Measurement with Options

Measurement with Options

The following measurement is available depending on the installed option.

- Option 010 Time Domain/Fault Location Analysis
- Option 005 Impedance Analysis

Option 005 Impedance Analysis

Option 005 Impedance Analysis

- Quick Start
- Overview
- Setting Up Measurement
- Making Measurement
- Analyzing the Measurement

The option 005 can only be used with E5061B Option 3L5 and it requires the firmware revision A.02.00 and above.

Overview

Overview

- Feature
- Preparation for Measurement

Other topics about Option 005 Impedance Anaysis

Feature

- The E5061B Option 005 enables the analyzer to measure impedance parameters of electric components such as capacitors, inductors, and resonators.
- You can evaluate a broad range of components. This option supports the reflection, series-thru and shunt-thru methods using the S-parameter test port or Gain-Phase test port. These methods are suitable for low-to-middle, middle-to-high, and very low milliohm impedance range respectively.
- Agilent 7 mm and 4 TP (4-terminal pair) type test fixtures can be used with E5061B to provide a good repeatable measurement. The 7 mm type fixtures are connected to port 1 with the 16201A terminal adapter.

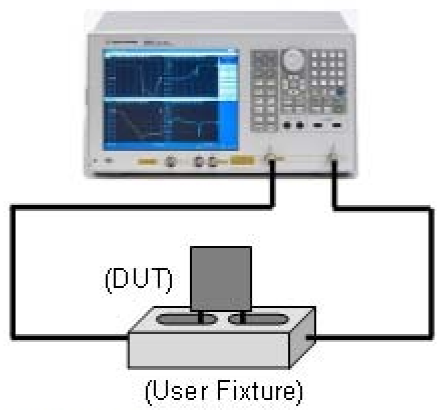
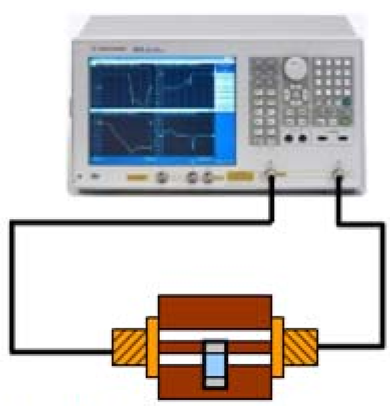
Other topics about Overview

Preparation for Measurement

- Measurement using ports 1 and 2
- Measurement using Gain-Phase Port

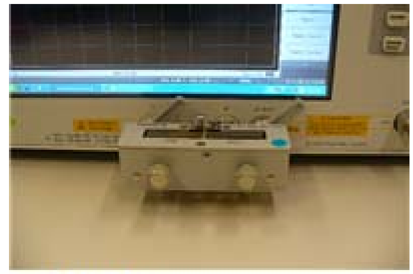
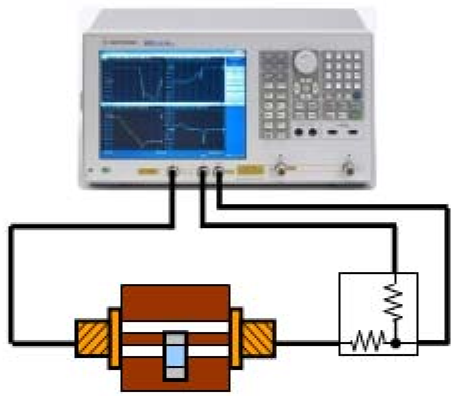
Other topics about Overview

Measurement using Ports 1 and 2

Method	Required Items	Connection
Port 1 Reflection	16201A Terminal Adapter, Agilent 7 mm type test fixture, Calibration Kit 16195B (or 85031B)	 e5061b075
Port 1-2 Series - Through	User-prepared fixture, Cables, 50 Ω precision resistor for calibration at fixture	 e5061b104
Port 1-2 Shunt - Through	User-prepared shunt-through fixture, Cables, Calibration kit	 e5061b079

Measurement using Gain-Phase Port

Method	Required Items	Connection

Gain-Phase Series - Through	Agilent 4 terminal-pair type test fixture (Recommendation 16047E for leaded DUTs, 16034E/G/H for SMDs), 50 Ω precision resistor for calibration at fixture	 e5061b111
Gain-Phase Shunt - Through	User-prepared fixture, Cables, Power splitter (11667L or equivalent)	 e5061b105

Setting Up Measurement

Setting Up Measurement

- Setting Measurement Conditions
- Performing Calibration
- Connecting Test Fixture
- Eliminating the Error Factor of Fixture

Other topics about Option 005 Impedance Analysis

Setting Measurement Condition

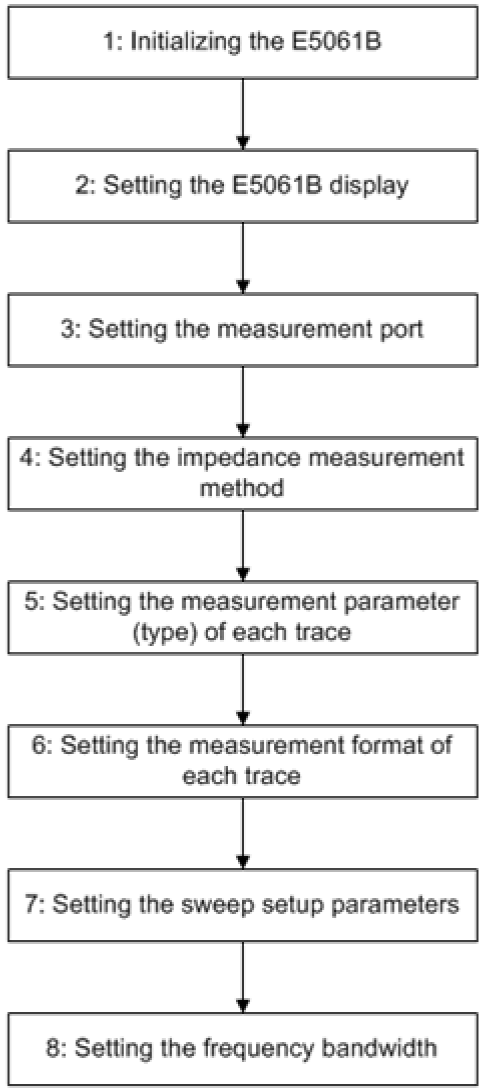
Setting Measurement Condition

- Flow of Setup
- Setting Measurement Parameters and Display Formats
- Setting Measurement Points, Sweep Parameters and Sweep Type

Other topics about Setting Up Measurement

Flow of Setup

The basic procedure of setting measurement condition is as shown in the flow chart below.



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Other topics about Setting Measurement Condition

Setting Measurement Parameters and Display Formats

- Initializing the E5061B (Preset the E5061B)
- Setting the E5061B display
- Setting the measurement port
- Setting the impedance measurement method
- Setting the measurement parameter (type) of each trace
- Setting the measurement format of each trace

Other topics about Setting Measurement Condition

To set the measurement parameters and display formats:

Initializing the E5061B (Preset the E5061B)

1. Press **Preset** in the INSTR STATE block on the front panel.
2. Click **OK** from the menu bar.

Setting the E5061B display

1. Set the trace display (number of traces).
2. Press **Display** > **Num of Traces.**
3. Press the desired softkey to set the number of traces.
4. Set the trace layout (graph layout).
5. Press **Display** > **Allocate Traces.**
6. Select the preferred graph layout from the windows layout.

Setting the measurement port

1. Press **Meas** in the RESPONSE block on the front panel.
2. Click **Measurement Port**.
3. Select **S-Parameter** or **Gain-Phase**.

Setting the impedance measurement method

1. Press **Meas** in the RESPONSE block on the front panel.
2. Click **Impedance Analysis Menu**.
3. Click **Method** and select one of the method from the available options.

Method options	Measurement method details
Port 1 Refl	Reflection method at S-Parameter Port-1
Port 2 Refl	Reflection method at S-Parameter Port-2

Port 1-2 Series	Series-through method at S-Parameter Port-1 and 2
Port 1-2 Shunt	Shunt-through method at S-Parameter Port-1 and 2
GP Series T 50Ω, R 1 MΩ	Series-through method at Gain-phase test port with input impedance of R:1 Mohm and T:50 ohm
GP Shunt T 50Ω, R 50 Ω	Shunt-through method at Gain-phase test port with input impedance of R:50 ohm and T:50 ohm

Setting the measurement parameter (type) of each trace

1. Select the trace that you want to change its measurement parameter as the active trace.
2. To select the active trace, use the following hardkeys:

Hardkey	Function
Trace Next	Change the active trace to the next trace with the larger trace number.
Trace Prev	Change the active trace to the previous trace with the smaller trace number.

3. After selecting the active trace, press **Meas** hardkey.
4. Click **Impedance Analysis Menu**.
5. Select the measurement parameter from the available options.

Measurement parameter	Measurement parameter details
|Z|	Impedance magnitude
θz	Impedance phase in degree
|Y|	Admittance magnitude
θy	Admittance phase in degree
Cp	Parallel capacitance
Cs	Series capacitance
Lp	Parallel inductance
Ls	Series inductance

Rp	Parallel resistance
Rs	Series resistance
D	Dissipation factor
Q	Quality factor
R	Resistance
X	Reactance
G	Conductance
B	Susceptance

6. Repeat the step for other traces, if available.

Setting the measurement format of each trace

1. Select the trace that you want to change its measurement parameter as the active trace.
2. Press **Format** in the RESPONSE block on the front panel.
3. If **Impedance Analysis Menu** is selected as the measurement method, then the only available format is Expand Phase (**Exp Phase**).
4. Click the **Exp Phase** button to turn it **ON** or **OFF**.

Setting Measurement Points, Sweep Parameter and Sweep Type

- Setting the measurement points
- Setting the sweep setup parameters

Other topics about Setting Measurement Condition

To set the measurement points, sweep parameter and sweep type:

Setting the measurement points

The number of points is the number of data items collected in one sweep. It can be set to any number from 2 to 1601 for each channel independently.

1. Press **Sweep Setup** in the STIMULUS block on the front panel.
2. Click **Points** from the Sweep menu bar.
3. Then, using either the keyboard or ENTRY keys on the front panel, enter the desired number of points.

Setting the sweep setup parameters

1. Press **Sweep Setup** in the STIMULUS block on the front panel.
2. Click **Power** from the Sweep menu bar.
3. Using either the keyboard or ENTRY keys on the front panel, enter the power value.
4. To set the sweep type, click **Sweep Type** from the Sweep menu bar and select the type from the available option.

Sweep type	Sweep parameter details
Lin freq	Sweep frequencies in linear scale
Log freq	Sweep frequencies in logarithmic scale
Segment	Performs a sweep with linear sweep conditions (segments) combined
Power sweep	Sweeps power levels in linear scale
DC bias sweep	Sweeps DC bias levels

Performing Calibration

Performing Calibration

- Connecting Adapter
- Defining Calibration Kit
- Performing Impedance Calibration
- Using S-Parameter Calibration for Impedance Measurement

Other topics about Setting Up Measurement

Connecting Terminal Adapter

In the Port 1 Reflection method, the 7 mm terminal adapter can be used for connecting the Agilent’s 7 mm type component test fixtures to the E5061B’s Port 1.

- Required Parts
- Replacement Procedure

Other topics about Performing Calibration

Required Parts

The following parts are furnished with the 16201A Terminal Adapter kit.

Description	Agilent Part Number
Terminal Adapter Main Unit	16201-60102
Semi-rigid Cable, N connector	16201-61601
Attachment (Front)	16201-20002
Attachment (Bottom)	16201-20001
Screws for Attachment	0515-1013 (2 ea.)

Replacement Procedure

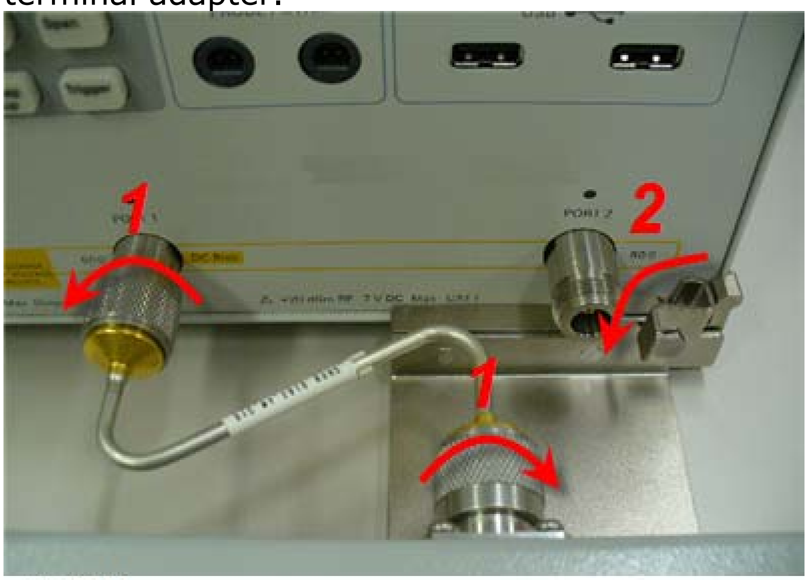
1. Fasten the front and bottom attachments with two screws. Do not tighten the screw at this moment.

e5061b072

2. Place the attachment at the right-bottom of the E5061B. Fix it by tightening the two screws.

e5061b073

3. Place the semi-rigid cable between Port 1 on E5061B and port of the terminal adapter.



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4. Rotate the lock so that the terminal adapter is fixed with the attachment.

Performing Impedance Calibration

Other topics about Performing Calibration

Overview

The impedance calibration is a calibration function dedicated to the impedance analysis with the E5061B option 005. The impedance calibration executes the 3-term calibration (open/short/load calibration) directly in the impedance domain instead of the S-parameter domain, after the raw S-parameter measurement data or the gain-phase T/R measurement data is converted to the impedance data. Therefore, you need to select your desired impedance measurement method before performing the impedance calibration. The impedance calibration basically consists of the open, short, and load calibrations. You can perform the optional low-loss capacitor calibrations in addition to the open/short/load calibrations. The impedance calibration is applied only to the impedance parameters (see Data Processing). It is not applied to the S-parameter and Gain-Phase T/R ratio measurements.

The following table shows the recommended calibration for each method. Note that the calibrations for network analysis such as the 2 port full and response through are used in the Shunt-Thru methods, instead of the impedance calibration.

Recommended Calibration

Method	Configuration	Calibration Device	Calibration	Calibration Plane	Fixture Compensation
Port 1 Refl	16201A Terminal Adapter + Agilent 7mm Fixture	7 mm calibration kit	Impedance Calibration (open/short/load/[low-loss C])	7 mm connector on the terminal adapter	Required (open/short and electrical length)
Port 1 Refl / Port 2 Refl	User-prepared fixture	50 Ω resistor	Impedance Calibration (open/short/load)	The measurement terminals of Fixture	Not required
Port 1-2 Series	User-prepared fixture	50 Ω resistor	Impedance Calibration (open/short/load)	The measurement terminals of	Not required

				Fixture	
Port 1-2 Shunt	User-prepared fixture	Coaxial calibration kit	2 Port Full calibration and Port extension.	End of test cable	Not required
GP Series T 50 Ω, R 1 MΩ	Agilent 4 terminal-pair fixtures (2 Terminal contact Type)	50 Ω resistor	Impedance Calibration (open/short/load)	The measurement terminals of Fixture	Not required
	User-prepared fixture	50 Ω resistor	Impedance Calibration (open/short/load)	The measurement terminals of Fixture	Not required
GP Shunt T 50 Ω, R 50 Ω	User-prepared fixture	User-prepared through device or user prepared open, short and load	Response Calibration (Through) or Impedance Calibration (open/short/load)	The measurement terminals of Fixture	Not required

Difference of Calibration (for S-parameter) and Impedance Calibration

- The impedance calibration executes the 3-term calibration in the impedance domain after the S-parameter or Gain-Phase T/R ratio is converted to the impedance.
- The impedance calibration supports the low-loss capacitor calibration.
- The impedance calibration is not applied to the network analysis data (S-parameters and Gain-Phase T/R ratio).

The impedance calibration and the calibrations for network analysis, such as the 1-port full, 2-port full, and response through cannot be performed at the same time. If you perform the impedance calibration after performing these network-analysis calibrations in the same channel, the data of network-analysis calibrations is overwritten and deleted.

