Fibre Channel Consortium

FC-PI-4 Clause 6
Optical Physical Layer Test Suite
Version 1.0

Technical Document

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Modification Record

- June 26, 2008 – Version 1.0
    Daniel Reynolds: Created test suite based off of the UNH-IOL FC-PI-2 Test Suite but with the addition of the 8G speed defined in FC-PI-4 Rev 8. Also updated 1GFC, 2GFC, 4GFC. Included additional testing information mentioned in FC-PI-4.

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Acknowledgments

The University of New Hampshire would like to acknowledge the efforts of the following individuals in the development of this test suite.

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 6 of the **FC-PI-4 Rev 8.0** Fibre Channel Standard (hereafter referred to as "FC-PI-4"). The test also covers information relating to **FC-MJSQ Rev 14.1** Fibre Channel Standard (hereafter referred to as "FC-MJSQ"). 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.

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Group 1: Transmitter Verification

Overview:
This group of tests verifies the optical signaling specifications for optical Fibre Channel signals, as defined in Clause 6 of FC-PI-4.

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Test #6.1.1: Signal Rate

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

References:
[1] FC-PI-4 - Clause 6
[2] Ibid., Table 6 and 10

Resource Requirements:
- Digital oscilloscope capable of sampling a 8GFC signal at the appropriate wavelength.
- 0.5m – 5m fiber patch cord (MM).
- 2m – 5m fiber patch cord (SM).

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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 obviously 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 MMF and SMF technologies. Furthermore, note 10 of reference [2] indicates that this tolerance must be maintained over a period of 200,000 transmitted bits, which is approximately ten maximum length frames.

Table 1 - Signaling Speeds

	1GFC	2GFC	4GFC	8GFC
Nominal Signaling Rate	1.0625 GBd	2.125 GBd	4.250 GBd	8.500 GBd
Rate Tolerance	± 100ppm (± 106250 Bd)	± 100ppm (± 212500 Bd)	± 100ppm (± 425000 Bd)	± 100ppm (± 850000 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 state.

Procedure:
1) Instruct the Testing Station to transmit a LPB to the DUT.
2) Instruct the Testing Station to begin sourcing D21.5 continuously.
3) Measure the average TX signaling speed. The measurement should be made over a length of 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: If the DUT does not support LPB (Loop Port Bypass), or sending of the above patterns, then the above measurements will be made with a set of continuous IDLE primitives or ARB(FF,FF) Primitives.

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Test #6.1.2: Average Launched Power

Purpose:
- To verify that the average launch power of the DUT's transmitter is within the conformance limits.

References:
[1] FC-PI-4 - Clause 6
[2] Ibid., Table 6 and 10
[3] FC-MJSQ – Appendix A.2

Resource Requirements:
- Optical Power Meter.
- Digital oscilloscope capable of sampling a 4GFC signal at the appropriate wavelength and performing optical average power readings.
- 0.5m – 5m fiber patch cord (MM).
- 2m – 5m fiber patch cord (SM).

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Discussion:
The average launched optical power is measured using an average-reading power meter when transmitting valid 8B10B transmission characters. The launched power shall fall between the minimum specified average launched power and the maximum receiver tolerance or class 1 laser safety limits.

Reference [3] indicates that the test bit sequences RPAT, JTPAT and SPAT are defined for both jitter and tolerance testing. These represent the worst case patterns for random data, jitter tolerance and supply noise conditions. Appendix B. specifies the bit sequences, as defined in reference [3], as the Fibre Channel compliant versions of the mentioned sequences defined as CRPAT, CJTPAT and CSPAT. For compliance testing the pattern with the worst case output or tolerance shall be used.

