Revision 1.10

April 7, 2015

Method of Implementation (MOI) for 100BASE-TX Ethernet Cable Tests Using Keysight E5071C ENA Option TDR

Keysight MOI for 100BASE-TX Ethernet Cable Tests

Table of Contents

1. Revision History

Revision	Comments	Issue Date
1.10	• Keysight rebranding • Updated test fixture part number	April 7, 2015
1.00	• Initial revision	Sep 24, 2013

2. Purpose

This test procedure was written to explain how to use the Keysight ENA Option TDR to make the 100BASE-TX Ethernet cable measurements.

3. References

➢ IEEE 802.3-2008 Section 2 (Jun. 2010)

4. Required Equipments

Description	Test Equipment	QTY
Network Analyzer	E5071C ENA Series Network Analyzer ➢ Option 440/445 (4.5 GHz) or 460/465 (6.5 GHz) or 440/485 (8.5 GHz) or 4D5 (14 GHz) or 4K5 (20 GHz) ➢ Option TDR (Enhanced time domain analysis)	1 ea.
4-port ECal	N4431B (for E5071C 4.5 / 6.5 / 8.5 GHz) or N4433A (for E5071C 14 / 20 GHz)	1 ea.
Test Fixture	Test Fixture for Ethernet Application. (i.e. Keysight P/N: N5392-66402)	2 ea.
Adapter	3.5 mm (f) to Type-N (m) (ex. Keysight 1250-1744) for E5071C 8.5 GHz or	4 ea.

	83059B coaxial adapter for E5071C 14 / 20 GHz.	
RF cable	3.5 mm or SMA cables of 9 GHz bandwidth or more.	4 ea.
50 ohm terminator	To terminate unused differential pairs (ex. Keysight 909D-301)	12 ea.

5. Test Procedure

5.1. Outline of Test Procedure

1. Instrument Setup

➢ Automatic setup by recalling a state file or manual setup.

2. Calibration

➢ ECal Calibration and Fixture Compensation (Time-domain measurements)

➢ ECal Calibration and Port Extension (Frequency-domain measurements)
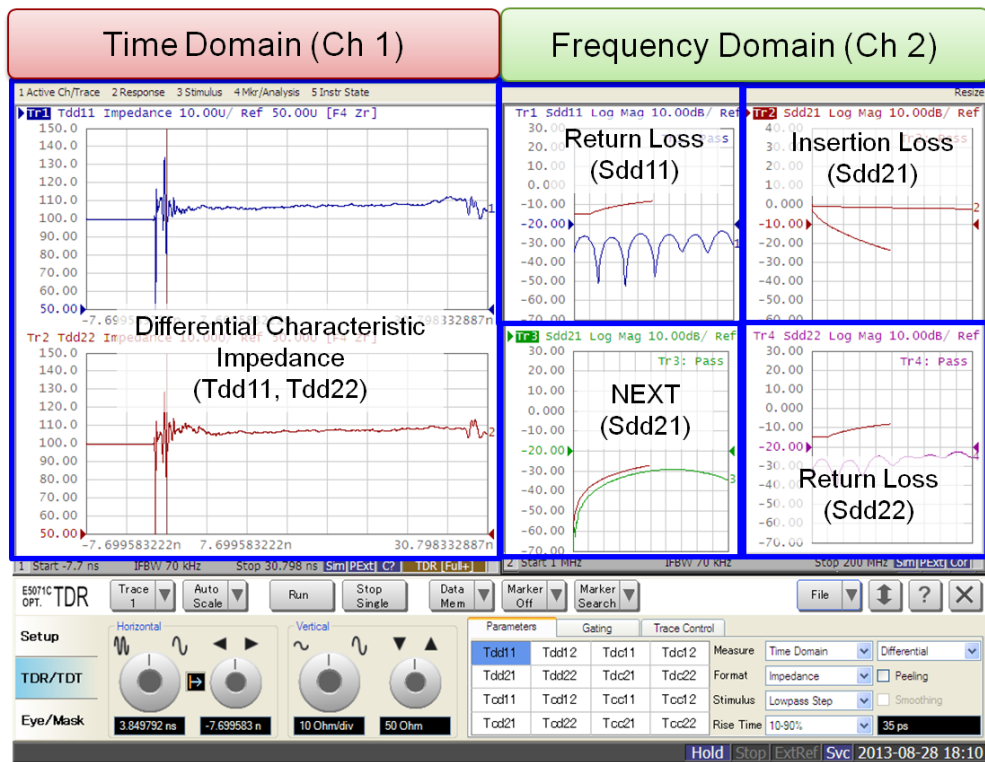
3. Measurements

4-1. Time-domain Measurements

- Differential Characteristic Impedance

4-2. Frequency-domain Measurements

- Insertion Loss

- Return Loss

- Differential Near-end Crosstalk (NEXT)

Note: Hard Keys (Keys on the E5071C's front panel) are displayed in Blue color and **Bold**. (Example: **Avg**, **Analysis**)

