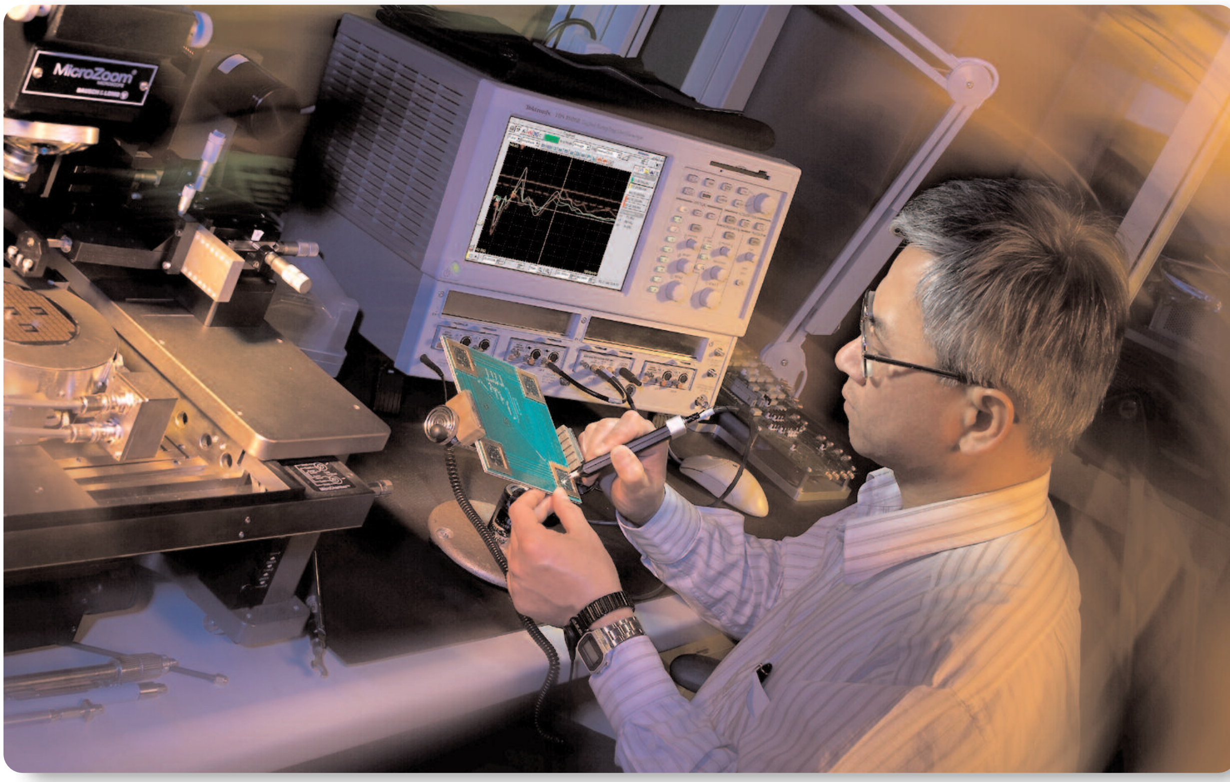
# Effects of InfiniBand Fixture Crosstalk on Synthesized Eye Diagram




## Introduction

In working with Infiniband designs, the crosstalk that is created by attached fixtures may result in inaccurate eye diagram representation. This application note will take you through the process of de-embedding fixture crosstalk from synthesized eye diagram when working on characterization of your Infiniband designs.

Synthesized eye diagram begins with an accurate TDT measurement of a linear device. This allows the device s eye response to be accurately generated by advanced synthesis algorithm such as that employed in IConnect TDR/T and VNA software. The validity of this approach was proved by a number of case studies[1] and is commonly accepted in the communication industry. Majority of compliance measurements require specially designed fixtures. The synthesized eye diagram test that is performed for serial link standards is not an exception. An ideal test fixture would have uncoupled signal traces up to the measurement reference plane. However, it is not always possible to design a fixture that does not exhibit any coupling between its traces before the reference plane.

