Set Up the General Purpose Interface Bus (GPIB)" on page 21 for further information.
7	REF 1 R IN	SMA (f) connector, used as an input reference signal
8	REF 1 R OUT	SMA (f) connector, used as an output reference signal
9	IEEE-488	24-pin IEEE-488/PCB (f) connector. The GPIB is the communication bus with the PC and the network analyzer.

ID Number	Rear Panel Feature	Feature Description
10	Power Cord Connector	Connector, 100-120 Vac or 220-250Vac input and Fuse, T 2.5 A 250 V (Agilent part number 2110-0681)
11	REF 2 R OUT	SMA (f) connector, used as an output reference signal

N4421A

N4421A Front Panel

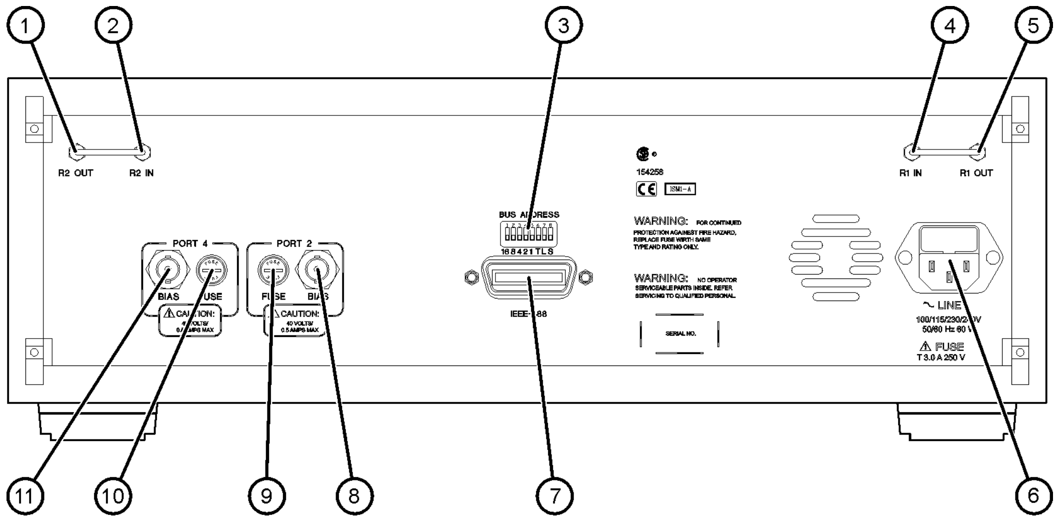


n4421_frtpnl

ID Number	Front Panel Feature	Feature Description
1	R1 OUT	2.4 mm (f) connector that connects to the network analyzer REFERENCE 1 OUT connector using a semirigid cable.
2	R1 IN	2.4 mm (f) connector that connects to the network analyzer REFERENCE 1 RCVR R1 connector using a semirigid cable.
3	PORT 2	2.4 mm bulkhead test port connector that is connect to the DUT or fixture. (+17 dBm maximum operating level)
4	GPIB STATUS	Three LEDs (R, T, and L) that display the GPIB status of the test set when it is communicating with the network analyzer. R = Remote Operation, T = Talk mode, L = Listen mode.
5	PORT 4	2.4 mm bulkhead test port connector that is connect to the DUT or fixture. (+17 dBm maximum operating level)

ID Number	Front Panel Feature	Feature Description
6	R2 IN	2.4 mm (f) connector that connects to the network analyzer REFERENCE 2 RCVR R2 connector using a semirigid cable.
7	R2 OUT	2.4 mm (f) connector that connects to the network analyzer REFERENCE 2 OUT connector using a semirigid cable.
8	SOURCE OUT	2.4 mm (f) connector that connects to the network analyzer PORT 2 SOURCE OUT connector using a semirigid cable.
9	CPLR ARM	2.4 mm (f) connector that connects to the network analyzer PORT 2 CPLR ARM connector using a semirigid cable.
10	B IN	2.4 mm (f) connector that connects to the network analyzer PORT 2 B IN connector using a semirigid cable.
11	CPLR THRU	2.4 mm (f) connector that connects to the network analyzer PORT 2 CPLR THRU connector using a semirigid cable.
12	AUXILIARY	15-pin ribbon (f) connector. Not currently used.
13	CPLR THRU	2.4 mm (f) connector that connects to the network analyzer PORT 1 CPLR THRU connector using a semirigid cable.
14	A IN	2.4 mm (f) connector that connects to the network analyzer PORT 1 A IN connector using a semirigid cable.
15	LINE	ON/OFF switch that disconnects the mains circuits from the mains supply before other parts of the test set. The front panel POWER switch disconnects the mains circuits from the mains supply after the EMC filters and before other parts of the instrument.
16	CPLR ARM	2.4 mm (f) connector that connects to the network analyzer PORT 1 CPLR ARM connector using a semirigid cable.
17	SOURCE OUT	2.4 mm (f) connector that connects to the network analyzer PORT 1 SOURCE OUT connector using a semirigid cable.

N4421A Rear Panel



4421_rearpnl

ID Number	Rear Panel Feature	Feature Description
1	REF 2 R OUT	SMA (f) connector, used as an output reference signal
2	REF 2 R IN	SMA (f) connector, used as an input reference signal.
3	BUS ADDRESS	Switch that is used to set the GPIB address. Refer to "Step 7. Set Up the General Purpose Interface Bus (GPIB)" on page 21 for further information.
4	REF 1 R IN	SMA (f) connector, used as an input reference signal
5	REF 1 R OUT	SMA (f) connector, used as an output reference signal
6	Power Cord Connector	Connector, 100-120 Vac or 220-250Vac input and Fuse, T 2.5 A 250 V (Agilent part number 2110-0681)
7	IEEE-488	24-pin IEEE-488/PCB (f) connector. The GPIB is the communication bus with the PC and the network analyzer.
8	PORT 2 BIAS	BNC (f) connector. The bias port is used to supply a dc voltage to an active DUT, such as an amplifier or a transistor.

ID Number	Rear Panel Feature	Feature Description
9	PORT 2 FUSE	Bias Fuse, 0.5 A, 250 V (Agilent part number 2110-0012)
10	PORT 4 FUSE	Bias Fuse, 0.5 A, 250 V (Agilent part number 2110-0012)
11	PORT 4 BIAS	BNC (f) connector. The bias port is used to supply a dc voltage to an active DUT, such as an amplifier or a transistor.

13 Troubleshooting and Maintenance

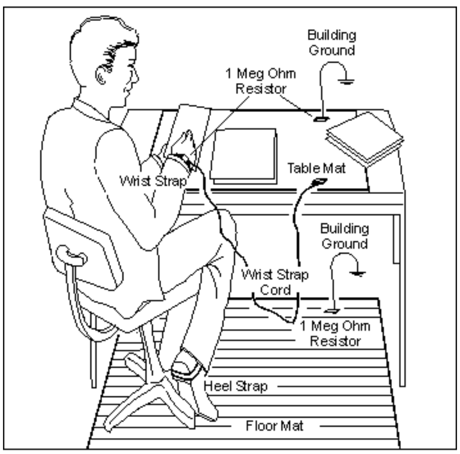
Electrostatic Discharge

Although protected internally, test systems are sensitive to electrostatic discharge (ESD). Static discharges too small to feel can damage or degrade the test equipment or your devices.

Use standard precautions to protect against ESD before using the test system for calibration or measurement.

Use the following illustration and list of equipment to set up a static-safe workstation.

Figure 13-1 Static-Safe Workstation



- static-control table mat and earth ground wire: part number 9300-0797
- wrist-strap cord: part number 9300-0980
- wrist-strap: part number 9300-1367
- heel-straps: part number 9300-1308
- floor mat: not available through Agilent Technologies

Troubleshooting

Use the following table to help troubleshoot your test system.