Note: Soft keys (Keys on the E5071C's screen) are displayed in **Bold**. (Example: **S11**, **Real**, **Transform**)

Note: Buttons of the TDR software are displayed in Green color and **Bold**. (Example: **Trace**, **Rise Time**)

Note: Tabs of the TDR software are displayed in Brown color and **Bold**. (Example: **Setup**, **Trace Control**)

5.2. Instrument Setup

5.2.1. Recalling a State File

This section describes how to recall a state file of the E5071C that includes all the measurement settings for 100BASE-TX Ethernet cable tests. The state file can be downloaded at: www.keysight.com/find/ena-tdr_ethernet-cabcon

Copy the state file into the E5071C's directory via USB mass storage device and recall the state file using the TDR software. Necessary parameters for testing are automatically set up in the E5071C. Refer to Appendix for the details about manual setup.

If TDR setup wizard is shown, click **Close** button in the TDR setup wizard main window.

1. Open **Setup** tab.

2. Click **Advanced Mode** to show the dialog box.
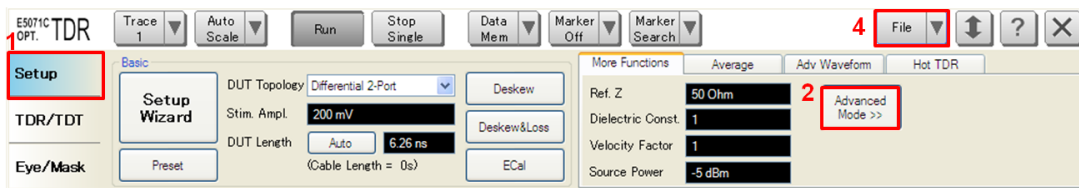
3. A dialog box appears requesting for confirmation. Then click **Yes**. (Uncheck "Use Advanced Calibration Methods")
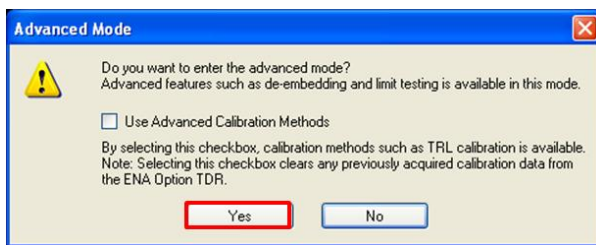
4. Click **File** and select **Recall State** to open the Recall State dialog box.

5. Specify a folder and a file name, and click **Open**.

The E5071C's channel 1 is used for time-domain measurements by using the TDR software at the bottom of the E5071C's screen. The channel 2 is used for frequency-domain measurements by using the soft key on the right side of the screen or hard key on the front

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panel.
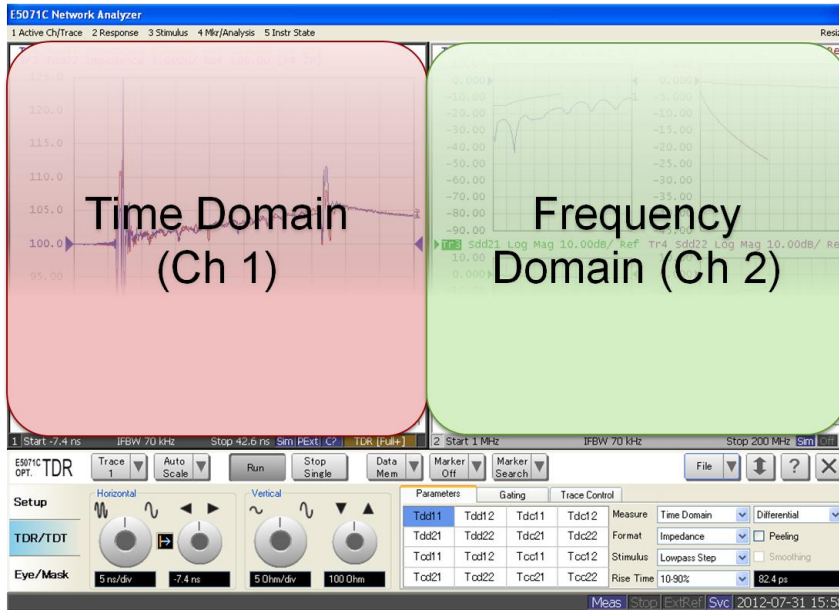
5.2.2. Saving a State File

All the measurement settings including calibration information can be saved in a state file (*.tdr). After performing calibration, all necessary calibration coefficients are saved in a state file and can be recalled for the next measurements.