Low-Loss Capacitor Calibration

When you measure Q, D, and ESR of RF capacitors and RF inductors by using the reflection method with the 16201A terminal adapter and Agilent’s 7 mm test fixtures, performing the low-loss capacitor (LLC) calibration in addition to the open/short/load improves the accuracy of Q, D, and ESR measurements at high frequencies over 1GHz. The LLC provides a reference for calibration with respect to the 90°-phase component of impedance. Agilent 16195B calibration kit provides a low-loss capacitor termination in addition to the open/short/load terminations

Selecting Calibration Kit for Impedance Calibration

You need to select calibration kit before you perform the impedance calibration.

Method	Configuration	Required Calibration Kit
Port 1 Refl	Terminal Adapter + 7 mm test fixture	85031B (open/short/load only), or 16195B (open/short/load, plus low-loss-C)
Others	Test fixture for SMD	SMD 50ohm
	Test fixture for leaded DUT	Leaded 50ohm

1. Press **Cal** > **Cal Kit.**
2. Select your calibration kit.

Performing Open/Short/Load/(Low-Loss C) Calibration (Impedance Calibration)

Impedance calibration should be performed at the following location.

Configuration	Calibration Plane
16201A Terminal Adapter + 7 mm test fixture	7mm Connector on the terminal adapter
Test fixture for SMD	Measurement terminals of the fixture
Test fixture for leaded DUT	Measurement terminals of the fixture

1. Press **Channel Next** (or **Channel Prev**) to select the channel for which you want to calibrate (If you are using multiple channels).
2. Confirm if the desired method is selected (**Meas** > **Method**).
3. Press **Cal** > **Calibrate** > **Impedance Calibration.**
4. Connect the open termination, or leave the fixture’s measurement terminals open.
5. Click **Open** to execute open calibration (After the calibration is performed, a check mark is displayed at the left of the softkey).
6. Connect the short termination to the location of the open termination, or short the measurement terminals of the fixture.

7. Click **Short** to execute short calibration.
8. Connect the load termination in place of the short termination, or connect the 50 Ω resistor to the fixture.
9. Click **Load** to execute load calibration.
10. If you use the 16201A terminal adapter and the 16195B 7 mm calibration kit, you can perform the optional low-loss capacitor calibration here. Follow the procedure below:
    a. Connect the Low-Low capacitor termination instead of the load termination.
    b. Click **Low-Loss C (Optional)** to execute the low loss capacitor calibration.
11. Click **Done** to complete the impedance calibration process. Upon pressing this key, calibration coefficients are calculated and saved. The error correction function is also enabled automatically.
12. **Cor** is displayed at the Channel Window.
    (If there is no impedance parameters in the channel, **Cor** is not displayed. For example, when only S11 is displayed at the trace, **Cor** is not displayed even after impedance calibration. Changing the parameter to |Z| displays **Cor**.)

Acquisition Status of Calibration Coefficient

As in the S-Parameter measurement, the calibration property (**Cal** > **Property**) shows the acquisition status of Impedance calibration.

Method	S	R	Property Value
Port 1 Refl	1	1	G
Port 2 Refl	2	2	G
Port 1-2 Series	1	2	S
Port 1-2 Shunt	1	2	P
GP Series T 50 Ω, R 1 MΩ	G	G	S
GP Shunt T 50 Ω, R 50 Ω	G	G	P

The following example shows that impedance calibration performed with Port 1-2 Series method.

```
   S
  1 2 G
1 - - -
```

R2 S- -
G- - -

Defining Calibration Kit

- Overview
- Procedure Defining Calibration Kit
- Preset of Calibration Kit Definition

Other topics about Performing Calibration

Overview

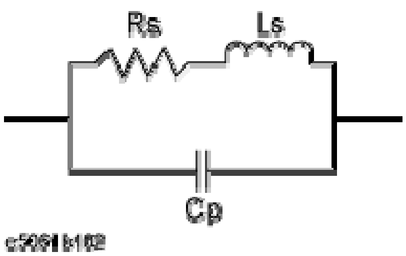
When option 005 impedance analysis is installed, the calibration kit can be defined by the following three standard models. The equivalent circuit and table models are available only when option 005 is installed.

Polynomial

This model is the same as the calibration kit definition of S-Parameter measurements. See Modifying Calibration Kit Definition.

Equivalent Circuit

This model allows you to define the calibration kit by the following model. When you use the equivalent circuit model, one of either Open, Short, Load or Arbitrary should be selected as the Standard Type.



Table

You can specify the frequency characteristic of impedance for the termination. The definition cannot be set using the softkey. You need to specify it by using the commands. See the following command to specify the calibration kit.

- SCPI.SENSe(Ch).CORRection.COLLect.CKIT.STAN(Std).TABLe / :SENS:CORR:COLL:CKIT:STAN:TABL

When you use the table model, either one of these: Open, Short, Load or Arbitrary should be selected as the Standard Type.

Procedure of Defining Calibration Kit

This section provides the procedure to change the definition of a calibration kit.

Polynomial

See Defining Parameters for Standards.

Equivalent Circuit/Table

a. Select and define a calibration kit

1. Press **Cal** > **Cal Kit**, then select the calibration kit to be redefined.
2. Click **Modify Kit**.
3. If necessary ,click **Label Kit** and type a new label for the calibration kit.

b. Select the standard type and define standard coefficient

4. Click **Define STDs** and select the standard number to be redefined.
5. If necessary, click **Label**, then type your desired name for the selected standard.
6. Click **STD Type**, then select the **type of standard**.
7. Click **STD Model** > **Equiv Ckt** or **Table**
8. When **STD Model** is set at **Equiv Ckt**, set the **standard coefficient**.
9. Repeat steps 4 to 8 to redefine all the standards for which changes are necessary, then click **Return**.

Standard Class allows you to use different standards for each port. Generally, this is not used in the impedance calibration.

Preset of Calibration Kit Definition

See Preset the definition for calibration kits

Using S-Parameter Calibration for Impedance Measurement

It is not possible to apply both the network-analysis calibration and impedance calibration to the same channel of the E5061B. Also, the impedance calibration is not applied to the S-Parameter measurement traces. For example, if you want to measure the circuit’s input/output impedance with both S11 and impedance parameter traces, 1 port full calibration should be performed instead of the impedance calibration, because the impedance calibration is not applied to the S11 traces.

Connecting Test Fixture

Connecting Test Fixture

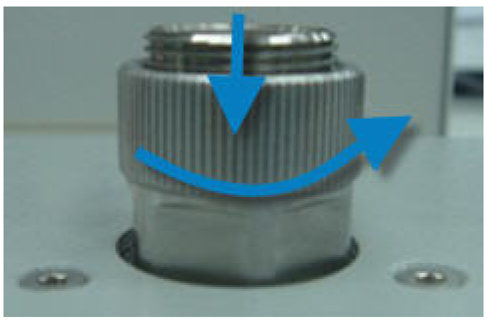
- Connecting Fixture (S-Parameter)
- Connecting Fixture (Gain-Phase)

Other topics about Setting Up Measurement

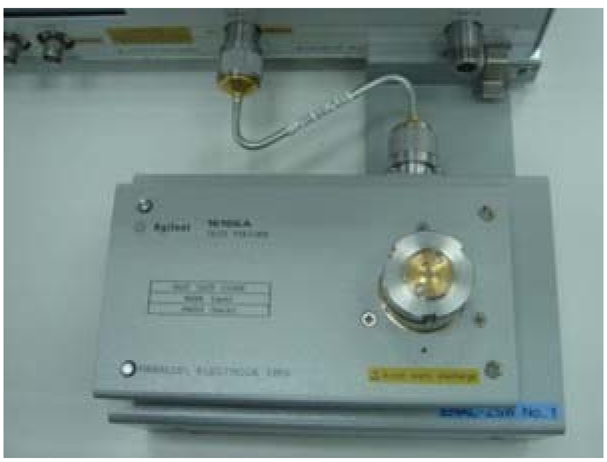
Connecting Fixture for Port 1 Reflection Method

In the Port 1 reflection method, Agilent’s 7 mm-type component test fixtures can be connected to the E5061B’s Port 1 via the 16201A terminal adapter. If you perform impedance calibration using the 7 mm calibration kit, the test fixture should be connected after the calibration is completed. Once the fixture is connected, open/short compensation should be performed at the measurement terminals of the fixture. Or, if you perform impedance calibration at the measurement terminals of the fixture by using the leaded or SMD 50 Ω resistors, the fixture should be connected before performing the calibration.

1. Turn the 7-mm connector nut of the test head counterclockwise until the connector sleeve is fully retracted.



2. Set the test fixture on top of the terminal adapter with the 7-mm connectors aligned. Ensure that the two holes on the test fixture is mounted on the two mount posts of the terminal adapter.
3. Turn the 7-mm connector nut of the terminal adapter counterclockwise to secure the connection, as shown in the following figure. Use both hands to turn the connector nut because the space between the terminal adapter and test fixture is narrow.



Connecting Fixture for Gain-Phase Series-through Method

You can use the Agilent's 4-terminal-pair type fixtures for the Gain-Phase series-through method. Although the E5061B does not have a 4-terminal pair configuration, you can perform the impedance measurement by directly connecting the 4-terminal-pair fixture to the Gain-Phase test port and performing impedance calibration (open/short/load calibration) at the fixture's measurement terminals. Note that the measurement technique of this configuration is not an auto balancing bridge method but a simpler VNA-based series-through method..

- Available Test Fixtures
- Connecting Procedure

Other topics about Connecting Test Fixture

Available Test Fixtures

4-terminal-pair fixture for the Gain-Phase series-through method should be a 2-terminal contact type, and the fixture's measurement terminals should have good contact repeatability so that the 50 Ω resistor is tightly fixed when performing the impedance calibration.

The following fixtures are recommended:

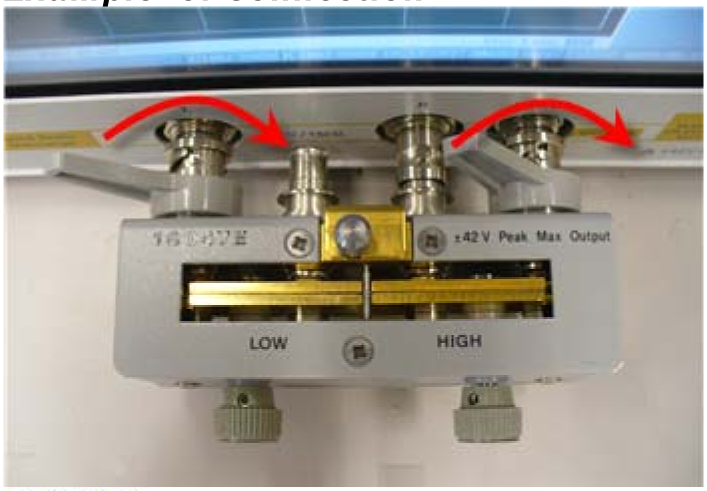
- 16047E (for leaded DUTs)
- 16034E/G/H (for SMDs)

The 4-terminal contact (Kelvin contact) type fixtures such as 16044A are not recommended, because the contacting method to the DUT will not be a 4-terminal contact when used with the E5061B's Gain-Phase series-thru method and there is no advantage in using these fixtures.

Connecting Procedure

1. Connect the fixture on the Ports T, R and LF Out. The second connector (for Lpot) from the left of fixture is not connected.
2. Turn the knobs (of the fixture) to fix the fixture.

Example of Connection



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Eliminating Error Factor of Fixture

Eliminating Error Factor of Fixture (Fixture Compensation)

The following function allows you to eliminate the error factor of fixture and cable.

- Open/Short/Load Compensation
- Z Port Extension (Fixture Electrical Length)

Generally, these functions are used in one of these ways.

- Open/Short Compensation and Z Port Extension (Fixture Electrical Length)
- Open/Short/Load Compensation

Other topics about Setting Up Measurement

Other topics about Eliminating Error Factor of Fixture

Overview

When you measure the impedance by using the Agilent 16201A terminal adapter and performing the impedance calibration at the adapter's 7 mm plane, the error factors of the 7 mm fixture mounted on the adapter can be eliminated with the fixture compensation. The recommended fixture compensation method up to a few hundreds of MHz is the open/short compensation. For the measurement at higher frequencies over a few hundreds of MHz, it is recommended to perform the combination of the fixture electrical length compensation and the open/short compensation.

The open/short compensation eliminates the error factors of the fixture's non-coaxial section. The open admittance and the short impedance of the fixture can be eliminated by measuring the impedance with the fixture's measurement terminals opened and shorted, respectively.

The open/short compensation is applicable only to the impedance measurement data, and is not applicable to the S-parameter and gain-phase T/R measurement data.

The fixture electrical length compensation eliminates the measurement error induced by the phase shift in the fixture's coaxial section. The fixture electrical length compensation eliminates the phase-shift error by selecting the fixture's model number, or by manually entering the fixture's electrical length in meters.

Another method for eliminating the phase-shift error is to define the delay with the Z Port Extension function. The Z Port Extension is the port extension function dedicated to the impedance measurement of the E5061B option 005. For example, if you connect an extension coaxial cable between the 7 mm calibration plane and the fixture, the phase-shift error that occurs in the cable can be eliminated with the Z Port Extension.

Z Port Extension and Fixture Electrical length compensation is the same idea and the only difference is the unit. Z Port Extension is expressed in a delay time in seconds. On the other hand, the Fixture Electrical length is expressed in meters (mili-meter).

Electrical Length =Port Extension × (velocity of the signal in free space: 3×10^8) .

The fixture electrical length compensation and the Z port extension are applicable only to the impedance measurement data, and are not applicable to the S-parameter and gain-phase T/R measurements. (See the Data Processing)

Open/Short Compensation

Open/Short compensation provides the same functionality as the one in Agilent RF Impedance Analyzer such as the E4991A.

1. Set the open state of the fixture.
2. Press **Cal** > **Fixture Compen** > **Compensate** > **Open.**
3. Set the short state of the fixture.
4. Click **Short**.
5. Click **Done**.
6. Open/Short compensations are turned ON automatically. **Comp OS** is displayed at the Channel Window.

If you use the fixture electrical length compensation or the Z Port Extension in addition to the open/short compensation, the fixture electrical length or the Z Port Extension values must be set before performing the open/short compensation.

Z Port Extension and Fixture Electrical Length

Z Port Extension

Z Port Extension provides the same functionality as the one in Agilent RF Impedance Analyzer such as the E4991A. This is used when the coaxial cable is connected from where the calibration is performed. In Z port extension, loss is not compensated. Z Port Extension is applied even if **Cal** > **Fixture Compen** is OFF.

1. Press **Cal** > **Fixture Compen** > **Z Port Extension**
2. Enter the port extension value, then press **Enter**.
3. **ZExt** is displayed at the Channel Window.

Fixture electrical length

Fixture Electrical length compensation provides the same functionality as the one in Agilent RF Impedance Analyzer such as the E4991A. Since the electrical length of an exclusive-use test fixture is registered in the E5061B, the necessary electrical length can be set by simply selecting the model number of the test fixture used. It is also possible to input the specified electrical length value. Fixture Electrical length is applied even if **Cal** > **Fixture Compen** is OFF.

1. Press **Cal** > **Fixture Compen** > **Fixture.**
2. Select the fixture used.
3. **Fixtr {Fixture Model Number}** is displayed at the Channel Window.

Using User Fixture

If you use the fixture whose electrical length is not pre-defined in the firmware menu, you can manually define its electrical length. If you use the 16092A fixture, for example, define its electrical length of 3.4 mm by using the following procedure:

1. Press **Cal** > **Fixture Compen** > **Modify User Fixt.** > **User Fixture**
2. Enter the electrical length value of your fixture, then press **Enter.**
3. Press **Cal** > **Fixture Compen** > **Fixture** > **User.**
4. **Fixtr User** is displayed at the Channel Window.

