

Agilent Technologies Differential S-Parameter Measurements of PCI Express Connector Using the ENA Series Network Analyzer

Application Note 1463-3

- **Integrated differential measurements**
- **Automatic calibration with 4-port ECal**
- **Built-in VBA for total NEXT calculation**
- **Test fixture de-embedding**

Introduction

Frequency domain differential S-parameter measurements are becoming important for the components used in the latest high-speed digital communication technologies such as Gigabit Ethernet, Infiniband, PCI Express, and so on. This application note introduces the differential S-parameter measurements needed for a PCI Express connector using the ENA Series 8.5 GHz 4-port network analyzers.

Measurement Parameters

The standard test procedure of the PCI Express connector specifies the following test items.

- Differential insertion loss
- Differential return loss
- Differential near-end crosstalk (NEXT)

The test frequency range is from 100 MHz to 4 GHz. Figure 2 shows the definitions of these measurement parameters. The near-end crosstalk of PCI Express connectors is defined as the sum of the near-end crosstalk values from all of the adjacent differential signal line pairs:

$$\text{Total NEXT} = \text{NEXT-1} + \text{NEXT-2} + \dots + \text{NEXT-n}$$

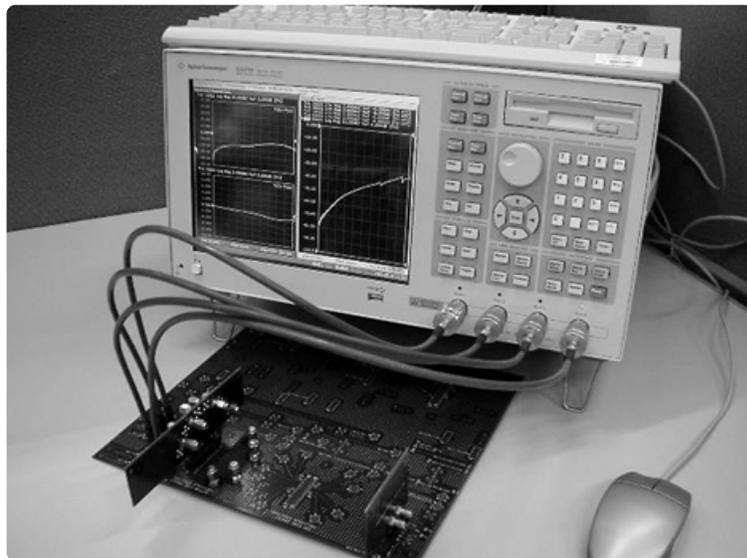


Figure 1. ENA Series network analyzer

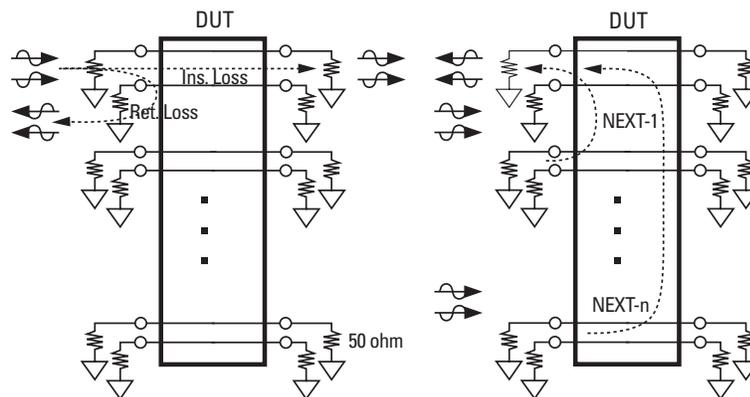


Figure 2. Measurement parameters of PCI Express connector



Insertion Loss and Return Loss Measurements

Figures 3a and 3b show an example of a test fixture used for measuring the differential insertion loss and return loss.

After making the 4-port full calibration at test cables, the ENA is connected to the DUT's signal line pair to be tested, and 4 x 4 single-ended S-parameters (S11 to S44) are measured. Then the ENA's built-in fixture simulator function converts them to the mixed mode S-parameters (differential and common mode S-parameters).