Table 2 - Average Launch Powers

	MM					SM					
	1GFC (SN)	2GFC (SN)	4GFC (SN)	8GFC (SN)	8GFC (SA)	1GFC (LC-L)	2GFC (LC-L)	4GFC (LC-L)	4GFC (LC-M)	8GFC (LC-L)	8GFC (LC-I)
Max* (dBm)	0	0	0	0	0	-3	-3	-1	-1	+0.5	+0.5
Min (dBm)	-10	-10	-9	-8.2	-8	-9.5	-11.7	-8.4	-11.2	-8.4	-10.6

*Maximum values listed correspond to the maximum receiver power tolerance. The maximum transmit power is defined as either the maximum receiver power tolerance, or class 1 laser safety limits as defined by CDRH.

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Test Setup:
   Use the fiber patch cord to connect the DUT to the Optical Power Meter (or appropriate oscilloscope). If an oscilloscope is used the DUT should be setup as defined in Appendix A., configured for the appropriate speed and should be transitioned into the monitoring state.

Procedure:
   1) Instruct the Testing Station to transmit a LPB to the DUT.
   2) Instruct the Testing Station to begin sourcing CRPAT continuously.
   3) Measure the average launched power.
   4) Repeat steps 2 and 3 with CJTPAT and CSPAT.

Observable Results:
   The average launched power, of the worst value measured, shall fall between the maximum and minimum limits shown in Table 2.

Possible Problems: Equipment to verify class 1 laser safety limits may not be available. If this is the case, then verify the averaged launched power does not exceed the maximum receiver tolerance.   If the DUT does not support LPB (Loop Port Bypass), or sending of the above patterns, then the above measurements will be made with a set of continuous IDLE primitives or ARB(FF,FF) Primitives.

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Test #6.1.3: Optical Modulation Amplitude

Purpose:
- To verify that the Optical Modulation Amplitude of the DUT's transmitter is within the conformance limits.

References:

    [1] FC-PI-4 - Clause 6
    [2] Ibid., Table 6 and 10
    [3] Ibid., Clause 3.1.73
    [4] Ibid., Figure 26
    [5] FC-MJSQ – Appendix A.2

Resource Requirements:
- Digital oscilloscope capable of sampling a 4GFC signal at the appropriate wavelength.
- 0.5m – 5m fiber patch cord (MM).
- 2m – 5m fiber patch cord (SM).

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Discussion:
    Optical Modulation Amplitude (OMA) is defined as the positive difference in power between the averaged value of logic one bits and the averaged value of logic zero bits. A long string of 8B10B encoding should be considered to be 5 bits high or 5 bits low.

    Reference [4] indicates that the test bit sequences RPAT, JTPAT and SPAT are defined for both jitter and tolerance testing. These represent the worst case patterns for random data, jitter tolerance and supply noise conditions. Appendix B. specifies the bit sequences, as defined in reference [4], as the Fibre Channel compliant versions of the mentioned sequences defined as CRPAT, CJTPAT and CSPAT. For compliance testing the pattern with the worst case output or tolerance shall be used.

Table 3 - OMA Values

	MM					SM					
	1GFC (SN)	2GFC (SN)	4GFC (SN)	8GFC (SN)	8GFC (SA)	1GFC (LC-L)	2GFC (LC-L)	4GFC (LC-L)	4GFC (LC-M)	8GFC (LC-L)	8GFC (LC-I)
Min (mW)	.156	.196	.247	.302	*	.174	.134	.290	.150	.290	.174
Min (dBm)	-8.1	-7.1	-6.1	-5.2	*	-7.6	-8.7	-5.4	-8.2	-5.4	-7.6

    * OMA minimum values are described by reference [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 state.

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Procedure:
1) Instruct the Testing Station to transmit a LPB to the DUT.
2) Instruct the Testing Station to begin sourcing CRPAT continuously.
3) Configure the oscilloscope to capture the waveform data.
4) Measure the OMA.
5) Repeat steps 2 through 4 with CJTPAT and CSPAT.

Observable Results:
The optical modulation amplitude, of the worst value measured, shall fall above the limits shown in Table 3.

Possible Problems: If the DUT supports sending random bit patterns this test should be tested by measuring the stable 1 and stable 0 levels of the following pattern: 1111100000. If the DUT does not support LPB (Loop Port Bypass), or sending of the above patterns, then the above measurements will be made with a set of continuous IDLE primitives or ARB(FF,FF) Primitives.

