Fibre Channel Consortium

FC-PI-6 Clause 6.3
32GFC Transmitter Electrical Physical Layer Test Suite
Version 1.0

Technical Document

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UNH IOL Fibre Channel Consortium
InterOperability Laboratory
University of New Hampshire

121 Technology Drive, Suite 2
Durham, NH 03824
Phone: (603) 862-0090
Fax: (603) 862-4181
http://www.iol.unh.edu/consortiums/fc

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Modification Records

- March 31, 2015 – Version 0.1 – Internal Release
  - Daniel Gray: Initial Release for internal review.
- April 28, 2015 – Version 0.9 – Internal Release
  - Daniel Gray: Final Release for Internal Review.
- May 15, 2015 – Version 1.0 – Final Release.
  - Daniel Gray: Initial public release.

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Daniel Gray	University of New Hampshire
Mike Klempa	University of New Hampshire
Tim Sheehan	University of New Hampshire

Introduction

Overview

The University of New Hampshire's InterOperability Laboratory (UNH-IOL) is an institution designed to improve the interoperability of standards based products by providing an environment where a product can be tested against other implementations of a standard. This particular suite of tests has been developed to help implementers evaluate the Physical Layer functionality of their Fibre Channel products.

These tests are designed to determine if a Fibre Channel product conforms to specifications defined in **Clause 6** of the **FC-PI-6 Rev 3.10** Fibre Channel Standard (hereafter referred to as "**FC-PI-6**"). The test also covers information relating to **FC-MSQS-2 Rev 2.3** Fibre Channel Standard (hereafter referred to as "**FC-MSQS-2**"), as well as **FC-FS-4 Rev 1.10** Fibre Channel Standard (hereafter referred to as "**FC-FS-4**"). Successful completion of all tests contained in this suite does not guarantee that the tested device will operate with other devices. However, combined with satisfactory operation in the IOL's interoperability test bed, these tests provide a reasonable level of confidence that the device under test (DUT) will function properly in many Fibre Channel environments.

Organization of Tests

The tests contained in this document are organized to simplify the identification of information related to a test and to facilitate in the actual testing process. Each test contains an identification section that describes the test and provides cross-reference information. The discussion section covers background information and specifies why the test is to be performed. Tests are grouped in order to reduce setup time in the lab environment. Each test contains the following information:

Test Number

The Test Number associated with each test follows a simple grouping structure. Listed first is the Clause followed by the Test Group Number followed by the test's number within the group. This allows for the addition of future tests to the appropriate groups of the test suite without requiring the renumbering of the subsequent tests.

Purpose

The purpose is a brief statement outlining what the test attempts to achieve. The test is written at the functional level.

References

This section specifies all reference material *external* to the test suite, including the specific subclauses references for the test in question, and any other references that might be helpful in understanding the test methodology and/or test results. External sources are always referenced by a bracketed number (e.g., [1]) when mentioned in the test description. Any other references in the test description that are not indicated in this manner refer to elements within the test suite document itself (e.g., "Appendix 6.A", or "Table 6.1.1-1")

Resource Requirements
The requirements section specifies the test hardware and/or software needed to perform the test. This is generally expressed in terms of minimum requirements, however in some cases specific equipment manufacturer/model information may be provided.

Last Modification
This specifies the date of the last modification to this test.

Discussion
The discussion covers the assumptions made in the design or implementation of the test, as well as known limitations. Other items specific to the test are covered here.

Test Setup
The setup section describes the initial configuration of the test environment. Small changes in the configuration should be included in the test procedure.

Procedure
The procedure section of the test description contains the systematic instructions for carrying out the test. It provides a cookbook approach to testing, and may be interspersed with observable results.

Observable Results
This section lists the specific observables that can be examined by the tester in order to verify that the DUT is operating properly. When multiple values for an observable are possible, this section provides a short discussion on how to interpret them. The determination of a pass or fail outcome for a particular test is often based on the successful (or unsuccessful) detection of a certain observable.

Possible Problems
This section contains a description of known issues with the test procedure, which may affect test results in certain situations. It may also refer the reader to test suite appendices and/or whitepapers that may provide more detail regarding these issues.

Group 1: Transmitter Verification

Overview:
This group of tests verifies the transmitter's electrical specifications for 32GFC devices as defined in Clause 6 of FC-PI-6. Results for each test are dependent on the nature of the device under test (DUT), with different ranges and requirements for Hosts or Modules (transceivers).

Test #6.1.1: Nominal Bit Rate

Purpose:

- To verify that the signaling rate of the DUT's transmitter is within the conformance limit.

References:

[1] FC-PI-6 – Clause 6.1
[2] Ibid., Table 12
[3] FC-FS-4

Resource Requirements:

- See Appendix A

Last Updated:

- April 28, 2015

Discussion:

In order to ensure that a link partner's receiver can track and recover the transmitter's clock, it is important to establish a tolerance on the amount of skew that the clock can have. This is important as the recovered clock is used to make decisions about where the bit boundaries are located in the signal.

