Fibre Channel Consortium

FC-PI-5 Clause 9
Electrical Physical Layer Test Suite
Version 2.1

Technical Document

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Modification Record

- January 7, 2010 – Version 1.0 – Release
  Joshua Beaudet: Based off of Version 1.2 of FC-PI-2 Electrical Test Suite. Addition of 8G and 16G speeds and removal of 2G and lower speeds.
- June 29, 2010 – Version 1.0
  Joshua Beaudet: Fixed various grammatical errors and missing tables based on comments by Mikkel Hagen.
- August 24, 2011 – Version 2.0
  Joshua Beaudet: Updated required test patterns for 16G testing.
- March 3, 2015 – Version 2.1
  Daniel Gray: Updated the test suite to match current revisions of FC Standards. Editorial changes made throughout the document.

- The University of New Hampshire
  InterOperability Laboratory

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Joshua Beaudet	University of New Hampshire
Andy Baldman	University of New Hampshire
Mikkel Hagen	University of New Hampshire

- The University of New Hampshire
InterOperability Laboratory

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 optical Fibre Channel products.

These tests are designed to determine if a Fibre Channel product conforms to specifications defined in **Clause 9** of the **FC-PI-5 Rev 6.10** Fibre Channel Standard (hereafter referred to as "**FC-PI-5**"). The test also covers information relating to **FC-MJSQ Rev 14.1** Fibre Channel Standard (hereafter referred to as "**FC-MJSQ**"). The test also covers information relating to **FC-MSQS Rev 3.2** Fibre Channel Standard (hereafter referred to as "**FC-MSQS**"). The test also covers information relating to **FC-FS-3 Rev 0.92** Fibre Channel Standard (hereafter referred to as "**FC-FS-3**"). 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 for 4G, 8G, 16G Fibre Channel devices, as defined in Clause 9 of FC-PI-5. Depending on the device under test, certain tests may be run using two sets of circumstances for compliance. Please refer to Appendix C for more information.

Test #9.1.1: Nominal Bit Rate

Purpose:

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

References:

[1] FC-PI-5 - Clause 9
[2] Ibid., Table 21
[3] FC-FS-3 Table 4
[4] FC-MSQS – Clause 9.2

Resource Requirements:

- See Appendix C

Last Updated: September 30, 2014

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 since the recovered clock is used to make decisions about where the bit boundaries are located in the signal. Reference [2] shows the nominal signaling rates for each link speed with a rate tolerance of ± 100 ppm, for both single ended and differential signaling. Furthermore, note 2 of reference [2] indicates that this tolerance must be maintained over a period of 200,000 transmitted bits, which is approximately ten maximum length FC frames. Reference [3] refers to various valid data characters including D21.5. D21.5 for either running disparity is a pattern of 1010101010b.

For 16GFC devices using 64B66B encoding, reference [5] describes patterns to used when testing devices configured for 16GFC speeds.

Table 1 - Signaling Speeds

	4GFC	**8GFC**	**16GFC**
Nominal Signaling Rate	4.25 GBd	8.5 GBd	14.025 GBd
Rate Tolerance	± 100ppm (± 425000 Bd)	± 100ppm (± 850000 Bd)	± 100ppm (± 1402500 Bd)

Test Setup:

The DUT should be setup as defined in Appendix A. Configure the DUT for the appropriate speed. The DUT should be transitioned into the monitoring (port-bypassed) state or the active state.

Procedure:

For 4GFC and 8GFC:

1) Instruct the Testing Station or DUT to begin sourcing D21.5 continuously.
2) Measure the average TX signaling speed. The measurement should be made over a length of at least 200,000 transmitted bits.

For 16GFC:

1) Instruct the Testing Station or DUT to begin sourcing a repeating 1010 pattern.
2) Measure the average TX signaling speed. The measurement should be made over a length of at least 200,000 transmitted bits.

Observable Results:

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

Possible Problems: For 4GFC and 8GFC, if the DUT does not support sending of the above patterns, then the above measurements will be made with a set of continuous IDLE primitives or ARB(FF,FF) Primitives. For 16GFC devices, if sending the above patterns are not possible, the above measurements will be made with scrambled idle.

Test #9.1.2: Voltage Modulation Amplitude

Purpose:
- To verify that the differential output voltage of the DUT's transmitter device is within the conformance limits.

References:
[1] FC-PI-5 - Clause 9
[2] Ibid., Table 22
[3] Ibid., Clause 9.5: Table 33
[4] FC-MSQS

Resource Requirements:
- See Appendix C

Last Updated: March 3, 2015

Discussion:
Reference [2] states the minimum and maximum voltage required for a device. Reference [3] states the requirements for 8GFC devices at the Beta and Epsilon Interoperability Points. Reference [4] refers to various valid data characters including K28.7. K28.7 is a special character that transmits a pattern of 0011111000 for both positive and negative running disparities.
For 16GFC devices using 64B66B encoding, reference [4] describes patterns to used when testing devices configured for 16GFC speeds.

Table 2 - Differential Output Voltage Requirements

	4GFC		**8GFC**		**16GFC**	
Compliance Point	Min DOV	Max DOV	Min DOV	Max DOV	Min DOV	Max DOV
β_T	310mV	1.6V	N/A	1.2 V	N/A	N/A
δ_T	650mV	1.6V	180 mV	700 mV	180mV	700mV
γ_T	310mV	1.6V	N/A	N/A	N/A	N/A
ε_T	N/A	N/A	N/A	1.2V	N/A	N/A

Test Setup:
The DUT should be setup as defined in Appendix A. Configure the DUT for the appropriate speed. The DUT should be transitioned into the monitoring (port-bypassed) state or the active state.

Procedure:
For 4GFC and 8GFC:
1) Instruct the Testing Station or DUT to begin sourcing K28.7 continuously.
2) Capture the waveform on the oscilloscope and compute the differential output voltage.

For 16GFC:

1) Instruct the Testing Station or DUT to begin sourcing a Square wave pattern.
2) Capture the waveform on the oscilloscope and compute the differential output voltage.

Observable Results:

The differential output voltage shall fall within the limits in Table 2.

Possible Problems: For 4GFC and 8GFC, if the DUT does not support sending of the above patterns, then the above measurements will be made with a set of continuous IDLE primitives or ARB(FF,FF) Primitives. For 16GFC devices, if sending the above patterns are not possible, the above measurements will be made with scrambled idle.

Test #9.1.3: Rise and Fall Times

Purpose:
- To verify that the rise and fall times of the DUT's transmitter are within the conformance limits.

References:
[1] FC-PI-5 - Clause 9
[2] Ibid., Table 22
[3] FC-FS-3 Table 4
[4] FC-MSQS – Clause 9.2

Resource Requirements:
- See Appendix C

Last Updated: January 21, 2010

Discussion:
Reference [2] specifies the TX signal characteristics for Fibre Channel electrical devices. This specification includes conformance and informative specifications for the minimum rise/fall times of the transmitter device. Reference [2], note 8 specifies that these values are informative.

The specification states that the rise/fall times are to be measured from 20% to 80% of the transition while transmitting the D21.5 data codeword on the physical link. (Note that part of the CJTPAT test pattern may be used for this purpose). Reference [3] refers to various valid data characters including D21.5. D21.5 for either running disparity is a pattern of 1010101010b. For 16GFC devices using 64B66B encoding, reference [4] describes patterns to used when testing devices configured for 16GFC speeds.