1. Press **Save/Recall** > **Save Type** and select **State & Cal** as a state file type.
2. Click **File** of the TDR software.
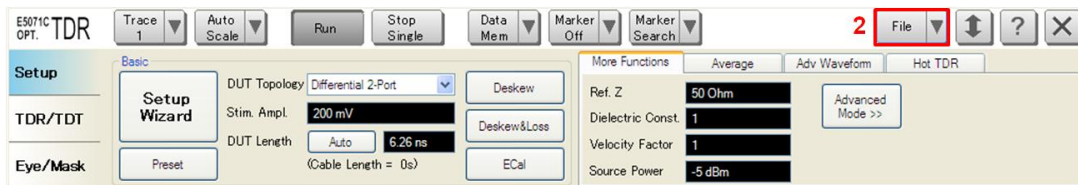
3. Select "Save State".
4. Enter file name and save the state file with calibration information

5.3. Calibration

5.3.1. Time Domain Calibration

The purpose of this step is to calibrate the delay and loss of the RF cables (and test fixtures) by following the wizard of the E5071C TDR software. Full calibration is performed by using the 4-port ECal Module at the end of RF cables connected to the E5071C's test ports. After connecting the test fixture to the cables, the effect of the fixture is removed by the fixture compensation function of the TDR software. This calibration is applied for time-domain measurements in Channel 1.

5.3.1.1. ECal Calibration & Fixture Compensation

Calibration for time-domain measurements is performed by the TDR software. The 4-port ECal Module (i.e. N4431B) connected to the USB port of the E5071C is necessary for the calibration procedure.

1. Press **Channel Next** to select Channel 1.
2. Open **Setup** tab of the TDR software.
3. Click **ECal** to launch calibration wizard.
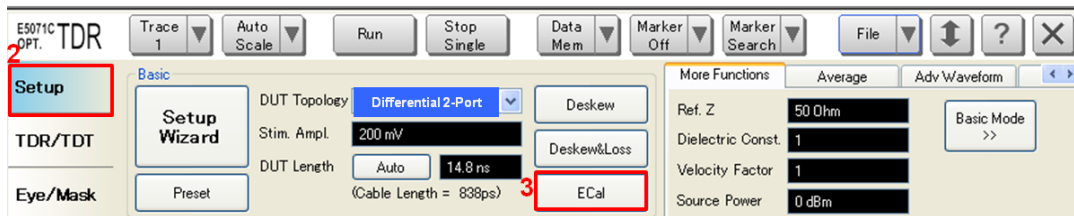
4. Connect all test cables to the ECal Module and click **Calibrate**. Once green check mark appears, click **Next>**.
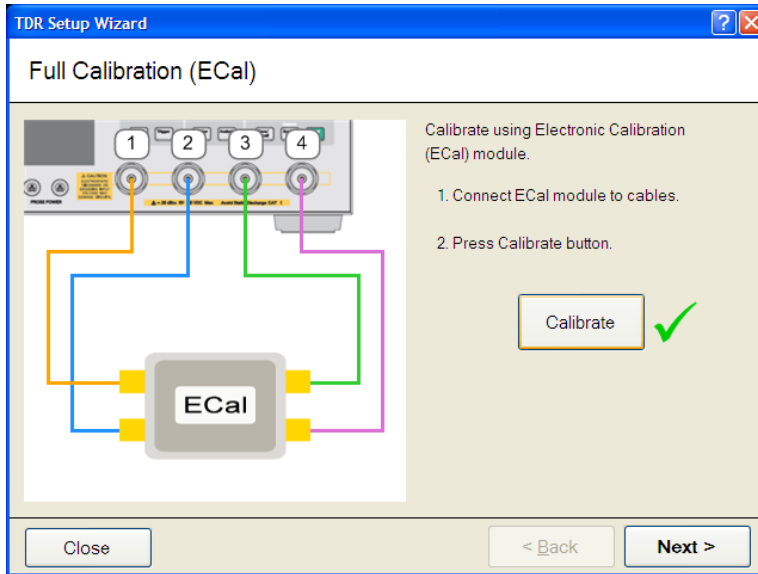
5. Disconnect the ECal Module and connect the RF cables to the test fixtures. Click **Fixture Comp** to perform fixture compensation. Once green check mark appears, click **Finish** to complete the compensation.
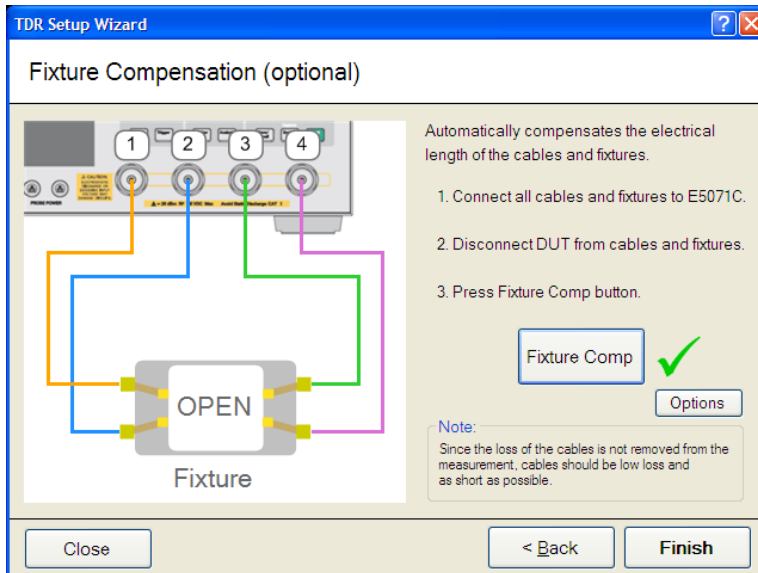
6. Connect DUT to the test fixtures.