Reference [2] shows the nominal signaling rate for 32GFC with a rate tolerance of ±100 ppm for all signaling. Reference [2] also states that this may be verified by determining the time to transmit at least 200,000 bits, or 10 max length FC frames. For this test, we will test the bit rate over 200,000 transmitted bits.

Reference [3] indicates that a valid data character for 8GFC could be D21.5; for either running disparity, this is a pattern of 1010101010b. As such, for 32GFC devices, a repeating 1010 pattern will be used.

Table 1: Signaling Speed

Requirement	Host	Module
Nominal Signaling Rate	28.05 GBd	28.05GBd
Rate Tolerance	±100ppm (± 2805000 Bd)	±100ppm (± 2805000 Bd)

Test Setup:

- For Host devices, see Appendix B.1
- For Modules, see Appendix B.2

Procedure:

1. Instruct the DUT to begin sourcing 1010 continuously.
2. Configure the oscilloscope to capture the waveform.
3. Measure the average signaling rate over 200,000 bits.

Observable Results:
The average signaling rate, measured over 200,000 transmitted bits, shall be within the limits shown in Table 1.

Possible Problems:
If the DUT does not support sending the patterns above, the above measurements will be made with scrambled idle.

Test #6.1.2: Differential Output Voltage

Purpose:

- To verify that the transmitter's differential output voltage falls within the conformance limits.

References:

[1] FC-PI-6 Clause 6.3
[2] Ibid., Table 13
[3] FC-MSQS-2 Clause 3

Resource Requirements:

- See Appendix A

Last Update:

- May 15, 2015

Discussion:
Requirements for peak-to-peak differential output voltage limits are defined by reference [2]. The measurements will be taken using an oscilloscope's peak-to-peak measurement. This to-peak measurement will provide the desired value for differential output voltage. The pattern used should be a square wave. Given the encoding scheme for 32GFC as 256/257B, which involves encoding four 64/66B words, a square wave shall consist of a 1111111100000000 (eight ones, eight zeros).

Table 2: Differential Output Voltage Requirements

Requirement	Host	Module
Maximum Differential Output Voltage	900 mV	900 mV

Test Setup:

- For Host devices, see Appendix B.1
- For Modules, see Appendix B.2

Procedure:

1. Configure the oscilloscope to record a waveform.
2. Instruct the DUT to source square wave.
3. Capture the waveform data on the oscilloscope.

Observable Results:
The eye diagram measured from the transmitter should provide measurements that fall within the conformance limits provided above in Table 4.

Possible Problems:
If the DUT does not support sending the patterns above, the above measurements will be made with scrambled idle. The results will be marked INFORMATIVE only.

Test #6.1.3: Rise and Fall Times

Purpose:

- To verify the transmitter's transition between logic levels (using 20% and 80% of signal as delimiters) falls within the conformance limits.

References:

[1] FC-PI-6 Clause 6.3
[2] Ibid., Table 13
[3] FC-MSQS-2 Clause 3

Resource Requirements:

- See Appendix A

Last Update:

- April 28, 2015

Discussion:

This test verifies that the rise and fall times of the signal are at least those defined by reference [2]. Rise and fall times for Fibre Channel technologies are defined by the transition between 20% and 80% of the mean values for logic one and logic zero. Reference [3] defines patterns used by 32GFC for certain test conditions. While source transition testing does not have a pattern explicitly designated to it by reference [3], similar tests are defined using an alternating 0101 pattern. For the purposes of this test, a clock pattern, 0101, will be used.

Table 3: Minimum Rise and Fall Times

Requirements	Host	Modules
Minimum Transition Time (20%-80%)	10 ps	9.5 ps

Test Setup:

- For Host devices, see Appendix B.1
- For Modules, see Appendix B.2

Procedure:

1. Configure the oscilloscope to record an eye diagram.
2. Instruct the DUT to transmit 0101 continuously.
3. Capture the waveform data on the oscilloscope.
4. Measure the rise time and fall time, separately, from 20% and 80% of the mean values of logic one and logic zero.
5. Repeat steps two through four using square wave.

Observable Results:

The values obtained shall meet the requirements in Table 6.

Possible Problems:
If the DUT does not support sending the patterns above, the above measurements will be made with scrambled idle. The results will be marked INFORMATIVE only.

Test #6.1.4: Eye Height and Width

Purpose:

- To verify that the height and width of the transmitted electrical signal's eye diagram falls within the conformance limits.