When the electrical length value of user fixture is set at 0, **Fixtr User** is not displayed at the Channel Window even if **User** is selected at **Cal** > **Fixture Compen** > **Fixture** > **User.**

Open/Short/Load Compensation

- Overview
- Defining Compensation Kit
- Open/Short/Load Compensation

Other topics about Eliminating Error Factor of Fixture

Overview

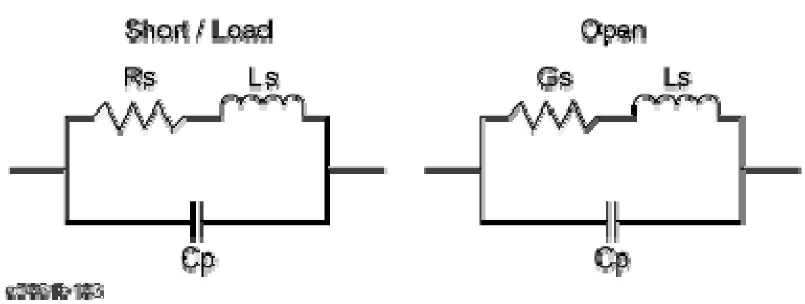
The open/short/load compensation gives the same calibration result as the open/short/load calibration at the fixture. In the impedance measurement methods such as the Gain-phase series-thru method, which require the open/short/load calibration at the fixture, you can use the open/short/load compensation as an alternative method to the open/short/load calibration. Similarly to the open/short/load calibration at the fixture, you can use the SMD or leaded 50 Ω resistor as a load device.

The difference from Impedance Calibration

- Open/Short/Load can be turn ON/OFF independently
- Definition of standard

Method	Standard Model
Impedance Calibration	Polynomial, Equivalent Circuit and Table
Compensation	Equivalent Circuit only

In the fixture compensation, you can define the open Gs value by the Admittance.



Defining Compensation Kit

1. Press **Cal** > **Fixture Compen** > **Compen STDs**.
2. Click the parameter which you want to define.
3. Enter the value.

Open/Short/Load Compensation

1. Set the open state of the fixture.
2. Press **Cal** > **Fixture Compen** > **Compensate** > **Open**.
3. Set the short state of the fixture.
4. Click **Short**.
5. Set the load state of the fixture.
6. Click **Load**.
7. Click **Done**.
8. Open/Short/Load compensations are turned ON automatically. **Comp OSL** is displayed at the Channel Window.

Making Measurement

Making Measurement

- Connecting DUT to Test Fixture
- Making a Trigger
- Scaling
- Having Stable Measurement Result
- Changing Sweep Conditions
- Measuring Other DUTs

Other topics about Option 005 Impedance Analysis

Connecting DUT to Test Fixture

The method to connect DUT to test fixture differs depending on the test fixture being used. Refer to the Operation and Service Manual of the respective test fixture to learn more.

Making a Trigger

To perform a measurement, it is necessary to generate a trigger. The trigger source may either be internal, external, manual or bus.

Scaling

Other topics about Making Measurement

Scale Type

To make the measurement, the scale of the impedance measurement, |Z| trace should be set to log scale:

To set the scale of the |Z| trace to log scale, perform the following procedure:

1. Select the trace as an active trace.
2. Press **Scale** in the RESPONSE block on the front panel.
3. Click **Y-Axis**.
4. Click **Log**.

When the scale of the Y-axis is changed from Linear to Log, the trace parameter display at upper-left of the trace window changes.

The setting of Log and Linear scale is independent, hence:

- When Y-Log is selected, Y-Linear Scale Division and Reference Position values are not used. Instead, Top/ Bottom scale values are used.
- Top/Bottom scale values are not used in Y-Linear.

Top/Bottom

Top/bottom value has the following limitation:

$$2 \leq \text{Top/Bottom} \leq 10^{24}$$

If one of these values (Top or Bottom) exceeds the limit, the other value changes automatically so that the Top/Bottom value is within the limit.

Auto Scaling

Auto scale sets the appropriate scale for Y-axis of all the traces. In the case of Log scale, auto scale sets the top and bottom of the waveform within 80% of the full scale.

To set the scale automatically, perform the following procedure:

1. Press **Scale** in the RESPONSE block on the front panel.
2. Click **Auto Scale** to perform the auto scale function on a specific trace.
3. OR click **Auto Scale All** to perform the auto scale function on all traces within a channel.

Manual Scaling

To adjust the scale manually, perform the following procedure:

1. Press **Scale** in the RESPONSE block on the front panel.
2. Click **Log Y-Axis Top/Bottom.**
3. At Log Y-Axis Top/Bottom menu bar, using either the keyboard or ENTRY keys on the front panel, enter the Top value and Bottom value.

Having Stable Measurement Result

For more stable measurement you can choose to set the followings:

- Setting IF Bandwidth
- Setting Averaging
- Setting Smoothing

Other topics about Making Measurement

Setting IF Bandwidth

To set the IF bandwidth perform the following procedure:

1. Press **Avg** in the RESPONSE block on the front panel.
2. Click **IF Bandwidth**.
3. Using either the keyboard or ENTRY keys on the front panel, enter the bandwidth value.

Alternatively, you can set the IF bandwidth automatically. The procedure is as follows:

1. Press **Avg** in the RESPONSE block on the front panel.
2. Click **IFBW Auto** to turn ON the IF bandwidth auto mode.

If you want to set an upper limit of IF bandwidth in auto mode:

1. Click **IFBW Auto Limit**.
2. Using either the keyboard or ENTRY keys on the front panel, enter the upper limit of IF bandwidth.

Setting Averaging

To turn ON the averaging, perform the following procedure:

1. Press **Avg** in the RESPONSE block on the front panel.
2. Click **Averaging**.
3. Click **ON**.

Setting Smoothing

To turn ON the smoothing, perform the following procedure:

1. Press **Avg** in the RESPONSE block on the front panel.
2. Click **Smoothing**.
3. Click **ON**.

Changing Sweep Conditions

When the below conditions change:

- IF bandwidth
- Power level
- Power range
- Sweep time / Sweep delay time
- Sweep type
- Number of points

When these conditions change, interpolation is executed. Error correction status symbol, **C?** is displayed at the channel status bar at the lower part of the window. This indicates that the changes in the conditions are within an acceptable range. At this point, calibration is advisable but not mandatory.

When the below conditions change:

- Start/Stop
- Centre/Span

When these conditions change and the sweep span is extended, the extrapolation is executed. Error correction status symbol, Hence **C!** is displayed at the channel status bar at the lower part of the window. This indicates that the changes in the conditions are far from the acceptable range. At this point, calibration is mandatory.

Changing Measurement Points

To change the number of measurement points, refer to Setting the measurement points.

Changing Sweep Parameter

To change the sweep parameter, refer to Setting the sweep parameter.

Measuring Other DUTs

If you measure another DUT of the same type and size as the one used in the previous measurement, start measurement with Connecting DUT to Test Fixture. If you use the same test fixture to measure a DUT of a different type and size, start measurement with calibration or fixture compensation. When using a different test fixture, start measurement with Connecting Test Fixture.

When measuring a DUT in the initial state after turning the power ON, start measurement with Setting Measurement Conditions.

Analyzing the Measurement

Analyzing the Measurement

- Using Equivalent Circuit Analysis
- Other Analyzing Functions

Other topics about Option 005 Impedance Analysis

Using Equivalent Circuit Analysis

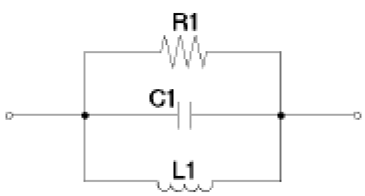
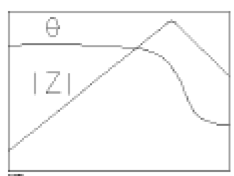
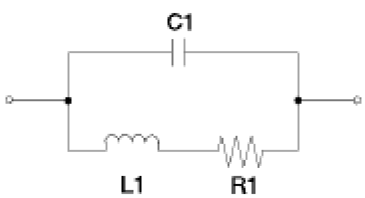
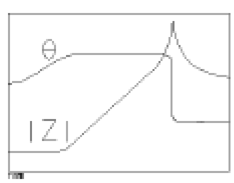
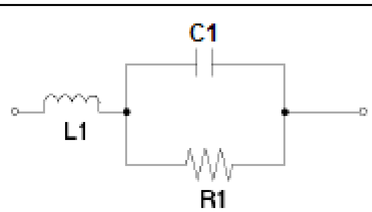
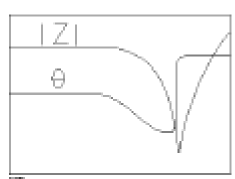
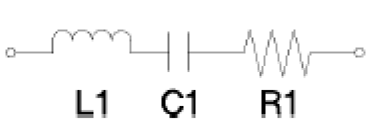
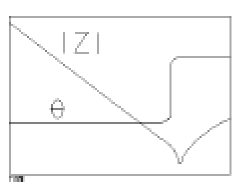
- Overview
- Equivalent Circuit Menu
- Performing Equivalent Circuit Analysis

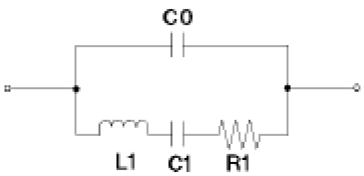
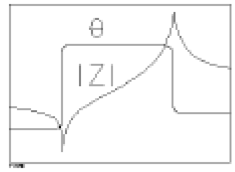
Other topics about Analyzing the Measurement

Overview

The E5061B Option 005 provides five types of equivalent circuit models; four types of 3-element equivalent circuits and one type of 4-element equivalent circuits. These circuits can be used to calculate the approximate values of the equivalent circuit parameters from the measurement data as well as to display the frequency characteristics on the screen based on the input equivalent circuit parameter.

The following table shows the selection of equivalent circuit:

Equivalent Circuit Model		Typical Frequency Characteristics	DUT Example
A		 *1	Inductor with high core loss
B		 *1	Inductor Resistor
C		 *1	High-value resistor
D		 *1	Capacitor

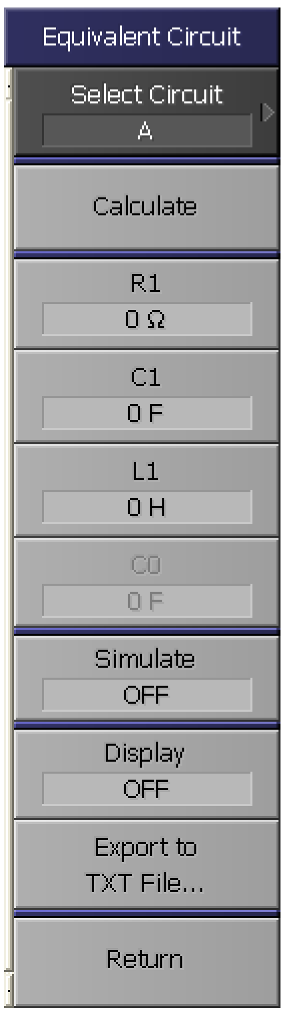
E		 *2	Resonator

*1. Measurement parameter: |Z| - θ, Sweep type: log, Vertical axis: |Z| is log and θ is linear.

*2. Measurement parameter: |Z| - θ, Sweep type: linear (or log), Vertical axis: |Z| is log and θ is linear.

Equivalent Circuit Menu

The equivalent circuit analysis function is only available when option 005 Impedance Analysis is installed and impedance measurement is selected (**Meas**> **Impedance Analysis Menu**).



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Select Circuit

Shows the menu bar to select one of the five equivalent circuit model:

Model A - Generally suited to analyze inductors with high core loss.

Model B - Generally suited to analyze general inductors and resistors.

Model C - Generally suited to analyze resistors with high resistance.

Model D - Generally suited to analyze capacitors.

Model E - Generally suited to analyze resonators and oscillators.

Calculate

Calculates the equivalent circuit parameters based on the measurement results and the selected equivalent circuit model.

R1

Allows you to enter the R1 parameter for the equivalent circuit model selected at Select Circuit. Also displays the equivalent R1 parameter calculated when Calculate is selected.

C1

Allows you to enter the C1 parameter for the equivalent circuit model selected at Select Circuit. Also displays the equivalent C1 parameter calculated when Calculate is selected.

L1

Allows you to enter the L1 parameter for the equivalent circuit model selected at Select Circuit. Also displays the equivalent L1 parameter calculated when Calculate is selected.

C0

Allows you to enter the C0 parameter for the equivalent circuit model selected at Select Circuit. When equivalent circuit model E is not selected, C0 is disabled. Also displays the equivalent C0 parameter calculated when Calculate is selected.

Simulate

Simulates the selected equivalent circuit model frequency characterization based on the equivalent circuit parameter entered or calculated by the **Calculate** button. It is performed for all traces. The simulated results are stored into the memory trace and displayed on screen. When the Simulate is ON, Memory Trace is updated automatically.

Display

Displays the equivalent circuit model in schematic and the value of each equivalent parameter on the bottom-left of the channel window.

Export to TXT File...

Saves the equivalent circuit parameters in text file at user-defined location.

Performing Equivalent Circuit Analysis

Step 1: Performing impedance measurement

Step 2: Selecting equivalent circuit

1. Press **Analysis** in the MKR/ANALYSIS block on the front panel.
2. Click **Equivalent Circuit**.
3. Click **Select Circuit**.
4. Select the desired equivalent circuit model from the five equivalent circuit models.

Step 3: Calculating equivalent circuit

1. Click **Calculate** to execute calculation of the equivalent circuit parameter.

The calculated equivalent circuit parameters are displayed in each box of **R1**, **C1**, **L1** and **C0**.

Step 4: Simulating equivalent circuit

1. Click **Simulate**.

The selected equivalent circuit model frequency characterization is simulated based on the equivalent circuit parameter entered or calculated by the **Calculate** button. The simulated results are stored into the memory trace and displayed on screen.

Step 5: Saving equivalent circuit

1. Click **Export to TXT File...**.
2. **Save As** dialog box shows.
3. Select the desired file name and location. The default file name is D:\EqvCkt01.txt.
4. Click **Save**.

Other Analyzing Functions

Besides Equivalent Circuit Analysis, other available analyzing functions are:

- Marker
  - Reference Marker
  - Clear Marker
- Marker Search
  - Max
  - Min
  - Peak
  - Target
  - Multi Peak
  - Multi Target
  - Tracking
  - Search Range
- Marker Function
  - Marker -> Start
  - Marker -> Stop
  - Marker -> Center
  - Marker - Reference
  - Discrete
  - Couple
  - Marker Table
  - Statistics
  - Annotation Options
    - Marker Info
    - Align
    - Active Only

Option 010 Time Domain/Fault Location Analysis

Option 010 Time Domain/Fault Location Analysis

- Fault Location Analysis
- Structural Return Loss Measurement

Fault Location Analysis

Fault Location Analysis

- Theory
- Making Fault Location Measurement
- Deleting Unnecessary Data in Fault Location (gating)

Other topics about Option 010 Time Domain/Fault Location Analysis

Theory

This section describes basic fault location measurement theory, how the analyzer converts frequency-domain data to distance-domain data, and the relationship between start distance, stop distance and frequency span.

- Overview
- How the Analyzer Converts Frequency Data to Distance Data
- Start/Stop Distance and Frequency Span Explanation

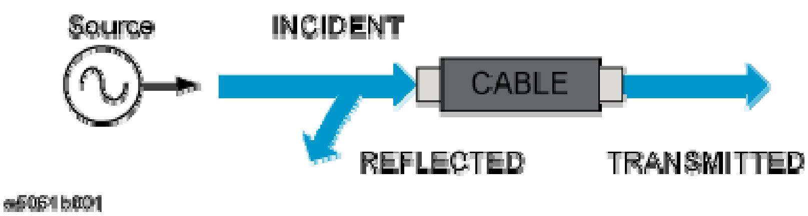
Other topics about Fault Location Analysis

Overview

Fault location measurements are designed to quickly and easily locate faults, or discontinuities, in either 50 Ω or 75 Ω transmission lines.

The network analyzer has an RF signal source that produces an incident signal that is used as a stimulus to locate and measure discontinuities in your transmission line or cable. Each fault or discontinuity responds by reflecting a portion of the incident signal and transmitting the remaining signal.

The analyzer measures the frequency response of the cable and then transforms the frequency data to distance data.



