

**Agilent E5070B/E5071B ENA Series RF Network Analyzers**

# **TRL/LRM Calibration**

**First Edition**



**Agilent Technologies**

**No. 16000-95026**

**January 2004**

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# TRL/LRM Calibration

## Overview

The TRL/LRM Calibration VBA Macro lets you perform the 2-, 3-, and 4-port TRL (Through-Reflect-Line), LRL (Line-Reflect-Line), TRM (Through-Reflect-Match), and LRM (Line-Reflect-Match) calibrations for the E5070B/E5071B ENA RF network analyzers. These calibration techniques are generally used in non-coaxial environments such as in-fixture measurements and on-wafer measurements.

TRL calibration is performed by using the zero-length through, reflection (short, or open), and line standards. When the non-zero-length through is used instead of the zero-length through standard, the calibration is called LRL. TRM calibration is performed by using the zero-length through, reflection (short, or open), and match (load) standards. When the non-zero-length through is used instead of the zero-length through standard, the calibration is called LRM.

TRM and LRM calibrations are suitable for measurements at relatively low frequencies where the line standards of the TRL and LRL calibrations can become physically too long for practical use. The TRL/LRM Calibration VBA Macro allows you to perform calibration over a broad frequency range with a combination of TRM (or LRM) and TRL (or LRL) calibrations while using up to three line standards.

**Table 1. Key features (comparison with old version)**

Function	TRL Cal. VBA Macro (old version)	TRL/LRM Cal. VBA Macro
TRL and LRL calibrations	Yes	<b>Yes</b>
TRM and LRM calibrations	No	<b>Yes</b>
Multiport calibrations	Yes	<b>Yes</b>
Number of line standards	Up to 2	<b>Up to 3</b>
Setting negative delay values for cal. stds	No	<b>Yes</b>
Averaging for calibration measurements	No	<b>Yes</b>

## NOTE

We recommend that you use the E5070B/E5071B firmware revision 3.5 and above.

To perform TRL/LRM calibration, you need to prepare calibration standards that meet the following requirements:

**Through** (zero-length, or non-zero-length through)

Zero-length through

- S21 and S12 are defined as equal to 1.
- S11 and S22 are defined as equal to zero.

Non-zero-length through

- Z0 of the through and lines must be the same.
- Attenuation need not be known.
- Accurate electrical length must be known to set the reference plane.

**Reflect** (short, or open termination)

- Reflection coefficient magnitude (optimally 1.0) need not be known.
- Phase of the reflection coefficient must be specified within 1/4 wavelength or +/-90 degrees.
- Must be the same reflection coefficient on all ports.

**Line** (transmission line)

- Electrical length need only be specified within 1/4 wavelength.
- Cannot be the same length as the through. Difference between the through and lines must be between 20 degrees and 160 degrees.
- Optimal line length is 1/4 wavelength or 90 degrees relative to the through at the center frequency.
- Usable bandwidth for a single line standard is 8:1 (frequency span : start frequency).
- Attenuation need not be known.

**Match** (load termination)

- Must be the same Z0 on all ports.
- Z0 of the match standard establishes the reference impedance of the measurement.

For more detailed information on the requirements for TRL/LRM standards, refer to the following documents.

- Product Note 8510-8A, "Agilent Network Analysis Applying the 8510 TRL Calibration for Non-Coaxial Measurements", PN 5091-3645E
- Product Note 8720-2, "In-fixture Microstrip Device Measurements Using TRL\* Calibration", PN 5091-1943E

## **Installation of TRL/LRM Calibration VBA Macro**

### **NOTE**

Before installing this VBA macro, make sure that your E5070B/E5071B's firmware revision is 3.5 or above.

### **Installation Procedure**

- 1) Prepare the floppy disk that contains the installation program, "E507X\_TRL\_LRM\_CAL\_100.msi".
- 2) Reboot the ENA (Turn the ENA's power OFF, and then turn it ON again).
- 3) Insert the floppy disk in the ENA.
- 4) Press [**Save/Recall**], **Explorer** to open the Windows Explorer and double-click on the installation program in the A drive.
- 5) Install the TRL/LRM Calibration VBA Macro by following the instructions of the installation program.
- 6) The TRL/LRM Calibration VBA Macro program "TRL\_LRM\_cal.vba" will be installed under the path D:/VBA.