7. Open **Setup** tab.

8. Click **Auto** to launch the diagram.

9. Click **Measure** to specify DUT's electrical length in the dialog box. Once green check mark appears, click **Finish**.
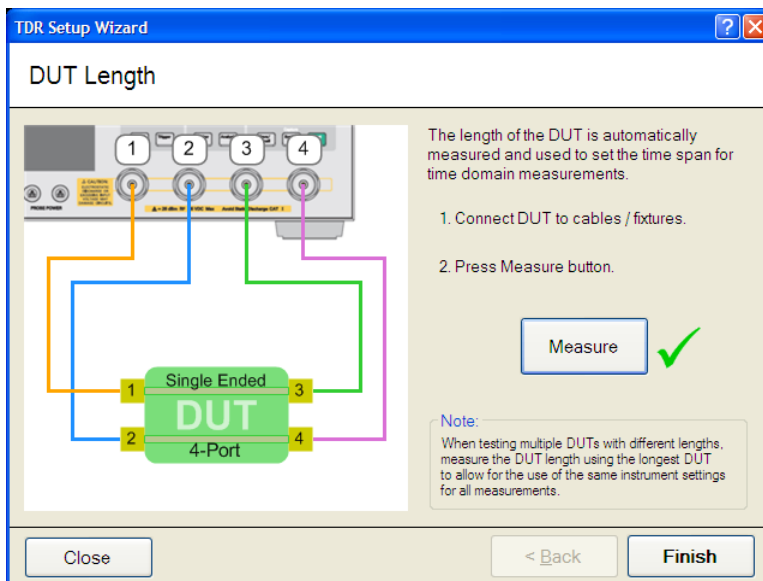
5.3.2. Frequency Domain Calibration

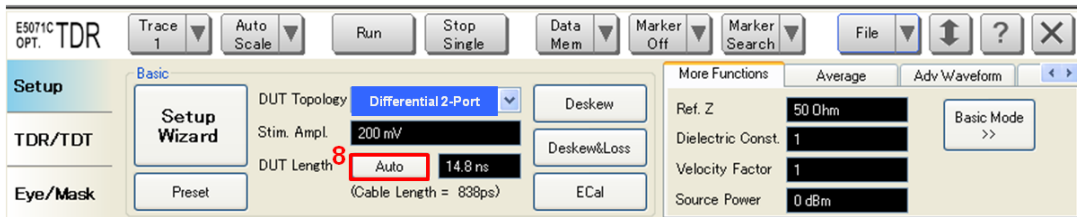The purpose of this step is to calibrate out the RF effects (i.e. mismatch, loss or delay) of RF cables and test fixtures. Full calibration is performed by using the 4-port ECal Module at the end of RF cables connected to the E5071C's test ports. And then the test fixtures are connected to the RF test cables, and the fixture's effect will be eliminated by auto port extension function of the E5071C's firmware.

The calibration is applied for frequency-domain measurements in Channel 2.

5.3.2.1. ECal Calibration

Calibration for the frequency-domain measurement is performed by selecting the E5071C's

soft key. The 4-port ECal Module (i.e. N4431B) connected to the USB port of the E5071C is necessary for the calibration procedure.

1. Press **Channel Next** key to select Channel 2.
2. Connect all RF test cables to the ECal Module.
3. Press **Calibrate** > **ECal** > **4-Port Cal.**

5.3.2.2.   Auto Port Extension

The effect of the test fixtures (i.e. delay) are removed by auto port extension function of the E5071C's firmware. The calibration plane (at the RF test cables by ECal calibration) is moved to the end of test fixtures by auto port extension.

1. Connect the RF cables to the test fixtures. The DUT is not connected to the test fixture (the fixture end is left open).
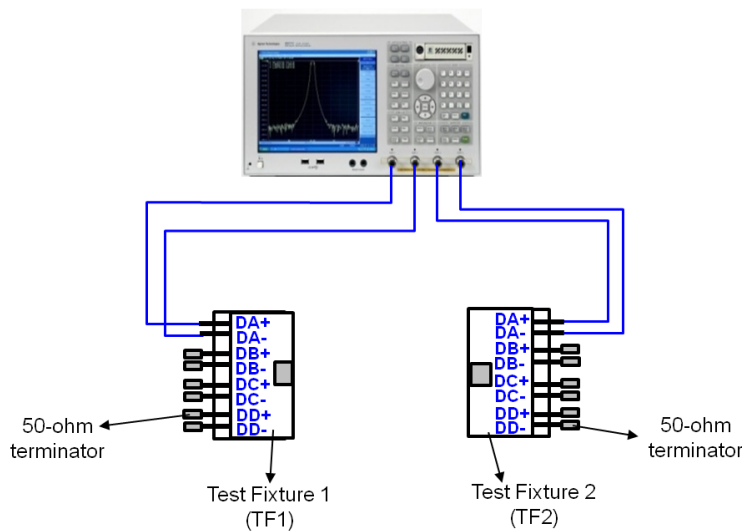

Figure 5-1 Auto Port Extension Test Setup

2. Press **Cal** > **Port Extension** > **Auto Port Extension > Select Ports** and check all ports (Port 1 to Port 4).

3. Press **Cal** > **Port Extension** > **Auto Port Extension > Measure Open** and select **All** to enable auto port extension.