Table 13-1 Troubleshooting the Test System

Symptom	Cause	Cure
One or more biases not applied.	Bias fuse blown.	Check bias fuses. Replace blow fuse with fuse of the same type and rating. Refer to the test set rear-panel information in Chapter 12.
Control computer can't communicate with the test set.	Accidental change to GPIB switch settings.	Set the GPIB address as needed. Restart the test system. See "Step 7. Set Up the General Purpose Interface Bus (GPIB)" on page 21.
The test set does not come on the first time you use it.	Line fuse not installed, or incorrect line fuse installed.	Install the line fuse. Refer to "Replacing the Test Set Line Fuse" on page 332.
Excessive ripple in data.	Load termination damaged by excessive RF power.	Contact Agilent Technologies. See "Contacting Agilent" on page 350 for more information.
	Loose connections between VNA and test set and/or between test set and DUT.	Check and torque the connectors.
	Poor test cable repeatability.	Replace test cables as needed. You can replace a single cable, without replacing the entire set.
High loss on one path with poor raw data match (as seen during analyzer sweep) or inability to make a good calibration.	Possible signal channel damage.	Contact Agilent Technologies. See "Contacting Agilent" on page 350 for more information.

Additional Troubleshooting Assistance

Situation

During installation, the PLTS software does not recognize the Agilent GPIB card. The GPIB card default address is “gpib0” (though it could be any address “gpib1” thru “gpib7” as well).

Background: The software first looks for the presence of a National Instruments GPIB card by looking in the National Instruments library for addresses “gpib0” through “gpib7”. Because the software does not find the card because it is an Agilent GPIB card that is not supported by National Instruments. Then the software looks for the presence of a Hewlett-Packard HP-IB or Agilent Technologies GPIB card in the SICL library. The program looks for the following six addresses in this file: “hpib”, “hpib7”, “HPIB”, “HPIB7”, “Hpib”, and “Hpib7”. However, the Agilent GPIB address is not found.

Solution: In Windows, select **Start**, **Programs**, **Agilent IO Libraries**, then **IO Config**. Click “gpib0” in the **Configured Interfaces** list, then click **Edit**. Change the **SICL Interface Name** to “hpib7” and click **OK**. Then click **OK** to confirm the change. Restarting the software should allow the software to recognize the Agilent GPIB card.

Maintenance

This section provides basic maintenance information such as cleaning, fuse replacement, cable care, and connector care.

Cleaning

Clean the cabinet, using a dry or damp cloth only.

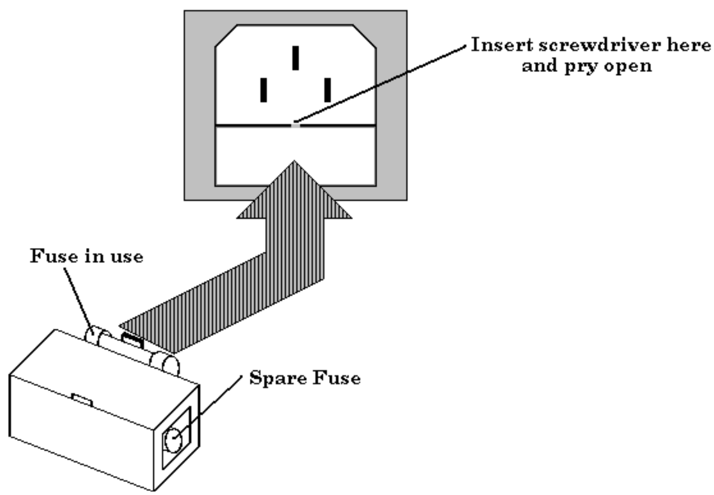
WARNING **To prevent electrical shock, disconnect the Agilent Technologies (N4415A, N4416A, N4417A, N4418A, N4419A, and N4421A) S-parameter test set from mains before cleaning. Use a dry cloth or one slightly dampened with water to clean the external case parts. Do not attempt to clean internally.**

Replacing the Test Set Line Fuse

To replace the line fuse, disconnect the power cord from the rear of the test set, use a small screwdriver to pry open the line fuse holder and slide it open until it reaches its stop. Replace the fuse in use with the spare fuse and slide the fuse holder back into the instrument.

WARNING **For continued protection against fire hazard replace the test set line fuse only with same type and rating (115V and 230V operation: T2.5A 250V). The use of other fuses or material is prohibited.**

Figure 13-2 Line Fuse Replacement



Care of Test Cable Assemblies

Proper use and care of your test cable assemblies will yield positive results including:

- longer life
- higher performance
- better repeatability

Performing the routine inspection and cleaning of the test cable assemblies, especially the connectors, is very important to making the best possible measurements.

Connector Mating

Alignment of the center lines of the connectors of the test cables with the test set and DUT connectors before mating is important. It is possible to start the threads on the connector nuts without good alignment, but this will result in bent pins and damaged inserts. Resistance encountered while turning the connector nut may be due to one of the following:

- The pins are not aligned.
- The coupling nut is cross-threaded.
- The connector (or its mate) has been damaged by excessive torque.

Stop and determine the reason. To proceed without doing so risks the destruction of the assembly and the mating connector.

Holding a connector nut stationary while screwing the socket into the connector will wear away the connector plating and score the connector parts. If the pins lock up, serious damage can be caused.

Connector Torque

Make sure to grasp the body of the connector before applying final torque. If the connector body is allowed to rotate with the nut, the connector plating, outer interface rim, or pin assembly may be damaged. Excess torque applied to the connector will be transferred to the cable assembly. Refer to "Care of RF and Microwave Coaxial Connectors" on page 335 for more information.

Depending on the connector, over-torque can cause damage to connectors in a variety of ways:

- mushroomed outer interface shells
- mushroomed pin shoulders
- recessed or protruding pins
- recessed or protruding dielectrics
- bent pins
- chipped plating
- coupling nut retaining ring damage
- damage to coupling threads

Cable Handling

The test cables have a 1 inch minimum bend radius. Exceeding this radius can result in poor measurements and poor repeatability. Be alert to tight bends where they are not necessarily obvious — like at the end of connector strain relief tubing.

Swept 90° adapters may be used (typically, at the test set front panel) to minimize cable bending. However, if the adapters are used, they must be in place during the calibration.

Cables are often stored in a coiled configuration. Coiled cable “set” (the tendency to stay coiled) can occur if the cables are left coiled. Use large coil diameters (one or two feet) to minimize cable set. Unroll coiled cables prior to use – never just pull out the loops.

Avoid pinching, crushing, or dropping objects on cable assemblies. Dragging a cable over a sharp edge will tend to flatten one side, and it is highly likely that the minimum bend radius will be exceeded.

Care of RF and Microwave Coaxial Connectors

Proper connector care is critical for accurate and repeatable measurements. The following information will help you preserve the precision and extend the life of your connectors - saving both time and money. Prior to making connections to your test system, review the connector care information within this section.

This section is made up of three main subjects:

- **Connector Care Reference**
  which contains information about:
  - ❏ Safety Reminders
  - ❏ Connector Cleaning Supplies
  - ❏ Connector Care Quick Reference
- **Connector Care Concepts**
  which contains information about:
  - ❏ Connector Service Life
  - ❏ Connector Grades and Performance
  - ❏ Adapters as Connector Savers
  - ❏ Connector Mating Plane Surfaces
  - ❏ Gaging Fundamentals
  - ❏ Handling and Storing Connectors
- **Connector Care Procedures**
  which contains information about:
  - ❏ Inspecting Connectors
  - ❏ Cleaning Connectors
  - ❏ Making Connections
  - ❏ Separating Connections
  - ❏ Gaging Connectors
  - ❏ Using a Torque Wrench

Connector Care Reference

This section includes the following information:

- Safety Reminders
- Connector Cleaning Supplies
- Connector Care Quick Reference

Safety Reminders When cleaning connectors:

- Always use protective eyewear when using compressed air or nitrogen.
- Keep isopropyl alcohol away from heat, sparks and flame. Use with adequate ventilation. Avoid contact with eyes, skin and clothing.
- Avoid electrostatic discharge (ESD). Wear a grounded wrist strap (having a 1 MΩ series resistor) when cleaning device, cable or test port connectors.

Connector Cleaning Supplies Products commonly used to clean connectors are listed below. To order these and other connector care products, contact Agilent Technologies.