References:

[1] FC-PI-6 Clause 6.3
[2] Ibid., Table 13
[3] FC-MSQS-2 Clause 3
[4] Ibid., Figure 3.12

Resource Requirements:

- See Appendix A

Last Update:

- April 28, 2015

Discussion:

The transmitter pulse shape characteristics are specified through analysis of the transmitter eye diagram, shown in reference [3]. Specifications given for signal quality are given in terms of Eye Height and Eye Width, and those limits are provided in reference [2]. Specific test procedures and further description of the test methods are given by reference [3]. Test patterns to be used to measure the Eye Height and Eye Width for 32GFC are provided by reference [3]. Once the waveforms are captured, normalized cumulative distribution functions of the signals are constructed to a probability of 10^{-6}. Reference [4] provides the following diagram to define the measurement points for both EH6 and EW6.

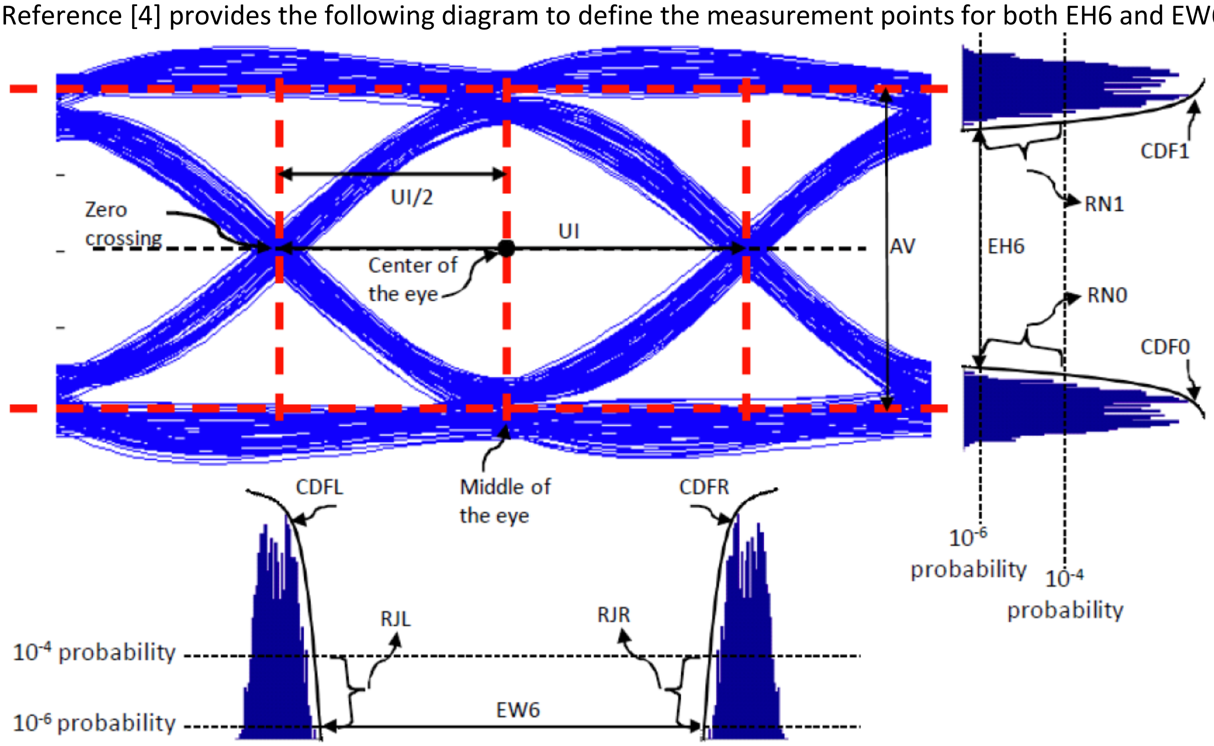


Figure 1: Eye Height and Width Measurement Points

Once EH6 and EW6 are calculated, those values must fall within the following values:

Table 4: Eye Height and Width Measurement Requirements

Requirement	Host	Module
Eye Width (EW6)	> 0.46 UI	> 0.65 UI
Eye Height (EH6)	> 50 mV	> 250 mV

Test Setup:

- For Host devices, see Appendix B.1
- For Modules, see Appendix B.2

Procedure:

1. Configure the Oscilloscope to record an eye diagram.
2. Instruct the DUT to source PRBS9.
3. Capture the waveform data and measure the eye height and eye width of the signal.

Observable Results:

The eye diagram measured from the transmitter should provide measurements that fall within the conformance limits provided above in Table 2.

Possible Problems:

If the DUT does not support sending the patterns above, the above measurements will be made with scrambled idle. The results will be marked INFORMATIVE only.

Test #6.1.5: Vertical Eye Closure (Modules Only)

Purpose:

- To verify the vertical eye closure of a module is within conformance limits.