Typically, fault location measurement results are expressed in one of the four ways:

Format	Description
Return Loss (RL)	The number of dB that shows the reflected signal is below the incident signal. Its relationship to the reflection coefficient (ρ) is described by the following formula: RL = -20 log ρ.
Reflection Coefficient (ρ)	The ratio of the reflected voltage wave to the incident voltage wave.
Standing Wave Ratio (SWR)	Any two waves traveling in opposite directions (the incident and reflected for example) cause a "standing wave" to be formed on the transmission line. SWR is defined as the

	maximum voltage over the minimum voltage of the standing wave. SWR can also be mathematically derived from the reflection coefficient (ρ) with the following formula: *SWR=(1+ρ)/(1-ρ)*
Impedance Magnitude	The magnitude of the complex impedance at each measurement point. $\lvert Z\rvert=\sqrt{(Z_{real}^2+Z_{imaginary}^2)}$

How the Analyzer Converts Frequency Data to Distance Data

Fault-location measurements are single-ended measurements, meaning that only one end of a cable under test needs to be connected to the analyzer's RF OUT test port.

This type of measurement is generally called a reflection measurement and typically displays a response commonly known as return loss.

The analyzer performs swept-frequency measurements of return loss versus frequency, then uses the Fourier transform to convert the response-versus-frequency to a response-versus-distance. The analyzer's internal computer makes the calculation by using either the inverse discrete Fourier transform (inverse FFT) technique or the chirp-Z Fourier transform technique.

The Fourier transform technique is essentially a process of adding the signals measured by the analyzer in the frequency domain and combining them to create the fault-location response in the time domain.

The resulting measurement is an error-corrected fault-location response of the cable under test.

Start/Stop Distance and Frequency Span Explanation

When the analyzer is set up for a fault location measurement, you can determine the center frequency (when in band pass mode), and start and stop distances for the measurement. The distance range (start distance - stop distance) determines the frequency span, which in turn determines the start and stop frequencies.

NOTE In band pass mode (as opposed to low pass mode), you can select center frequency. Changes to the distance range do not affect the user-chosen center frequency.

The analyzer attempts to set the frequency span to the setting required for the distance range. The maximum setting for the frequency span cannot exceed the analyzer's frequency capability. For instance, the start frequency cannot be lower than the analyzer's low frequency limit, and the stop frequency cannot be higher than the analyzer's high frequency limit.

Making Fault Location Measurement

- Basic Measurement Procedures

  The basic measurement procedures of fault location measurement consists of the following steps:

  1. Enabling the fault location function
  2. Selecting the transformation types
  3. Calculating the measurement conditions
  4. Setting the window
  5. Setting the frequency range and the number of points
  6. Setting the velocity factor
  7. Setting the cable loss
  8. Setting the display range
  9. Calibrate the analyzer
  10. Connect the cable under test

- Fault Location Measurement Setup using the VBA Utility Program

  The VBA utility program which facilitates measurement setup is available.

Other topics about Fault Location Analysis

Enabling the fault location function

1. Press **Channel Next** (or **Channel Prev**) and **Trace Next** (or **Trace Prev**) to activate a trace for which you want to use the conversion type.
2. Press **Analysis** > **Fault Location** to display the Fault Location menu.
3. Press **Fault Location** to enable the conversion feature (ON).

NOTE To enable the conversion feature, the following conditions must be met. Otherwise, an error occurs.

- The sweep type is linear sweep.
- The number of measurement points is 3 or more.

Selecting the transformation type

Select the conversion type. The E5061B simulates the response from the DUT of two types of stimulus signals: impulse signal and step signal. The impulse signal is a pulse-shaped signal in which the voltage rises from 0 to a certain value and returns to 0 again. The pulse width depends on the frequency sweep range. The step signal is a signal in which the voltage rises from 0 to a certain value. The rise time depends on the maximum frequency within the frequency sweep range.

1. Press **Channel Next** (or **Channel Prev**) and **Trace Next** (or **Trace Prev**) to activate a trace for which you want to set the conversion type.
2. Press **Analysis** > **Fault Location** to display the Fault Location menu.
3. Press **Type** and then select softkeys to specify the **type**.

Calculating Measurement Conditions

To use the transformation function efficiently, you need to make the following two settings appropriately.

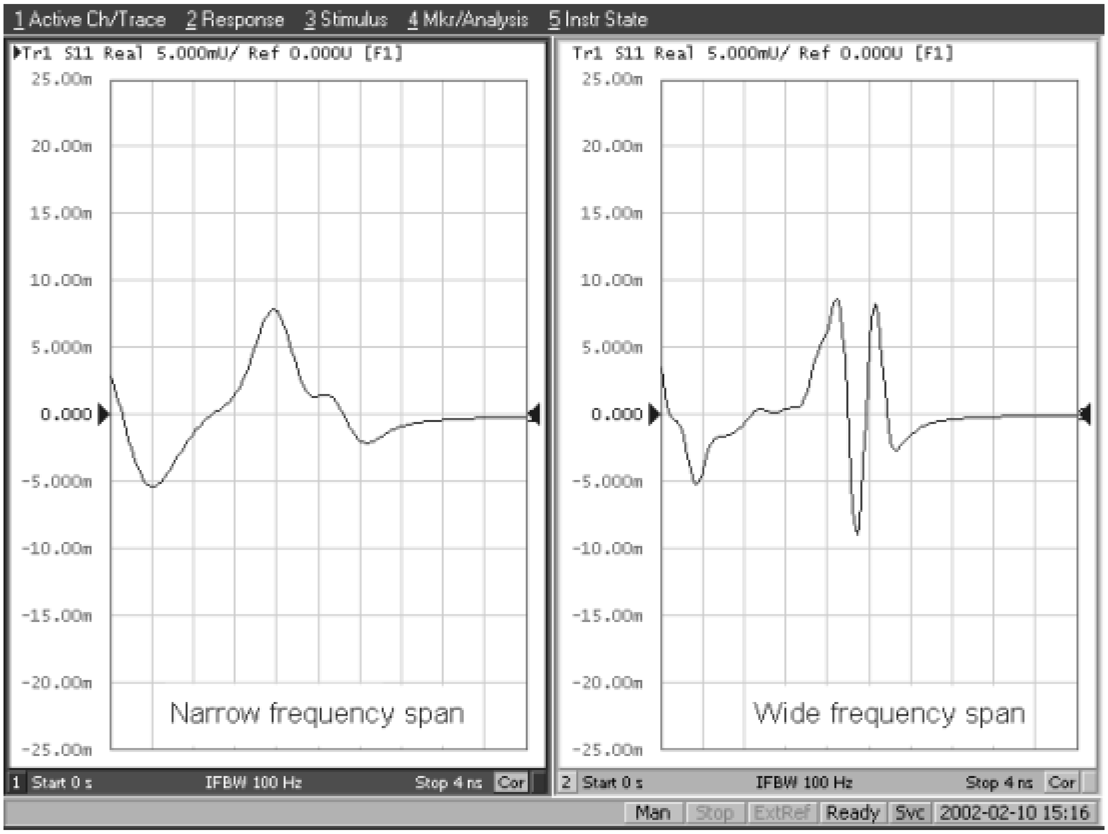
- Window
- Sweep conditions: frequency range and number of points

> NOTE The VBA utility program for the fault location measurement, calculates and sets up frequency sweep range to get the highest resolution available for the required display distance range. See Fault Location Measurement Setup using the VBA Utility Program.

Effect of frequency sweep range on response resolution

The following figure shows an example when measuring the same cable while changing the sweep span. When measured in a narrower sweep range, the overlap between 2 peaks is larger than when measured in a wider sweep range. By performing measurement in a wider sweep range, adjacent peaks can be clearly separated, which means that the response resolution is smaller.

Effect of frequency sweep range on resolution



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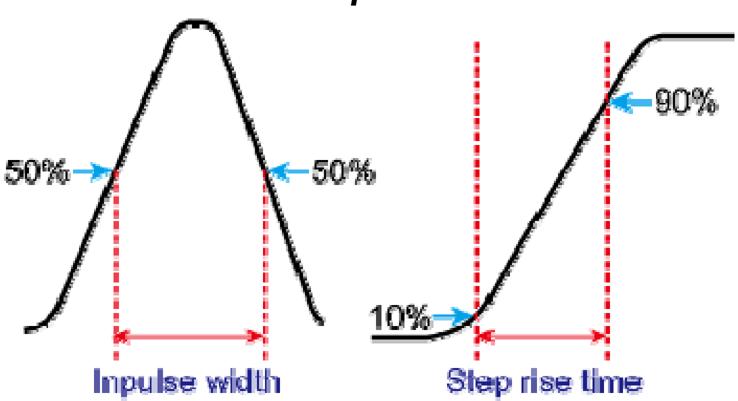
The sweep range affects the width of the impulse signal and the rise time of the step signal. The width of the impulse signal and the rise time of the step signal are inversely proportional to the sweep range. Therefore, the wider the sweep range is, the shorter these times are.

The resolution is equal to the width defined at the point of 50 % of the impulse signal or the rise time defined at the points of 10 % and 90 % of the step signal.

Definition of the impulse width and the step rise time



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Effect of the window function on the response resolution

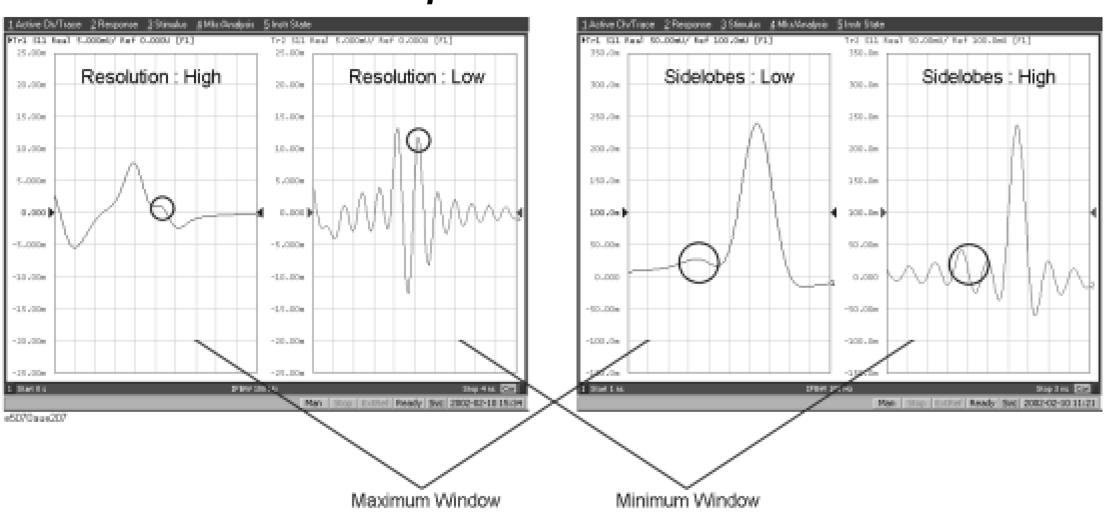
Lowering the sidelobe level with the window function elongates the width of the impulse signal and the rise time of the step signal. As described in Effect of frequency sweep range on response resolution, because the response resolution is equal to the width of the impulse signal and the rise time of the step signal, lowering the sidelobe level enlarges the response resolution. The following table shows the relation between the approximate response resolution and the window setting.

The shape of window and response resolution

Window	Low pass step	Low pass impulse	Band pass
Minimum	0.45/stop frequency	0.60/stop frequency	1.20/frequency span
Normal	0.99/stop frequency	0.98/stop frequency	1.95/frequency span
Maximum	1.46/stop frequency	1.39/stop frequency	2.78/frequency span

The following figure shows how the response changes when changing the window shape. You can see that, if the magnitudes of adjacent peaks are comparable, you need to make the resolution higher and, if they differ significantly, you need to set the window so that smaller peaks with lower sidelobes appear.

Effect of window on response resolution



Effect of the transformation type on the response resolution

Although both transformation types, band pass and low pass impulse, simulate the response of the impulse signal, the impulse width in the low pass impulse mode is half the width in the band pass mode. Therefore, the resolution is better in the low pass mode. If the DUT can be measured in the low pass mode, response data with better resolution is obtained in the low pass mode.

Measurement range

In the fault location function, the measurement range means the range within which the response can be measured without repetition. The repetition of the response occurs because measurement in frequency domain is performed discretely instead of continuously. The measurement range is inversely proportional to the frequency difference between adjacent measurement points.

The frequency difference between measurement points ΔF is expressed as follows using the span of the sweep frequency F_{span} and the number of points N_{meas}.

$$\Delta F = \frac{F_{span}}{N_{meas} - 1}$$

Therefore, the measurement range is proportional to (the number of points- 1) and inversely proportional to the span of the sweep range. To enlarge the measurement range, use one of the following methods:

- Increase the number of points.
- Narrow the span of the sweep range.

NOTE When you change the above settings after performing calibration, you need to perform calibration again.

The sweep range is expressed as time or distance. The time of the measurement range T_{span} is as follows:

$T_{span} = 1/\Delta F$

The distance of the measurement range L_{span} is expressed as follows using the velocity factor V and the speed of light in a vacuum C (3×10^8 m/s).

$L_{span} = V_c/\Delta F$

NOTE The maximum length of the DUT that can be measured in the transmission measurement is L_{span}. On the other hand, in the reflection measurement, because the signal goes and returns, it is 1/2 of L_{span}.

The velocity factor varies depending on the material through which the signal propagates. For polyethylene, it is 0.66; for Teflon, it is 0.7.

The change of the setting and the change of the response

The following table shows the effect of the change of the measurement conditions on the response resolution and the measurement range.

Change of setting	Response resolution	Measurement range	Sidelobe
Widen the sweep range	Becomes smaller	Becomes narrower	Does not change
Sets the window type to maximum	Becomes larger	Does not change	Becomes lower
Increase the number of points	Does not change	Becomes wider	Does not change

Setting Window

Because the E5061B transforms data within a finite frequency domain to data in distance or time domain, unnatural change of data at the end points within the frequency domain occurs. For this reason, the following phenomena occur.

- The width of the impulse signal and the rise time of the step signal

  The time width occurs in the impulse signal and the rise time occurs in the step signal.
- Sidelobe

  Sidelobes (small peaks around the maximum peak) occur in the impulse signal and the step signal. Ringing occurs on the trace due to sidelobes, which reduces the dynamic range.

By using the window function, you can lower the level of sidelobes. However, the width of the impulse and the rise time of the step become larger as a penalty. You can select from 3 types of windows: maximum, normal, and minimum. The following table shows the relationship between the window and the sidelobe/impulse width.

Characteristics of window

Window	Sidelobe level of	Width of the impulse (50%	Sidelobe level of	Rise time of the step

	the impulse signal	in low pass mode)	the step signal	signal (10 - 90%)
Minimum	-13 dB	0.60/frequency span	-21 dB	0.45/frequency span
Normal	-44 dB	0.98/frequency span	-60 dB	0.99/frequency span
Maximum	-75 dB	1.39/frequency span	-70 dB	1.48/frequency span

The window function is available only when the response in time domain is displayed. It does not have any effect when the response in frequency domain is displayed.

Procedure

1. Press **Channel Next** (or **Channel Prev**) and **Trace Next** (or **Trace Prev**) to activate a trace of which you want to set the window.
2. Press **Analysis** > **Fault Location** to display the Fault Location menu.
3. Press **Window** and then select a **window type**.

   NOTE By specifying Kaiser Beta, Impulse Width, or Step Rise, you can specify a window that is not classified into the three window types. When you specify a window type, these values are set automatically.

Setting Frequency Range and Number of Points

Set the sweep range and the number of points.

Procedure

1. Press **Channel Next** (or **Channel Prev**) to activate a channel you want to set.

   The frequency range and the number of points are common to all the traces in the channel. If you want to use different settings, use another channel.
2. Press **Sweep Setup** > **Sweep Type** > **Lin Freq** to set the sweep type to linear sweep.

   When the sweep type is set to other than the linear sweep, the fault location feature is not available.
3. Use the **Start**/**Stop** (or **Center**/**Span**) to set the sweep range.

4. Press **Sweep Setup** > **Points** and enter the number of measurement points in the data entry bar in the upper part of the screen.
5. When performing measurement in the low pass mode, press **Analysis** > **Fault Location** > **Set Freq Low Pass** to adjust the frequency range so that it is appropriate for the low pass mode. The start/stop frequencies are set as shown below.