Table 13-2 Connector Cleaning Supplies

Cleaning Supplies Description	Agilent Part Number
Lint-Free Swabs, small 100 ct.	9301-1243
IPA 99.5% alcohol, 30 ml bottle	8500-5344
Compressed Air, 235 ml can	8500-6659

Connector Care Quick Reference Use the following table as a quick guide for connector care:

Table 13-3 Connector Care Quick Reference

Handling and Storage			
Do	Keep connectors clean	**Do Not**	Touch mating-plane surfaces
	Extend sleeve or connector nut		Set connectors contact-end down
	Use plastic end-caps during storage		
Visual Inspection			
Do	Inspect all connectors carefully	**Do Not**	Use a damaged connector - ever
	Look for metal particles, scratches, and dents		
Connector Cleaning			
Do	Try compressed air first	**Do Not**	Use any abrasives
	Use isopropyl alcohol		Get liquid into plastic support beads
	Clean connector threads		
Gaging Connectors			
Do	Clean and zero the gage before use	**Do Not**	Use an out-of-spec connector
	Use the correct gage type		
	Use correct end of calibration block		
	Gage all connectors before first use		
Making Connections			
Do	Align connectors carefully	**Do Not**	Apply bending force to connection
	Make preliminary connection lightly		Over tighten preliminary connection
	Turn only the connector nut		Twist or screw any connection
	Use a torque wrench for final connect		Tighten past torque wrench “break” point

Connector Care Concepts

This section includes the following concepts:

- Connector Service Life
- Connector Grades and Performance
- Adapters as Connector Savers
- Connector Mating Plane Surfaces
- Gaging Fundamentals
- Handling and Storing Connectors

Connector Service Life Even though calibration standards, cables, and test set connectors are designed and manufactured to the highest standards, all connectors have a limited service life. This means that connectors can become defective due to wear during normal use. For best results, all connectors should be inspected and maintained to maximize their service life.

Visual Inspection should be performed each time a connection is made. Metal particles from connector threads often find their way onto the mating surface when a connection is made or disconnected. See Inspection procedure.

Cleaning the dirt and contamination from the connector mating plane surfaces and threads can extend the service life of the connector and improve the quality of your calibration and measurements. See Cleaning procedure.

Gaging connectors not only provides assurance of proper mechanical tolerances, and thus connector performance, but also indicate situations where the potential for damage to another connector may exist. See “Gaging Fundamentals” on page 341.

Proper connector care and connection techniques yield:

- Longer Service Life
- Higher Performance
- Better Repeatability

Connector Grades and Performance The three connector grades (levels of quality) for the popular connector families are listed below. Some specialized types may not have all three grades.

- **Production grade** connectors are the lowest grade and the least expensive. It is the connector grade most commonly used on the typical device under test (DUT). It has the lowest performance of all connectors due to its loose tolerances. This means that production grade connectors should always be carefully inspected before making a connection to the analyzer. Some production grade connectors are not intended to mate with metrology grade connectors.
- **Instrument grade** is the middle grade of connectors. It is mainly used in and with test instruments, most cables and adapters, and some calibration standards. It provides long life with good performance and tighter tolerances. It may have a dielectric supported interface and therefore may not exhibit the excellent match of a metrology grade connector.
- **Metrology grade** connectors have the highest performance and the highest cost of all connector grades. This grade is used on calibration standards, verification standards, and precision adapters. Because it is a high precision connector, it can withstand many connections and disconnections and, thus, has the longest life of all connector grades. This connector grade has the closest material and geometric specifications. Pin diameter and pin depth are very closely specified. Metrology grade uses an air dielectric interface and a slotless female contact which provide the highest performance and traceability.

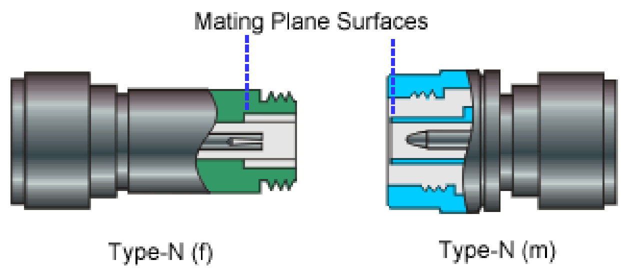
NOTE In general, Metrology grade connectors should not be mated with Production grade connectors.

Adapters as Connector Savers Make sure to use a high quality (Instrument grade or better) adapter when adapting a different connector type to the analyzer test ports. It is a good idea to use an adapter even when the device under test is the same connector type as the analyzer test ports. In both cases, it will help extend service life, and protect the test ports from damage and costly repair.

The adapter must be fully inspected before connecting it to the analyzer test port and inspected and cleaned frequently thereafter. Because calibration standards are connected to the adapter, the adapter should be the highest quality to provide acceptable RF performance and minimize the effects of mismatch.

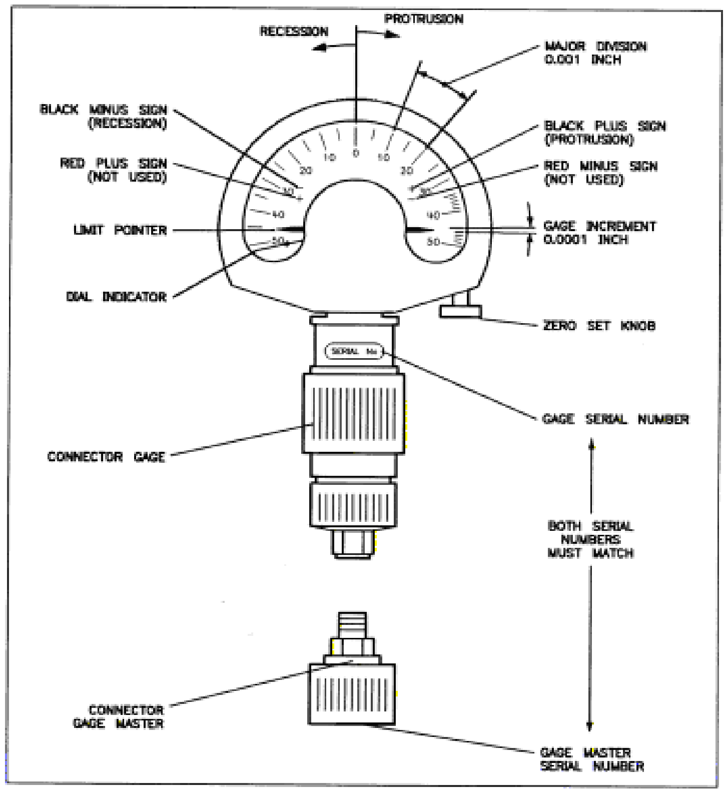
Connector Mating Plane Surfaces An important concept in RF and microwave measurements is the reference plane. For a network analyzer, this is the surface or point that measurements are referenced to at calibration. In connectors, the reference plane is defined as the plane where the mating plane surfaces meet. Good connections require perfectly flat contact between connectors at all points on the mating plane surfaces (see Figure 13-3).

Figure 13-3 Connector Mating Surfaces (Reference Plane)



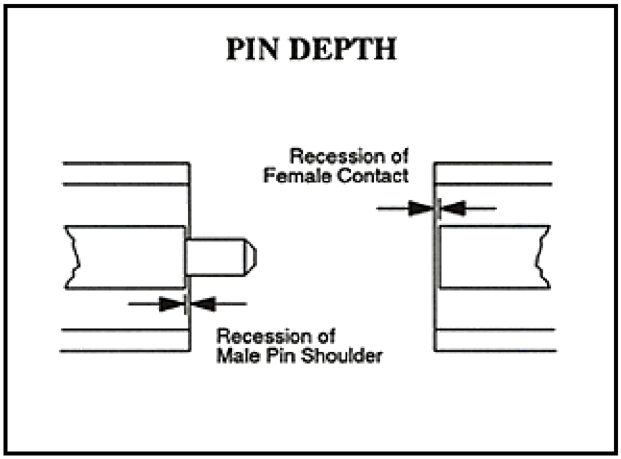
Gaging Fundamentals Connector gages are important tools used to measure center conductor pin depth in connectors. See Figure 13-4. Connector pin depth is generally the distance between the mating plane of the outer conductor and the end of the center conductor, or the shoulder of the center conductor for a stepped male pin.

Figure 13-4 Typical Connector Gage



Recession and Protrusion Pin depth is negative (recession) if the center conductor is recessed below the outer conductor mating plane, usually referred to as the “reference plane”. Pin depth is positive (protrusion) if the center conductor projects forward from the connector reference plane. See Figure 13-5.