References:

[1] FC-PI-6 Clause 6.3
[2] Ibid., Table 13
[3] FC-MSQS-2 Clause 3

Resource Requirements:

- See Appendix A

Last Update:

- April 28, 2015

Discussion:

The transmitter pulse shape characteristics are specified through analysis of the transmitter eye diagram, shown in reference [3]. For modules, vertical eye closure is defined by reference [3] as the following:

$$VEC = 20\log\frac{AV}{EH6}$$

In this equation, AV is the eye amplitude of the equalized waveform. This is defined as the mean value of logic one minus the mean value of logic zero in the central 5% of the eye. The following image from reference [3] defines, visually, the measurement for both AV and EH6.

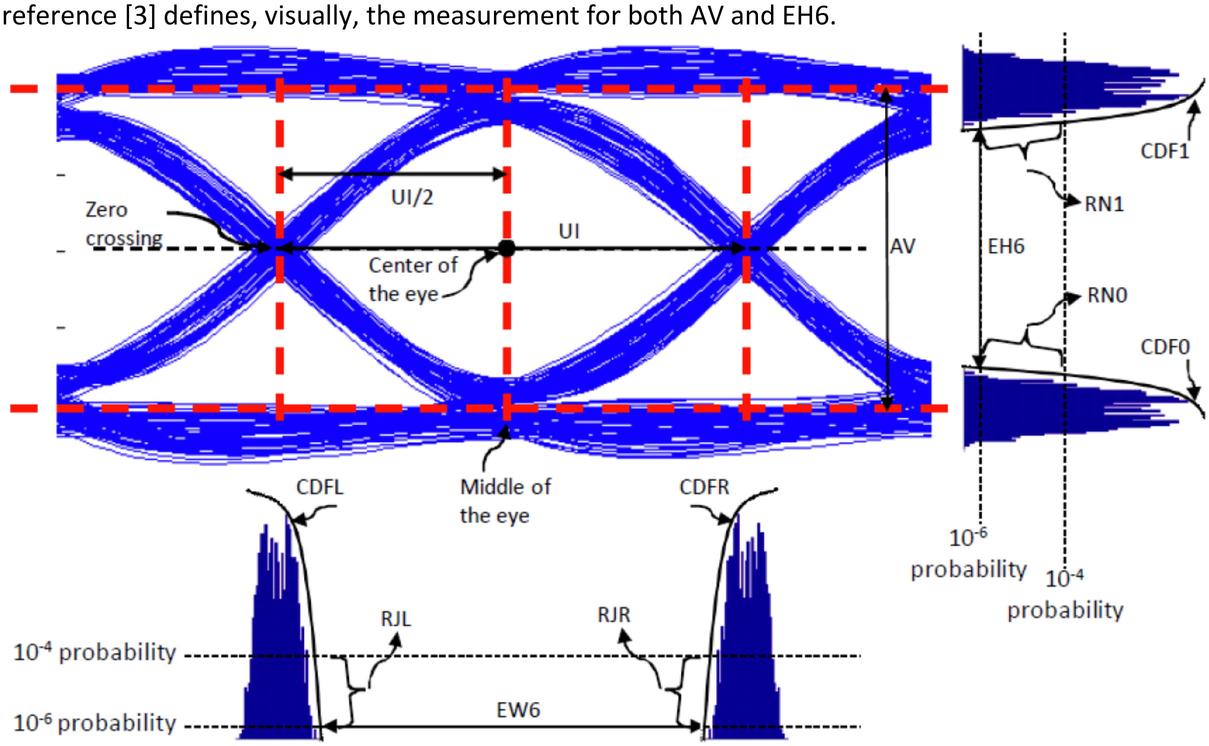


Figure 2: Eye Diagram Measurement Points

Notice that EH6 is the same measurement taken in test 6.1.2 Once VEC is calculated, the value must fall below the value given below.

Table 5: Maximum VEC Allowance

Requirements	Modules
Maximum VEC	4 dB

Test Setup:

- See Appendix B.2.

Procedure:

1. Configure the oscilloscope to record an eye diagram.
2. Configure the DUT to transmit PRBS9.
3. Capture the waveform data on the oscilloscope.
4. Calculate VEC.

Observable Results:
The calculated value of VEC shall not exceed the value listed in Table 3.

Possible Problems:
If the DUT does not support sending the patterns above, the above measurements will be made with scrambled idle. The results will be marked INFORMATIVE only.

Test #6.1.6: Common Mode Noise, RMS (Host Devices Only)

Purpose:

- To verify the transmitter's common mode noise falls within the conformance limits.