5.4. Measurement
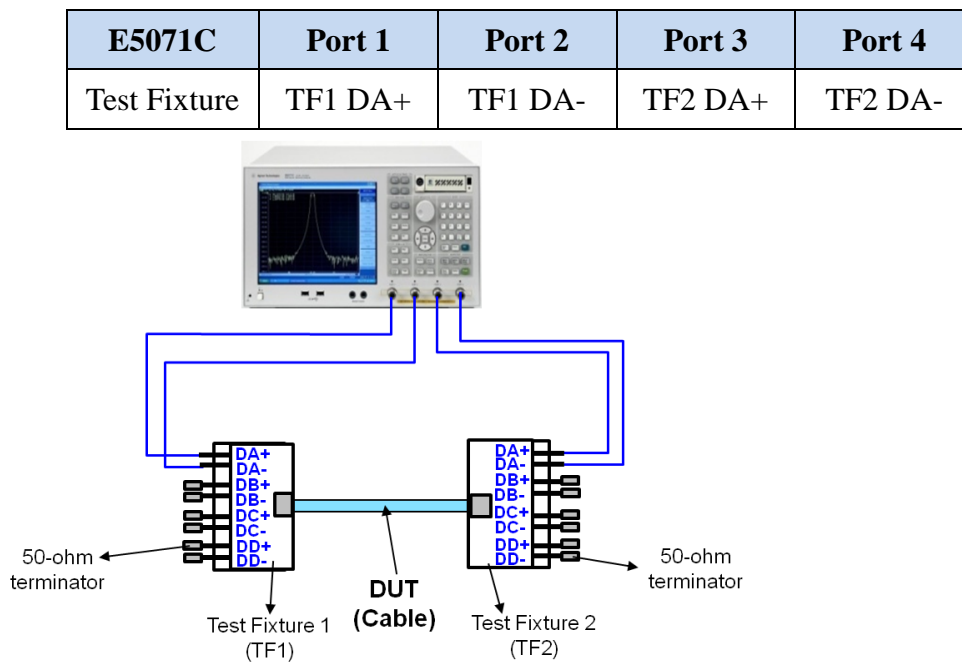
The procedures for time-domain and frequency-domain measurements are introduced in this section.

5.4.1. Differential Characteristic Impedance

1. Connect the DUT to the test fixtures to measure differential characteristic impedance of link segment #1. (Figure 5-2).

E5071C	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF1 DA+	TF1 DA-	TF2 DA+	TF2 DA-

Note: Unused fixture ports should be terminated with 50 ohm terminators.

Figure 5-2 Differential Characteristic Impedance Test Setup (Link Segment #1)

2. Press **Channel Next** to select Channel 1 of the E5071C.

3. Select **Trace 1**. (Tdd11)

4. Press **Stop Single**.

5. Select **Auto Scale** and select **X**.

6. Confirm the nominal differential characteristic impedance at the near end of DUT is 100 ohm.

7. Select **Trace 2** (Tdd22) and repeat the same operations of Step 5 to 6 at the far end of

DUT.

8. Connect the E5071C ports to the test fixtures with the RF cables to measure differential characteristic impedance of link segment #2. (Figure 5-3).

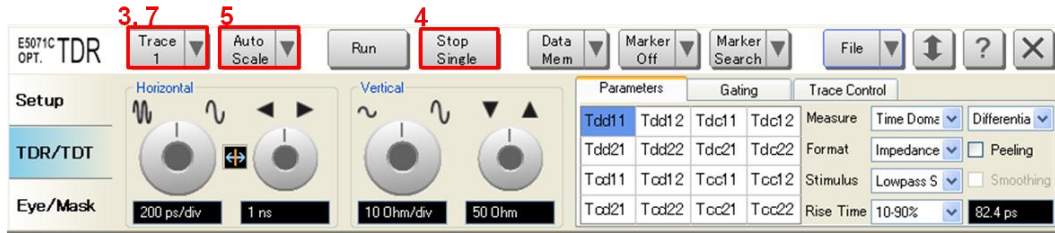| E5071C	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF1 DB+	TF1 DC-	TF2 DB+	TF2 DC-
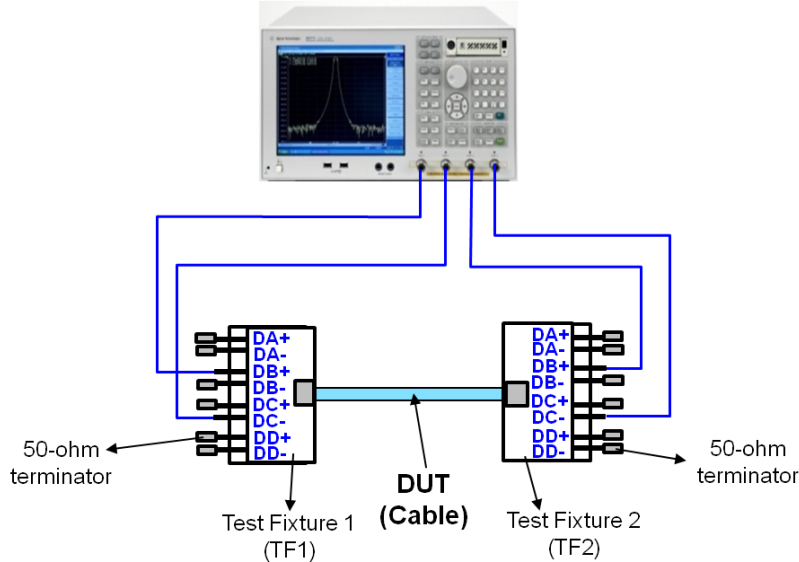
Note: Unused fixture ports should be terminated with 50 ohm terminators.