You can read the differential insertion loss and return loss measurement results directly on the ENA's screen as Sdd21 (differential to differential transmission) and Sdd11 (differential to differential reflection) without needing to make any external calculations. This is the key advantage of using the 4-port ENA compared to the conventional 2-port network analyzers, which require complicated external calculations for delivering differential S-parameters.

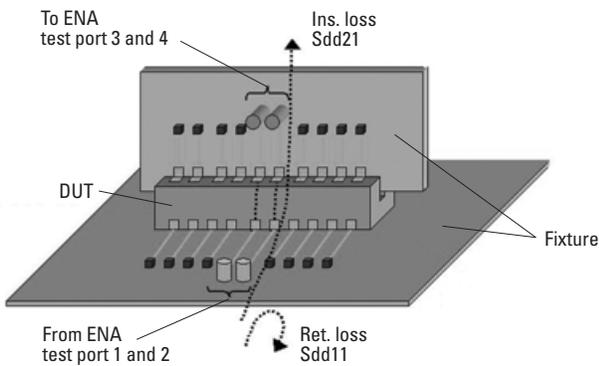


Figure 3a. Test fixture for insertion loss and return loss measurements

The calibration technique used for differential component measurements with 4-port network analyzers is 4-port full calibration. When performing 4-port full calibration with mechanical standards, you need to make numerous connections, and this may cause calibration errors. The ENA supports the N4431A 4-port electronic calibration module (ECal) which enables automatic calibrations. Using the 4-port ECal module, you can make the 4-port full calibration with single connection and one-key operation.

Near-end Crosstalk Measurements

Figure 4a and 4b show the test fixture example for the differential near-end crosstalk (NEXT) measurements. In the same measurement setup as the insertion loss and return loss, the test port 3 and 4 are connected to the victim signal line pair and the test port 1 and 2 are connected to adjacent signal line pairs to be stimulated. All the signal line pairs not connected to the ENA should be terminated with 50 ohm coaxial terminators. By changing the connection of test cables and 50 ohm terminators, you can measure the NEXT of different pair combinations.

The total NEXT is obtained as follows:

- Measure the NEXT of Pair 2 to Pair 1 in the linear scale.
- Change the connections of cables and terminators, and measure the NEXT of Pair 3 to Pair 1.
- In the same manner, measure the NEXT of Pair 4 to Pair 1.
- Calculate the sum of these NEXT measurement results.

The ENA's built-in VBA programming capability is useful for making this calculation.

Figure 5 shows the measurement example of the differential insertion loss, return loss and total NEXT sum. In the channel 2, a VBA program calculates the total NEXT from four NEXT measurement results on the trace 1 to 4 (not displayed on the screen), and plots the calculated result on the trace 5 in the dB scale.

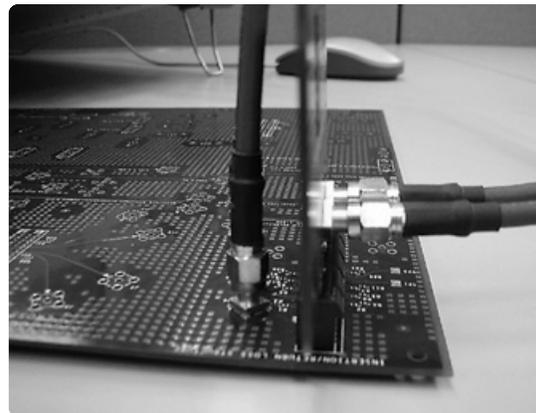


Figure 3b. Test fixture for insertion loss and return loss measurements

Test Fixture De-embedding

In this measurement example, the test fixture transmission line effects are not removed from the measurement results in accordance with the PCI Express connector's standard test procedure. By carefully designing the test fixture to minimize its effect on the measurements, you can reduce the measurement errors.

If you want to remove the effect of the test fixture to evaluate the DUT's characteristics more precisely, you can use the ENA's de-embedding function.

The de-embedding function mathematically removes the 2-port or 4-port networks defined as Touchstone (s2p or s4p) S-parameter data files. Figure 6 shows a 2-port de-embedding example.

Before performing the text fixture de-embedding, it is necessary to characterize the test fixture's transmission lines to get their S-parameters as Touchstone data files.