References:

[1] FC-PI-6 Clause 6.3
[2] Ibid., Table 13
[3] FC-MSQS-2 Clause 3

Resource Requirements:

- See Appendix A

Last Update:

- May 15, 2015

Discussion:

Reference [2] indicates the range of common mode noise that the transmitter is allowed. The common mode voltage is defined as the addition of the V+ and V- signals. The RMS voltage waveform produced from this addition must fall within the RMS common mode voltages specified by reference [2]. Patterns and specific methodologies used in this test are dictated by reference [3]. In order to account for instrumentation noise, the following equation should be used, where N_{CM} is half the RMS value of the vertical histogram of the signal:

$$N_{cm} = \sqrt{measured_{N\,CM}^{\;2} - instrumentation_{Noise}^{2}}$$

Table 6: RMS Common Mode Noise Allowances

Requirement	Host
Module RMS Common Mode Noise Ceiling	17.5mV
Host RMS Common Mode Noise Ceiling	17.5mV

Test Setup:

- For Host devices, see Appendix B.1

Procedure:

1. Configure the oscilloscope to capture the waveform in common mode.
2. Without transmitting data, record the RMS voltage of the instrument's inherent noise.
3. Instruct the DUT to source PRBS9.
4. Measure the RMS voltage of the signal.
5. Apply the equation listed above.

Observable Results:

The value provided – Ncm – shall not exceed the values listed in Table 5, provided by reference [2].

Possible Problems:

If the DUT does not support sending the patterns above, use PRBS9. If the DUT does not support PRBS9 or PRBS 31, the above measurements will be made with scrambled idle. In either case, the results will be marked INFORMATIVE only.

Group 2: Transmitter Return Loss Verification

Overview:
This group of tests verifies the return loss specifications of 32GFC devices as defined in Clause 6 of FC-PI-6.

Test #6.2.1: Transmitter Differential Return Loss (SDD22)

Purpose:

- To verify the differential mode return loss of the DUT's transmitter is within the conformance limits.

References:

[1] FC-PI-6 Clause 6.3, 6.6
[2] Ibid., Table 13
[3] FC-MSQS-2 Clause 3

Resource Requirements:

- See Appendix A

Last Updated:

- April 28, 2015

Discussion:

Reference [1] defines the return loss specifications for electrical interfaces. FC-PI-6 defines the differential mode return loss as the following equations:

$$SDD11, SDD22\ (dB) = \begin{cases} -11 & 0.05 < f < 4\ GHz \\ -6.0 + 9.2\log_{10}\left(\frac{f}{14.025GHz}\right) & 4 < f < 28.05\ GHz \end{cases}$$

A device is conformant if it does not violate the spectral limit line specified by reference [1]. Reference [2] designates the same process for both modules and host devices.

Test Setup:

- See Appendix B.3 for Return Loss setup.

Procedure:

1. Connect the DUT to the VNA.
2. Instruct the DUT to source PRBS 9 continuously.
3. Measure the differential mode return loss of the DUT transmitter.

Observable Results:

The differential mode return loss of the DUT transmitter device shall be fall within the conformance limits defined by the spectral line limit, and the equation listed in the *discussion.*

Possible Problems:

If the DUT does not support transmitting PRBS9, then the test will be performed using scrambled idle.

Test #6.2.2: Common Mode Return Loss (SCC22)

Purpose:

- To verify the common mode return loss of the DUT's transmitter is within the conformance limits.

References:

[1] FC-PI-6 Clause 6.3, 6.6
[2] Ibid., Table 13
[3] FC-MSQS-2 Clause 3

Resource Requirements:

- See Appendix A

Last Updated:

- April 28, 2015

Discussion:

Reference [1] defines the return loss specifications for electrical interfaces. FC-PI-6 defines the common mode return loss requirements at a maximum loss of 2dB for both modules and host devices for all frequencies between 250MHz and 30GHz.

Test Setup:

- See Appendix B.3 for Return Loss setup.

Procedure:

1. Connect the DUT to the VNA.
2. Instruct the DUT to source PRBS 9 continuously.
3. Measure the differential mode return loss of the DUT transmitter.

Observable Results:

The common mode return loss of the DUT transmitter device shall be under 2dB at all frequencies between 250MHz and 30GHz.

Possible Problems:

If the DUT does not support transmitting PRBS9, then the test will be performed using scrambled idle.

Test #6.2.3: Common Mode to Differential Mode Conversion Ratio (SDC22)

Purpose:

- To verify the common mode to differential mode conversion ratio of the DUT's transmitter is within the conformance limits.

References:

[1] FC-PI-6 Clause 6.3, 6.6
[2] Ibid., Table 13
[3] FC-MSQS-2 Clause 3

Resource Requirements:

- See Appendix A

Last Updated:

- April 28, 2015

Discussion:

Reference [1] defines the common mode to differential mode conversion ratio, SDC22, limits throughout the frequency spectrum for 32GFC devices. These limits are intended to limit the amount of unwanted signal energy that is generated due to conversion of common mode voltage to differential mode voltage. A device is conformant if it does not violate the spectral limit line specified by reference [1]. Reference [2] designates the same process for both modules and host devices. The equation used to define these limits is as follows:

$$SCD22, SDC22\ (dB) = \begin{cases} -25 + 20\left(\dfrac{f}{28.05\ GHz}\right) & 0.05 < f < 4\ GHz \\ -18 + 6\left(\dfrac{f}{28.05\ GHz}\right) & 4 < f < 28.05\ GHz \end{cases}$$

Test Setup:

- See Appendix B.3 for Return Loss setup.