Table 3 - Rise/Fall Time Values

	4GFC		**8GFC**		**16GFC**	
Compliance Point	Min Rise/Fall Time(ps)	Max Rise/Fall Time(ps)	Min Rise/Fall Time(ps)	Max Rise/Fall Time(ps)	Min Rise/Fall Time(ps)	Max Rise/Fall Time(ps)
β_T	60	N/A	40	N/A	N/A	N/A
δ_T	N/A	N/A	N/A	N/A	N/A	N/A
γ_T	60	N/A	N/A	N/A	N/A	N/A
ε_T	N/A	N/A	40	N/A	24	N/A

Test Setup:
The DUT should be setup as defined in Appendix A. Configure the DUT for the appropriate speed. The DUT should be transitioned into the monitoring (port-bypassed) state or the active state.

Procedure:

For 4GFC:

1) Instruct the Testing Station or DUT to begin sourcing PRBS9 continuously.
2) Measure the rise and fall times.

For 8GFC:

1) Instruct the Testing Station or DUT to begin sourcing JSPAT continuously.
2) Measure the rise and fall times.

For 16GFC:

1) Instruct the Testing Station or DUT to begin sourcing a repeating PRBS31 pattern.
2) Measure the rise and fall times.

Observable Results:

The rise/fall times, of the worst value measured, shall fall within the limits set in Table 3.

Possible Problems:

This test must be run with the D21.5 test pattern to eliminate the effects of pre-compensation. The measurements are to be made using an oscilloscope with a bandwidth including probes of at least 1.8 times the baud rate. If the DUT does not support sending of the above patterns, then the above measurements will be made with a set of continuous IDLE primitives or ARB(FF,FF) Primitives and marked as INFORMATIVE.

For 16GFC devices using 64B66B encoding, this test must be run with a repeating 1010 pattern. If the DUT does not support sending of the above patterns, the the above measurements will be made using scrambled idle and results will be marked as INFORMATIVE.

Test #9.1.4: Transmitter Eye Mask

Purpose:

- To verify that the transmitter eye of the DUT, at the Delta Interoperability Point, is within the conformance limits.

References:

[1] FC-PI-5 - Clause 9
[2] Ibid., Table 22
[3] Ibid., Clause 9.5.2 Figure 38
[4] FC-MSJQ
[5] FC-MSQS – Clause 9

Resource Requirements:

- See Appendix C

Last Updated: September 30, 2014

Discussion:

The transmitter pulse shape characteristics are specified in the form of a mask of the transmitter eye diagram, shown in reference [3]. The DUT must conform to this mask. The points used to create this mask are found in reference [2]. The transmitter is required to fit the absolute eye mask only. For 4GFC devices, patterns used are defined by reference [4], while patterns for 8GFC and 16GFC are defined by reference [5].

Test Setup:

The DUT should be setup as defined in Appendix A. Configure the DUT for the appropriate speed. The DUT should be transitioned into the monitoring (port-bypassed) state or the active state.

Procedure:

For 4GFC:

1) For 4G instruct the Testing Station or DUT to begin sourcing CJTPAT continuously. For 16G instruct the Testing Station or DUT to begin sourcing PRBS9.
2) Configure the oscilloscope to capture the waveform data and place these waveforms into the normalized and absolute mask definitions.
3) Process the captured waveform, observing the number of mask violations.
4) Repeat steps 1 through 3 for 4G with CRPAT and CSPAT. Repeat steps 1 through 3 for 16G with PRBS31, Square wave, and Scrambled idle.

For 8GFC:

1) For 8G instruct the Testing Station or DUT to begin sourcing JSPAT.
2) Configure the oscilloscope to capture the waveform data and place these waveforms into the normalized and absolute mask definitions.
3) Process the captured waveform, observing the number of mask violations.

For 16GFC:

1) Instruct the Testing Station or DUT to begin sourcing PRBS31.
2) Configure the oscilloscope to capture the waveform data and place these waveforms into the normalized and absolute mask definitions.
3) Process the captured waveform, observing the number of mask violations.

Observable Results:
All of the waveforms shall not violate the absolute eye mask at any point for any test case.

Possible Problems: For 4GFC and 8GFC devices, if the DUT does not support sending of the above patterns, then the above measurements will be made with a set of continuous IDLE primitives or ARB(FF,FF) Primitives and marked as INFORMATIVE. For 16GFC devices, if the DUT does not support sending of the above patterns, then the above measurements will be made using scrambled idle, and the the results marked as INFORMATIVE.

Test #9.1.5: Transmitter Jitter

Purpose:
- To verify that the jitter of the DUT's transmitter, at the Delta Interoperability Point, is within the conformance limits.

References:
[1] FC-PI-5- Clause 9
[2] Ibid., Table 29
[3] FC-MJSQ
[4] FC-MSQS – Clause 9

Resource Requirements:
- See Appendix C

Last Updated: August 24, 2011

Discussion:
Reference [2] describes the maximum deterministic and total transmit jitter for electrical devices. The total jitter is the sum of deterministic and random jitter. These jitter values are specified at the 10^{-12} probability. Patterns to be used in this test are defined in reference [3] for 4GFC, and reference [4] for 8GFC and 16GFC devices.

Table 4 - Transmit Jitter Requirements

	400-DF-EL-S		800-DF-EL-S		1600-DF-EA-S		1600-DF-EL-S	
Compliance	DJ (UI)	TJ (UI)	DJ (UI)	TJ (UI)	DJ (UI)	TJ (UI)	DJ (UI)	TJ (UI)
β_T	0.33	0.52	N/A	N/A	N/A	N/A	N/A	N/A
δ_T	0.14	0.26	0.17	0.31	N/A	0.24	0.31	0.45
γ_T	0.37	0.57	N/A	N/A	N/A	N/A	N/A	N/A
ε_T	N/A	N/A	N/A	N/A	N/A	0.24	N/A	N/A

Test Setup:
The DUT should be setup as defined in Appendix A. Configure the DUT for the appropriate speed. The DUT should be transitioned into the monitoring (port-bypassed) state or the active state.

Procedure:

For 4GFC:
1) For 4G instruct the Testing Station or DUT to begin sourcing CJTPAT continuously. For 8G
2) Capture the waveform on the oscilloscope and computer the jitter values.
3) Repeat steps 1 and 2 for 4G with CRPAT and CSPAT.

For 8GFC:

1) instruct the Testing Station or DUT to begin sourcing JSPAT.
2) Capture the waveform on the oscilloscope and computer the jitter values.

For 16GFC:

1) Instruct the Testing Station or DUT to begin sourcing PRBS9.
2) Capture the waveform on the oscilloscope and computer the jitter values.
3) Repeat steps 1 and 2 using PRBS31 and Scrambled Idle.

Observable Results:
The deterministic and total jitter, of the worst value measured, shall be less than the values shown in Table 4.

Possible Problems: For 4GFC and 8GFC devices, if the DUT does not support sending of the above patterns, then the above measurements will be made with a set of continuous IDLE primitives or ARB(FF,FF) Primitives and marked as INFORMATIVE. For 16GFC devices, if the DUT does not support sending of the above patterns, then the above measurements will be made with scrambled idle and the results will be marked as INFORMATIVE.