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Test #6.1.4: Rise and Fall Times (1G, 2G, 4G)

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

References:
    [1] FC-PI-4 - Clause 6
    [2] Ibid., Table 6 and 10
    [3] Ibid., Clause A.1.2.2
    [4] FC-MJSQ – Appendix A.2

Resource Requirements:
- Digital oscilloscope capable of sampling a 4GFC signal at the appropriate wavelength.
- 0.5m – 5m fiber patch cord (MM).
- 2m – 5m fiber patch cord (SM).

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Discussion:
    Signal rise is defined as the transition from the baseline optical 0 power to optical 1 power. Signal fall time is defined as a transition from optical 1 power back to the baseline optical 0 power. The signal rise and fall times are defined to be the time difference between the points where the signal transitions crosses the 20% and 80% of the transmitted waveform.

    Optical rise and fall time calculations are based on unfiltered waveforms. If a filter is applied to the waveform in order for it to conform to the mask, then the filter response should be removed before performing rise and fall time calculations.

    Reference [4] indicates that the test bit sequences RPAT, JTPAT and SPAT are defined for both jitter and tolerance testing. These represent the worst case patterns for random data, jitter tolerance and supply noise conditions. Appendix B. specifies the bit sequences, as defined in reference [4], as the Fibre Channel compliant versions of the mentioned sequences defined as CRPAT, CJTPAT and CSPAT. For compliance testing the pattern with the worst case output or tolerance shall be used.

Table 4 - Rise/Fall Time Values

	MM				SM			
	1GFC	2GFC	4GFC	8GFC	1GFC	2GFC	4GFC	8GFC
Max	300 ps	150 ps	90 ps	NA*	320 ps	160 ps	90 ps	NA*

*This measurement is Not Applicable.

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 state.

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Procedure:
1) The Oscilloscope should be setup without any filtering.
2) Instruct the Testing Station to transmit a LPB to the DUT.
3) Instruct the Testing Station to begin sourcing CRPAT continuously.
4) Configure the digital oscilloscope to capture the waveform data.
5) Measure the rise and fall times.
6) Repeat steps 2 through 4 with CJTPAT and CSPAT.

Observable Results:
The rise/fall times, of the worst value measured, shall be no greater than the values shown in Table 4.

Possible Problems: If the DUT does not support LPB (Loop Port Bypass), or sending of the above patterns, then the above measurements will be made with a set of continuous IDLE primitives or ARB(FF,FF) Primitives.

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Test #6.1.5: Transmitter Eye Mask

Purpose:
- To verify that the transmitter eye of the DUT is within the conformance limits.

References:
[1] FC-PI-4 - Clause 6
[2] Ibid., Table 8 and 12.
[3] Ibid., Figure 18 and 27 – transmitter eye diagram mask (1GFC, 2GFC, 4GFC)
[4] Ibid., Figure 19 and 28 – transmitter eye diagram mask (8GFC)
[5] Ibid., Appendix A.1.2.1
[6] FC-MJSQ – Appendix A.2

Resource Requirements:
- Digital oscilloscope capable of sampling a 4GFC signal at the appropriate wavelength.
- 0.5m – 5m fiber patch cord (MM).
- 2m – 5m fiber patch cord (SM).

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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 mask should be measured after applying the specified fourth-order Bessel-Thomson filter. The points used to create this mask are found in reference [2]. The measurement shall be made while the DUT is transmitting CJTPAT.

Reference [6] indicates that the test bit sequences RPAT, JTPAT and SPAT are defined for both jitter and tolerance testing. These represent the worst case patterns for random data, jitter tolerance and supply noise conditions. Appendix B. specifies the bit sequences, as defined in reference [4], as the Fibre Channel compliant versions of the mentioned sequences defined as CRPAT, CJTPAT and CSPAT. For compliance testing the pattern with the worst case output or tolerance shall be used.