## 2-port TRL/LRM Calibration Operating Procedure

### 1. Setting stimulus conditions

Select the ENA's active channel to the one for which you want to perform calibration and set the stimulus conditions of the channel by manual operation. Typical setup items includes:

- Start and stop frequencies
- Sweep type
- Number of points
- Source power level
- IF Bandwidth
- Averaging factor and Averaging ON/OFF

For information on the setting procedure, refer to Chapter 3 "Setting Measurement Conditions" in the *E5070B/E5071B User's Guide*.

### 2. Starting VBA macro

Load and run the TRL/LRM Calibration VBA Macro.

Press **[Macro Setup]**, **Load&Run**, and select **TRL\_LRM\_cal**.

(Alternatively, you can press **[Macro Setup]**, **Load Project**, load "TRL\_LRM\_cal.vba" at D:/VBA, and press **[Macro Run]**.)

### 3. Turning off system correction

When the message shown in Figure 1 appears, press **OK** to turn off the system error correction.

#### NOTES

- This message does not appear when the system error correction has already been turned off.
- System error correction of all channels is turned off.
- System error correction can be turned on by **[Preset]**.

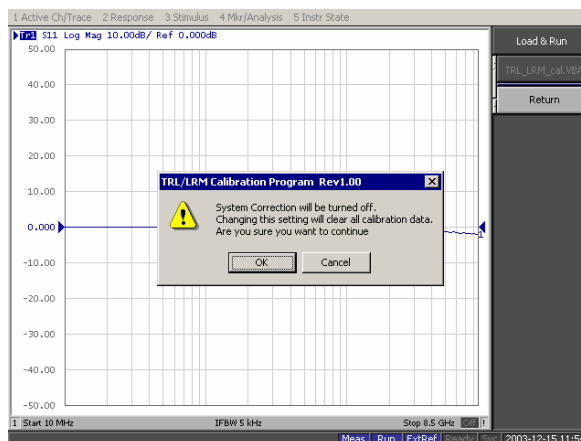


Figure 1. Turning off system error correction

If you press OK, the TRL/LRM Calibration main control panel appears as shown in Figure 2.

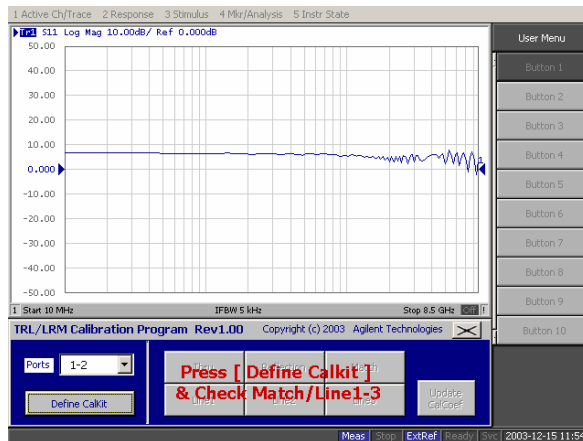


Figure 2. TRL/LRM main control panel

#### 4. Selecting ports

In the **Ports** menu, select the test ports for which you want to perform calibration. For example, to perform 2-port TRL/LRM calibration for test ports 1 and 2, select **Ports:1-2**.

#### NOTE

The TRL/LRM Calibration VBA Macro automatically detects the ENA's active channel, and calibration is performed for the active channel. The macro does not perform calibration for the ENA's inactive channels.

#### 5. Defining calibration kit

Define the values of the calibration standards you use in the calibration.

5-1) Press the **Define CalKit** key to bring up the calibration kit definition menu shown in Figure 3.