Condition of the stop frequency	Frequency setting
> 5 Hz × the number of points	Start frequency = stop frequency/number of points
< 5 Hz × the number of points	Start frequency = 5 Hz Stop frequency = 5 Hz × number of points

NOTE If the above condition is met, the Set Freq Low Pass softkey is displayed in gray.

Setting the Velocity Factor

NOTE The velocity factor setting affects the cable loss setting and the display range setting. Thus it is recommended to set the velocity factor prior to the cable loss and display range.

Procedure

1. Press **Channel Next** (or **Channel Prev**) and **Trace Next** (or **Trace Prev**) to activate a trace of which you want to set the cable loss value.
2. Press **Cal** > **Velocity** (need to scroll to display this softkey).
3. Enter the value in the data entry bar in the upper part of the screen.

Setting the cable loss

Procedure

1. Press **Channel Next** (or **Channel Prev**) and **Trace Next** (or **Trace Prev**) to activate a trace of which you want to set the cable loss value.
2. Press **Analysis** > **Fault Location** > **Cable Loss**.
3. Enter the cable loss value in the data entry bar in the upper part of the screen. The unit differs depending on the display unit: dB/us for the display unit of time (second), dB/100 m for distance (m), and dB/100 Ft for distance (Ft). If the display unit is changed after entry, the cable loss value also changes appropriately for the display unit.

Setting Display Range

Set the range displayed on the graph. The displayed range can be set not only by time but also by distance. The number of response points displayed on the graph is the same as the number of points regardless of the response resolution. Note that, for reflection measurement, the E5061B lets you set the values on the horizontal axis for one-way data or round-trip data.

Procedure

1. Press **Channel Next** (or **Channel Prev**) and **Trace Next** (or **Trace Prev**) to activate a trace of which you want to set the display range.
2. Press **Analysis** > **Fault Location** > **Unit**.
3. Select a unit to set the display range from the following. The unit selected here determines the type of display: in time (**Seconds**) or in distance (**Meters**/**Feet**).
4. Use the **Start**/**Stop** (or **Center**/**Span**) to enter the display range in the data entry bar in the upper part of the screen. The data entry bar displays the distance (time when setting distance) corresponding to the set time (or set distance) next to the setting value.

   NOTE You cannot use the stimulus setting hardkeys (**Start**/**Stop**/**Center**/**Span**) to set the display range.

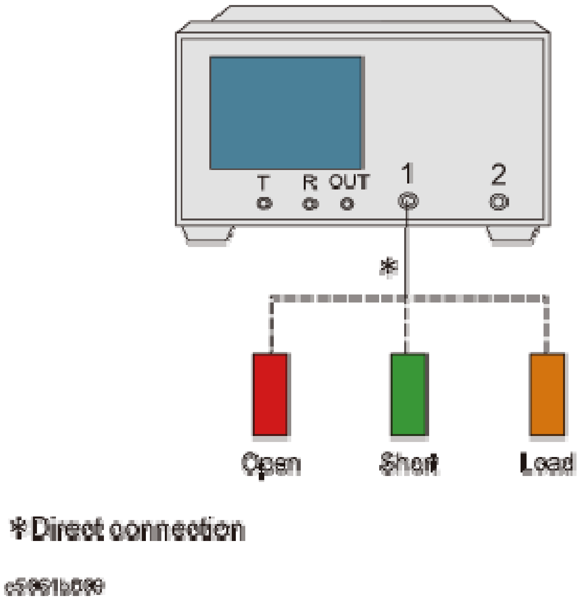
5. Press **Reflection Type** to select the type of the values on the horizontal axis in reflection measurement from one-way or round-trip.

Calibrate the Analyzer

In practical, a calibration should be done at the measurement reference plane using open, short, and load calibration standards to correct the instrument and optimize accuracy. Refer to calibration procedures.

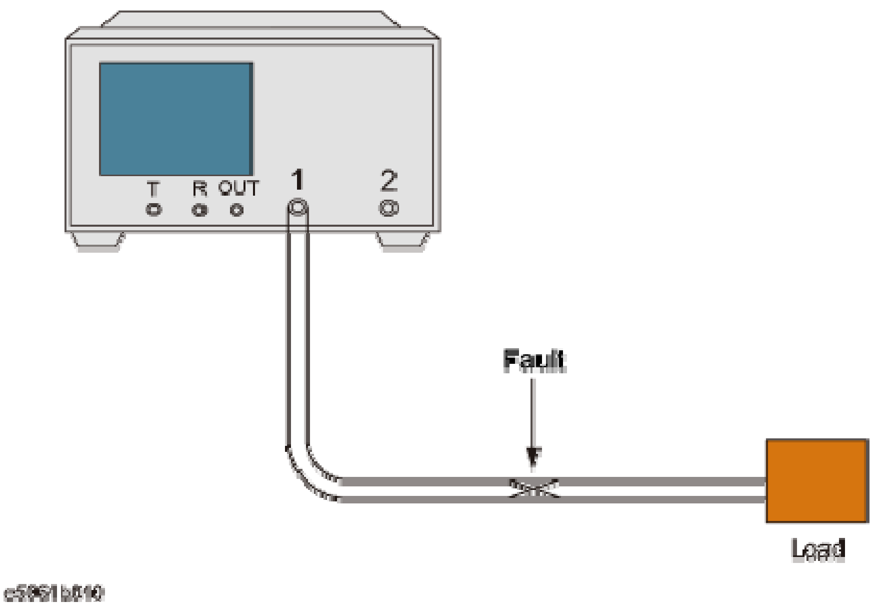
NOTE Most fault location measurements are made by connecting the cable under test directly to the analyzer's Port 1 test port. In this case the measurement reference plane would be the analyzer's port and you would connect calibration standards to the test port as shown in the following figure. Fault location measurements may also be made using a test lead cable. If this is the case, the measurement reference plane would be the end of the test lead cable, and calibration standards would be connected to the end of the test lead cable.

Calibrate the Instrument



Connect the Cable Under Test

The basic equipment setup for fault location measurements is shown below.



Fault Location Measurement Setup using the VBA Utility Program

The E5061B provides a macro program called **flt_util.vba**, which facilitates the measurement setup for fault location analysis. The utility program calculates and sets up frequency sweep range to get the highest resolution available for the required display distance range. (See Calculating Measurement Conditions for more information on frequency range calculation.) The utility program sets up following measurement conditions as well as the frequency sweep range so that you can start fault location analysis from the preset condition by using the utility program:

- Sweep type - Linear Frequency
- Unit - meter
- Reflection Type - One Way
- Fault Location- ON

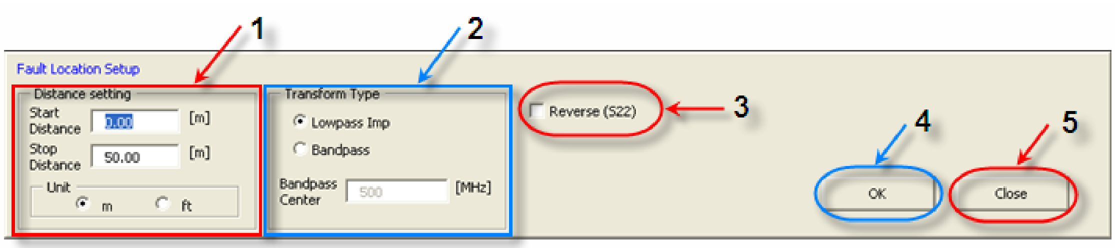
You need to set up the following parameters manually according to your measurement requirements:

- Number of points
- Cable loss
- Velocity factor
- Window

Procedure

1. Press **Channel Next** (or **Channel Prev**) and **Trace Next** (or **Trace Prev**) to activate a trace for which you want to perform fault location analysis.
2. Press **Macro Setup** > **Load Project**.
3. From the open dialog box, select the VBA project file **D:\Agilent\flt_util.vba**, and press **Open**.
4. Press **Select Macro** > **Module1 main** to execute the macro program.
5. The Fault Location Setup window appears in the lower part of the screen. Following procedures is performed with this setup window.

Fault Location Setup Window



1. Select the unit of distance (meter or feet), then enter the start and stop distance values.
2. Select the transformation type: Lowpass impulse or Bandpass. In the case of bandpass mode, enter the center frequency.

NOTE Center frequency can be from 1.3 MHz to the analyzer's highest frequency minus 1 MHz.

3. If you measure S22 (instead of S11) check the Reverse (S22) check box.
4. Press **OK** to setup the analyzer using the parameters entered in the setup window.

   NOTE The velocity factor and number of points need to be properly set before this step because these parameters are used to calculate the frequency sweep range. If you change these values after this step, the analyzer setup can be invalid.
5. Press **Close**, once you have completed the setup, to close the fault location setup window.

Deleting Unnecessary Data in Fault Location (Gating)

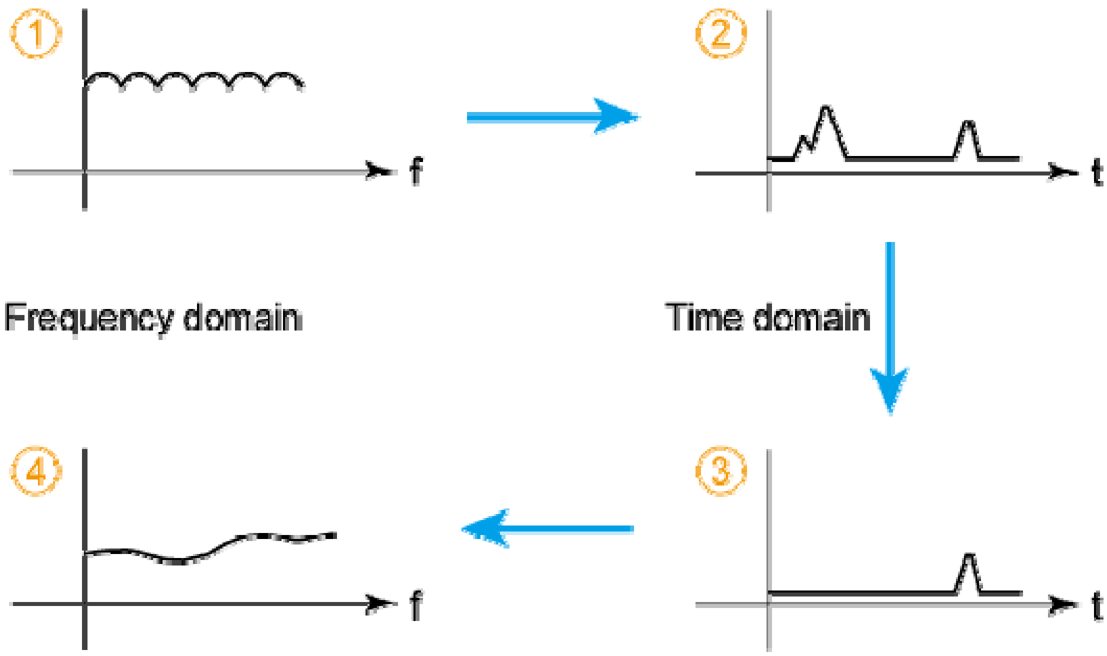
- Measurement Flow
- Setting Gate Type
- Setting Gate Shape
- Setting Unit
- Setting Gate Range
- Enabling Gating Function

Other topics about Time Domain Analysis

Measurement Flow

Item	Description
1. Measurement in frequency domain	Executes measurement in frequency domain
2. Transformation to time domain	Enables transformation function and transforms measurement data to data in time domain
3. Setting the gate	Makes the following settings of the gate to select the necessary domain: • Gate type • Gate shape • Gate range
4. Transformation back to frequency domain	Disables transformation function and displays response in frequency domain corresponding to the data selected with the gate

The following figure shows the change in the waveform at each step of the flow.



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Setting Gate Type

The E5061B lets you choose from the following two gate types:

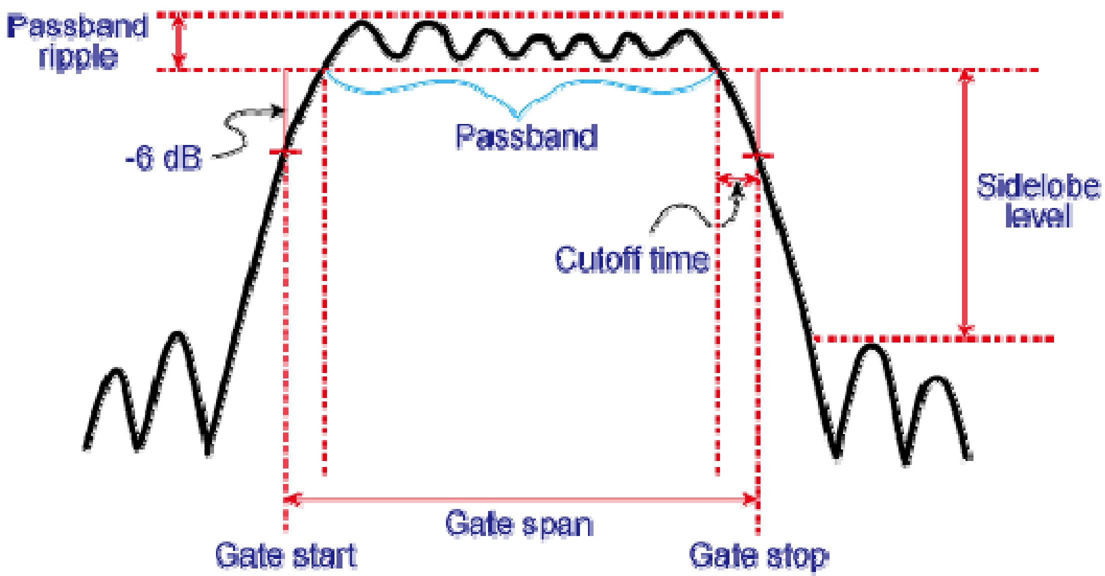
Gate type	Description
Band pass	Deletes response outside the gate range
Notch	Deletes response inside the gate range

Operational procedure

1. Press **Channel Next** (or **Channel Prev**) and **Trace Next** (or **Trace Prev**) to activate the trace of which you want to set the gate type.
2. Press **Analysis** > **Gating**.
3. Click **Type** to toggle between band pass (**Bandpass**) and notch (**Notch**).

Setting Gate Shape

The gate is a filter whose shape looks like a band pass filter. There are several parameters that indicate the gate shape. The following figure shows the definition of the gate shape parameters.



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The following table compares the characteristics according to the gate shape. When the shape is "minimum," the cutoff time is shorter and the response is deleted abruptly, but the sidelobe level and band pass ripples become larger. When it is "maximum," cutoff is gentler, but the sidelobe level and the band pass ripple become smaller. The minimum gate span in the following table is the minimum gate range you can set. This value is defined as the minimum gate span necessary for the existence of the pass band and is equal to 2 times the cutoff time.

Gate shape	Passband ripple	Sidelobe level	Cutoff time	Minimum gate span
Minimum	± 0.13 dB	- 48 dB	1.4/frequency span	2.8/frequency span
Normal	± 0.01 dB	- 68 dB	2.8/frequency span	5.6/frequency span
Wide	± 0.01 dB	- 57 dB	4.4/frequency span	8.8/frequency span
Maximum	± 0.01 dB	- 70 dB	12.7/frequency span	25.4/frequency span

Procedure

1. Press **Channel Next** (or **Channel Prev**) and **Trace Next** (or **Trace Prev**) to activate a trace of which you want to set the gate shape.
2. Press **Analysis** > **Gating**.
3. Press **Shape** and then select the gate shape.

Setting Unit

Setting Gate Range

Specify the gate range in time. The ends of the range are defined as the -6 dB attenuation points shown in the figure above. You can set the gate range by specifying the start and stop times or the center and span. The E5061B has the following limitations on the gate range you can set.

Lower limit	$-T_{span}$
Upper limit	T_{span}

T_{span} is the measurement range expressed in time obtained in Measurement range.

Procedure

1. Press **Channel Next** (or **Channel Prev**) and **Trace Next** (or **Trace Prev**) to activate the trace of which you want to set the gate range.
2. Press **Analysis** > **Gating**.
3. Press each of the **Start**/**Stop** (or **Center**/**Span**) softkeys to specify the gate range. Distance corresponding to the setting time is displayed at the side of the set value area in the data entry bar. The displayed distance is a value that takes the velocity factor into consideration.