Procedure:

1. Connect the DUT to the VNA.
2. Instruct the DUT to source PRBS 9 continuously.
3. Measure the differential mode return loss of the DUT transmitter.

Observable Results:

The differential mode return loss of the DUT transmitter device shall be fall within the conformance limits defined by the spectral line limit, and the equation listed in the *discussion.*

Possible Problems:

If the DUT does not support transmitting PRBS9, then the test will be performed using scrambled idle.

Test #6.2.4: Differential Mode to Common Mode Conversion Ratio (SCD22)

Purpose:

- To verify the common mode to differential mode conversion ratio of the DUT's transmitter is within the conformance limits.

References:

[1] FC-PI-6 Clause 6.3, 6.6
[2] Ibid., Table 13
[3] FC-MSQS-2 Clause 3

Resource Requirements:

- See Appendix A

Last Updated:

- April 28, 2015

Discussion:

Reference [1] defines the differential mode to common mode conversion ratio, SCD22, limits throughout the frequency spectrum for 32GFC devices. These limits are intended to limit the amount of unwanted signal energy that is generated due to conversion of differential mode voltage to common mode voltage. A device is conformant if it does not violate the spectral limit line specified by reference [1]. Reference [2] designates the same process for both modules and host devices. The equation used to define these limits is as follows:

$$SCD22, SDC22\ (dB) = \begin{cases} -25 + 20\left(\dfrac{f}{28.05\ GHz}\right) & 0.05 < f < 4\ GHz \\ -18 + 6\left(\dfrac{f}{28.05\ GHz}\right) & 4 < f < 28.05\ GHz \end{cases}$$

Test Setup:

- See Appendix B.3 for Return Loss setup.

Procedure:

1. Connect the DUT to the VNA.
2. Instruct the DUT to source PRBS 9 continuously.
3. Measure the differential mode return loss of the DUT transmitter.

Observable Results:

The differential mode return loss of the DUT transmitter device shall be fall within the conformance limits defined by the spectral line limit, and the equation listed in the *discussion.*

Possible Problems:

If the DUT does not support transmitting PRBS9, then the test will be performed using scrambled idle.

Appendix A: Hardware Requirements, Test Fixtures

Purpose:

- To specify the measurement hardware, test fixtures, and setups used in this test suite.

References:

[1] FC-PI-6 Clause 6
[2] FC-MSQS-2

Last Updated:

- May 15, 2015

A.1 – Introduction

Clause 6 of FC-PI-6, as well as FC-MSQS-2, defines test fixtures and methods required for performing the physical layer tests covered in this test suite. The purpose of this appendix is to present a reference implementation of these fixtures and methods, as well as to specify the test equipment necessary to complete the tests.

A.2 – Test Fixture Requirements

FC-PI-6 clearly defines requirements for test fixtures necessary for testing of modules and host devices. The UNH-IOL employs the use of and Host Compliance Board (HCB) and Module Compliance Board (MCB) from *Wilder Technologies*:

Functional Block	Equipment
HCB Test Fixture	Fibre Channel HCB Test Adapter FC16-TPA-HCB-P
MCB Test Fixture	Fibre Channel MCB Test Adapter FC16-TPA-MCB-R

Each of these devices converts the appropriate output SFP connection to SMA, as well as input SMA to input SFP, appropriately.

Figure 2: SFP to SMA Test Fixtures

Appendix B: Test Setup

Purpose:

- To define the test and calibration setups used throughout the test suite.