Test #9.1.6: Transmitter RMS Common Mode Voltage

Purpose:

- To verify that the RMS common mode voltage of the DUT's transmitter is within the conformance limits.

References:

[1] FC-PI-5 - Clause 9
[2] Ibid., Table 22
[3] FC-FS-3 Table 4

Resource Requirements:

- See Appendix C

Last Updated: January 21, 2010

Discussion:

Reference [2] describes the maximum common mode voltage the transmitter shall produce. The common mode voltage is defined as the addition of the V+ and V- signals. The RMS voltage waveform produced from this addition shall never surpass the maximum RMS common mode voltage specified at any point. Reference [3] refers to various valid data characters including D21.5. D21.5 for either running disparity is a pattern of 1010101010b.

Table 5 - Transmit RMS Common Mode Voltage Requirements

	4GFC	**8GFC**		**16GFC**	
Compliance Point	400-DF-EL-S	800-DF-EL-S	800-DF-EA-S	1600-DF-EL-S	1600-DF-EA-S
β_T	30mV	N/A	30mV	N/A	N/A
δ_T	30mV	30mV	30mV	30mV	30mV
γ_T	30mV	N/A	N/A	N/A	N/A
ε_T	N/A	N/A	30mV	N/A	30mV

Test Setup:

The DUT should be setup as defined in Appendix A. Configure the DUT for the appropriate speed. The DUT should be transitioned into the monitoring (port-bypassed) state or the active state.

Procedure:

For 4GFC and 8GFC:

1) Instruct the Testing Station or DUT to begin sourcing D21.5 continuously.
2) Configure the oscilloscope to capture the waveform data and compute the RMS common mode voltage.

For 16GFC:

1) Instruct the Testing Station or DUT to begin sourcing a repeating 1010 pattern.
2) Configure the oscilloscope to capture the waveform data and compute the RMS common mode voltage.

Observable Results:

The RMS common mode voltage shall never exceed the values defined in Table 5.

Possible Problems:

This test must be run with the D21.5 test pattern – or a repeating pattern of 1010 for 16GFC devices using 64B66B encoding – to eliminate the effects of pre-compensation. The measurements are to be made using an oscilloscope with a bandwidth including probes of at least 1.8 times the baud rate. If the DUT does not support sending of the above patterns, then the above measurements will be made with a set of continuous IDLE primitives or ARB(FF,FF) Primitives – or scrambled idle for 16GFC devices – and results will be marked as INFORMATIVE.

Test #9.1.7: Transmitter Waveform Distortion Penalty (TWDP) (8GFC Only)

Purpose:

- To verify that the WDP of the DUT's transmitter is within the conformance limits.

References:

[1] FC-PI-5 - Clause 9
[2] Ibid., Table 31
[3] FC-MSQS Clause 2
[4] Ibid., Clause 4
[5] Ibid., Clause 9

Resource Requirements:

- See Appendix C

Last Updated: August 24, 2011

Discussion:

[1] TWDP is a measure of the deterministic penalty of the waveform from a particular transmitter and reference emulated multimode fibers or metallic media, with a reference receiver. Patterns for this test are defined by reference [3].

Table 6 - Transmit WDP Requirements

	8GFC		
Compliance Point	Case 1 (dBe)	Case 2 (dBe)	Case 3 (dBe)
β_T	7.1	10.5	N/A
δ_T	N/A	N/A	N/A
γ_T	N/A	N/A	N/A
ε_T	7.1	10.5	15.4

Test Setup:

The DUT should be setup as defined in Appendix A. Configure the DUT for the appropriate speed. The DUT should be transitioned into the monitoring (port-bypassed) state or the active state.

Procedure:

1) Instruct the Testing Station or DUT to begin sourcing JSPAT continuously.
2) Configure the oscilloscope to capture the waveform data and compute the WDP using the Matlab code defined in the FC-MSQS.

Observable Results:

The WDP shall never exceed the values defined in Table 6.

Possible Problems:

If the DUT does not support sending of the above patterns, then the above measurements will be made with a set of continuous IDLE primitives or ARB(FF,FF) Primitives and marked as INFORMATIVE.

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Group 2: FC Return Loss Verification

Overview:
This group of tests verifies the return loss specifications for 4G, 8G, 16G Fibre Channel devices, as defined in Clause 9 of FC-PI-5.

Test #9.2.1: Transmitter Differential Mode 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-5 - Clause 9
[2] Ibid., Table 25
[3] MJSQ – A.2.2
[4] MSQS

Resource Requirements:
- See Appendix C

Last Updated: September 30, 2014

Discussion:

Reference [2] describes the transmitter differential mode return loss specifications at all compliance points. Reference [1] describes impedance characteristics in terms of return loss instead of an impedance profile. A conformant device shall not violate the spectral limit line as specified by reference [2]. Reference [3] refers to the use of CRPAT as a FC compliant test pattern used in attaining a flat spectrum for 4GFC devices. Similarly, reference [4] refers to the use of JSPAT as a FC compliant test pattern used in attaining a flat spectrum for 8GFC devices, and PRBS 9 for 16GFC devices.

Table 6 - S parameter at the Transmit Compliance Points (SDD22)

	4GFC						**8GFC**						**16GFC**											
	400-DF-EL-S						800-DF-Ex-S						1600-DF-EL-S						1600-DF-EA-S					
Compliance Point	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)
β_T	-12	-5	0	11.3	50	3200	-10	-5.9	0	13.33	50	8500	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
δ_T	-12	-6	0	11.3	50	3200	-10	-5.9	0	13.33	50	8500	-10	-5.9	0	13.33	50	14000	-10	-5.9	0	13.33	50	14000
γT	-12	-5	0	11.3	50	3200	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
εT	N/A	N/A	N/A	N/A	N/A	N/A	-10	-5.9	0	13.33	50	8500	N/A	N/A	N/A	N/A	N/A	N/A	-10	-5.9	0	13.33	50	14000

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Test Setup:

The DUT should be setup as defined in Appendix A. Configure the DUT for the appropriate speed. The DUT should be transitioned into the monitoring (port-bypassed) state or the active state.

Procedure:

For 4GFC:

1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing CRPAT continuously.
3) Measure the differential mode return loss of the DUT transmitter device.

For 8GFC:

1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing JSPAT.
3) Measure the differential mode return loss of the DUT transmitter device.

For 16GFC:

1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing PRBS9.
3) Measure the differential mode return loss of the DUT transmitter device.

Observable Results:

The differential mode return loss of the DUT transmitter device shall be greater than L while $y(f) \leq L$, $y(f)$ while $L < y(f) < H$, and H while $H \leq y(f)$.

Possible Problems:

If the DUT does not support transmitting CRPAT for 4GFC, or JSPAT for 8GFC, this test will be performed with the DUT transmitting continuous Idle or ARB(FF,FF) Primitives. For 16GFC devices, if the DUT does not support transmitting PRBS9, the test will be performed with the DUT transmitting scrambled idle.

Test #9.2.2: Transmitter 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-5 - Clause 9
[2] Ibid., Table 25
[3] MJSQ – A.2.2
[4] MSQS

Resource Requirements:

- See Appendix C

Last Updated: September 30, 2014

Discussion:

Reference [2] describes the transmitter differential mode return loss specifications at all compliance points. Reference [1] describes impedance characteristics in terms of return loss instead of an impedance profile. A conformant device shall not violate the spectral limit line as specified by reference [2]. Reference [3] refers to the use of CRPAT as a FC compliant test pattern used in attaining a flat spectrum for 4GFC devices. Similarly, reference [4] refers to the use of JSPAT as a FC compliant test pattern used in attaining a flat spectrum for 8GFC devices, and PRBS 9 for 16GFC devices.