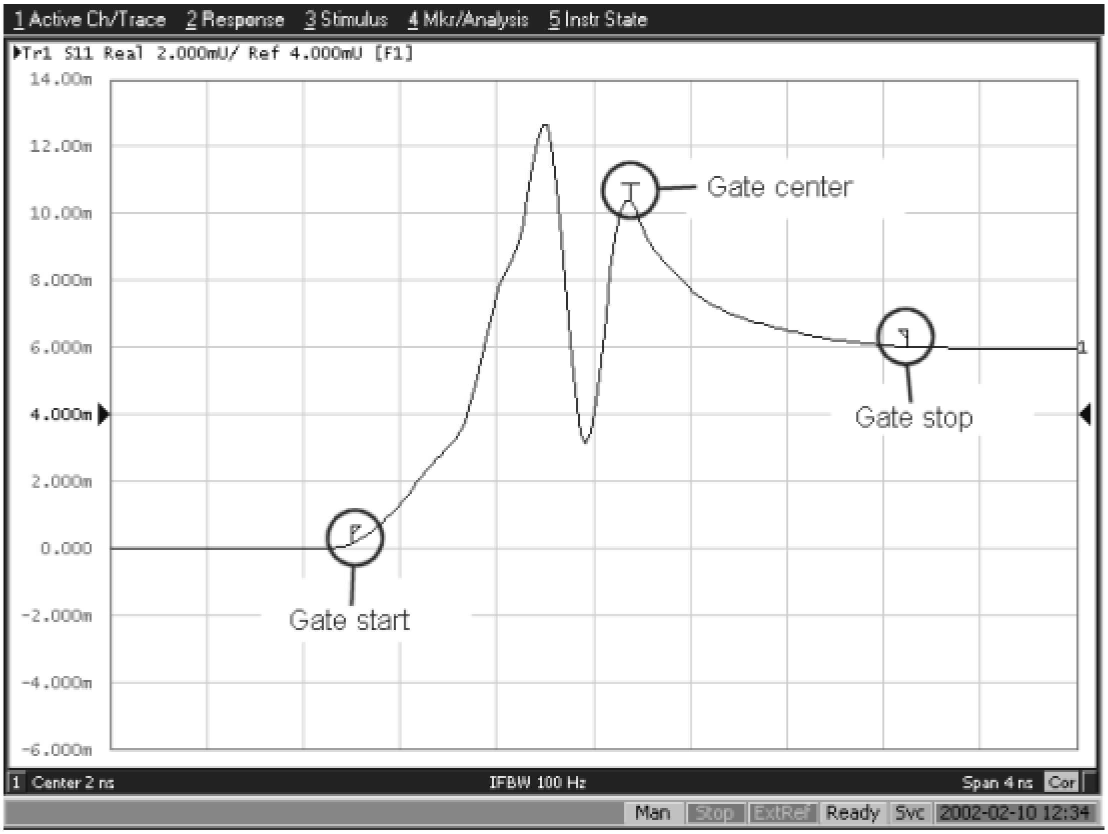
   NOTE You can not set this by **Start**/**Stop**/**Center**/**Span** hardkeys. The hardkeys are dedicated to setting the sweep range.

   NOTE You can set the center and span by dragging and dropping flags indicating the gate range.

Enabling Gating Function

When you enable the gating function, data within the specified range is deleted. When the transformation function is enabled, the flags indicating the gate range is displayed as shown in the following figure.

NOTE In the figure, the gate type is set to band pass. When it is set to notch, the directions of the flags indicating the ends of the gate range are reversed.



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Procedure

1. Press **Channel Next** (or **Channel Prev**) and **Trace Next** (or **Trace Prev**) to activate the trace of which you want to use the gate function.
2. Press **Analysis** > **Gating**.
3. Use **Gating** to enable (**ON**) the gate function.

Structural Return Loss Measurement

Structural Return Loss Measurement

- Theory
- Cable Preparation
- Making SRL Measurement

Other topics about Option 010 Time Domain/Fault Location Analysis

Theory

The SRL feature is designed to measure cable impedance and structural return loss. Cable impedance is the ratio of voltage to current of a signal traveling in one direction down the cable. Structural return loss is the ratio of incident signal to reflected signal in a cable, referenced to the cable's impedance.

The network analyzer uses a synthesized RF signal source to produce an incident signal as a stimulus. A reflection measurement is made and then used to compute the cable impedance. The structural return loss measurement is displayed referenced to the measured cable impedance.

For CATV cable, the cable is measured from 5 MHz to 1000 MHz at narrow frequency resolutions down to 125 kHz. The analyzer, with a furnished VBA utility program, automatically scans the cable, then reports the worst-case responses.

The following items are described in this topic.

- Cable Impedance
- SRL and Periodic Cable Faults
- SRL and Discrete Cable Faults
- Techniques for Removing Connector Effects
- Measurement Uncertainties

Other topics about Structural Return Loss Measurement

Cable Impedance

The analyzer automatically computes the cable impedance (Z). However, if you wish to turn OFF this "auto Z" function and input your own value of impedance, you can. See Connector Model for Short Cables.

In coaxial cable, the value of the impedance depends upon the ratio of the inner and outer conductor diameters, and the dielectric constant of the material between the inner and outer conductors. The cable impedance is also affected by changes in conductivity. These changes are a natural consequence of RF currents that flow near the surface of a conductor. This effect is known as the "skin effect." Also, the construction of the cable can change along the length of the cable, with differences in conductor thickness, dielectric material and outer conductor diameter changing due to limitations in manufacturing. Thus the cable impedance may vary along the length of the cable.

The extent to which manufacturing imperfections degrade cable performance is characterized by a specification called structural return loss (SRL). SRL is the ratio of incident signal to reflected signal in a cable. This definition implies a known incident and reflected signal. In practice, the SRL is loosely defined as the reflection coefficient of a cable referenced to the cable's impedance. The reflection seen at the input of a cable, which contributes to SRL, is the sum of all the tiny reflections along the length of the cable. In terms of cable impedance, the SRL can be defined mathematically as:

Equation 1

$$Z_{SRL}(\omega) = \frac{Z_{in}(\omega) - Z_{cable}}{Z_{in}(\omega) + Z_{cable}}$$

Z_{in} is the impedance seen at the input of the cable, and Z_{cable} is the nominal cable impedance.

Cable impedance is a specification that is defined only at a discrete point along the cable, and at a discrete frequency. However, when commonly referred to, the impedance of the cable is some average of the impedance over the frequency of interest. Structural return loss, on the other hand, is the cumulative result of reflections along a cable as seen from the input of the cable. The above definitions need to be expressed in a more rigorous form in order to apply a measurement methodology.

Defining Cable Impedance

Following are three common methods of defining cable impedance. Although all three methods may be commonly used in your industry, your network analyzer uses the third method (Z-average normalization) to define cable impedance.

Method 1

One definition of cable impedance is that impedance which results in minimum measured values for SRL reflections over the frequency of interest. This is equivalent to measuring a cable with a return loss bridge that can vary its reference impedance. The value of reference impedance that results in minimum reflection, where minimum must now be defined in some sense, is the cable impedance. Mathematically, this is equivalent to finding a cable impedance such that:

Equation 2

$$\frac{\partial[\bar{\rho}(\omega, Z_{cable})]}{\partial(Z_{cable})} = 0$$

where ρ is some mean reflection coefficient. Thus, cable impedance and SRL are somewhat inter-related: the value of SRL depends upon the cable impedance, and the cable impedance is chosen to give a minimum SRL value.

Method 2

An alternate definition of cable impedance is the average impedance presented at the input of the cable over a desired span. This can be represented as:

Equation 3

$$Z_{avg} = \frac{\int_{F_{min}}^{F_{max}} Z_{in}(F)\,dF}{(F_{max} - F_{min})}$$

The value found for Z_{avg} would be substituted for Z_{cable} in Equation 1 to obtain the structural return loss from the cable impedance measurement.

Method 3 (Z-average normalization)

The mathematics for the Z-average normalization as performed by the analyzer are shown below.

Equation 4

$$Z_{in}(\omega) = Z_0 \times \frac{(1 + \rho(\omega))}{(1 - \rho(\omega))}$$

Z_0 = system impedance, 50 Ω.

Equation 5

$$Z_{cable} = \frac{\sum_{n=1}^{N} \left|Z_{in}(\omega_n)\right|}{N}$$

Equation 6

$$\rho_{SRL}(\omega) = \frac{Z_{in}(\omega) - Z_{cable}}{Z_{in}(\omega) + Z_{cable}}$$

In Equation 4, ρ(ω) is the reflection coefficient from the analyzer measured at each frequency and Z_{in}(ω) is the impedance of the cable for that measured reflection coefficient.

1. The calculation of Z_{cable}, described in Equation 5, is the Z-average impedance of the cable over the number of frequency points (N). The

default frequency range is approximately 5 MHz to 200 MHz. This frequency range is chosen because mismatch effect of the input connector is small. High quality connectors must be used if the average impedance is calculated over a wider span. The frequency range for this calculation can be modified by using the **Z Cutoff Freq.** softkey in the connector model menu to change the cable impedance cutoff frequency.

Equation 6 is the structural return loss for the cable. This calculation can be done by the analyzer or an external computer.

SRL and Periodic Cable Faults

SRL is the measurement of the reflection of incident energy that is caused by imperfections or disturbances (bumps) in the cable which are distributed throughout the cable length. These bumps may take in the form of a small dent, or a change in diameter of the cable. These bumps are caused by periodic effect on the cable during the manufacturing process. For example, consider a turn-around wheel with a rough spot on a bearing. The rough spot can cause a slight tug for each rotation of the wheel. As the cable is passed around the wheel, a small imperfection can be created periodically corresponding to the tug from the bad bearing.

Each of these small variations within the cable causes a small amount of energy to reflect back to the source due to the non-uniformity of the cable diameter. Each bump reflects so little energy that it is too small to observe with fault location techniques. However, reflections from the individual bumps can sum up and reflect enough energy to be detected as SRL. As the bumps get larger and larger, or as more of them are present, the SRL values will also increase. The energy reflected by these bumps can appear in the return loss measurement as a reflection spike at the frequency that corresponds to the spacing of the bumps. The spacing between the bumps is one half the wavelength of the reflection spike and is described by equations 7 and 8.

Equation 7

$$wavelength \approx \frac{c}{f}$$

$c =$ speed of light $\qquad f =$ frequency

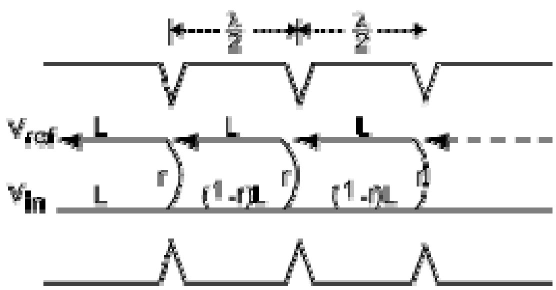
Equation 8

$$\frac{wavelength}{2} = \text{spacing between the bump}$$

The wavelength/2 spacing corresponds to the frequency at which down and back reflections add coherently (in-phase). The reflections produce a very narrow response on the analyzer display that is directly related to the spacing of the bumps. The amount of reflected energy is observed as return loss. When this return loss measurement is normalized to the cable impedance, the return loss becomes structural return loss.

The following figure diagrams reflections from bumps in a cable. We can combine the energy reflected by each bump in a cable and make a few basic assumptions, to mathematically describe SRL with the series shown in Equation 9.

Periodic Bumps in a Cable



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Equation 9

$$V_{ref} = [V_{in}L\Gamma L] + [V_{in}L(1-\Gamma)L\Gamma LL] + [V_{in}L(1-\Gamma)L(1-\Gamma)L\Gamma LLL] + \ldots$$

V_{ref} = reflected Voltage

V_{in} = incident Voltage

L = cable loss

Γ = reflection coefficient of the bumps

The bumps are assumed to be uniform in reflection and spaced by a wavelength/2 separation.

The series may be reduced to a simple form to leave us with the relationship shown in Equation 10. The term L is a function of the loss of the cable at a specific frequency and the wavelength at that frequency.

Equation 10

$$\mathrm{SRL} = \frac{Vref}{Vin} = \Gamma\left(\frac{L^2}{1-L^2}\right)$$

The term $(L^2)/(1-L^2)$ can be thought of as the number of bumps that are contributing to SRL. It represents a balance between the contribution of loss in a single bump and further bumps in the cable for the specified frequency and cable loss. Calculate the distance into the cable by multiplying the term $(L^2)/(1-L^2)$ by the distance between bumps.

The following table illustrates some calculated values for a typical trunk cable. From the table, bumps spaced 1.5 meters apart out to 307 meters contributes to SRL.

SRL Equation Constant

Frequency	**Spacing (λ/2) m**	**Loss (dB)/ m**	**dB/bump**	**bumps $(L^2)/(1-L^2)$**	**Distance (m)**
100 MHz	1.5	0.014	-0.02	205	307
500 MHz	0.3	0.033	-0.01	433	129
1 GHz	0.15	0.05	-0.0075	554	83

How to Use Table

Refer to Periodic Bumps in a Cable and Equation 10 for the following discussion.

- Γ = the reflection coefficient of each bump ($V_{reflected}/V_{incident}$)
- L = the cable loss between bumps ($V_{transmitted}/V_{incident}$)
- The distance between bumps equals λ/2 (1/2 wavelength).

Typical values:

- Γ << 1
- L ≤ 1 for low loss cable

Derivation of L

In Equation 10, L is the cable loss for a 1/2 wavelength length of cable, expressed in linear.

1. Find the cable loss from a spec sheet. Cable loss is typically expressed in loss per foot.
2. Convert loss per foot to loss per meter.
3. Find the 1/2 wavelength in meters. This will be the spacing between bumps.
4. Multiply loss per meter × 1/2 wavelength to get dB loss per bump.

5. Convert dB loss per bump to linear.

Example

1. A spec sheet states that the cable loss spec at 300 MHz is 1 dB per 100 feet.
2. Convert loss per foot to loss per meter:
   1 dB/100 ft ≈ 1 dB/30 m ≈ 0.033 dB/m
   This is the Loss (dB)/m column in SRL Equation Constant.
3. Find the 1/2 wavelength in meters:
   1/2 wavelength at 300 MHz ≈ 0.5 meters
   This is the Spacing (λ/2)m column in SRL Equation Constant.
4. Multiply loss/meter × 1/2 wavelength:
   0.033dB/meter × 0.5 meters = 0.0165 dB = L_{dB}
   This is the dB/bump column in SRL Equation Constant.
5. Convert L_{dB} (loss) in dB to linear:
   20 log (L_{dB}) = -0.0165 L = $10^{(-0.016/20)}$ = 0.998
6. $(L^2)/(1-L^2) \approx 262$
7. There are approximately 262 bumps contributing to SRL at 300 MHz.
8. 262 × 0.5 = 131. The distance into the cable for 262 bumps is 131 meters.

In actual cables, the reflections from the bumps and the spacing of the bumps may vary widely. The best case for a minimum SRL, is that the bumps are totally random and very small. Real world examples are somewhere in between the uniform bumps and scattered case. As the sizes of the bumps, their spacing, and the number of bumps vary within the manufacturing process, varying amounts of SRL are observed.

SRL and Discrete Cable Faults

In addition to a set of periodic bumps, a cable can also contain one or more discrete faults. For this discussion, discrete imperfections is referred to as “faults,” and periodic imperfections is referred to as "bumps."

Reflections from discrete faults within the cable also increases the level of SRL measured. The energy reflected from a fault sums with the energy reflected from the individual bumps and provide a higher reflection level at the measurement interface. Examining the cable for faults before the SRL measurement is a worthwhile procedure. The time required to perform the fault location measurement is small compared to the time spent in performing an SRL measurement scan.

A fault within the cable provides the same type of effect as a bad connector. If the fault is present within the end of the cable nearest to the analyzer, the effect is noticed throughout the entire frequency range. As the fault is located further into the cable, the cable attenuation reduces the effect at higher frequencies. The reflected energy travels further through the cable at lower frequencies where the cable attenuation per unit distance is lower.

Techniques for Removing Connector Effects

Connector Effects on SRL

To remove the unwanted effects of worn connectors, the SRL measurement uses a built-in connector model. The connector model consists of compensation for connector length and compensation for connector capacitance (connector C).