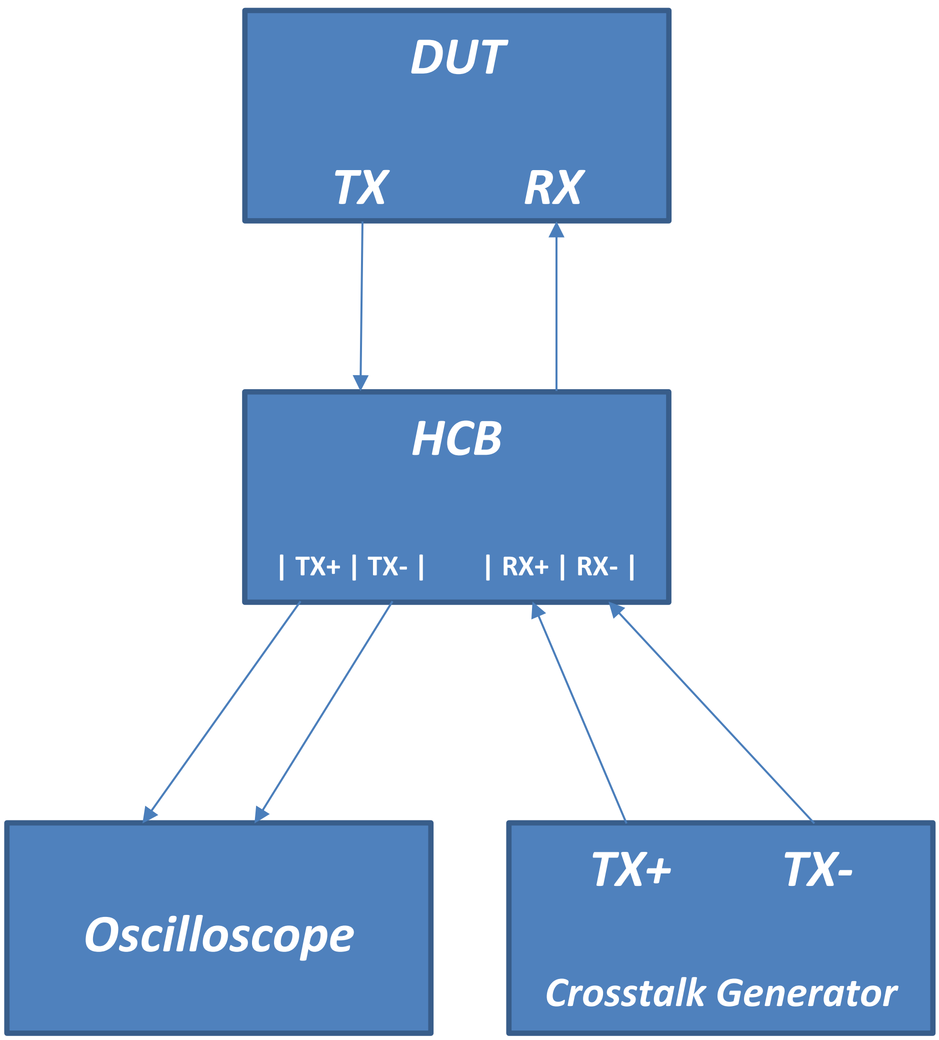
References:

[1] FC-MSQS-2 Clause 3

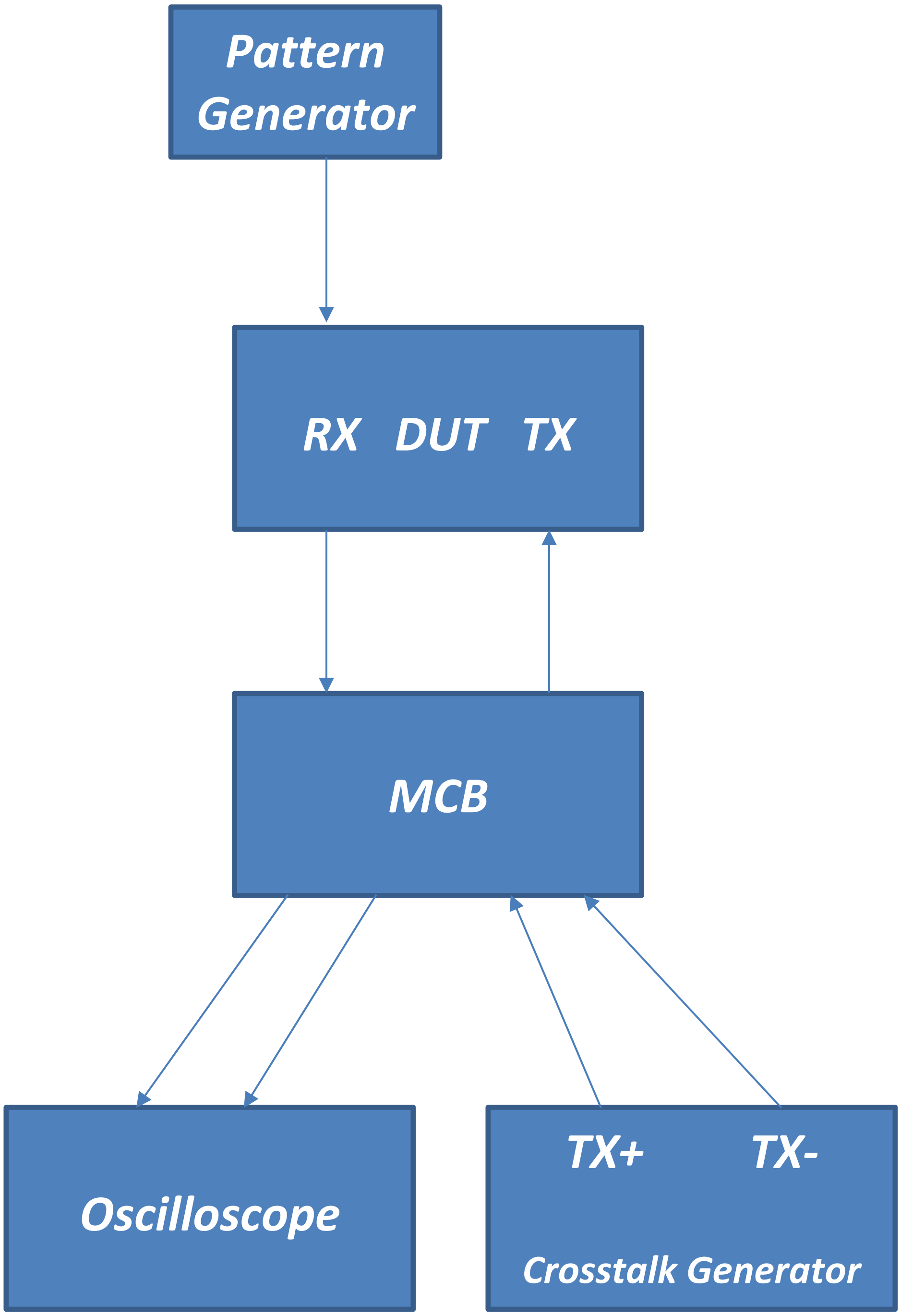
Last Updated:

- April 28, 2015

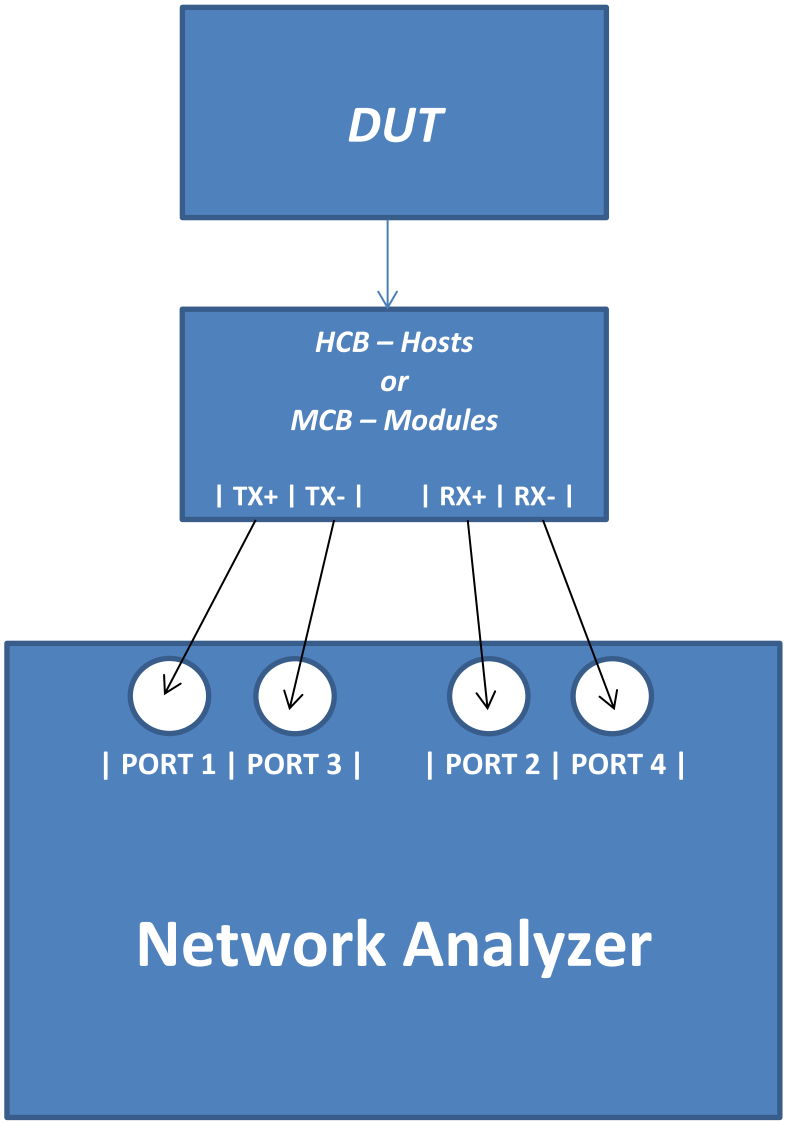
B.1 – Host Compliance Test Setup



B.2 – Module Compliance Test Setup



B.3 – Return Loss Verification Test Setup



Return Loss Setup for both Hosts and Modules. The HCB will be used with Hosts; the MCB will be used with Modules. Port assignments remain the same for both Hosts and Modules.