Table 7 - S parameter at the Transmit Compliance Points (SCC22)

	4GFC						**8GFC**						**16GFC**											
	400-DF-EL-S						800-DF-Ex-S						1600-DF-EL-S						1600-DF-EA-S					
Compliance Point	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)
βT	-6	-3	0	11.3	50	3200	-6	-3	0	13.33	50	8500	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
δT	-6	-4	0	11.3	50	3200	-6	-3	0	13.33	50	8500	-6	-3	0	13.33	50	14000	-6	-3	0	13.33	50	14000
γT	-6	-3	0	11.3	50	3200	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
εT	N/A	N/A	N/A	N/A	N/A	N/A	-6	-3	0	13.33	50	8500	N/A	N/A	N/A	N/A	N/A	N/A	-6	-3	0	13.33	50	14000

Test Setup:

The DUT should be setup as defined in Appendix A. Configure the DUT for the appropriate speed. The DUT should be transitioned into the monitoring (port-bypassed) state or the active state.

Procedure:

For 4GFC:

1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing CRPAT continuously.
3) Measure the common mode return loss of the DUT transmitter device.

For 8GFC:

1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing JSPAT.
3) Measure the common mode return loss of the DUT transmitter device.

For 16GFC:

1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing PRBS9.
3) Measure the common mode return loss of the DUT transmitter device.

Observable Results:

The common mode return loss of the DUT transmitter device shall be greater than L while $y(f) \le L$, y(f) while $L < y(f) < H$, and H while $H \le y(f)$.

Possible Problems:

If the DUT does not support transmitting CRPAT for 4GFC, or JSPAT for 8GFC, this test will be performed with the DUT transmitting continuous Idle or ARB(FF,FF) Primitives. For 16GFC devices, if the DUT does not support transmitting PRBS9, the test will be performed with the DUT transmitting scrambled idle.

Test #9.2.3: Receiver Differential Mode Return Loss (SDD11)

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

References:
[1] FC-PI-5 - Clause 9
[2] Ibid., Table 25
[3] MJSQ – A.2.2
[4] MSQS

Resource Requirements:
- See Appendix C

Last Updated: September 30, 2014

Discussion:
Reference [2] describes the transmitter differential mode return loss specifications at all compliance points. Reference [1] describes impedance characteristics in terms of return loss instead of an impedance profile. A conformant device shall not violate the spectral limit line as specified by reference [2]. Reference [3] refers to the use of CRPAT as a FC compliant test pattern used in attaining a flat spectrum for 4GFC devices. Similarly, reference [4] refers to the use of JSPAT as a FC compliant test pattern used in attaining a flat spectrum for 8GFC devices, and PRBS 9 for 16GFC devices.

Table 8 - S parameter at the Transmit Compliance Points (SDD11)

	4GFC						8GFC						16GFC											
	400-DF-EL-S						800-DF-Ex-S						1600-DF-EL-S						1600-DF-EA-S					
Compliance Point	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)
β_T	-12	-5	0	11.3	50	3200	-10	-8	0	13.33	50	8500	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
δ_T	-12	-9	0	11.3	50	3200	-10	-6.4	0	10	50	8500	-10	-6.4	0	10	50	14000	-10	-6	0	6	50	14000
γT	-12	-5	0	11.3	50	3200	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
εT	N/A	N/A	N/A	N/A	N/A	N/A	-10	-8	0	13.33	50	8500	N/A	N/A	N/A	N/A	N/A	N/A	-10	-4	0	3	50	14000

Test Setup:
The DUT should be setup as defined in Appendix A. Configure the DUT for the appropriate speed. The DUT should be transitioned into the monitoring (port-bypassed) state or the active state.

Procedure:

For 4GFC:
1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing CRPAT continuously.
3) Measure the differential mode return loss of the DUT transmitter device.

For 8GFC:

1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing JSPAT.
3) Measure the differential mode return loss of the DUT transmitter device.

For 16GFC:

1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing PRBS9.
3) Measure the differential mode return loss of the DUT transmitter device.

Observable Results:

The common mode return loss of the DUT transmitter device shall be greater than L while $y(f) \leq L$, $y(f)$ while $L < y(f) < H$, and H while $H \leq y(f)$.

Possible Problems:

If the DUT does not support transmitting CRPAT, or JSPAT this test will be performed with the DUT transmitting continuous Idle or ARB(FF,FF) Primitives. For 16GFC devices, if the DUT does not support transmitting PRBS9, the test will be performed with the DUT transmitting scrambled idle.

Test #9.2.4: Receiver Common Mode Return Loss (SCC11) (16GFC Only)

Purpose:

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

References:

[1] FC-PI-5 - Clause 9
[2] Ibid., Table 25
[3] MSQS – Clause 9

Resource Requirements:

- See Appendix C

Last Updated: September 30, 2014

Discussion:

Reference [2] describes the transmitter differential mode return loss specifications at all compliance points. Reference [1] describes impedance characteristics in terms of return loss instead of an impedance profile. A conformant device shall not violate the spectral limit line as specified by reference [2]. Reference [3] refers to the use of PRBS 9 for 16GFC devices. This test applies to only 16GFC devices.

	400-DF-EL-S						800-DF-Ex-S						1600-DF-EL-S						1600-DF-EA-S					
Compliance Point	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)
β_T	N/A						N/A						N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
δ_T													-6	-3	0	13.33	50	14000	-6	-3	0	6	50	14000
γT													N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
εT													N/A	N/A	N/A	N/A	N/A	N/A	-6	-3	0	3	50	14000

Table 9 - S parameter at the Transmit Compliance Points (SCC11)

Test Setup:

The DUT should be setup as defined in Appendix A. Configure the DUT for 8G speed. The DUT should be transitioned into the monitoring (port-bypassed) state or the active state.

Procedure:

1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing PRBS9.
3) Measure the common mode return loss of the DUT transmitter device.

Observable Results:

The common mode return loss of the DUT transmitter device shall be greater than L while $y(f) \leq L$, y(f) while $L < y(f) < H$, and H while $H \leq y(f)$.

Possible Problems:

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

Test #9.2.5: Transmitter Differential to Common Mode Conversion Ratio (SCD22) (8GFC, 16GFC Only)

Purpose:

- To verify the Differential to Common Mode Conversion Ratio of the DUT's transmitter is within the conformance limits.

References:

[1] FC-PI-5 - Clause 9
[2] Ibid., Table 25
[3] MSQS

Resource Requirements:

- See Appendix C

Last Updated: September 30, 2014

Discussion:

Reference [2] describes the transmitter differential mode return loss specifications at all compliance points. Reference [1] describes impedance characteristics in terms of return loss instead of an impedance profile. A conformant device shall not violate the spectral limit line as specified by reference [2]. Reference [3] refers to the use of JSPAT as a FC compliant test pattern used in attaining a flat spectrum for 8GFC devices, and PRBS 9 for 16GFC devices.