The "connector C" compensation emulates the C trim value of a variable impedance bridge.

The connector length is used to compensate for the effects of an electrically long connector and extends the calibration reference plane.

NOTE A calibration reference plane is established at the point where the short, open, and load standards are measured.

The analyzer can automatically measure the optimum values for your connector model, or you may enter them manually.

The default values for the connector model are 0.00 mm length, and 0.00 pF capacitance (no compensation).

When measuring spools of the cable, typically two connectors are used: the test-lead connector and the termination connector. (See the following figure.) These connectors provide the cable interface and are measured as part of the cable data.

Basic SRL Measurement Setup and Connections

Often, slight changes in the test-lead connector can cause significant changes in the values of structural return loss measured at high frequencies. This is because the reflection from a connector increases for high frequencies. In fact, the return loss of a test-lead connector can dominate the SRL response at frequencies above 500 MHz. This is where training, good measurement practices, and precision cable connectors are needed, especially for measurements up to 1 GHz. Precision connectors are required to provide repeatability over multiple connections. Slip-on connectors are used to provide rapid connections to the cables, but require careful attention in obtaining good measurement data. Repeatability of measurement data is directly affected by the connector's ability to provide a consistently good connection. This is the major cause of repeatability problems in SRL measurements.

Effects of the test-lead connector at the measurement interface are observed as a slope in the noise floor at higher frequencies.

By observing the SRL measurement display and slightly moving the connector, the effects of the connection can be observed at the higher frequencies. The test-lead connector should be positioned to obtain the lowest possible signal level and the flattest display versus frequency. The mechanical interface typically provides an increasing slope with frequency and flattens out as the connection is made better.

The termination connector may also affect the SRL measurement if the cable termination connector and load provide a significant amount of reflection and the cable is short enough. As longer lengths of cable are measured, the cable attenuation provides isolation from the termination on the far end. Use a fault location measurement technique to observe the reflection from the termination at the far end of the cable. If the termination is shown as a fault, the reflection from the terminating connector is contributing to the reflection from the cable. A more suitable termination is required or a longer section of cable must be measured. The cable must provide sufficient attenuation to remove the effects of the connector and load for a good SRL measurement. Performing a good measurement on a short length of cable is quite difficult and requires connectors with very low reflections to be effective.

Fixed Bridge with Connector Compensation

The analyzer employs the fixed-bridge method and instrument software to emulate the traditional variable-bridge method. Vector error correction is used to provide the most accurate measurements up to the calibration plane defined by the calibration standards. Additional corrections can also be used to minimize the effects of the test-lead connector on the measured SRL response.

The error corrections done for a fixed bridge can also include connector compensation. The fixed bridge method with connector compensation technique mathematically removes the effects of the test-lead connector by compensating the predicted connector response given by a connector model.

Shunt C Connector Model

One model that can be used for the cable connector is the shunt C connector model. With this model, the adjustment of the C value given in a variable impedance bridge can be emulated. The shunt C connector model assumes the discontinuity at the interface is abrupt and much smaller than a half wavelength of the highest frequency of measurement. With this assumption, the discontinuity can be modeled as a single-shunt twisted pair, where $C = C_0$ + second and third order terms.

Intuitively this is the right model to choose because the effect of a typical poor connector on structural return loss measurement is an upward sloping response, typically worst at the high frequencies.

Using a shunt C to model the connector, a value of the susceptance, -C, may be chosen by the network analyzer to cancel the equivalent C of the connector and mathematically minimize the effect of the connector on the response measurement.

The equations for computing structural return loss and the average cable impedance with capacitive compensation are described next.

Equation 11

$$Z'_{in}(\omega) = \frac{Z_{in}(\omega) \cdot \frac{1}{jwC}}{Z_{in}(\omega) + \frac{1}{jwC}}$$

Equation 12

$$Z'_{cable} = \frac{\sum |Z'_{in}(\omega)|}{N}$$

Equation 13

$$\rho'_{SRL}(\omega) = \frac{Z'_{in}(\omega) - Z'_{cable}}{Z'_{in}(\omega) + Z'_{cable}}$$

In Equation 11, $Z_{in}(w)$ is calculated from the measured return loss as described in Equation 4, previously. The primed values are the new calculation values using the capacitive compensation. With these equations, the network analyzer can compute values for the cable impedance and mathematically compensate for the connector mismatch with a given value of C connector compensation.

Connector Length

The shunt C connector model can be improved with the addition of connector length. Connector length is used to compensate the phase shift caused by the electrical length within the connector. The calibration plane can be moved from one side of the cable connector to the other side, so that the shunt C is placed exactly at the discontinuity of the connector and cable under test.

Measurement Uncertainties

In any comparison of cable impedance or structural return loss data, it is important to understand the measurement uncertainty involved in each type of measurement. This is critical for manufacturers, who often use the most sophisticated techniques to reduce manufacturing guard bands. It is also important in field measurements that users choose the proper equipment for their needs, and understand the differences that can occur between manufacturers' data and field data. Also, note that measurement uncertainty is usually quoted as the worst-case result if the sources of error are at some maximum value. This is not the same as error in the measurement, but rather a way to determine measurement guard band, and to understand how closely to expect measurements to compare on objects measured on different systems.

The errors that can occur in a reflection measurement are reflection tracking (or frequency response), T, source match, Γ_M, and directivity, D. The total error in a measurement can be shown to be

Equation 14

$$\Gamma_{MEAS} = T \cdot \left[D + \frac{(\Gamma_{DUT})}{(1 - \Gamma_M \Gamma_{DUT})} \right]$$

where Γ_{DUT} is the reflection response of the DUT.

Error correction techniques can effectively remove the effects of tracking. Also, source match effects are small if Γ_{DUT} is small. This leaves directivity as the largest error term in the reflection measurement. The causes and effects of these error terms will be described for each of the measurement methodologies.

For variable bridge measurements, the directivity of the bridge is the major error term. One-port vector error correction reduces the effects of tracking and source match, and improves directivity. The directivity after error correction is set by the return loss of the precision load, specified to be better than 49 dB at 1 GHz. However, the directivity is only well known at the nominal impedance of the system, and the directivity at other impedances should be assumed to be that specified by the manufacturer. For best performance, the bridge should be connected directly to the cable connector, with no intervening cable in between.

The directivity of the bridge could be determined at impedances other than 75 ohms, by changing the impedance and measuring the resulting values. This can be done by changing the reference impedance to the new value, say 76 ohms, changing the bridge to that value, and measuring the impedance on a Smith chart display. The difference from exactly 75 ohms represents the directivity at that impedance.

For fixed bridge methods, the reflection port is often connected to the cable connector through a length of test lead. A one-port calibration is performed at the end of the test lead. The directivity is again set by the load, but any change in return loss of the test lead due to flexing degrades the directivity of the measurement system. In both fixed and variable bridge measurements, the repeatability and noise floor of the analyzer may limit the system measurement. A convenient way to determine the limitation of the measurement system is to perform a calibration, make the desired measurement, then re-connect the load to check the effective directivity. A very good result is better than -80 dB return loss of the load. Typically, flexure in the test leads, connector repeatability, or noise floor in the network analyzer limits the result to between -60 to -40 dB. If the result is better than -49 dB, then the system repeats better than the load specification for the best available 75 Ω loads. Thus, the effective directivity should be taken to be the load spec of -49 dB. It is possible to reduce this limitation by having loads certified for better return loss.

Measurement Uncertainty for Impedance Measurements

The fixed bridge method calculates the cable impedance by averaging the impedance of the cable over frequency. The variable bridge uses a reading of the impedance from the dial on the bridge. The directivity at any impedance can be determined, as stated earlier, but only to the limit of the return loss of the load, and the system repeatability.

Any connectors and adapters used to connect the test-lead cable to the cable under test can have a significant effect on the impedance measurement. With the variable bridge method, the operator determines the appropriate setting, taking into account the capacitive tuning adjustment. With the fixed bridge method, it is also possible to compensate somewhat for the connector. However, it is often the case that the cable impedance is determined by the low frequency response, up to perhaps 200 MHz to 500 MHz, where the connector mismatch effect is still small. The choice of frequency span to measure cable impedance can itself affect the value obtained for cable impedance. In general, as the connector return loss becomes worse, it has a greater effect on the resulting impedance measurement. The uncertainty caused by the connector is difficult to predict, but large errors could occur if the low frequency return loss is compromised to achieve better high frequency structural return loss.

Finally, note that since both methods average, in some way, the measurement over the entire frequency range, it is probable that the worst case error will never occur at all frequencies, and with the same phase. In fact, it is more likely that the errors will cancel to some extent in cable impedance measurements. Also, the loads that are used will invariably be somewhat better than specified, especially over the low frequency range.

Measurement Uncertainty for Structural Return Loss

The same factors that affect cable impedance - directivity, system and test lead stability, and cable connector mismatch - also affect structural return loss. However, since structural return loss is measured at all frequencies, it is much more likely that a worst case condition can occur at any one frequency. For that reason, the measurement uncertainty must include the full effect of the above listed errors.

Cable Preparation

Cable preparation (for slip-on connectors) can be critical for some SRL measurements, especially when measuring mainline cables with an SRL of -30 dB or lower. An improperly prepared cable can degrade the cable/connector response which may affect the measurement enough to make a "good" cable fail.

This section describes the most common cable preparation problems that should be avoided in order to obtain good measurements.

- Cable Preparation Problems
- Recommended Tools and Cables

Other topics about Fault Location Analysis

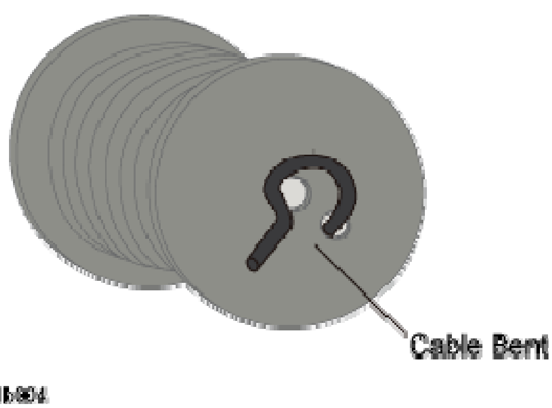
Cable Preparation Problems

Follow the preparation instructions provided by the connector manufacturer and take great care to avoid the following cable preparation problems:

- bent cable
- deformed cable
- contaminated dielectric
- damaged outer conductor
- non-flush cut

Bent Cable

Poor measurement results can occur if the cable is bent or kinked near the end of the spool. The bend should be removed before proceeding with the SRL measurement.

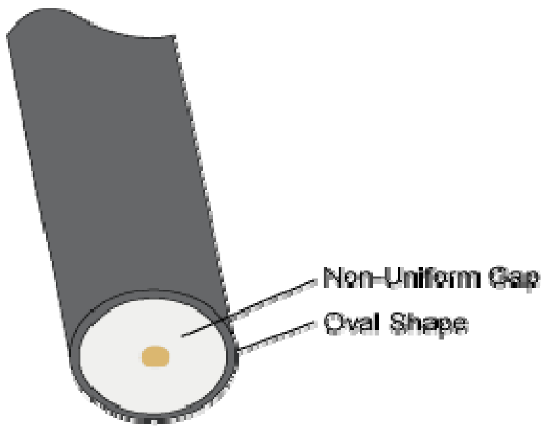


Bent/Kinked Cable

NOTE The built-in connector modeling will attempt to remove the effects of the connector. The connector response is shown at 0.0 ft. on the bottom trace. The extent to which the effects of the connector can be removed may depend on the quality of the cable preparation as well as the connector.

Deformed Cable

Compressing the dielectric (the gap) produces egg-shaped or oval deformations which can cause impedance mismatches and affect the quality of the connector model compensation. This can easily happen when using diagonal cutters to cut the cable.



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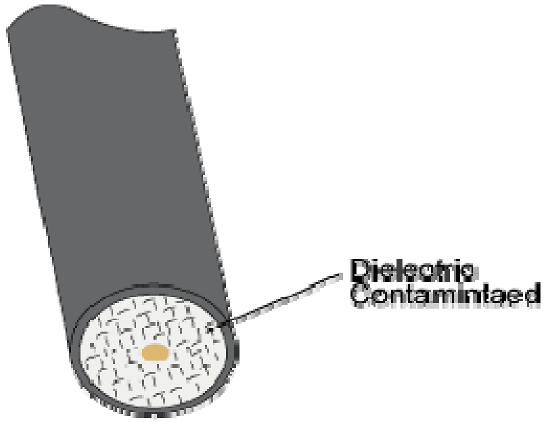
Deformed Cable (cut with diagonal cutters)

NOTE The built-in connector modeling will attempt to remove the effects of the connector. However, the modeling cannot remove the effects of the cable bend.

Contaminated Dielectric

When a cable is cut, contamination of the dielectric can occur from cuttings or shrapnel from the outer or inner conductor. This type of contamination can cause problems and change the connector model compensation needed.



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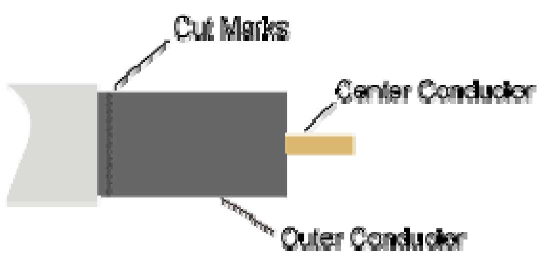
Contaminated Cable Dielectric

NOTE The built-in connector modeling will attempt to remove the effects of the connector. The extent to which the effects of the connector can be removed may depend on the quality of the cable preparation as well as the connector.

Damaged Outer Conductor

The outer conductor may be cut or dented when the outer insulation is removed. This can cause a close-in fault which cannot be compensated by the connector model.



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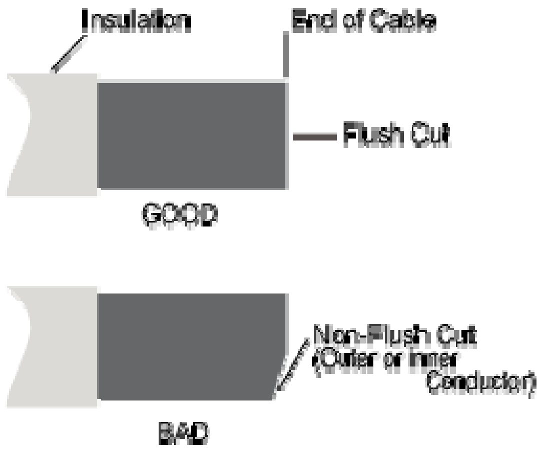
Scarred Outer Conductor of Cable

NOTE The built-in connector modeling will attempt to remove the effects of the connector at 0.0 ft. However, the modeling may not remove the effects of the outer conductor damage (which is a few inches into the cable).

Non-Flush Cut

Cables which require a flush cut, such as for GTC-XXX-TX-N ("Pogo") connectors, might not actually be cut in such a way. This can cause an inconsistent connection or poor repeatability of the SRL measurement.



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Cable Cut Flush (good) and Non-Flush (bad)

NOTE The built-in connector modeling will attempt to remove the effects of the connector. The extent to which the effects of the connector can be removed may depend on the quality of the cable preparation as well as the connector.

Recommended Tools and Cables

Recommended Tools

For connectors such as the GTC-XXX-TX-GHZ-N ("GHZ") connector, cable prep tools similar to CableMatic Model SST-A (Ripley Company) are recommended.

Recommended Cables

The following table lists the recommended test lead cables for use in cable testing applications.

Cable Description	Part Number
75 Ω Type-N 10 ft. (m-m)	8120-6737
75 Ω Type-N 10 ft. (m-f)	8120-6740
75 Ω Type-N 15 ft. (m-m)	8120-6738
75 Ω Type-N 15 ft. (m-f)	8120-6741
75 Ω Type-N 30 ft. (m-m)	8120-6739
75 Ω Type-N 30 ft. (m-f)	8120-6742

Making SRL Measurement

A typical SRL measurement consists of the following steps:

1. Setting the sweep type, the sweep range, and the number of points
2. Enabling the SRL function.
3. Setting the average impedance.
4. Calibrate the analyzer.
5. Connect the cable under test
6. Determine the connector model.
7. Perform the SRL Cable Scan
8. Interpret the SRL Measurement

Other topics about Structural Return Loss Measurement

Setting Sweep Type, Sweep Range, and Number of Points

Set the sweep range and the number of points. If you perform the SRL cable scan, use the VBA utility program to set up the analyzer as described in SRL Cable Scan Setup using the VBA Utility Program instead of the following manual procedures.