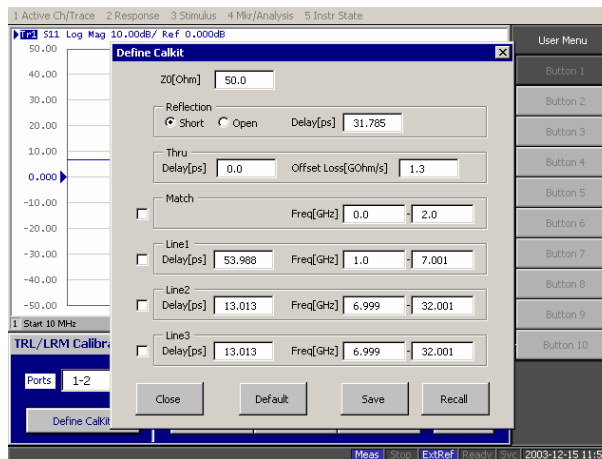


Figure 3. Calibration kit definition menu

5-2) Define each standard as follows:

**Reference impedance Z0**

Enter the reference impedance value for the through, match and line standards.

**Reflection**

Select the standard type you use (short or open) and enter its delay value.

**Thru**

Enter the delay value of the through standard. If necessary, also enter its offset loss value.

**Match**

Enter the frequency range of the match standard.

**Line**

You can define up to three lines: Line 1, Line 2, and Line 3. For each line standard, enter the delay value and the frequency range.

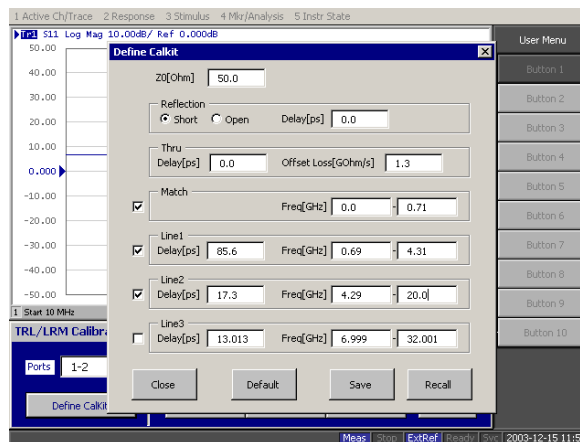
5-3) Activate the match and line standards you use for the calibration by entering check marks in the checkboxes.

**NOTES**

- Reference impedance Z0 of the TRL/LRM Calibration VBA Macro must be set to the same value as the ENA's system impedance Z0 value.
- Calibration reference plane is set to the middle of the through standard. It is not possible to set the calibration reference plane with the reflection standard.
- When the frequency ranges of the line and the match overlap, the data of the line is used in the overlapped frequency area. When the frequency ranges of multiple lines overlap, the data of the line measured later is used in the overlapped frequency areas.

For example, if you define the calibration kits as shown in Figure 4 and perform the Match, Line 1, and Line 2 measurements in this order, the analyzer uses the following three different calibrations depending on the frequency ranges:

- TRM calibration: below 690 MHz
- TRL calibration with Line 1: 690 MHz to 4.29 GHz
- TRL calibration with Line 2: over 4.29 GHz



**Figure 4. Calibration kit definition example**



5-4) If you want to save the current calibration kit definition, press the **Save** key and save the definition to your desired file. Saved calibration kit definition files can be recalled by pressing the **Recall** key.

**NOTES**

- If you save the calibration kit definition as “D:/Agilent/Trldata/Default.dat,” the file is handled as the default definition file. The default definition file is automatically recalled when the macro starts.
- If you press the **Default** key, the calibration kit definition is set to the factory default setting (the definition of the 85052C calibration kit).

5-5) Press the **Close** button to finish defining the calibration kit.

**6. Performing calibration measurement**

If the frequency ranges of match and line standards are correctly defined to cover the ENA’s measurement frequency range, the red warning message “Press [Define CalKit] & Check Match/Line1-3” disappears and the **Thru**, **Reflection**, and selected **Match/Lines** keys appear in the main control panel.