Figure 13-5 Connector Pin Depth



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

Some connectors, like Type-N connectors, have the mating plane of the center conductors offset from the connector reference plane. In this case the zero setting “gage masters” generally offset the nominal distance between the center conductor mating plane and the connector reference plane.

When to Gage Connectors Connectors should be gaged at each of the following events:

- Before using a connector or adapter the first time.
- When visual inspection or electrical performance suggests the connector interface may be out of range.
- After every 100 connections, depending on use.

Connector Gage Accuracy Connector gages (those included with calibration and verification kits), are capable of performing coarse measurements only. This is due to the repeatability uncertainties associated with the measurement. It is important to recognize that test port connectors and calibration standards have mechanical specifications that are extremely precise. Only special gaging processes and electrical testing (performed in a calibration lab) can accurately verify the mechanical characteristics of these devices. The pin depth specifications in the Agilent calibration kit manuals provide a compromise between the pin depth accuracy required, and the accuracy of the gages. The gages shipped with calibration and verification kits allow you to measure connector pin depth and avoid damage from out-of-specification connectors.

NOTE Before gaging any connector, the mechanical specifications provided with that connector or device should be checked.

Handling and Storing Connectors Use the following precautions when handling or storing connectors.

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

Connector Care Procedures

This section includes the following procedures:

- Inspecting Connectors
- Cleaning Connectors
- Making Connections
- Separating Connections
- Gaging Connectors
- Using a Torque Wrench

Inspecting Connectors Use the following procedures when inspecting connectors.

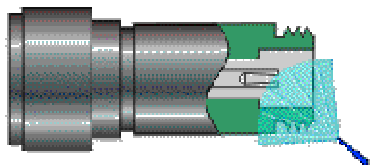
1. Wear a grounded wrist strap (having a 1 MΩ series resistor) when cleaning device, cable or test port connectors.
2. Use a magnifying glass (>10×) and inspect the connector for the following conditions:
   - Badly worn plating or deep scratches
   - Deformed threads
   - Metal particles on threads and mating plane surfaces
   - Bent, broken, or mis-aligned center conductors
   - Poor connector nut rotation

CAUTION A damaged or out-of-specification device can destroy a good connector attached to it even on the first connection. Any connector with an obvious defect should be marked for disposal or sent out for repair.

Cleaning Connectors Use the following procedures when cleaning connectors.

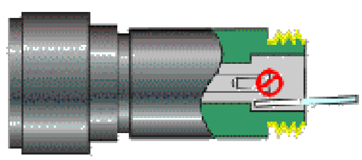
1. Wear a grounded wrist strap (having a 1 MΩ series resistor) when cleaning device, cable or test port connectors.
2. Use clean, low-pressure air to remove loose particles from mating plane surfaces and threads (see Figure 13-6). Inspect connector thoroughly. If additional cleaning is required, continue with the following steps.

Figure 13-6 Removing Loose Particles using Clean, Low Pressure Air



3. Moisten-do not saturate-a lint-free swab with isopropyl alcohol. See Cleaning Supplies for recommended type.
4. Clean contamination and debris from mating plane surfaces and threads. When cleaning interior surfaces, avoid exerting pressure on center conductor and keep swab fibers from getting trapped in the female center conductor. See Figure 13-7.

Figure 13-7 Cleaning Surfaces using a Lint-Free Swab



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

Gaging Connectors Use the following procedures when gaging connectors.

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

CAUTION If the gage indicates excessive protrusion or recession, the connector should be marked for disposal or sent out for repair.

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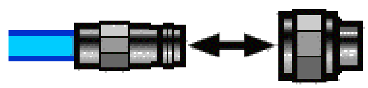
6. For maximum accuracy, measure the device a minimum of three times and take an average of the readings. After each measurement, rotate the gage a quarter-turn to reduce measurement variations.
7. If there is doubt about measurement accuracy, be sure the temperatures of the parts have stabilized. Then perform the cleaning, zeroing, and measuring procedure again.

Making Connections Use the following procedures when making connections.

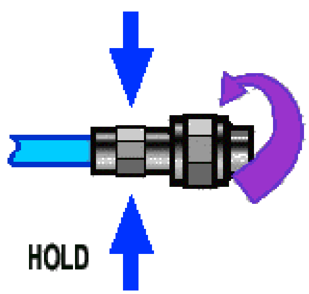
1. Wear a grounded wrist strap (having a 1 MΩ series resistor) when cleaning device, cable or test port connectors.
2. Inspect, clean, and gage connectors. All connectors must be undamaged, clean, and within mechanical specification.
3. Carefully align center axis of both devices. The center conductor pin-from the male connector-must slip concentrically into the contact finger of the female connector. See Figure 13-8.

Figure 13-8 Aligning the Center Axis of Both Connectors



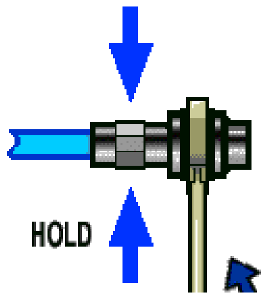
4. Carefully push the connectors straight together so they can engage smoothly. Rotate the connector nut (not the device itself) until finger-tight, being careful not to cross the threads. See Figure 13-9.

Figure 13-9 Pushing the Connectors Together and Rotating the Nut



5. Use a torque wrench to make final connection. Tighten until the “break” point of the torque wrench is reached. Do not push beyond initial break point. Use additional wrench, if needed, to prevent device body from turning. See Figure 13-10.

Figure 13-10 Using a Torque Wrench to Make the Final Connection



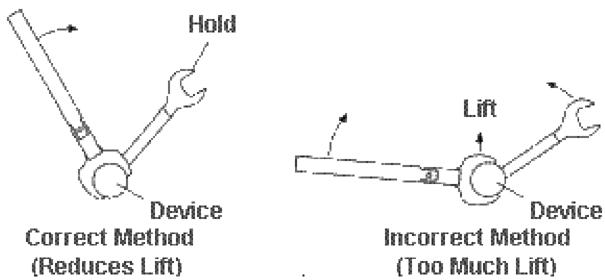
Separating Connections Use the following procedures when separating connections.

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

Using a Torque Wrench Use the following procedures when using a torque wrench.

1. Make sure torque wrench is set to the correct torque setting.
2. Position torque wrench and a second wrench (to hold device or cable) within 90° of each other before applying force. Make sure to support the devices to avoid putting stress on the connectors. See Figure 13-11.

Figure 13-11 Positioning the Wrenches



3. Hold torque wrench lightly at the end of handle-then apply force perpendicular to the torque wrench handle. Tighten until the “break” point of the torque wrench is reached. Do not push beyond initial break point. See Figure 13-12.

Figure 13-12 Torquing with the Torque Wrench

Contacting Agilent

You may use the following table to contact Agilent Technologies for assistance with any Agilent product.

Table 13-4 Contacting Agilent

`Online assistance: www.agilent.com/find/assist`

United States *(tel)* 1 800 452 4844	**Latin America** *(tel)* (305) 269 7500 *(fax)* (305) 269 7599
New Zealand *(tel)* 0 800 738 378 *(fax)* (+64) 4 495 8950	**Japan** *(tel)* (+81) 426 56 7832 *(fax)* (+81) 426 56 7840
Malaysia *(tel)* 1 800 828 848 *(fax)* 1 800 801 664	**India** *(tel)* 1-600-11-2929 *(fax)* 000-800-650-1101
Taiwan *(tel)* 0800-047-866 *(fax)* (886) 2 25456723	**Hong Kong** *(tel)* 800 930 871 *(fax)* (852) 2506 9233
Canada *(tel)* 1 877 894 4414 *(fax)* (905) 282-6495	**Europe** *(tel)* (+31) 20 547 2323 *(fax)* (+31) 20 547 2390
Australia *(tel)* 1 800 629 485 *(fax)* (+61) 3 9210 5947	**Singapore** *(tel)* 1 800 375 8100 *(fax)* (65) 836 0252
Thailand *(tel) outside Bangkok:* (088) 226 008 *(tel) within Bangkok:* (662) 661 3999 *(fax)* (66) 1 661 3714	**People's Republic of China** *(tel) (preferred):* 800-810-0189 *(tel) (alternate):* 10800-650-0021 *(fax)* 10800-650-0121
Philippines *(tel)* (632) 8426802 *(tel) (PLDT subscriber only):* 1 800 16510170	 *(fax)* (632) 8426809 *(fax) (PLDT subscriber only):* 1 800 16510288

Make sure have the following information readily available when you call:

- the serial number of the test set
- a list of any options or accessories installed in or in use with the test set
- the type of GPIB board in your computer
- any information you can supply about the DUT
- the nature of the problem
- the version number of software

Shipment for Service

If you are sending the instrument to Agilent Technologies for service, ship the test set to the nearest service center for repair, including a description of any failed test and any error message. Ship the instrument using the original or comparable antistatic packaging materials.