There are two possible ways to accomplish these measurements:

- Mathematically characterizing the test fixture's transmission lines using simulation tools such as the Agilent Advanced Design System (ADS).
- Characterizing the test fixture's transmission lines by directly measuring them with the ENA and a RF probe station.

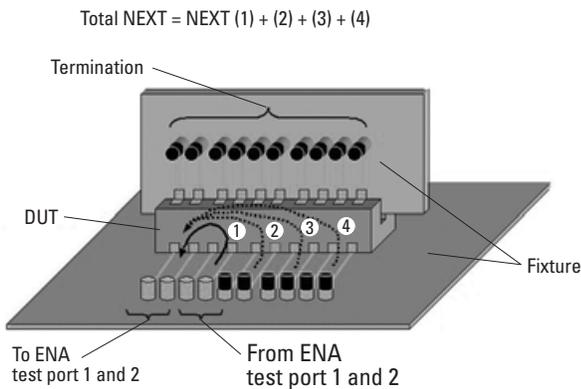


Figure 4a. Test fixture for near-end crosstalk measurements

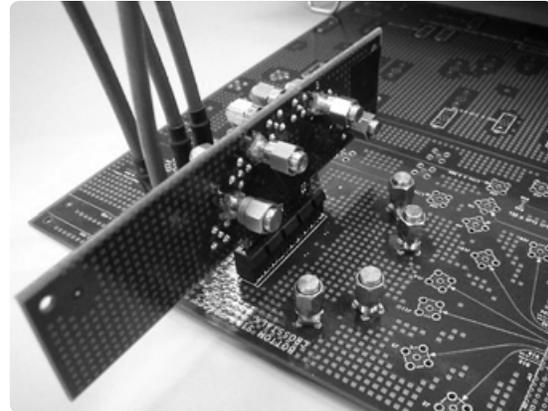


Figure 4b. Test fixture for near-end crosstalk measurements

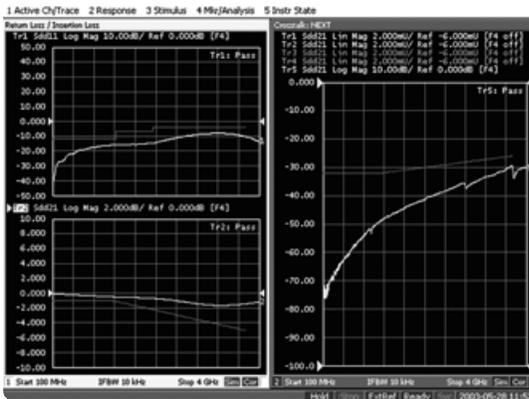


Figure 5. Measurement results:
Channel-1 (left): Return loss and insertion loss
Channel-2 (right): Total NEXT calculated with VBA

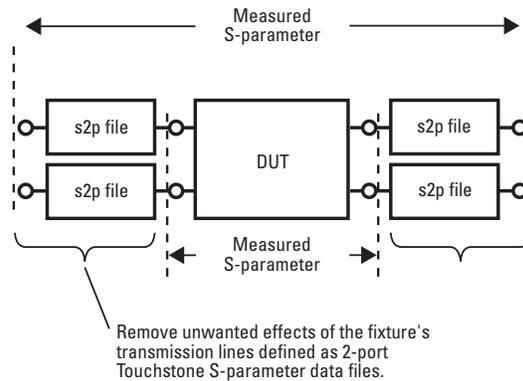


Figure 6. Removing test fixture's effects using 2-port de-embedding function

For more information about the test fixture characterization, refer to the Product Note E5070/71-4, "In-Fixture Characterization using the ENA Series RF Network Analyzer with Cascade Microtech Probing System" (PN 5988-9463EN).

For more information about the ENA Series network analyzers, visit:
www.agilent.com/find/ena

Agilent Solutions Up to 50 GHz

The N1900A Series physical layer test system (PLTS) is a differential measurement system based on the network analyzer that is capable of measurements up to 9 GHz, 20 GHz, and 50 GHz. The PLTS has powerful functions for high-speed interconnect characterizations such as eye diagram analysis, RLCG parameter extraction, and more.

For more information, visit:
<http://www.agilent.com/find/plts>



Figure 7. Physical layer test system

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