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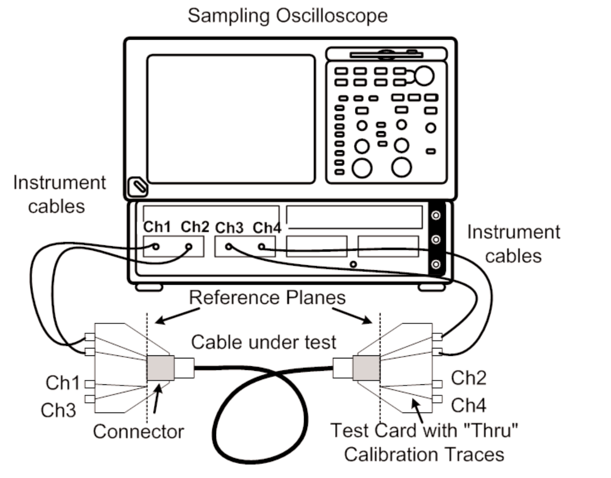
When an eye diagram in the presence of aggressors is measured, coupling from the adjacent lines adds to the crosstalk magnitude and causes overestimation of the actual crosstalk value. Nevertheless, the eye diagram can be measured more accurately if an engineer will be able to determine crosstalk contribution from the fixture only. This would allow subtracting fixture s noise contribution from the overall crosstalk measurements providing with a more accurate eye diagram measurement. IConnect measurement software has a built-in feature that allows de-embedding the effects of the fixture crosstalk from the synthesized eye diagram measurements. This paper covers a process of the correct data acquisition to de-embed fixture crosstalk from the eye diagram measurements.




▶ **Figure 1.** *Cable testing measurement setup. Dashed lines indicate locations of reference planes.*

## Reference Plane for Interconnect Measurements

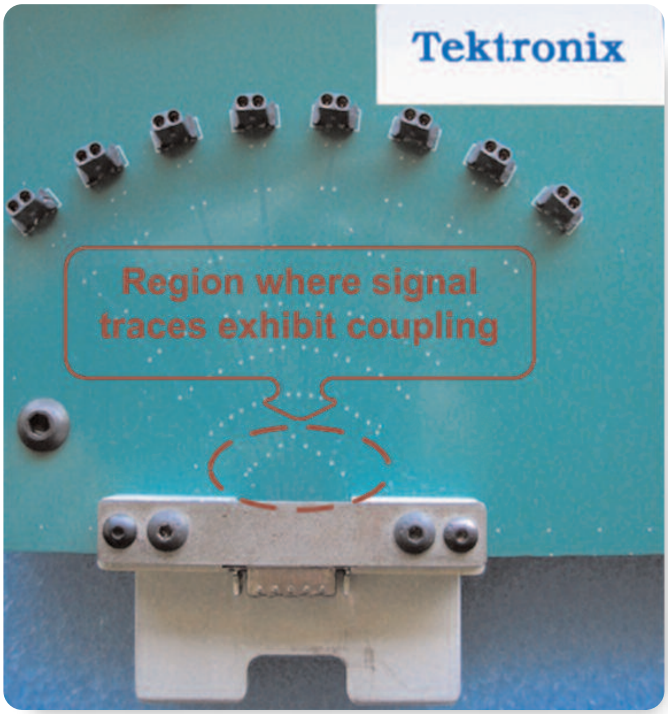
When performing any measurement, the engineer may desire to obtain the device under test (DUT) characteristics only, excluding or de-embedding any effects of probes and fixtures connected to the DUT. The DUT is commonly defined by location of the reference planes, which usually coincide with the locations of where an interconnect is positioned in the system. For example, in a cable testing assembly the reference planes are usually located just before a high-speed connector that is used to connect a cable under test as illustrated in Figure 1. This replicates a real application environment where the cable would be connected to a board.