Reference [5] indicates that for 8GFC signaling the JSPAT pattern in annex F shall be used. Reference [1] indicates that for 8GFC a mask at a probability of 10^{-3} is applicable.

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 state.

a) 1GFC, 2GFC, 4GFC
   Procedure:
   1. Instruct the Testing Station to transmit a LPB to the DUT.
   2. Instruct the Testing Station to begin sourcing CRPAT continuously.
   3. Configure the oscilloscope to capture the waveform data and place these waveforms into the mask definition.
   4. Process the captured waveform, observing the number of mask violations.
   5. Repeat steps 2 through 4 with CJTPAT and CSPAT.

b)   8GFC
   Procedure:
   1. Disable Scrambling/De-Scrambling on the DUT.
   2. Instruct the Testing Station to transmit a LPB to the DUT.
   3. Instruct the Testing Station to begin sourcing JSPAT continuously.
   4. Configure the oscilloscope to capture the waveform data and place these waveforms into the mask definition.
   5. Process the captured waveform, observing the number of mask violations.

Observable Results:
   a) All of the waveforms shall not violate the eye mask at any point.
   b) All of the waveforms shall not violate the eye mask for more than the specific Hit Ratio as defined in Reference [5].

Possible Problems: If the DUT does not support LPB (Loop Port Bypass), or sending of the above patterns, then the above measurements will be made with a set of continuous IDLE primitives or ARB(FF,FF) Primitives.

Test #6.1.6: Transmitter Jitter (1G, 2G, 4G)

Purpose:
- To verify that the jitter of the DUT's transmitter is within the conformance limits.

References:
[1] FC-PI-4 - Clause 6
[2] Ibid., Table 8 and 12.
[3] FC-MJSQ – Appendix A.2

Resource Requirements:
- Digital oscilloscope capable of sampling a 4GFC signal at the appropriate wavelength.
- 0.5m – 5m fiber patch cord.

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Discussion:
Reference [1] describes the maximum peak to peak deterministic and total transmit jitter for all variants of SMF and MMF. The total jitter is the sum of deterministic and random jitter. These jitter values are specified at the 10^{-12} probability. An ideal reference clock can be extracted from the data in post processing software or in a hardware golden PLL. All measurements are performed at the Gamma-T point. Reference [2] indicates that jitter measurements at Gamma-T are limited by TDP/TWDP and therefore are not applicable measurements.

Reference [3] indicates that the test bit sequences RPAT, JTPAT and SPAT are defined for both jitter and tolerance testing. These represent the worst case patterns for random data, jitter tolerance and supply noise conditions. Appendix B. specifies the bit sequences, as defined in reference [3], as the Fibre Channel compliant versions of the mentioned sequences defined as CRPAT, CJTPAT and CSPAT. For compliance testing the pattern with the worst case output or tolerance shall be used.

Table 5 - Max Jitter Values

	1GFC	2GFC	4GFC
Max DJ	0.21 UI	0.26 UI	0.26 UI
Max TJ	0.43 UI	0.44 UI	0.44 UI

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 state.

Procedure:
1) Instruct the Testing Station to transmit a LPB to the DUT.
2) Instruct the Testing Station to begin sourcing CRPAT continuously.
3) Capture the waveform on the oscilloscope and computer the jitter values.
4) Repeat steps 2 and 3 with CJTPAT and CSPAT.

Observable Results:
The total jitter, of the worst value measured, shall be less than the values shown in Table 5.

Possible Problems: If the DUT does not support LPB (Loop Port Bypass) then another method not defined will have to be used to force the DUT to source CJTPAT.