**NOTES**

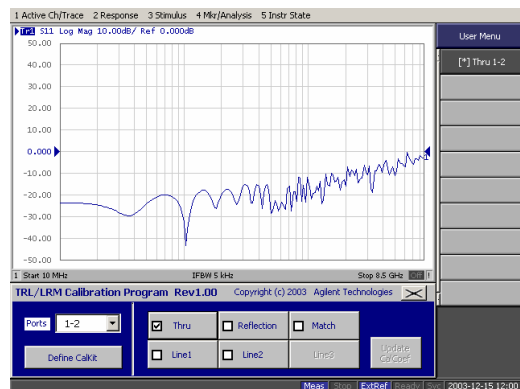
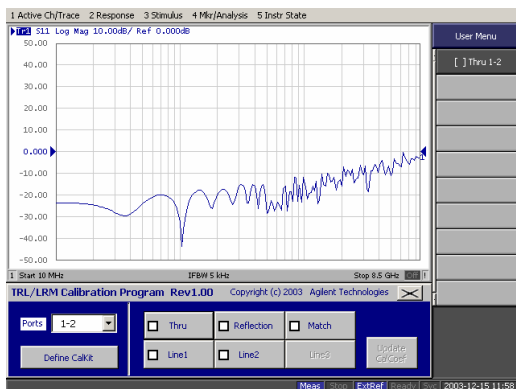
- If the **Thru**, **Reflection**, and **Match/Lines** keys do not appear, go back to the calibration kit definition menu and confirm that the frequency range definitions of match and lines are correctly entered to cover the ENA’s measurement frequency range.
- Isolation calibration measurement is not available.

6-1) Press each of the **Thru**, **Reflection**, and **Match/Lines** keys in the main control panel, and then press each calibration measurement key that appears in the User Menu area to perform the calibration measurements.

For example, if you perform 2-port TRL/LRM calibration between test ports 1 and 2 by using the Match, Line1 and Line2 standards, perform the calibration measurements as follows:

Through measurement:

- Press **Thru**.
- Make the through condition for the test ports 1 and 2, and press [ ]**Thru 1-2**. The through measurement is performed, and an asterisk is indicated.



a) Press [ ]Thru 1-2 to perform the thru measurement.

b) \* indicates when the measurement complete.

**Figure 5. Performing through calibration**

Reflection measurement:

- Press **Reflection**.
- Connect the Reflection standard to test port 1, and press [ **Reflection 1**]. The reflection measurement is performed, and an asterisk appears.
- Connect the Reflection standard to test port 2, and press [ **Reflection 2**]. The reflection measurement is performed, and an asterisk appears.

Match measurement:

- Press **Match**.
- Connect the Match standard to test port 1 and press [ **Match 1**]. The Match measurement is performed, and an asterisk appears.
- Connect the Match standard to test port 2 and press [ **Match 2**]. The Match measurement is performed, and an asterisk appears.

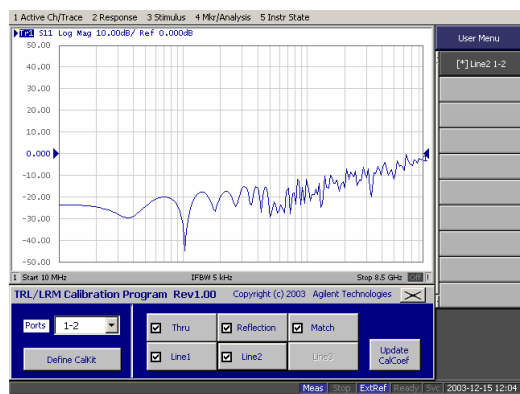
Line1 measurement:

- Press **Line1**.
- Connect the Line1 standard between test ports 1 and 2, and press [ **Line1 1-2**]. The Line1 measurement is performed, and an asterisk appears.

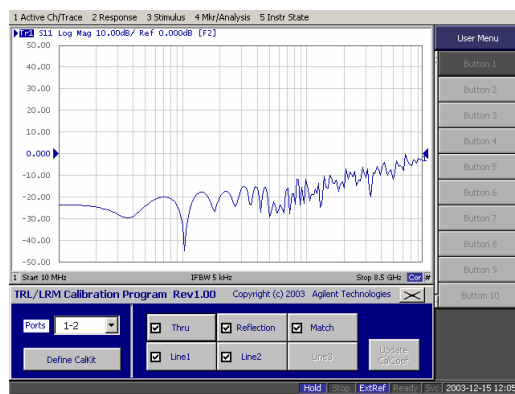
Line2 measurement:

- Press **Line2**.
- Connect the Line2 standard between the ports 1 and 2, and then press [ **Line2 1-2**]. The Line2 measurement is performed, and an asterisk appears.