To de-embed such fixture from the overall S-parameter measurement using the time domain network analysis (TDNA), someone would measure transmission waveform (TDT) using the calibration traces similar to shown in Figure 1, and then use the measured data as a  thru reference to de-embed effects of the fixture up to the defined reference plane. While this de-embedding approach is adequate in many cases of TDNA measurements, it may not have sufficient accuracy when a synthesized eye diagram under presence of aggressors is considered. The issue arises due to the coupling between adjacent lines that usually exists in the fixture but is not replicated in the calibration traces. Hence, the eye diagram measured using this conventional approach will overestimate the crosstalk value and produce an eye with a smaller opening potentially resulting in non-passing device for compliance testing.

Therefore, to accurately measure synthesized eye diagram under presence of aggressors, it is desirable to determine the amount of crosstalk that comes from the fixture alone, and then subtract it from the overall measurement. This methodology is implemented in IConnect software and explained in more details in the following sections.

## Infiniband 4x Fixture Example

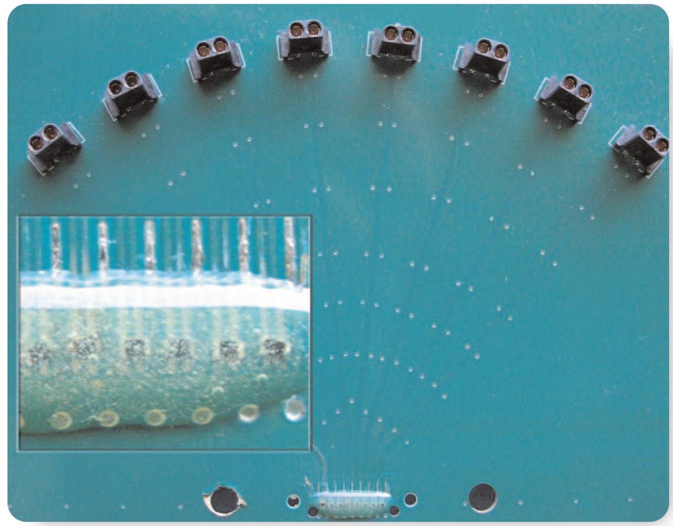
When subtracting the fixture contribution from the overall crosstalk figure, the near end crosstalk (NEXT) contribution has to be considered. However, if the far end is not terminated with matched terminations, then a part of the far end crosstalk (FEXT) will be reflected back to the near end and will change the magnitude of the NEXT. To provide matched terminations at the reference planes,




▶ **Figure 2.** *Gore Infiniband 4x test fixture. The differential traces become coupled at the high-speed connector receptacle area.*

extra calibration traces are required. These traces have to replicate the measurement traces up to the reference planes and be terminated with matched terminations. For the case of 100 Ohm differential traces, 100 Ohm resistors can be used. In this case when the aggressor s signal is applied the measured NEXT value will correspond to the crosstalk that exists in the fixture. This crosstalk waveform is then used in IConnect to take into account the noise contribution from the fixture only.

Consider an example of Gore Infiniband 4x fixture shown in Figure 2. The test fixture consists of differential connectors and PCB traces connected to the receptacle of a high-speed Infiniband connector. The various differential traces in this fixture become coupled at the area where they approach the high-speed connector. This coupling is not a part of the device under test and needs to be de-embedded from the eye diagram measurements.



▶ **Figure 3.** *Crosstalk calibration fixture used to measure noise contribution from the test fixture only. Each differential trace is terminated with matched (100 Ohm) resistors. The termination area is enlarged.*

To measure the cross-talk value of the test fixture alone, a replica of the test card was built. This new calibration structure allows determining the amount of the crosstalk that comes from the fixture alone. The connector s receptacle was replaced with matched termination resistors (100 Ohms), as it is illustrated in Figure 3. The purpose of placing these terminations is to minimize reflections from the far end of the fixture and to reproduce a real application environment while setting the correct reference plane. Now, the fixture-only cross-talk value can be accurately measured and used in the eye diagram with aggressors for de-embedding.