Refer to "Contacting Agilent" on page 350 for additional information.

14 Safety and Regulatory Information

Safety Information

Review to the safety information in this section before operating your physical layer test system.

Safety Symbols

The following safety symbols are used throughout this manual. Familiarize yourself with each of the symbols and its meaning before operating the physical layer test system.

CAUTION Caution denotes a hazard. It calls attention to a procedure that, if not correctly performed or adhered to, would result in damage to or destruction of the instrument. Do not proceed beyond a caution note until the indicated conditions are fully understood and met.

WARNING **Warning denotes a hazard. It calls attention to a procedure which, if not correctly performed or adhered to, could result in injury or loss of life. Do not proceed beyond a warning note until the indicated conditions are fully understood and met.**

Instrument Markings

Familiarize yourself with each of the markings and its meaning before operating the physical layer test system.

The ON symbol. The ON symbol is used to mark the positions of the instrument line switch.

The OFF symbol. The OFF symbol is used to mark the positions of the instrument line switch.

The ON symbol. The ON symbol is used to mark the positions of the instrument line switch.

The OFF symbol. The OFF symbol is used to mark the positions of the instrument line switch.

The AC symbol. The AC symbol is used to indicate the required nature of the line module input power.

The instruction documentation symbol. The product is marked with this symbol when it is necessary for the user to refer to the instructions in the documentation.

The CE mark is a registered trademark of the European Community. (If accompanied by a year, it is when the design was proven.)

The CSA mark is a registered trademark of the Canadian Standards Association.

ISM1-A — This is a symbol of an Industrial Scientific and Medical Group 1 Class A product.

ICES / NMB-001 — This is a marking to indicate product compliance with the Canadian Interference-Causing Equipment Standard (ICES-001).

N10149 — The C-Tick mark is a registered trademark of the Australian Spectrum Management Agency.

Safety Considerations

Familiarize yourself with each of the safety considerations before operating the physical layer test system.

NOTE Positioning the Test System for Use

When setting up the physical layer test system for use, position the equipment so that the front panel power switch is easy to reach.

NOTE This instrument has been designed and tested in accordance with the standards listed on the Manufacturer's Declaration of Conformity and has been supplied in a safe condition. This instruction documentation contains information and warnings which must be followed by the user to ensure safe operation and to maintain the instrument in a safe condition.

Safety Earth Ground

WARNING **This is a Safety Class 1 product (provided with a protective earthing ground incorporated in the power cord). The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. Any interruption of the protective conductor, inside or outside the instrument, is likely to make the instrument dangerous. Intentional interruption is prohibited.**

CAUTION Always use the three-prong AC power cord supplied with this product. Failure to ensure adequate earth grounding by not using this cord may cause product damage.

Before Applying Power

CAUTION Install the instrument so that the ON/OFF switch is readily identifiable and is easily reached by the operator. The ON/OFF switch or the detachable power cord is the instrument disconnecting device. It disconnects the mains circuits from the mains supply before other parts of the instrument. Alternately, an externally installed switch or circuit breaker (which is readily identifiable and is easily reached by the operator) may be used as a disconnecting device.

CAUTION Before switching on this instrument, make sure that the correct fuse is installed and the supply voltage is in the specified range.

Servicing

WARNING **No operator serviceable parts inside. Refer servicing to qualified personnel. To prevent electrical shock, do not remove covers.**

WARNING **These servicing instructions are for use by qualified personnel only. To avoid electrical shock, do not perform any servicing unless you are qualified to do so.**

WARNING **The opening of covers or removal of parts is likely to expose dangerous voltages. Disconnect the instrument from all voltage sources while it is being opened.**

WARNING **The power cord is connected to internal capacitors that may remain live for 5 seconds after disconnecting the plug from its power supply.**

WARNING **For continued protection against fire hazard replace line fuse only with same type and rating (115V and 230V operation: T2.5A 250V). The use of other fuses or material is prohibited.**

General

WARNING **To prevent electrical shock, disconnect the Agilent Technologies (N4415A, N4416A, N4417A, N4418A, N4419A, and N4421A) S-parameter test set from mains before cleaning. Use a dry cloth or one slightly dampened with water to clean the external case parts. Do not attempt to clean internally.**

WARNING **If this product is not used as specified, the protection provided by the equipment could be impaired. This product must be used in a normal condition (in which all means for protection are intact) only.**

CAUTION This product is designed for use in Installation Category II and Pollution Degree 2 per IEC 1010 and 664 respectively.

CAUTION VENTILATION REQUIREMENTS: When installing the product in a cabinet, the convection into and out of the product must not be restricted. The ambient temperature (outside the cabinet) must be less than the maximum operating temperature of the product by 4° C for every 100 watts dissipated in the cabinet. If the total power dissipated in the cabinet is greater that 800 watts, then forced convection must be used.

Regulatory Information

The Agilent Technologies S-Parameter test system complies with the regulatory requirements listed in this section.

Compliance with Canadian EMC Requirements

This ISM device complies with Canadian ICES-001.

Cet appareil ISM est conforme a la norme NMB du Canada.

Compliance with German Noise Requirements

This is to declare that this instrument is in conformance with the German Regulation on Noise Declaration for Machines (Laermangabe nach der Maschinenlaermrerordung –3. GSGV Deutschland).

Acoustic Noise Emission/Geraeuschemission	
LpA <70 dB	LpA <70 dB
Operator position	am Arbeitsplatz
Normal position	normaler Betrieb
per ISO 7779	nach DIN 45635 t. 19

Declaration of Conformity

DECLARATION OF CONFORMITY

According to ISO/IEC Guide 22 and CEN/CENELEC EN 45014

Manufacturer's Name: Agilent Technologies, Inc.

Manufacturer's Address: 40 Shatttuck Road
Andover, MA 01810
USA

Declares that the products

Product Name: Multiport Test Sets & Calibration Modules

Model Number: N4413A, N4414A, N4415A, N4416A, N4417A, N4418A, N4419A, N4421A, N4425A, N4430A, N4430B

Product Options: This declaration covers all options of the above products.

Conform to the following product standards:

EMC: EN 61326:1998

Standard	Limit
EN 55011/A-1999	Group 1, Class A
EN 61000-4-2:1995	4 kV CD, 8 kV AD
EN 61000-4-3:1998+AMD1	3 V/m, 80 - 1000 MHz
EN 61000-4-4:1995	0.5 kV sig., 1 kV power
EN 61000-4-5:1995	0.5 kV L-L, 1 kV L-G
EN 61000-4-6:1996	3 V, 0.15 – 80 MHz
EN 61000-4-11:1994	1 cycle, 100%

Safety: EN 61010-1:1993 +A2:1995

Supplementary Information:
The products herewith comply with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC and carry the CE-marking accordingly.

Andover, MA, USA [10/21/02]

Peter Rienzo/Order Fulfillment Manager

For further information, please contact your local Agilent Technologies sales office, agent or distributor.

Rev. A

IV Appendices

Appendices is a collection of supplementary information that you may find useful.

Appendix A, "Glossary"	Defines terms that you may encounter while performing measurements using the physical layer test system.
Appendix B, "Procedures"	Provides procedures that may be needed but are not commonly used while using the physical layer test system.