NOTE The SRL utility program not only sets sweep conditions but also enables the SRL function and sets the average impedance described in the following sections.

Procedure

1. Press **Channel Next** (or **Channel Prev**) to activate a channel you want to set.

   NOTE The frequency range and the number of points are common to all the traces in the channel. If you want to use different settings, make them on another channel.

2. Press **Sweep Setup** > **Sweep Type** and select a sweep type with the softkeys.
3. Use the **Start**/**Stop** (or **Center**/**Span**) to set the sweep range.
4. Press **Sweep Setup** > **Points** and enter the number of measurement points in the data entry bar in the upper part of the screen.

Enabling SRL Function

NOTE For channels of which SRL is enabled, it affects the calculation of the reflection coefficient and does not affect the transmission coefficient.

Procedure

1. Press **Channel Next** (or **Channel Prev**) to activate the channel of which you want to enable the SRL feature.
2. Press **Analysis** > **SRL**.
3. Press **SRL** to enable the SRL feature (ON).

Setting Average Impedance

The E5061B lets you select manual entry or auto calculation for the average cable impedance.

Procedure

1. Press **Channel Next** (or **Channel Prev**) to activate a channel of which you want to set the average impedance.
2. Press **Analysis** > **SRL**.
3. When calculating the average impedance automatically (the preset value has been set automatically), press **Z Cutoff Freq.** to specify the cutoff frequency to calculate the average impedance. If **Z Cutoff Freq.** is not available, the instrument is in manual entry mode, so press **Auto Z** to turn it ON and specify **Z Cutoff Freq.** again.

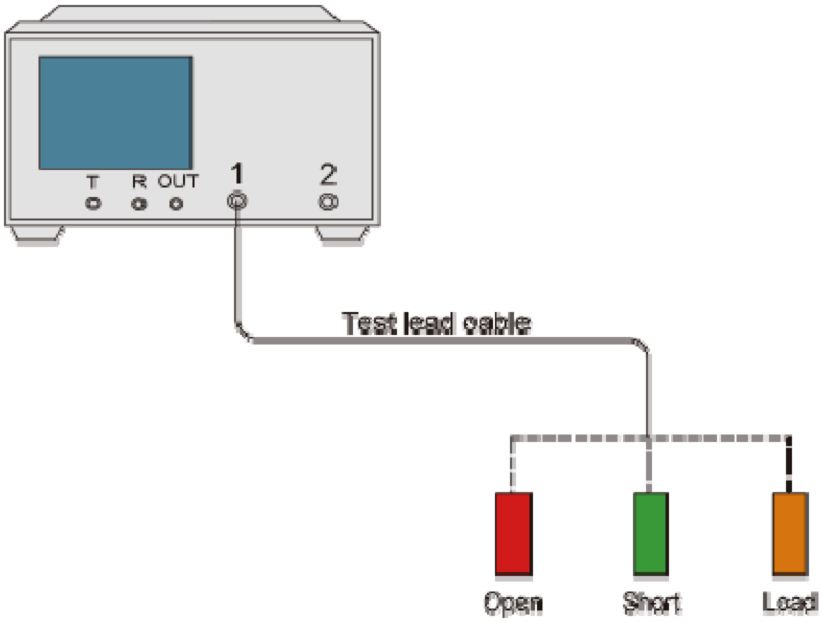
> NOTE
> If you want to enter the average impedance value manually, set **Auto Z** to OFF to switch to manual entry mode, in which you can enter **Manual Z**. Press **Manual Z** and specify the average impedance value.
>
> Note that, if there is no measurement value from the start frequency to the cutoff frequency, the value for manual entry is used as the average impedance value even in mode to calculate the average impedance automatically.

Calibrate the Analyzer

In practical, a calibration should be done at the measurement reference plane using open, short, and load calibration standards. Refer to calibration procedures.

> NOTE
> Most SRL measurements are made using a test lead cable. If this is the case, the measurement reference plane would be the end of the test lead cable as shown in the following figure. If you are testing cables by connecting them directly to the analyzer's test port, you should perform the calibration at the analyzer's port.

Calibrate the Instrument for an SRL Measurement



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Verifying the Calibration

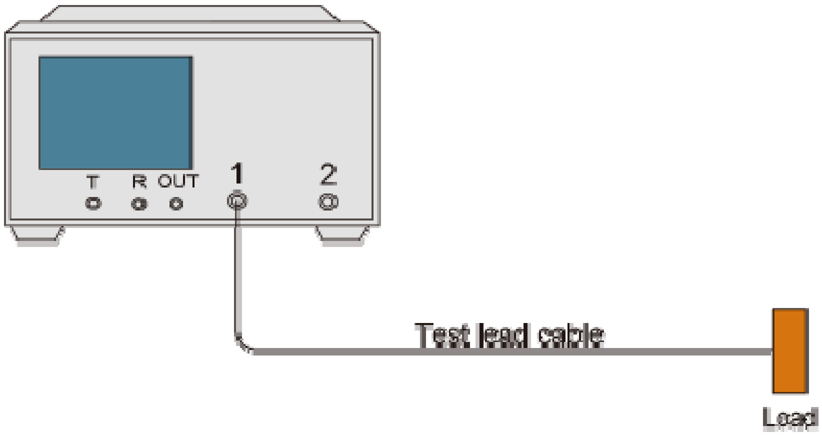
After calibrating, it is important to verify that the calibration is good. Always determine your system directivity and verify the quality of your test lead cable after performing a calibration.

When verifying the calibration and the quality of your test lead cable, you should look for a combination of good system directivity (<-50 dB, but acceptable up to -40 dB) and small variations in peak amplitudes (<10 dB) when the test lead cable is wiggled or moved.

Determine System Directivity

1. Determine the system directivity by connecting the load standard to the end of the test lead cable as shown in the following figure. (Or, if your reference plane is the analyzer's RF OUT (or PORT 1) test port, connect the load directly to that front panel connector.)

Connect the load



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2. Observe the magnitude of the response on measurement channel 1. The highest peak response on channel 1 is the system directivity. If the peak response on channel 1 is <-50 dB, the calibration is good. If the peak response is > -40 dB, you should recalibrate the analyzer.

   NOTE Measurement quality is related to the system directivity. For the highest quality measurements, system directivity should be < -50 dB, but measurement quality is acceptable up to -40 dB. See Measurement Uncertainties.

Determine the Quality of the Test Lead Cable

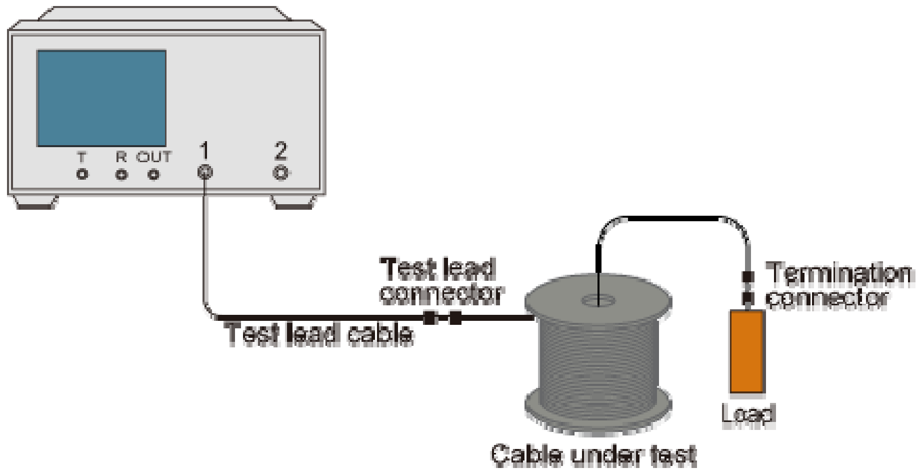
1. Leave the load connected to the end of the test lead cable and note the level of the peak response on measurement channel 1 (the system directivity).
2. Wiggle the test lead cable while observing the response on the analyzer's display.
   a. If the measurement trace is relatively stable, the test lead cable is of good quality.
   b. If you observe significant movement in the peaks of the measurement trace when wiggling the cable (>10 dB), the test lead cable may need to be replaced.

   NOTE Variation in the system directivity that occurs as a result of test lead cable movement degrades the quality and repeatability of SRL measurements. Take precautions to protect your test lead cables from mishandle or abuse. Do not step on or drive vehicles over test lead cables.

Connect the Cable Under Test

The basic equipment setup for SRL measurements is illustrated in the figure below.

Basic SRL Measurement Setup



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Determine the Connector Model

After connecting the cable under test, you should determine the connector model for the best response. The connector model may need to be determined each time a new cable is tested.

When using connectors that have very consistent interfaces, modeling the connector for each new connection to a cable may not be required. When using connectors that do not have a repeatable interface contact, modeling the connector for each new connection to a cable is necessary.

For some SRL measurements, the response of the connector can be critical for obtaining a true measurement of structural return loss. For example, a connector with a return loss of 30 dB swamps out SRL responses less than about -20 dB. A connector with a 40 dB return loss provides a more accurate measurement of the -20 dB responses.

The following table shows the effects of a connector mismatch on the measurement of a -35 dB SRL spike.

Corrected Connector Return Loss	SRL	Total Measured
-53 dB	-35 dB	-34 dB
-42 dB	-35 dB	-31.8 dB
-35 dB	-35 dB	-29 dB

The best true SRL measurement is made when the contribution of the connector is minimized by

- a good calibration
- a high-quality connector and connection (see Cable Preparation)

- a connector model which provides the lowest corrected connector response

The effect of the connector response can be minimized with the built-in connector model and the corrected connector response can be measured while the SRL measurement is being made. For some connectors, a response correction of up to 15 dB or more improvement is possible with the built-in connector model.

NOTE The maximum extent to which the effects of the connector response can be removed is to the accuracy and repeatability of the analyzer system (including the effects of test lead cable stability and quality). The accuracy of the system is given by the system directivity of the analyzer (which can be determined from the trace with a load connected after calibration).

Connector Model for Long Cables

If a long cable is being measured, you can use the Measure Connector feature to automatically determine the L and C values. (A long cable is defined as approximately 300 m (1000 ft)).

1. Press **Analysis** > **SRL**.
2. Press **Port1 Connector** (or **Port2 Connector**).
3. Connect the terminated cable, then press **Measure Connector** to set the length and C values automatically.

Connector Model for Short Cables

If you are measuring a short cable, or if you have very large mismatches in the cable under test, you may need to manually set the L and C values.

1. Press **Analysis** > **SRL**.
2. Press **Portx Connector** (x is the port to which the cable is connected).
3. Press **Length** and **Capacitance** to specify the connector length and the connector capacitance.
4. Observe the SRL measurement trace while adjusting the connector length and C values for the best (lowest overall) response.
5. Some cables may be best measured by adjusting only the connector length, other cables may require a connector C adjustment, and some others may require a combination of connector length and C values.

   NOTE When manually adjusting the connector length or connector C values, be sure to wait for the analyzer to complete a sweep and update the display before trying another value.

6. You may need to measure the connector using a Smith chart to get the best connector model:

Press **Format** > **Smith** > **Real/Imag**

Observe the display while adjusting the connector C and connector length parameters. The best response is obtained when the Smith chart response has been most compacted by the connector C and connector length adjustments.

NOTE If you cannot obtain a low enough response by adjusting the connector length and/or connector C values, you should perform a fault location measurement on the connector and the cable under test. (See Making Fault Location Measurement) Be sure to determine the quality of the connector being used; some cable connectors degrade rapidly with use. The response of a bad connector is often large enough to swamp out the response from cable SRL.

Connector L and C Values

The following table shows some typical values for two types of slip-on connectors for mainline cable:

Connector	L Value	C Value
GTC-700-TX-GHZ-N ("GHz")	40 to 80 mm	0 to 0.15 pF
GTC-700-TX-N ("Pogo")	-12 to 12 mm	0 to 0.125 pF

For these connectors, use of values within these ranges should be optimum for the best corrected connector fault response and lowest SRL spikes. Values far outside this range usually indicate a bad calibration, a poor connector or connection, or a close-in cable fault which cannot be compensated by the connector model.

NOTE The optimum calculated value for the connector lengths of "Gilbert Pogo" connectors may be slightly negative. This is a normal value and should not be a cause for concern.

For type-F connectors, which are typically used to measure 75 ohm drop cable, the range of connector L and C values varies widely and depends greatly on the quality of the type-F connector.

Perform the SRL Cable Scan

Once the connector model has been established for the best response, the cable should be scanned at narrow frequency resolution to look for narrow response spikes that are characteristic of periodic defects in the cable. The SRL cable scan is required to determine the cable's SRL with 125 kHz resolution.

By taking five sweeps of 1601 points each at slightly different frequency ranges (see Table 4-3), the analyzer can obtain 8005 distinct frequency points to achieve the desired frequency resolution of 125 kHz.

The resolution of the SRL measurement is determined by the following formula:

$Resolution = (F_{stop}-F_{start})/N$

where N is the number of measurement points. See the table below.

	F_{start}	F_{stop}	N	Resolution
No Cable Scan	5 MHz	1000 MHz	201	4.95 MHz
	5 MHz	1000 MHz	1601	612 kHz
Using Cable Scan	5 MHz	1000 MHz	8005	125 kHz

SRL Cable Scan Frequency Sweeps

Sweep Number	Start Frequency (MHz)	Stop Frequency (MHz)
1	5.000	999.500
2	5.125	999.625
3	5.250	999.750
4	5.375	999.875
5	5.500	1000.000

SRL Cable Scan Setup using the VBA Utility Program

The E5061B provides a macro program called **srl_util.vba**, which facilitates the measurement setup for SRL cable scan.

Procedure

1. Press **Channel Next** (or **Channel Prev**) to activate a trace of which you want to set up.
2. Press **Macro Setup** > **Load Project**.
3. From the open dialog box, select the VBA project file **D:\Agilent\srl_util.vba**, and press **Open**.
4. Press **Select Macro** > **Module1 main** to execute the macro program.

5. The SRL Setup window appears in the lower part of the screen. Click on the following 2 settings to check-mark them with the mouse as necessary and press **OK**.
    - Connector Fault - Splits the screen vertically into 2 sections and displays trace 2 with fault location on. The display range of trace 2 is set to 0 to 5 m.
    - Reverse(S22) - Sets the measurement parameter to S22.

NOTE Executing this macro program automatically makes the following settings in addition to the above.

Parameter	Value
Start frequency	5 MHz
Stop frequency	1 GHz (the display range of trace 1)
Sweep type	Linear Frequency
Number of points	1601
SRL	ON

Perform the SRL Cable Scan Using the VBA Utility Program

The E5061B provides a macro program called **srl_util.vba**, which performs SRL cable scanning.

NOTE It is recommended to do calibration before scanning a cable.

Procedure

1. Press **Channel Next** (or **Channel Prev**) to activate a trace of which you want to perform the cable scan.
2. Press **Macro Setup** > **Load Project**.
3. From the open dialog box, select the VBA project file **D:\Agilent\srl_util.vba**, and press **Open**.
4. Press **Select Macro** > **CableScan main** to execute the macro program.
5. The following processing is automatically performed.
    i. Set the following settings: SRL - ON, sweep type - Linear Frequency, number of points - 1601, display format - LogMag.
    ii. Set the measurement parameter of the active trace to S22 (or S11) and enter into reflection measurement status.

iii. Sweep five times with the frequency settings listed in SRL Cable Scan Frequency Sweeps.

iv. Perform the measurement again that gives the highest SRL value of the 5 sweeps.

v. Move the active marker to the maximum value.

Interpret the SRL Measurement

Periodically spaced SRL response bumps cause frequency spikes at a frequency given by the following formulas:

wavelength ≈ c/f

Where c= speed of light and f = frequency

wavelength/2 = spacing between the bumps

The bumps may be located near one end of the cable or somewhere in the middle. Although the bumps from individual defects may be small, fault location measurements may be useful to determine the location(s) of the cable's defect(s). See SRL and Periodic Cable Faults.