Figure 5-3 Differential Characteristic Impedance Test Setup (Link Segment #2)

9. Repeat the same operation of Step 3 to Step 7.

5.4.2. Insertion Loss

1. Connect DUT to the test fixtures to measure insertion loss of link segment #1(Figure 5-2).

E5071C	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF1 DA+	TF1 DA-	TF2 DA+	TF2 DA-

2. Press **Channel Next** to select Channel 2 of the E5071C.

3. Press **Trace Next** to select Trace 2 (Sdd21).

4. Press **Trigger** > **Single**.

5. Confirm the measured differential insertion loss is lower than the limit shown below.

$$\text{Insertion\_Loss}(f) < 2.1f^{0.529} + 0.4/f \qquad \text{(dB)}$$

6. Press **Meas** > Sdd12.

7. Press **Trigger** > **Single**.

8. Confirm the measured differential insertion loss is lower than the limit of Step 5.

9. Connect the E5071C and the test fixtures with the RF cables to measure insertion loss of link segment #2. (Figure 5-3).

E5071C	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF1 DB+	TF1 DC-	TF2 DB+	TF2 DC-

10. Repeat the same operation of Step 3 to Step 8.

5.4.3. Return Loss

1. Connect the E5071C and the test fixtures with the RF cables to measure return loss of link segment #1. (Figure 5-2)

E5071C	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF1 DA+	TF1 DA-	TF2 DA+	TF2 DA-

2. Press **Trigger** > **Single**.

3. Press **Trace Next** to select Trace 1 (Sdd11).

4. Confirm the measured return loss is lower than the limit shown below.

$$\text{Return\_Loss}(f) \begin{cases} 15 & (1-20 \text{ MHz}) \\ 15 - 10\log_{10}(f/20) & (20-100 \text{ MHz}) \end{cases} \text{(dB)}$$

Where *f* is the frequency in MHz. The reference impedance shall be 100 ohm.

5. Press **Trace Next** to select Trace 4 (Sdd22).

6. Confirm the measured return loss is lower than the limit of Step 4.

7. Connect the E5071C and the test fixture with the RF cables to measure return loss of link segment #2. (Figure 5-3).

E5071C	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF1 DB+	TF1 DC-	TF2 DB+	TF2 DC-

8. Repeat the same operation of Step 2 to Step 6.

5.4.4.   Differential Near-End Crosstalk (NEXT)

The differential pair-to-pair near-end crosstalk (NEXT) between two pairs of link segments is specified.

1. Connect the E5071C's ports (Port 1 to 4) and the test fixture with the RF cables to measure NEXT at the near end of DUT. (Figure 5-4)

E5071C	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF1 DB+	TF1 DC-	TF1 DA+	TF1 DA-
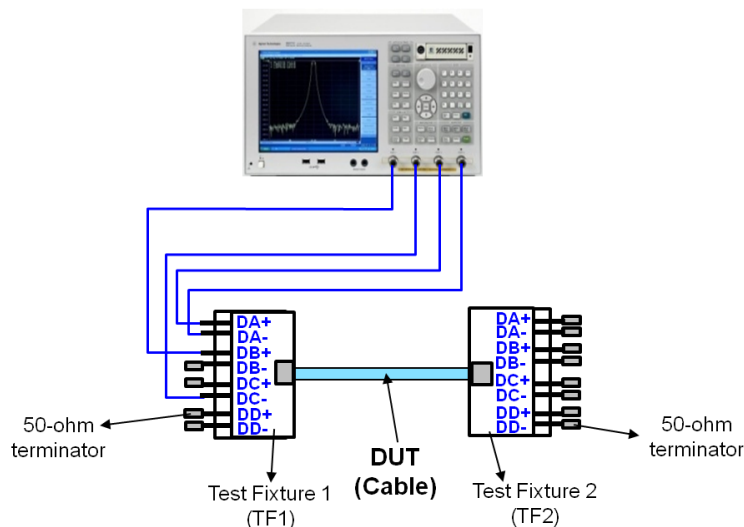
Figure 5-4 Differential Near-end Crosstalk (NEXT) Test Setup

2. Press **Trace Next** to select Trace 3 (Sdd21).

3. Press **Trigger** > **Single**.

4. Confirm the measured differential near-end crosstalk is lower than the limit shown below.

$$27.1 - 16.8\log_{10}\ (f/100)\ (\text{dB})$$

   Where f is the frequency over the range of 1 MHz to 100 MHz.