6-2) When all of the necessary calibration measurements are completed, the check marks are indicated on the **Thru/Reflection/Match/Lines** keys, and the **Update CalCoeF** key appears. Press the **Update CalCoeF** key to activate the measured calibration data. Confirm that the indication “**Cor**” appears on the display.



a) Press **Update CalCoeF** to activate cal. data.



b) “**Cor**” is indicated on the display.

**Figure 6. Update CalCoeF key to activate calibration data**

## 7. Finishing calibration

To leave TRL/LRM calibration, click on the close button [X] in the upper right hand corner of the main control panel.

## Multipoint TRL/LRM Calibration Operating Procedure

You can make 3- and 4-port TRL/LRM calibration in the same manner as 2-port TRL/LRM calibration.

### 1. Setting stimulus conditions

Select the ENA's active channel to the one for which you want to perform calibration and set the stimulus conditions of the channel by manual operation. Typical setup items includes:

- Start and stop frequencies
- Sweep type
- Number of points
- Source power level
- IF Bandwidth
- Averaging factor and Averaging ON/OFF

For information on the setting procedure, refer to Chapter 3 "Setting Measurement Conditions" in the *E5070B/E5071B User's Guide*.

### 2. Starting VBA macro

Load and run the TRL/LRM Calibration VBA Macro.

Press **[Macro Setup]**, **Load&Run**, and select **TRL\_LRM\_cal**.

(Alternatively, you can press **[Macro Setup]**, **Load Project**, load "TRL\_LRM\_cal.vba" at D:/VBA, and press **[Macro Run]**.)

### 3. Turning off system correction

When the message shown in Figure 1 appears, press **OK** to turn off the system error correction.

### NOTES

- This message does not appear when the system error correction has already been turned off.
- System error correction of all channels is turned off.
- System error correction can be turned on by **[Preset]**.

### 4. Selecting ports

In the **Ports** menu, select the test ports for which you want to perform the calibration. For example:

- To perform 3-port TRL/LRM calibration for test ports 1, 2, and 3, select **Ports:1-2-3**.
- To perform 4-port TRL/LRM calibration, select **Ports:1-2-3-4**.

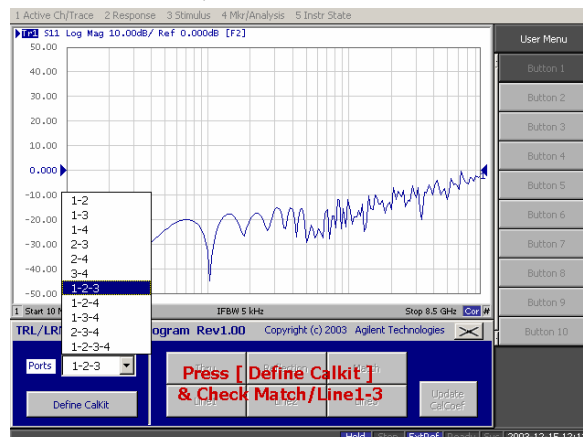


Figure 7. Selecting Ports:1-2-3 for 3-port TRL/LRM calibration

## 5. Defining calibration kit

Define the values of the calibration standards in the same manner as 2-port TRL/LRM calibration.

## 6. Performing calibration measurement

6-1) Press each of the **Thru**, **Reflection**, and activated **Match/Lines** keys in the main control panel, and then press each calibration measurement key that appears in the User Menu area to perform the calibration measurements.

### NOTE:

In multiport TRL/LRM calibration, the through and line calibration measurements are not performed at all of the paths among test ports. The following table shows the measured paths of the through and line calibration measurements. The through and line calibration data of non-measured paths is mathematically derived from the through and line calibration data of the measured paths.