A Glossary

– **Symbols** –	
.SnP	.SnP data format creates component data files that describe frequency dependent linear network parameters for n port components. This format is used to import/export S-parameter data.
γ (Gamma)	Gamma is the complex propagation constant. $\gamma = \alpha + \beta j$ where α is the attenuation per length and β is related to the wave velocity.
σ (Sigma)	Sigma represents standard deviation, which is the measure of the dispersion or spread of the statistical average of all results for a particular measurement. See “Standard deviation” on page 374.
– **Numeric** –	
2-Level	A 2-level data signal generates 1 bit per symbol.
4-Level	A 4-level data signal generates 2 bits per symbol consuming half the bandwidth of a 2-level signal.
– **A** –	
Attenuation	Attenuation is the process of reducing the amplitude of a waveform without introducing significant distortion. For example, the input waveform to a standard 10:1 probe will be reduced, or attenuated, by a factor of 20 dB.
Averaging	Averaging is a waveform acquisition mode in which the instrument acquires waveforms from multiple data acquisitions and then averages the waveforms together, point by point. Averaging significantly reduces noise and improves resolution of the displayed waveform. The noise sources can average to zero over time while the underlying waveform is preserved. The effective resolution of the displayed waveform increases as more acquisitions are averaged together. This improves the stability of both the display and waveform measurements.
– **B** –	
Balanced device	A balanced device is composed of two nominally identical halves. Practically speaking, the signals on each side of the device can have any relative amplitude and phase relationship, but they can be decomposed into a differential-mode (anti-phase) component, and a common-mode (in-phase) component.

– **C** –	
C (capacitance)	Capacitance (farads) is a measure of stored electric charge.
Calibration	In instrumentation, calibration is the process of periodically (usually annually) verifying an instrument is performing to specification. A calibration certificate is awarded after verification. In network analyzers, calibration is the process of removing systematic errors from measurements (also known as accuracy enhancement or error correction).
Calibration Kit	A calibration kit contains hardware and software required to perform error correction on a network analyzer for a specific measurement and/or test set.
Calibration, SOLT	SOLT is a calibration using four known standards: Short-Open-Load-Through.
Characteristic Impedance	Characteristic impedance is the impedance looking into the end of an infinitely long lossless transmission.
CITIfile	CITIfile (Common Instrumentation Transfer and Interchange file) is an ASCII data format that is useful when exchanging data between computers and instruments.
Common Mode	Common mode is the in-phase mode of a balanced measurement.
Continuous Sweep Mode	Continuous sweep mode is the analyzer condition where traces are automatically updated each time trigger conditions are met.
Crossing Percentage	Crossing percentage is a measure of the amplitude of an eye diagram crossing points relative to the one level and zero level. Crossing percentage is determined as: $$CrossingPercentage = 100\left(V_{Cross} - \frac{V_{ZeroLevel}}{V_{OneLevel} - V_{ZeroLevel}}\right)$$
Crossing Point (Eye)	Crossing point (eye) is the point in time, in an eye diagram, where the rising edge of a waveform intersects with the falling edge.
Crossstalk	Crosstalk is the occurrence of a signal at one port of a device being affected by a signal in any other path. Isolation is the measurement of crosstalk.

– D –	
De-embedding	De-embedding is the process of removing the effect of test fixtures and adapters from a measurement using the software to establish the reference planes of your device under test (DUT). The software can use measured files of the adapter or test fixture to remove their effects from the measurement of the DUT.
Differential Mode	Differential mode is the anti-phase mode of a balanced measurement.
DUT	DUT is an acronym commonly used for the device under test.
Dynamic Range	Dynamic range specifies the amplitude (size) of a signal that can be input into the instrument at a particular vertical scale without overdriving the front end, resulting in an inaccurate acquisition of data.
– E –	
Ethernet	Ethernet is a network that adheres to the IEEE 802.3 Local Area Network standard.
Extinction Ratio	Extinction ratio is the ratio of the one level and the zero level of an eye diagram. This measurement is made in a section of the eye referred to as the eye window.
Eye Diagram or Pattern	An eye diagram is a waveform display that is typically produced by convolving the time domain impulse response of SDD21 with a repetitive bit pattern.
Eye Height	Eye height is a measure of the vertical opening of an eye diagram.
Eye Opening Factor	Eye Opening Factor is a measure of the vertical opening of an eye diagram.
Eye Width	Eye width is a measure of the horizontal opening of an eye diagram.
Eye Window	The eye window provides the time boundaries within which signal parameters for eye diagrams are measured.

– **F** –	
Fall Time	Fall time is a measure of the mean one level to zero level transition time of the data of an eye diagram. The data crosses through the following thresholds: the upper, middle, and lower thresholds, as well as through eye crossing points.
Fixturing	Fixturing is the process of using a test fixture which as an interface between your test equipment and your device under test (DUT). The test fixture is used to hold the DUT, route signals to and from the DUT, and to apply bias voltages and ground paths to the DUT.
FR-4	FR-4 is a common, epoxy-resin glass laminate that is used as substrate for PC boards.
Frequency	Frequency is the number of periodic oscillations, vibrations, or waves per unit of time, usually expressed in cycles per second, or Hertz (Hz).
Frequency Accuracy	Frequency accuracy is the uncertainty with which the frequency of a signal or spectral component is indicated, either in an absolute sense or relative to another signal or spectral component. Absolute and relative frequency accuracies are specified independently.
Frequency Range	Frequency range is the range of frequencies over which a device or instrument performance is specified.
Frequency Response	In frequency mode, frequency response is the peak-to-peak variation in the displayed amplitude response over a specified center frequency range. Frequency response is typically specified in terms of dB, relative to the value midway between the extremes.
Frequency Span	Frequency span is represented by the horizontal axis of the display. Generally, frequency span is given as the total span across the full display. Sometimes frequency span (scan width) is represented as a per-division value.
Functions (Math)	Functions (Math) are mathematical operations (such as Add, Subtract, Multiply, Integrate, Versus for XY plots) that can be performed on input waveforms, stored waveform memories, or even other functions.

– G –	
G (conductance)	Conductance is the resistive component in shunt impedance across transmission lines.
Gamma (γ)	Gamma is the complex propagation constant. $\gamma = \alpha + \beta j$ where α is the attenuation per length and β is related to the wave velocity.
Golden Device	A device under test that is measured and its test results are saved for comparison against future measurements as a metric of calibration quality.
Graticule	The graticule is the enclosed area where all the waveform data and markers are displayed on the screen. The display graticule is also referred to as the display grid or waveform viewing area.
– H –	
Horizontal Scale	Horizontal scale is an instrument control that controls the x-axis or time per division of displayed waveforms. Horizontal scale is often referred to as sweep speed in some instruments.
– I –	
Impedance	Impedance is the ratio of voltage to current at a port of a circuit, expressed in ohms.
Insertion Loss	Insertion loss is the difference between the power measured before and after the insertion of a device or the attenuation between the input and output of a device.
Isolation	Isolation is the specification or measure of the immunity that one signal has to being affected by another adjacent signal. The occurrence is known as crosstalk
– J –	
Jitter	Jitter is the measure of the time variances of the rising and falling edges of an eye diagram as these edges affect the crossing points of the eye.
– K –	
K28.5	K28.5 is an industry standard finite length bit sequence (comma character, 8B/10B encoding).

– L –	
L (inductance)	Inductance (henries) is stored magnetic charge.
Load	A load is a one port microwave device used to terminate a path in its characteristic impedance.
Load	A Load is a calibration standard that is an actual line that terminates a path with the path’s characteristic impedance. See SOLT.
Load Match	Load match is a measure of how close the device's terminating load impedance is to the ideal transmission line impedance. Match is usually measured as return loss or standing wave ratio (SWR) of the load.
Log Display	Log display (logarithmic display) is the display mode in which vertical deflection is a logarithmic function of the input signal amplitude. The display calibration is set by selecting the value of the reference level position and scale factor in dB per division.
– M –	
Magnitude	Magnitude is the amplitude of a signal measured in its characteristic impedance without regard to phase.
Markers	Marker lines are used to determine the position or amplitude of the selected point on the display graticule. Marker lines can be positioned on either: • a selected waveform source (input channel, waveform memory or waveform function) • independently anywhere on the display graticule
Mask	A mask is a template consisting of numbered, shaded regions on the instrument display screen. The input waveform must remain within these regions in order to comply with industry standards. The waveforms that intrude these regions are mask violations.
Mask Test	A mask test is a test process used to verify that waveforms generated by a test device conform to industry standards.