Appendix A: Test Setup

Figure 1 - Test Setup
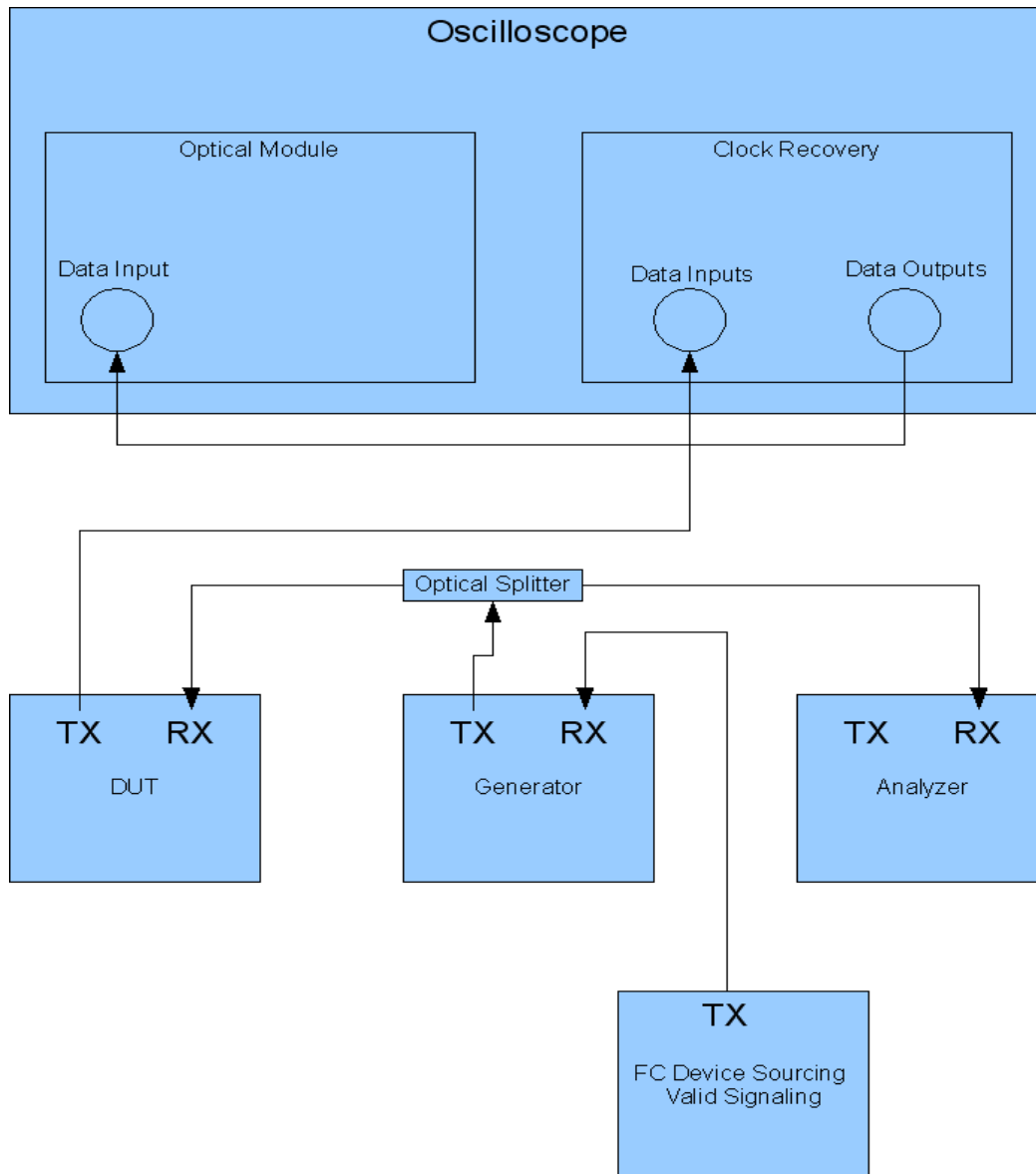
Appendix B: Test Patterns

References:
   [1] MJSQ – Table A.9, A.11, A.13
   [2] FC-PI-4 - Annex F, Table F.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 6 - 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 7 - 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 8 - CSPAT (SPAT in a FC compliant frame format)

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Table F.1 – Scrambled jitter pattern (JSPAT)

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

Table 9 - JSPAT (scrambled jitter pattern)