Table 10 – S parameter at the Transmit Compliance Points (SCD22)

	4GFC						8GFC						16GFC											
	400-DF-EL-S						800-DF-Ex-S						1600-DF-EL-S						1600-DF-EA-S					
Compliance Point	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)
β_T	N/A						-10	-10	-10	0	50	8500	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
δ_T							-10	-10	-10	0	50	8500	-10	-10	-10	0	50	14000	-10	-10	-10	0	50	14000
γT							N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
εT							-10	-10	-10	0	50	8500	N/A	N/A	N/A	N/A	N/A	N/A	-10	-10	-10	0	50	14000

Test Setup:

The DUT should be setup as defined in Appendix A. Configure the DUT for 8G speed. The DUT should be transitioned into the monitoring (port-bypassed) state or the active state.

Procedure:

For 8GFC:

1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing JSPAT.
3) Measure the differential mode to common mode ratio the DUT transmitter device.

For 16GFC:

1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing PRBS9.
3) Measure the differential mode to common mode ratio of the DUT transmitter device.

Observable Results:

The common mode return loss of the DUT transmitter device shall be greater than L while $y(f) \leq L$, $y(f)$ while $L < y(f) < H$, and H while $H \leq y(f)$.

Possible Problems:

For 8GFC devices, if the DUT does not support transmitting JSPAT this test will be performed with the DUT transmitting continuous Idle or ARB(FF,FF) Primitives. For 16GFC devices, if the DUT does not support transmitting PRBS9, the test will be performed with the DUT transmitting scrambled idle.

Test #9.2.6: Receiver Differential to Common Mode Conversion Ratio (SCD11) (8GFC, 16GFC Only)

Purpose:

- To verify the Differential to Common Mode Conversion Ratio of the DUT's receiver is within the conformance limits.

References:

[1] FC-PI-5 - Clause 9
[2] Ibid., Table 25
[3] MSQS

Resource Requirements:

- See Appendix C

Last Updated: September 30, 2014

Discussion:

Reference [2] describes the transmitter differential mode return loss specifications at all compliance points. Reference [1] describes impedance characteristics in terms of return loss instead of an impedance profile. A conformant device shall not violate the spectral limit line as specified by reference [2]. Reference [3] refers to the use of JSPAT as a FC compliant test pattern used in attaining a flat spectrum for 8GFC devices, and PRBS 9 for 16GFC devices.

Table 11 – S parameter at the Transmit Compliance Points (SCD22)

	4GFC						8GFC						16GFC											
	400-DF-EL-S						800-DF-Ex-S						1600-DF-EL-S						1600-DF-EA-S					
Compliance Point	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)	L(db)	N(db)	H(db)	S(db/sec)	Fmin (MHz)	Fmax (MHz)
β_T	N/A					N/A	-10	-10	-10	0	50	8500	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
δ_T						N/A	-10	-10	-10	0	50	8500	-10	-10	-10	0	50	14000	-6	-6	-6	0	50	14000
γT						N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
εT						N/A	-10	-10	-10	0	50	8500	N/A	N/A	N/A	N/A	N/A	N/A	-6	-6	-6	0	50	14000

Test Setup:

The DUT should be setup as defined in Appendix A. Configure the DUT for 8G speed. The DUT should be transitioned into the monitoring (port-bypassed) state or the active state.

Procedure:

For 8GFC:

1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing JSPAT.
3) Measure the differential mode to common mode ratio the DUT transmitter device.

For 16GFC:

1) Connect the DUT to the VNA using the appropriate FC→SMA test fixture.
2) Instruct the Testing Station or DUT to begin sourcing PRBS9.
3) Measure the differential mode to common mode ratio of the DUT transmitter device.

Observable Results:

The common mode return loss of the DUT transmitter device shall be greater than L while $y(f) \leq L$, $y(f)$ while $L < y(f) < H$, and H while $H \leq y(f)$.

Possible Problems:

For 8GFC devices, if the DUT does not support transmitting JSPAT this test will be performed with the DUT transmitting continuous Idle or ARB(FF,FF) Primitives. For 16GFC devices, if the DUT does not support transmitting PRBS9, the test will be performed with the DUT transmitting scrambled idle.

Appendix A: Test Setup

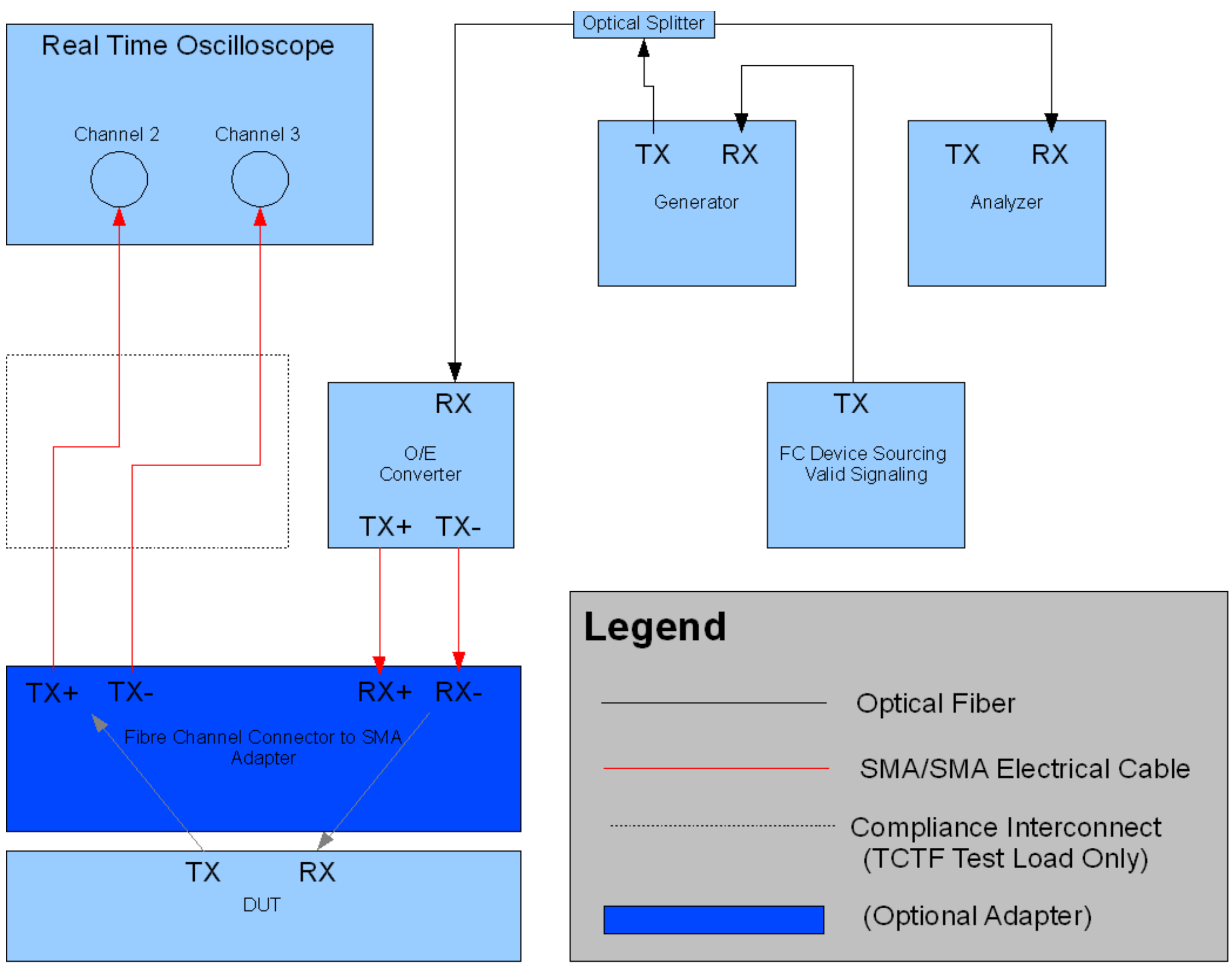

Figure 1 - Test Setup (Group 1)