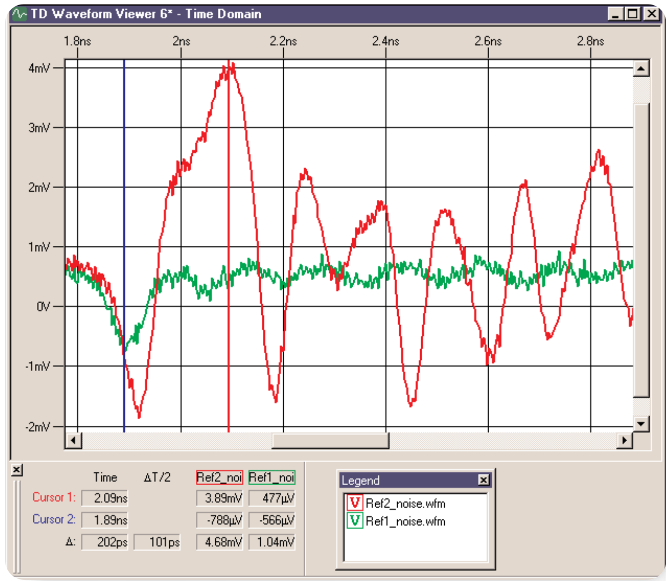
To illustrate the validity of this approach two test cases are considered. Case #1 consists of the NEXT measurements from the cross-talk calibration fixture shown in Figure 3. Case #2 considers the NEXT measurements from the test fixture with Infiniband connector receptacle. Since the high-speed connector exhibit additional coupling and is not terminated, it is expected that the Case #1 will measure a lower magnitude of the crosstalk than a similar measurement of the Case #2.

The measurement results shown in Figure 4 support the expectation. While the maximum magnitude of the NEXT value for the Case #1 is 1mV, the maximum magnitude of the NEXT value for the Case#2 is 3.9mV. Therefore, if the cross-talk value from not terminated test fixture was used to subtract fixture s noise contribution, the resulting eye opening would be overestimated and the amplitude of the jitter might not be accurate.

## Fixture Crosstalk De-embedding

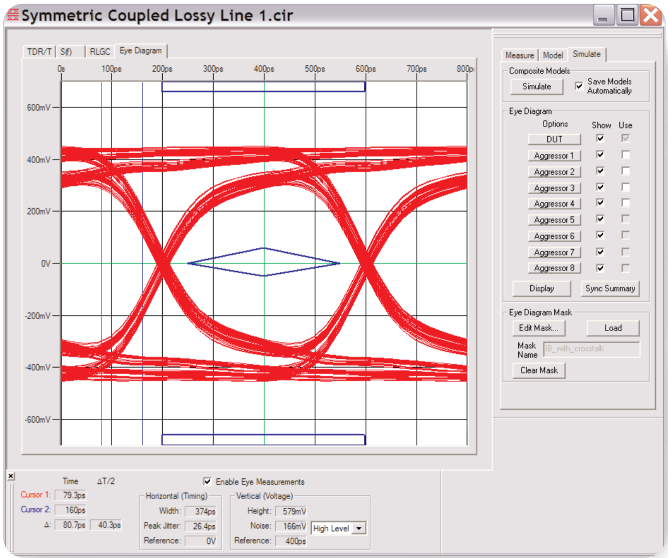
To demonstrate how the fixture crosstalk may affect the eye diagram measurements a 5m long InfiniBand cable assembly was considered. The eye diagram was generated for four cases: an eye diagram without any aggressor signal (Case A), an eye diagram with aggressor signal applied to all other traces of the cable assembly but without de-embedding the fixture effects (Case B), an eye diagram obtained with the fixture crosstalk de-embedded using the same fixture with the cable disconnected (Case C), and an eye diagram with crosstalk de-embedded using a special calibration fixture terminated with matched resistors at the reference plane (Case D).