Measurement Uncertainty	Measurement uncertainty is the quantified amount of error in a measurement situation. Calibrations are intended to reduce the amount of uncertainty. The following are sources of measurement errors that lead to uncertainty: • Systematic errors (imperfections in calibration standards, connectors, cables, and instrumentation) • Random errors (noise, connector repeatability) • Drift (source and instrumentation)
Microstrip	Microstrip is a planar transmission line that consists of a thin conductive trace (or traces) printed or etched on one side of an insulating substrate with a parallel ground plane (backplane) on the other side of the substrate. Microstrips are also used for antennas and antenna arrays.
Mixed Mode S-parameters	Mixed mode S-parameters describe the performance of a device when measuring a balanced device. Each balanced port will support both a common-mode and a differential mode signal.
– **N** –	
Noise	Noise is an unwanted disturbance (voltage or current) superimposed on a useful waveform.
Non-insertable Calibration	A non-insertable calibration is one in which the test port connectors are of the same gender (male-to-male or female-to-female).
– **O** –	
Offset	Offset is used to move or set off a determined amount. Used in instruments for offsetting frequencies, limits, delay, loss, impedance, etc.
One Level	One level is a measure of the mean value of the logical 1 of an eye diagram.
Open	An Open is a calibration standard that is an actual line that terminates a path with an electrical open. See SOLT.

– P –	
Phase	In network analysis, the phase response of the device under test is the change in phase as a function of frequency between the input stimulus and the measured response.
Physical Layer	The physical layer is layer 1, the lowest layer, of the seven-layer Open System Interconnection (OSI) model. In broad terms, the physical layer is responsible for activating and using physical connections for transfer of electronic bits (zeros and ones) between a device and its transmission medium. The physical layer defines the electrical, mechanical, and handshaking protocols that govern transmission media and signals over the interface connecting a device to the transmission medium. In doing so, the physical layer insulates the data link layer (layer 2) from the physical characteristics of the transmission medium, such as baseband, broadband, or fiber-optic transmission. The physical layer is subdivided into the physical medium-dependent (PMD) sublayer and the transmission convergence (TC) sublayer.
Port	A port is the physical input or output connection of an instrument or device.
Power Level	Power level (dBm) is the stimulus level at the test port required for the measurement of the device under test.
Probing	Probing is the process of using a probe to perform on-circuit measurements. The probe is a stylus-like device that is connected to the test equipment on one end with a cable. The other end of the probe is pressed onto your device under test (DUT) to measure the signal. The end that is being used to probe often has multiple conductors for signal and ground paths. It is also often spring loaded to apply a constant pressure to the DUT.
PRBS (Pseudo Random Binary Sequence)	PRBS is a repetitive, random, digital signal pattern.
– R –	
R (resistance)	Resistance (ohms) is the opposition to the flow of current in a transmission line.

Rack Units	A rack unit (U) is the vertical distance (height) between screw holes in an equipment rack. One rack unit (1U) equals 1.75 inches (44.45 mm) of rack space for equipment. 2U provides 3.5 inches of rack space for equipment, and so forth.
Record Length	Record length is the number of points per waveform trace acquired. You can set the record length of the data acquisition to a value of 16 to 4096 points per waveform.
Reference Level	Reference level is an instrument function that allows the user to set the amplitude value at the reference position. On network analyzers, the reference position is also selectable.
Reference Plane	A reference plane is the electrical location at which a network analyzer assumes the system connectors and fixturing ends and the DUT begins. The reference plane is set by using calibration standards with known electrical length. The closer the reference plane is to the device under test (DUT), the better the characterization of the device because of the elimination of test system uncertainties.
Reference Plane Rotation	Reference plane rotation is a technique to remove the time delay caused by a fixture. Since the SOLT calibration only calibrates to the end of the test cables, the effects added by the test fixture can be removed mathematically. Reference plane rotation moves the reference plane from the end of the test cables to the connection between the fixture and the DUT by accounting for the electrical length of each fixture path. Other terms for this process are phase skew and port extension.
Reflection	Reflection is the phenomenon in which a traveling wave strikes a discontinuity and returns to the original medium.
Reflection Coefficient	The reflection coefficient is the ratio of the reflected voltage to the incident voltage into a transmission line or circuit. If a transmission line is terminated in its characteristic impedance, the reflection coefficient is zero. If the line is shorted or open, the coefficient is 1.
Rho	Rho (ρ) in time domain is the ratio between the incident and the reflected voltages and can be either positive or negative.

Rise Time	Rise time is a measure of the mean transition time of the data on the upward slope of an eye diagram. The data crosses through the following thresholds: the lower, middle, and upper thresholds, as well as through the crossing points of eyes.
RMS	RMS is the root-mean-square (rms) of the voltage values of a waveform. Typically, the rms is taken over the first period of the displayed waveform.
– **S** –	
S-parameters (scattering parameters)	A convention used to characterize the way a device modifies signal flow using a network analyzer. A four port device has sixteen S-parameters: including forward transmission and reverse transmission, and forward reverse reflection for each set of ports.
Scale (horizontal)	Horizontal scale is an instrument control that controls the x-axis or time per division of displayed waveforms. Horizontal scale is often referred to as sweep speed in some instruments.
Scale (vertical)	Vertical scale is an instrument control that controls the y-axis or volts per division for the selected channel. This control allows you to adjust the sensitivity of the instrument.
Short	A Short is a calibration standard that is an actual line that terminates a path with an electrical short. See SOLT.
Signal-to-Noise Ratio	Signal-to-noise is a ratio of the signal difference between one level and zero level relative to the noise present at both levels.
Single-ended	A singled-ended or unbalanced device, has all of its signals referenced to a common ground potential.
Single-ended device	A single-ended device has all of its signals referenced to a common ground potential.
Skew	Skew changes the horizontal position of a waveform on the display independent of any other waveforms on the display. Skew is typically used for overlaying waveforms, or eliminating timing difference caused by different cable and probe lengths. The time base position control moves all of the waveforms on the display at the same time, whereas skew moves individual waveforms..
Slope (power)	See Power Slope.

SOLT	SOLT is a calibration using four known standards: Short-Open-Load-Thru.
Source	The source (input channel, function, waveform memory, or constant) used when performing tasks, such as measurements, math, or mask tests.
Standard deviation	Standard deviation is the measure of the dispersion or spread of the statistical average of all results for a particular measurement. Standard deviation is represented by the Greek letter sigma (σ). In a Gaussian distribution, two sigma, or within ±1σ of the mean is where 68.3 percent of the data points reside. Six sigma, or within ±3σ of the mean is where 99.7 percent of the data points reside.
Stop/Start Frequency	Terms used in association with the stop and start points of the frequency measurement range. Together they determine the span of the measurement range.
Stripline	Stripline is a planar transmission line that consists of a thin conductive trace (or traces) printed or etched on one side of an insulating substrate with a parallel ground plane (backplane) on the other side of the substrate. Another insulating substrate, also with a parallel ground plane on the other side, is placed over the conductive trace, encasing or sandwiching the trace between two pieces of substrate with ground planes.
Sweep	A sweep is the ability of the source to provide a specified signal level over a specified frequency range in a specified time period.
Sweep Cycle Time	Sweep cycle time is the time required for making a complete sweep and preparing for the next sweep. It can be measured as the time from the start of one sweep to the start of the next sweep.
Sweep Mode	Sweep mode is the way in which a sweep is initiated or selected.
Sweep Type	Sweep type is the method of sweeping the source, e.g., linear, log, or frequency step.
– **T** –	
Termination	A termination is a load connected to a transmission line or other device.

Test Set	A test set is the arrangement of hardware (switches, couplers, connectors and cables) that connect a test device input and output to the network analyzer's source and receiver to make S-parameter measurements
Thru	A Thru (through) is a calibration standard that is an actual through line. See SOLT.
Time Domain Network Analysis (TDNA)	TDNA includes both time domain reflectometry (TDR) and time domain transmission (TDT) measurements.
Time Domain Reflectometry (TDR)	TDR gives an intuitive measurement of any discontinuities in a circuit. It measures the location, electrical length, nature of circuit (resistive, capacitive, inductive), and amount of reflection from discontinuities.
Time Domain Transmission (TDT)	TDT is a measurement technique that measures both attenuation and propagation delay of your device under test.
TRL (Thru-Reflect-Line) Calibration	Microstrip devices in the form of chips, MMIC's, packaged transistors, or beam-lead diodes cannot be connected directly to the coaxial ports of the test system. The DUT must be physically connected to the test system by some kind of transition network or fixture. A calibration at the coaxial ports of the test system removes the effects of the system and any cables or adapters before the fixture; however, the effects of the fixture itself are not accounted for. An in-fixture calibration is preferable, but high-quality SOLT standards may not be readily available to allow a conventional full 4-port calibration at the desired measurement plane of the device. In microstrip, a short circuit is inductive, an open circuit radiates energy, and a high-quality purely resistive load is difficult to produce over a broad frequency range. The TRL calibration is an alternative to the full 4-port SOLT calibration technique that utilizes simpler, more convenient standards for device measurements in the microstrip environment.