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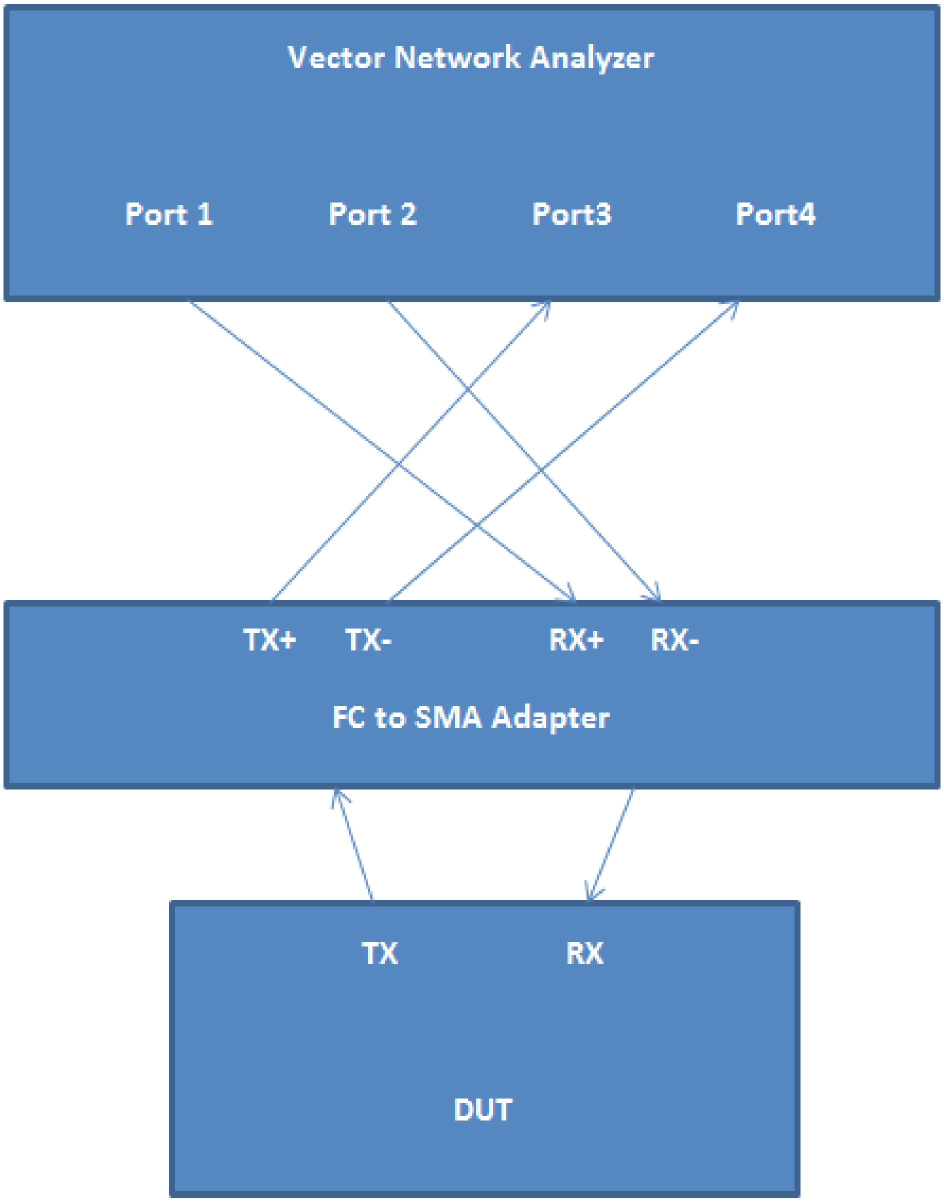


Figure 2 - Test Setup (Group 2)

Appendix B: Test Patterns

References:

[1] MJSQ – Table A.9, A.11, A.13
[2] MSQS – Table 9.1

	Primitive				Count
(Idle)	BC	95	B5	B5	6
(SOFn3)	BC	B5	36	36	1
	7E	7E	7E	7E	41
	7E	7E	7E	74	1
	7E	AB	B5	B5	1
	B5	B5	B5	B5	12
	B5	5E	4A	7E	1
	7E	7E	7E	FE	1
(CRC)	F5	2E	F6	DD	1
(EOFn)	BC	B5	D5	D5	1

Table 12 - CJTPAT (JTPAT in a FC compliant frame format)

	Primitive				Count
(Idle)	BC	95	B5	B5	6
(SOFn3)	BC	B5	36	36	1
	BE	D7	23	47	
	6B	8F	B3	14	16
	5E	FB	35	59	
(CRC)	EE	23	55	16	1
(EOFn)	BC	B5	D5	D5	1

Table 13 - CRPAT (RPAT in a FC compliant frame format)

	Primitive				Count
(Idle)	BC	95	B5	B5	6
(SOFn3)	BC	B5	36	36	1
	7F	7F	7F	7F	512
(CRC)	F1	96	DB	97	1
(EOFn)	BC	95	D5	D5	1

Table 14 - CSPAT (SPAT in a FC compliant frame format)

Table 9.1 - Scrambled jitter pattern (JSPAT) for 8GFC				
D1.4 0111010010	D16.2 0110110101	D24.7 0011001110	D30.4 1000011101	D9.6 1001010110
D10.5 0101011010	D16.2 1001000101	D7.7 1110001110	D24.0 0011001011	D13.3 1011000011
D23.4 0001011101	D13.2 1011000101	D13.7 1011001000	D1.4 0111010010	D7.6 1110000110
D0.2 1001110101	D21.5 1010101010	D22.1 0110101001	D23.4 0001011101	D20.0 0010110100
D27.1 1101101001	D30.7 1000011110	D17.7 1000110001	D4.3 1101010011	D6.6 0110010110
D23.5 0001011010	D7.3 1110001100	D19.3 1100101100	D27.5 1101101010	D19.3 1100100011
D5.3 1010010011	D22.1 0110101001	D5.0 1010010100	D15.5 0101111010	D24.7 0011001110
D16.3 1001001100	D1.2 0111010101	D23.5 0001011010	D20.7 0010110111	D11.7 1101001000
D20.7 0010110111	D18.7 0100110001	D29. 1011100100	D16.6 0110110110	D25.3 1001100011
D1.0 1000101011	D18.1 0100111001	D30.5 1000011010	D5.2 1010010101	D21.6 1010100110

Table 15 – JSPAT (Repeat this segment 10 times)

16G test patterns are defined in Clause 9.2 and 9.3 of FC-MSQS

Appendix C: Hardware Requirements, Test Fixtures and Setups

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

References:

[1] FC-PI-5 Standard Clause 9
[2] Ibid., Subclause 9.9.1 - TCTF Overview
[3] Ibid., Subclause 9.10 - Test Loads
[4] Ibid., Subclause 9.2 - Transmitter Device Characteristics
[5] Ibid., Subclause 9.3 - Receiver Characteristics

Last Modification: August 19, 2014

Discussion:

C.1 - Introduction

Clause 9 of FC-PI-5 defines several test fixtures that are required for performing the physical layer tests covered in that Clause 9. The purpose of this appendix is to present a reference implementation of these test fixtures, and to specify the test equipment and setups used by the UNH IOL for performing the tests as defined in this test suite.