Case A is an ideal case when no aggressor signal is applied to the adjacent traces. It shows the best performance for a single differential pair. Cases B through D are the worst case scenarios when the aggressor s signal is applied to the all other traces at the receiver s. Case B would happen if no crosstalk de-embedding was performed. It is expected to produce

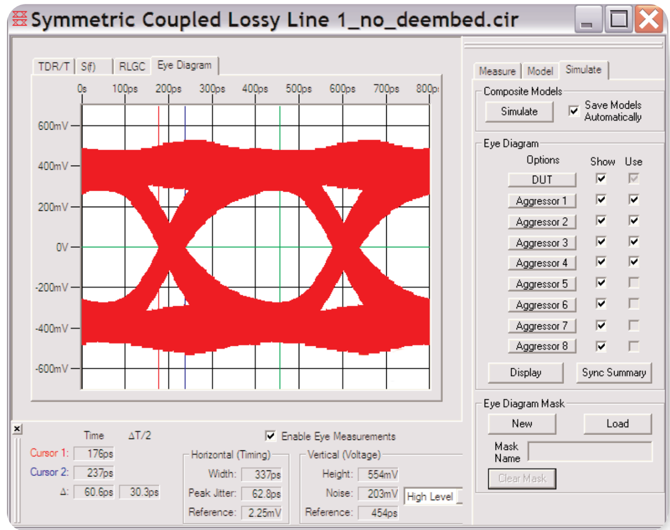



▶ **Figure 4.** *Near end cross talk (NEXT) measurement results from the test fixture with cable disconnected (red waveform, Case #2) and the calibration fixture terminated with matched resistors (green waveform, Case #1). The maximum magnitude of NEXT is much higher when the test fixture with open-ended connector was used.*

the largest NEXT contribution at the victim line. Case C from crosstalk measurements obtained from the same fixture with unplugged cable, will result in the excessive fixture crosstalk subtracted for the measurements. The reason is that the crosstalk of the high-speed connector is present in the fixture reference waveforms being de-embedded. Case D corresponds to the correct technique to de-embed fixture effect from the eye diagram measurement. In this case the calibration fixture is used.

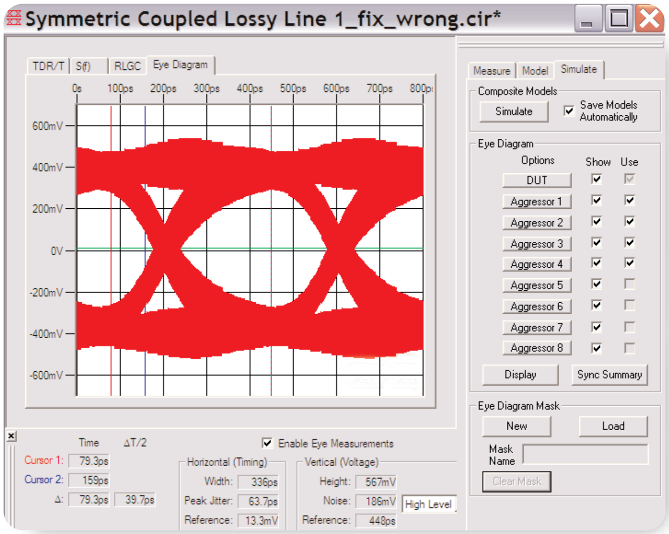



▶ **Figure 5.** *Eye diagram measurements for the InfiniBand cable assembly no signal applied to the aggressor lines (Case A). Eye diagram generated at 2.5Gbit/s and 80ps 20-80% rise time, shows peak jitter of 26.4ps, eye opening of 579mV and vertical noise of 166mV.*