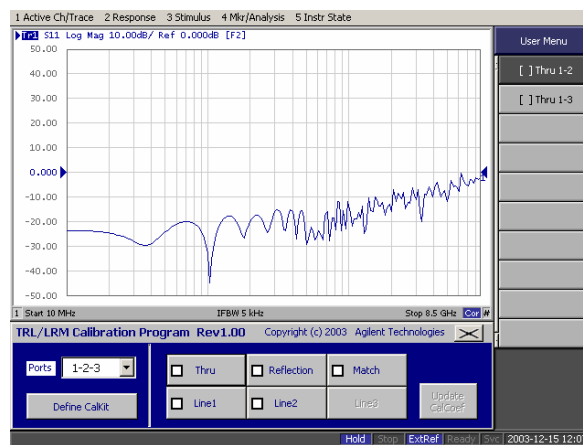
**Table 2. Measurement paths for Thru and Line calibrations**

Calibration type	Measurement ports of Reflection and Match cal.	Measurement paths of Thru and Line cal.
3-port TRL/LRM cal. for Ports:1-2-3	All ports (1, 2, and 3)	<b>1-2 and 1-3</b>
3-port TRL/LRM cal. for Ports:1-2-4	All ports (1, 2, and 4)	<b>1-2 and 1-4</b>
3-port TRL/LRM cal. for Ports:1-3-4	All ports (1, 3, and 4)	<b>1-3 and 3-4</b>
3-port TRL/LRM cal. for Ports:2-3-4	All ports (2, 3, and 4)	<b>2-3 and 3-4</b>
4-port TRL/LRM cal.	All ports (1, 2, 3, and 4)	<b>1-2, 1-3, and 3-4</b>

For example, if you perform 3-port calibration for test ports 1, 2, and 3 by using the Match, Line1 and Line2 standards, perform the calibration measurements as follows:

Through measurement (Figure 8):

- Press **Thru**.
- Make the through condition for test ports 1 and 2, and press [ ] **Thru 1-2**. The through measurement is performed, and an asterisk is indicated.
- Make the through condition for test ports 1 and 3, and press [ ] **Thru 1-3**. The through measurement is performed and an asterisk is indicated.



**Figure 8. Through calibration menu for 3-port TRL/LRM**

Reflection measurement:

- Press **Reflection**.
- Connect the Reflection standard to test port 1, and press [ **Reflection 1**. The reflection measurement is performed, and an asterisk is indicated.
- Connect the Reflection standard to test port 2, and press [ **Reflection 2**. The reflection measurement is performed, and an asterisk is indicated.
- Connect the Reflection standard to the test port 3, and press [ **Reflection 3**. The reflection measurement is performed, and an asterisk is indicated.

Match measurement:

- Press **Match**.
- Connect the Match standard to test port 1 and press [ **Match 1**. The Match measurement is performed, and an asterisk is indicated.
- Connect the Match standard to test port 2 and press [ **Match 2**. The Match measurement is performed, and an asterisk is indicated.
- Connect the Match standard to test port 2 and press [ **Match 3**. The Match measurement is performed, and an asterisk is indicated.

Line1 measurement:

- Press **Line1**.
- Connect the Line1 standard between test ports 1 and 2, and press [ **Line1 1-2**. The Line1 measurement is performed, and an asterisk is indicated.
- Connect the Line1 standard between test ports 1 and 3, and press [ **Line1 1-3**. The Line1 measurement is performed, and an asterisk is indicated.

Line2 measurement:

- Press **Line2**.
- Connect the Line2 standard between test ports 1 and 2, and then press [ **Line2 1-2**. The Line2 measurement is performed, and an asterisk is indicated.
- Connect the Line2 standard between test ports 1 and 2, and then press [ **Line2 1-3**. The Line2 measurement is performed, and an asterisk is indicated.

6-2) When all of the necessary calibration measurements are completed, the check marks are indicated on the **Thru/Reflection/Match/Lines** keys, and the **Update CalCoef** key appears. Press the **Update CalCoef** key to activate the measured calibration data. Confirm that the indication “**Cor**” appears on the display.

## 7. Finishing multipoint TRL/LRM calibration

To leave TRL/LRM calibration, click on the close button [X] in the upper right hand corner of the main control panel.