C.2 - Equipment

Table C-1 below summarizes the list of measurement equipment used by the UNH IOL for performing the tests contained in this test suite.

Functional Block	Equipment	Key Features
Digital Storage Oscilloscope	Keysight DCA-X 86100D with 86108D 50GHz Precision Waveform Analyzer	50GHz bandwidth dual channel signal analyzer
Vector Network Analyzer	Keysight E5071C ENA Series Network Analyzer	20GHz, full 4-port mixed-mode S-parameters

Table C-1: Equipment list

C.3 - Fixture Requirements

There are two test fixtures defined in Clause 9 of the FC-PI-5 Standard for the purpose of physical layer testing:

- Zero-Length test load
- TCTF test load

Each of these fixtures incorporates an FC connector at one end, with a network of passive elements that present a particular load termination to the FC device. Also, reference points are defined from which the measurements shall be made.

In addition, a test fixture will be needed to connect the DUT transmitter and receiver ports to the ENA for performing the return loss tests of Group 2. (As it turns out, a portion of the Zero-Length test fixture can be reused for this purpose, which will be shown later.)

Some of the tests in this test suite must be performed twice, once using the Zero-Length test load, and again using the TCTF test load. Other tests are defined for only one measurement case. Table C-2 below summarizes the fixtures required for each test, and indicates the tests that require multiple fixtures.

Test	Name	Fixture 1	Fixture 2
9.1.1	Nominal Bit Rate	Zero-Length	-
9.1.2	Differential Output Voltage	Zero-Length	TCTF
9.1.3	Rise and Fall Times	Zero-Length	TCTF
9.1.4	Transmitter Eye Mask	Zero-Length	TCTF
9.1.5	Transmitter Jitter	Zero-Length	TCTF
9.1.6	Transmitter RMS Common Mode Voltage	Zero-Length	TCTF
9.1.7	TWDP Test	Zero-Length	-
9.2.1	Transmitter Differential Mode Return Loss	Zero-Length	-
9.2.2	Transmitter Common Mode Return Loss	Zero-Length	-
9.2.3	Receiver Differential Mode Return Loss	Zero-Length	-
9.2.4	Receiver Common Mode Return Loss	Zero-Length	-

Table C-2: Fixture Requirements Per Test

C.4 - Fixture Implementations

In general, the fixtures may be viewed as having three sections: 1) a small PCB to convert the FC-specific connector to SMA, 2) a physical channel that represents the TCTF (which may be omitted for the Zero-Length case), and 3) a termination element. By substituting (or removing) each of these elements, all of the fixture cases can be implemented with a relatively small number of components.

Zero-Length Test Load

The Zero-Length test load is the simplest of the fixtures. Figure C-1 below shows a copy of the Zero-Length test load diagram found in Clause 9 of FC-PI-5 [3] for differential 100 Ω variants.

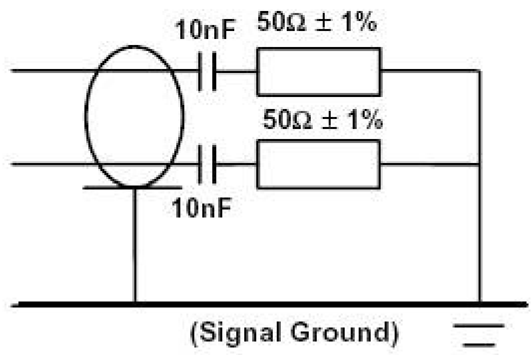


Figure C-1: 200 and 400-DF-EL-S Intra cabinet Zero-Length test load

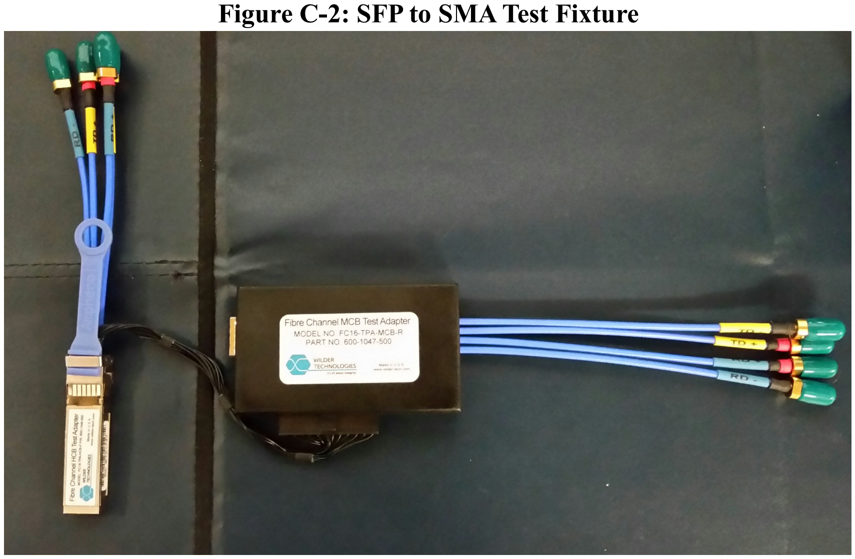
One implementation of this fixture could involve physical resistors and capacitors on a PCB that contains the appropriate FC connector. Probe points would need to be included in order to attach a high-impedance differential probe, which would also be required.

Note that a functionally equivalent implementation of this fixture can be realized by simply sending the Tx+ and Tx- signals directly into two separate channels of the SDA, through the specified DC blocking capacitors (if they are not already present on the DUT transmitter.) The SDA inputs themselves act as the 50-ohm terminating loads, with the probe points effectively being the input ports of the SDA. This configuration provides the benefit of not requiring a high-impedance active differential probe, and also results in a slightly enhanced vertical resolution. (In this configuration, the full quantizer range is applied to each *half* of the differential signal, as opposed to the case when a differential probe is used, where the entire quantizer range is applied across the full differential signal.) The two-channel method requires that the two channels be subtracted inside the SDA (or in the post-processing software) in order to create the differential signal.