5. Press **Meas** > **Sdd12**.

6. Confirm the measured differential near-end crosstalk is lower than the limit in Step 4.

7. Connect the E5071C's ports (Port 1 to 4) and the test fixture with the RF cables to measure NEXT at the far end of DUT.

E5071C	Port 1	Port 2	Port 3	Port 4
Test Fixture	TF2 DB+	TF2 DC-	TF2 DA+	TF2 DA-

8. Press **Meas** > **Sdd21**.

9. Press **Trigger** > **Single**.

10. Confirm the measured differential near-end crosstalk is lower than the limit in Step 4.

11. Press **Meas** > **Sdd12**.

12. Confirm the measured differential near-end crosstalk is lower than the limit in Step 4.

6. [Appendix] Manual Setup

The procedures of manual setup for time-domain and frequency-domain measurements are introduced in the section. All the following parameters are saved in the E5071C's state file, which is available at: www.keysight.com/find/ena-tdr_ethernet-cabcon

6.1. Channel & Trace Setup

If TDR setup wizard is shown when launching the TDR software, click **Close** button in the TDR setup wizard main window.

1. Open **Setup** tab in the TDR software.

2. Click **Preset** to preset the instrument. Click **OK** in a dialog box to continue.

3. Set **DUT Topology** to "Differential 2-Port". Click **OK** in a dialog box.
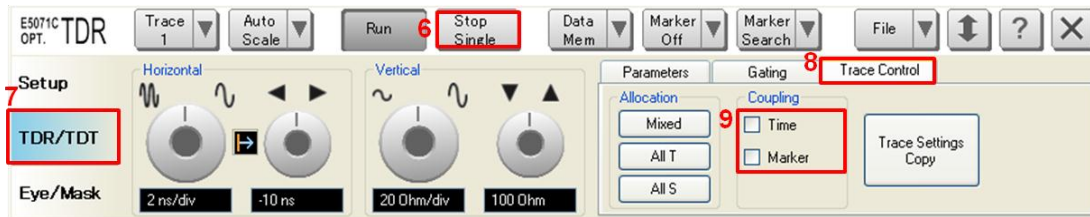
4. Click **Advanced Mode>>**.
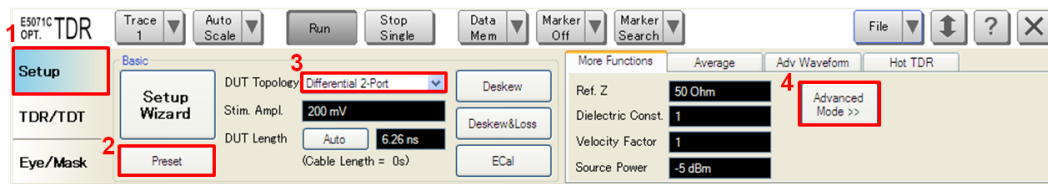
5. A dialog box appears requesting for confirmation. Then click **Yes**. (Clear the check box for "Use Advanced Calibration Methods")
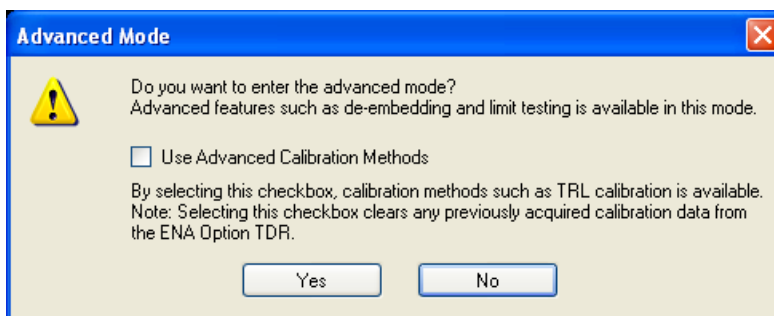
6. Click **Stop Single**.

7. Open **TDR/TDT** tab.

8. Click **Trace Control** tab.

9. Clear **Time** and **Marker** check box under Coupling.

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10. Press **Display** > **Allocate Channels** > ⊞ .