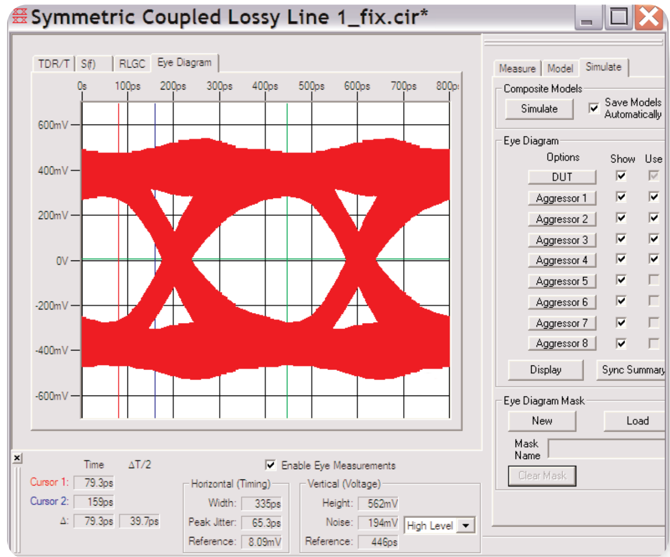



▶ **Figure 6.** *Eye diagram measurements for the InfiniBand cable assembly with fixture's crosstalk included (Case B). Eye diagram generated at 2.5Gbit/s and 80ps 20-80% rise time, shows peak jitter of 62.8ps, eye opening of 554mV and vertical noise of 203mV.*

The results of these test measurements are shown in Figure 5 through Figure 8 and are summarized in Table 1. The  ideal  case is shown in Figure 5; it results in 579mV of an eye opening, 166mV of noise and 26.4ps of the peak jitter.  Figure 6 shows the effects of the aggressors applied at the receiver s side of the cable assembly; no fixture s crosstalk is de-embedded in this case. The eye measurements reveal 554mV of the eye opening and 203 mV of the noise. Part of the eye closure and the noise is attributed to the fixture s crosstalk.




▶ **Figure 7.** *Figure 7. Eye diagram measurements for the InfiniBand cable assembly with fixture's crosstalk deembedded incorrectly (Case C). Eye diagram generated at 2.5Gbit/s and 80ps 20-80% rise time, shows peak jitter of 63.7ps, eye opening of 567mV and vertical noise of 186mV.*




▶ **Figure 8.** *Figure 8. Eye opening measurements for the InfiniBand cable assembly with fixture's crosstalk de-embedded using a terminated calibration fixture (Case D). Eye diagram generated at 2.5Gbit/s and 80ps 20-80% rise time, shows peak jitter of 65.3ps, eye opening of 562mV and vertical noise of 194mV.*

Figure 7 shows results for the case when the excessive crosstalk is subtracted form the overall measurements. Eye diagram readouts indicate the eye opening of 567mV and noise of 186mV. Since the amount of the fixture s crosstalk is overestimated, the resulting eye diagram shows a more open eye than it would be obtained if the reference planes were set correctly. The most accurate results are shown in Figure 8, where the special calibration fixture shown in Figure 3 was used. The eye opening in this case is 567mV and the noise is 194mV.

| | Eye opening | Noise | Peak Jitter | Crosstalk effect |
|---|---|---|---|---|
| Case A | 579mV | 166mV | 26.4ps | No crosstalk |
| Case B | 554mV | 203mV | 65.8ps | Overestimate |
| Case C | 567mV | 186mV | 63.7ps | Underestimate |
| Case D | 562mV | 194mV | 65.3ps | Most accurate |

▶ **Table 1.** *Summary of the results for different methods to de-embed fixture's crosstalk from the eye diagram measurements of 5m long InfiniBand cable assembly*

## Conclusion

The preferred method for de-embedding fixture crosstalk effects from eye diagram measurements is Tektronix' IConnect software. The measurements shown to you in this note illustrate the effects of crosstalk from adjacent lines as well as from the test fixture on a synthesized eye diagram. This technique will allow you to obtain accurate measurements of a synthesized eye diagram with Tektronix' TDR oscilloscope and IConnect software ensuring that the device meets compliance testing requirements.

## Bibliography

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