While the SDA acts as the termination component of the differential 100Ω Zero-Length test fixture, a separate adapter PCB must also be used to convert the FC-specific connector type to SMA (i.e., the connector type found on the inputs of the SDA). The UNH-IOL has currently been able to acquire certain test fixtures as seen in Figure C-2

Zero-Length Test Fixtures

Figure C-2: SFP to SMA Test Fixture



TCTF Test Load

Next, consider the TCTF test load required for four Gigabit devices. Figure C-3 below shows a copy of the TCTF test load diagram from FC-PI-5[1]:

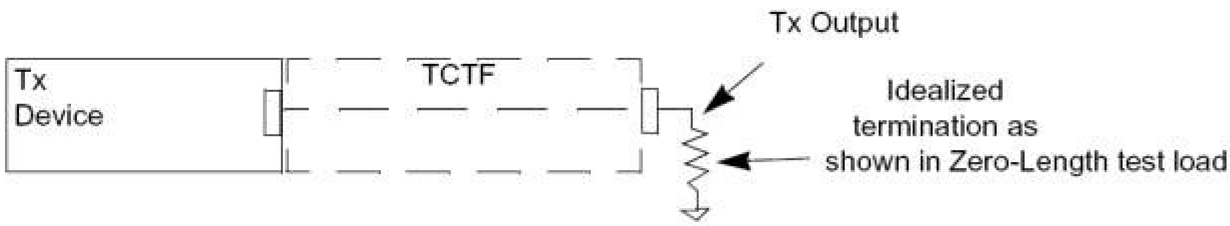


Figure C-3: TCTF test load diagram

Note that this diagram is similar to the Zero-Length test load, but has the added TCTF (Transmitter Compliance Transfer Function) component. FC-PI-5 specifies that, "The TCTF is the mathematical statement of the transfer function that the transmitter shall be capable of producing acceptable signals as defined by the receive mask." [2]

The implementation of the TCTF test load then simply involves adding a physical TCTF channel to the Zero-Length test fixture setup, between the FC-to-SMA adapter and the SDA. The setup then becomes:

DUT → FC-to-SMA adapter → Compliance Interconnect → SDA

It should also be noted that a valid Compliance Interconnect is defined as any channel that meets or exceeds the minimum loss requirements for the particular specification. Two separate loss curves are defined for FC (one for intra cabinet and one for inter cabinet), and a valid Compliance Interconnect is any physical channel that is at least as lossy as the limit line, or more so.

For the intra cabinet TCTF requirements, the UNH IOL uses a PCB containing approximately 36 inches of FR-4 trace. The PCB in combination with two HMZD adapters and SMA test cables to each end of the PCB is sufficient to make the entire channel fall below the intra cabinet TCTF curve. The addition of the SMA cabling can add noticeable losses, which should be taken into account for this application. If one were to start with a channel that by itself meets the TCTF requirement, the added cabling could unfairly penalize a DUT that might be on the edge of conformance. While in general, it is desirable to build as much margin as possible into any device, for the purposes of conformance testing, care must be taken not to use a Compliance Interconnect that is *too* lossy (above and beyond the minimum required loss) and risk falsely failing devices that may technically be conformant, but may not have excessive margin.

The intra cabinet TCTF PCB is shown in Figure C-5, below. Figure C-6 shows the frequency response of this channel with the added SMA cables.

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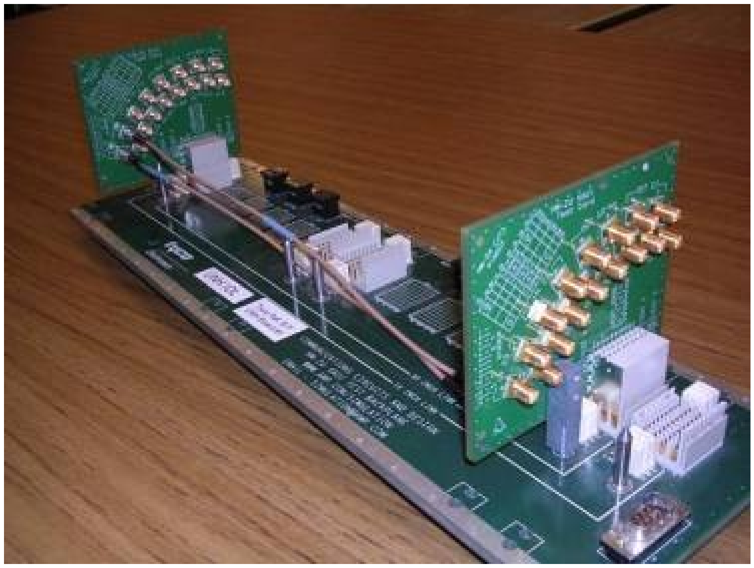

Figure C-4: Intra Cabinet TCTF Compliance Interconnect, including cables (Tyco XAUI Test Backplane)

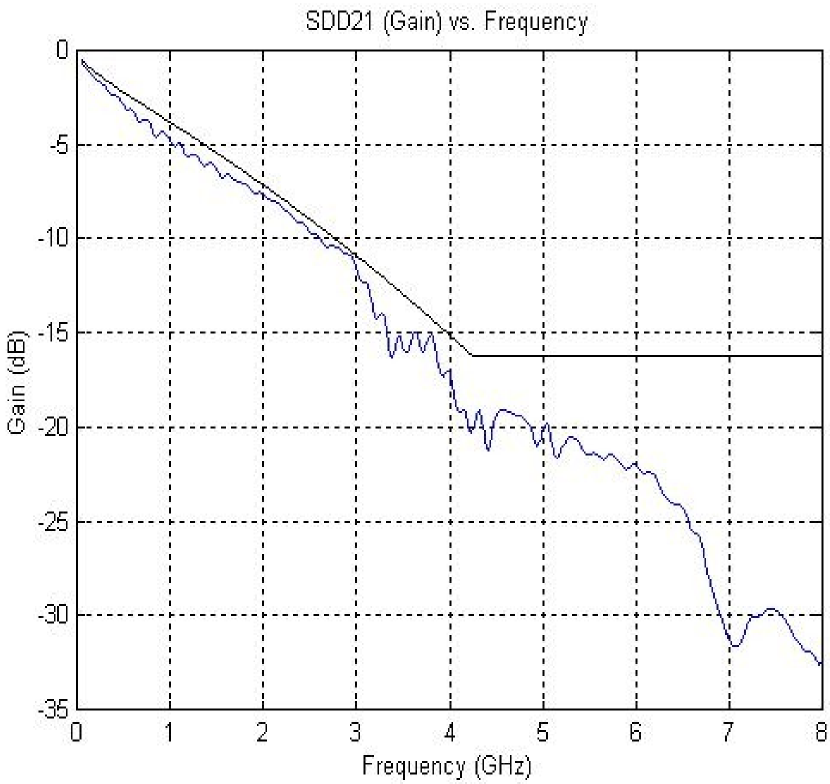

Figure C-5: Intra Cabinet TCTF Compliance Interconnect Frequency Response

The Inter Cabinet TCTF limit line specification is different than the Intra Cabinet limit line, and more accurately reflects the loss characteristics of the cabling used in these systems. The UNH IOL does not currently possess an Inter Cabinet TCTF.

VNA Test Setup

All of the tests in Group 2 of the test suite use the same test setup (and are performed in a single measurement) using an Agilent 4-port, 20GHz Serial Network Analyzer, shown in Appendix A. The port notation convention used by the UNH IOL assumes the RX pair of the DUT to be connected to Ports 1 and 2 of the ENA, and the DUT TX pair connected to Ports 3 and 4.

Table C-3 below, summarizes the port configuration setup for the VNA.

VNA Port Number	DUT Ports
Port 1	RX+
Port 2	RX-
Port 3	TX+
Port 4	TX-

Table C-3: VNA port assignments for return loss test setup

C.5 - Conclusion

In this appendix, reference implementations for all of the FC tests defined in this suite have been presented. A modular approach has been employed in order to simplify the setup. Images have been provided showing the specific adapter fixtures used by the UNH IOL. Specific details regarding the Intra Cabinet TCTF channel used by the IOL have been presented, including insertion loss characteristics. Together these components can be combined to create any of the fixtures specified by FC-PI-5 for performing these tests.