TRL (continued)	TRL calibration is convenient in that calibration standards can be fabricated for a specific measurement environment, such as a transistor test fixture or microstrip. The TRL calibration relies on the characteristic impedance of simple transmission lines rather than on a set of discrete impedance standards. Since transmission lines are relatively easy to fabricate (in a microstrip, for example), the impedance of these lines can be determined from the physical dimensions and substrate's dielectric constant.
– **V** –	
Velocity Factor	Velocity factor is a numerical value related to the speed of energy through transmission lines with different dielectrics (.66 for polyethylene). In making time domain measurements, a velocity factor of 1 = speed of light =299.7925 x 10^6 m/s.
Vertical Resolution	Vertical resolution is the degree to which an instrument can differentiate amplitude between two signals.
– **W** –	
Waveform	A waveform is a representation of a signal plotting amplitude versus time.
– **Z** –	
Zero Level	Zero level is a measure of the mean value of the logical 0 of an eye diagram.
Zo	Zo is the characteristic impedance of a transmission line.

B Procedures

The procedures in this appendix may be required while using the physical layer test system; however, they are not used commonly. The following is a list of the procedures.

- Using the Network Analyzer to Make 2-Port Measurements is used when you want to make 2-port measurements using only the network analyzer.
- Converting a CitiFile to a PLTS Adapter File is used when you want to convert a citifile (".cit") containing measured data to an adapter file (".txs") for de-embedding.
- IF Gain Adjustment is used to set up the N8362A or N8364A PNA network analyzer, with firmware revision less than 3.0, to be used in the PLTS system.

Using the Network Analyzer to Make 2-Port Measurements

You can make two port measurements using the front panel control of the network analyzer without having to disconnect the network analyzer from the test set using the following procedure.

1. Turn off the PLTS software.
2. Toggle the power on the test set to reset the switches.
3. Leave the power of the test set in the ON position.
4. Use the network analyzer from the front panel.

Converting a CitiFile to a PLTS Adapter File

The Physical Layer Test System uses adapter files to de-embed measurement data. PLTS adapter files (".txs" files) can be created by adding a two-line comment near the top of an S-parameter citifile (".cit" file) as shown below. You can use an MS Windows-based ASCII text editor such as Notepad to perform this procedure. The following shows a citifile for a thru device with 3.5mm connector at each end. (The measurement data within this example file has been replaced with a vertical ellipsis only as a space savings for this example.)

```
CITIFILE A.01.00
NAME S-Parameters
VAR FREQ MAG 400
DATA S[1,1] RI
DATA S[1,2] RI
DATA S[2,1] RI
DATA S[2,2] RI
SEG_LIST_BEGIN
SEG 50000000 20000000000 400
SEG_LIST_END
BEGIN
.
.
.
END
```

Using the two comment lines shown below, identified with "#TXS", the type of device and the connector type of its ports are identified.

```
#TXS TYPE=THRU
#TXS PORT1=3.5MM   PORT2=3.5MM
```

These two comment lines are inserted be the first and second line of the citifile as shown below. This is then saved as a ".txs" file in the PLTS deembedding directory.

```
CITIFILE A.01.00
#TXS TYPE=THRU
#TXS PORT1=3.5MM   PORT2=3.5MM
NAME S-Parameters
VAR FREQ MAG 400
DATA S[1,1] RI
DATA S[1,2] RI
DATA S[2,1] RI
DATA S[2,2] RI
```

```
SEG_LIST_BEGIN
SEG 50000000 20000000000 400
SEG_LIST_END
BEGIN
.
.
.
END
```

IF Gain Adjustment

This procedure is for N8362A and N8364A PNA network analyzers that have firmware revisions less than Revision 3.0.

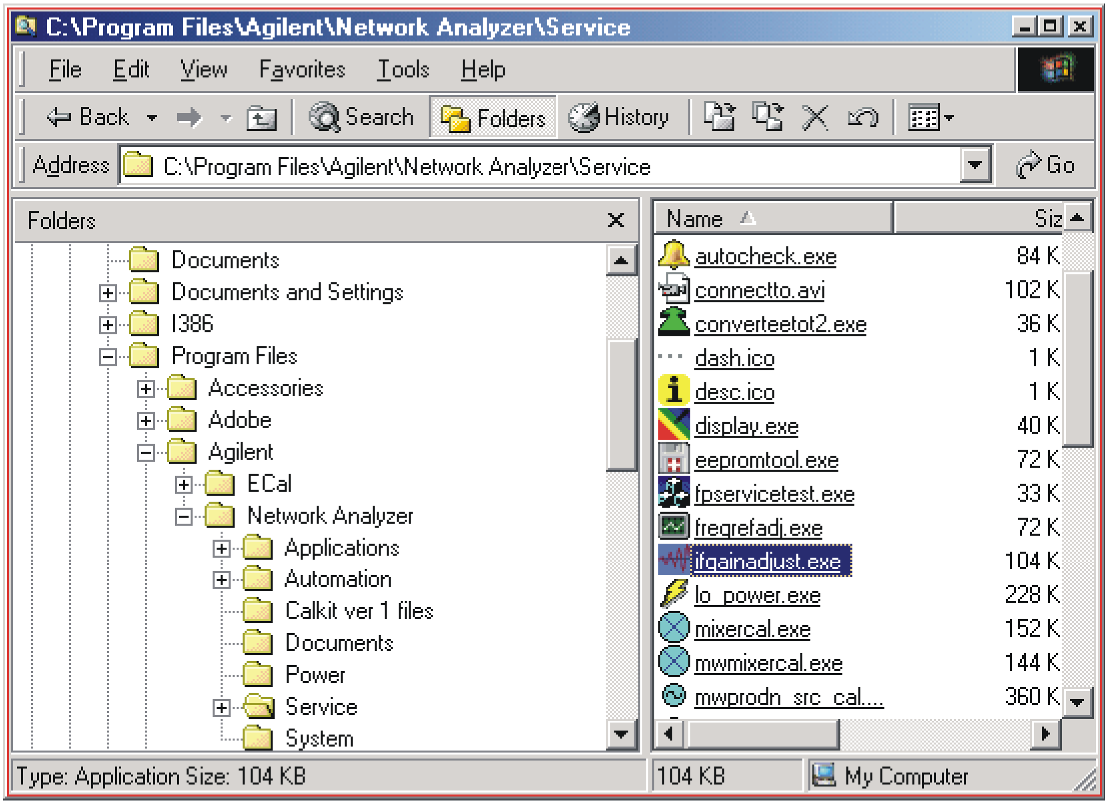
It is recommended that the Service IF Gain Adjustment test be run *before* using the test set. This routine adjusts the R Channel receivers ALC gain to ensure phase lock over the entire frequency range of the PNA Series Network Analyzer. Connect the test set to the analyzer before adjusting the IF gain.

NOTE When the analyzer is removed from the test set for service, or for other applications that do not require the test set, the IF gain adjustment must be run again to return the R Channel receiver ALC gain back to normal.

Adjustment Test

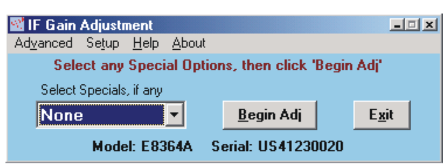
1. Close the PNA Series Network Analyzer window.
2. Open "My Computer", located on the desk top, double click on "Hard Disk (c:)." (You may also use Explorer). Refer to Figure B-1.
3. Open the following folder path: Programs Files/Agilent/Network Analyzer/Service

Figure B-1 File Path on PNA Network Analyzer Window



4. Double click “ifgainadjust.exe.”
5. Minimize the PNA Network Analyzer window when it appears. You should see the IF Gain Adjust window.

Figure B-2 IF Gain Adjustment Window



6. Select the test set in the “Select Specials, if any” pull down menu and click on “Begin Adj.”

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