11. Press **Display** > **Num of Traces** > 2.

12. Press **Display** > **Allocate Traces** > x2 (1 column by 2 rows).

13. Press **Channel Max** to maximize the screen of Channel 1.

6.2.   Differential Characteristic Impedance

1.   Select **Trace 1**.

2.   Open **TDR/TDT** tab.

3.   Open **Parameters** tab.

4.   Select "Time Domain" and "Differential" for Measure.

5.   Select Format to "Impedance"

6.   Click **Tdd11**.

7.   Click the box below the left knob under Vertical. Set the vertical scale to "10 Ohm/div" in a dialog box.

8.   Click the box below the right knob under Vertical. Set the vertical center to "50 Ohm" in a dialog box.
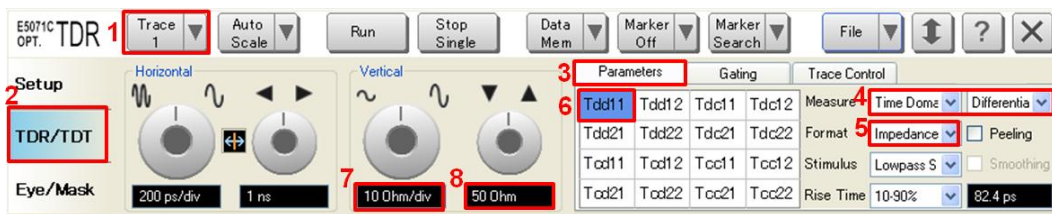
9.   Open **Trace Control** tab.

10. Click **Trace Settings Copy** to launch trace copy dialog box.

11. Select the Trace 1 in the From list.

12. Select the Trace 2 in the To list.

13. Click **Copy**.

14. Click **Close**.
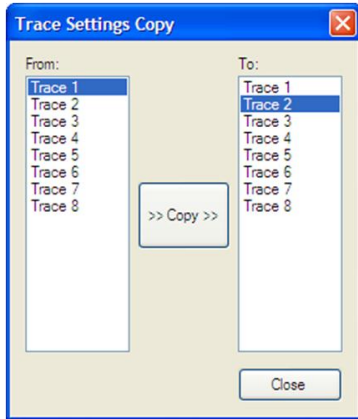
15. Select **Trace 2**.

16. Open **Parameter** tab.

17. Click **Tdd22**.

6.3.   Common Parameters Setup for Frequency-domain Measurements

1. Press **Channel Next** to select Channel 2.

2. Press **Start** > Set start value to "1 MHz".

3. Press **Stop** > Set stop value to "200 MHz".

   Note: The 100BASE-TX Ethernet cable is specified in the frequency range up to 100 MHz.

4. Press **Analysis** > **Fixture Simulator** and turn it **ON**.

6. Press **Analysis** > **Fixture Simulator** > **Topology** > **Device** > **Bal-Bal**

7. Press **Analysis** > **Fixture Simulator** > **Topology** > **Port1 (bal) > 1-2**

8. Press **Analysis** > **Fixture Simulator** > **Topology** > **Port2 (bal) > 3-4**

9. Press **Display** > **Num of Traces** > 4.

10. Press **Analysis** > **Fixture Simulator** > **BalUn ON All Traces** to enable mixed-mode

S-parameter (i.e. Sdd11) measurements on all traces.

11. Press **Display** > **Allocate Traces** > x4 (2 columns by 2 rows).

6.4. Insertion Loss

1. Press **Trace Next** to select Trace 2.

2. Press **Meas** > **Sdd21**.

3. Press **Scale** > Set **Scale/Div** to 10 dB/div.

4. Press **Scale** > Set **Reference Value** to -10 dB.

6.5. Return Loss

1. Press **Trace Next** to select Trace 1.

2. Press **Meas** > **Sdd11**.

3. Press **Scale** > Set **Scale/Div** to 10 dB/div.

4. Press **Scale** > Set **Reference Value** to -20 dB.

5. Press **Trace Next** to select Trace 4.

6. Press **Meas** > **Sdd22**.

7. Press **Scale** > Set **Scale/Div** to 10 dB/div.

8. Press **Scale** > Set **Reference Value** to -20 dB.

6.6. Differential Near-end Crosstalk (NEXT)

1. Press **Trace Next** to select Trace 3.

2. Press **Meas** > **Sdd21**.

3. Press **Scale** > Set **Scale/Div** to 10 dB/div.

4. Press **Scale** > Set **Reference Value** to -20 dB.

6.7. Defining Limit Line Tables

1. Press **Trace Next** to select trace to set the limit line table.

2. Press **Analysis** > **Limit Line** and turn it **ON** to display limit lines.

3. Press **Analysis** > **Edit Limit Line** to edit the limit line table.

	Type	Begin Stimulus	End Stimulus	Begin Response	End Response
1	MAX	0 s	600 ps	105 U	105 U
2	MIN	0 s	600 ps	75 U	75 U
3	▾				

4. Press **Analysis** > **Limit Test** and turn it **ON**.

5. Press **Analysis** > **Limit Test** > **Fail Sign** to switch the fail sign ON/OFF. When turned on, the Fail sign is displayed on the E5071C's screen, if one or more failed traces are within the channel.

6. Press **System** > **Misc Setup** > **Beeper** > **Beep Warning** to turn ON/OFF the warning beeper.