10 GIGABIT ETHERNET CONSORTIUM

Clause 54
10GBASE-CX4 PMD Test Suite
Version 1.0

Technical Document

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10Gigabit Ethernet Consortium

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MODIFICATION RECORD

Nov 20, 2003 Version 1.0

Andy Baldman: Clean-up and formal initial release.

Sep 17, 2003 Version 0.1

Matthew Fortier: Informal preliminary draft. Internal IOL use only.

The University of New Hampshire
InterOperability Laboratory

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Andy Baldman	UNH InterOperability Laboratory
Eric Lynskey	UNH InterOperability Laboratory
Bob Noseworthy	UNH InterOperability Laboratory
Matthew Fortier	UNH InterOperability Laboratory

INTRODUCTION

The University of New Hampshire's InterOperability Laboratory (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 functionality of the Physical Medium Dependent (PMD) sublayer of their 10GBASE-CX4 products.

These tests are designed to determine if a product conforms to specifications defined in Clause 54 of the IEEE 802.3ak Standard. 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 10GBASE-CX4 environments.

The tests contained in this document are organized in such a manner as to simplify the identification of information related to a test, and to facilitate in the actual testing process. Tests are organized into groups, primarily in order to reduce setup time in the lab environment, however the different groups typically also tend to focus on specific aspects of device functionality. A three-part numbering system is used to organize the tests, where the first number indicates the clause of the IEEE 802.3 standard on which the test suite is based. The second and third numbers indicate the test's group number and test number within that group, respectively. This format allows for the addition of future tests to the appropriate groups without requiring the renumbering of the subsequent tests.

The test definitions themselves are intended to provide a high-level description of the motivation, resources, procedures, and methodologies pertinent to each test. Specifically, each test description consists of the following sections:

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 source material *external* to the test suite, including specific subclauses pertinent to the test definition, or any other references that might be helpful in understanding the test methodology and/or test results. External sources are always referenced by number when mentioned in the test description. Any other references not specified by number are stated with respect to the test suite document itself.

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 not be included here, and are generally covered in the test procedure section, below.

Test 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 generally based on the successful (or unsuccessful) detection of a specific 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: ELECTRICAL SIGNALING REQUIREMENTS

Overview:

The tests defined in this section verify the electrical signaling characteristics of the Physical Medium Dependent (PMD) layer defined in Clause 54 of IEEE 802.3ak.

Test 54.1.1 - Signaling Speed Range

Purpose: To verify that the baud rate of the DUT is within the conformance limits

References:

[1] IEEE Std 802.3ak-2003, subclause 54.6.3 - Transmitter characteristics
[2] Ibid., subclause 54.6.3.3 - Signaling speed range
[3] Ibid., subclause 54.6.3.1 - Test fixtures
[4] IEEE Std 802.3ae-2002, Annex 48A.2 - Low-frequency test pattern

Resource Requirements: See Appendix 54.A

Last Modification: November 20, 2003 (Version 1.0)

Discussion:

Reference [1] specifies the transmitter characteristics for 10GBASE-CX4 devices. This specification includes conformance requirements for the per-lane signaling speed, which are specified in [2].

Reference [2] states that the 10GBASE-CX4 MDI signaling speed shall be 3.125 Gbaud +/- 100 ppm. This translates to 3.125 Gbaud +/- 312.5 Kbaud, with a nominal Unit Interval (UI) of 320 ps.

In this test, the signaling speed is measured while the DUT is connected to the test fixture defined in [3], or its functional equivalent. The signal being transmitted by the DUT may be any valid 10GBASE-CX4 signal, however the low-frequency jitter test pattern defined in [4] will be used, primarily out of convenience, as this pattern is also used for several other tests in this group.

Test Setup: See Appendix 54.A

Test Procedure:

1. Configure the DUT to transmit the low-frequency jitter test pattern.
2. Connect the DUT's Lane 0 transmitter to the test fixture.
3. Measure the average TX signaling speed for Lane 0.
4. Repeat steps 2 and 3 for Lanes 1, 2, and 3.

Observable Results:

a. For all lanes, the average signaling speed shall be 3.125 Gbaud +/- 312.5 Kbaud.

Possible Problems: None

Test 54.1.2 - Common Mode Output Voltage

Purpose: To verify that the DC common mode output voltage of the DUT is within the conformance limits

References:

[1] IEEE Std 802.3ak-2003, subclause 54.6.3 - Transmitter characteristics
[2] Ibid., subclause 54.6.3.4 - Output amplitude
[3] Ibid., subclause 54.6.3.1 - Test fixtures
[4] IEEE Std 802.3ae-2002, Annex 48A.2 - Low-frequency test pattern

Resource Requirements: See Appendix 54.A

Last Modification: November 20, 2003 (Version 1.0)

Discussion:

Reference [1] specifies the transmitter characteristics for 10GBASE-CX4 devices. This specification includes conformance requirements for the per-lane common mode output voltage, which are specified in [2].

In this test, the DC common mode output voltage is measured at the V_{com} test point while the DUT is connected to the test fixture defined in [3], or its functional equivalent. The signal being transmitted by the DUT may be any valid 10GBASE-CX4 signal, however the low-frequency jitter test pattern defined in [4] will be used, primarily out of convenience, as this pattern is also used for several other tests in this group.

Test Setup: See Appendix 54.A

Test Procedure:

1. Configure the DUT so that it is sourcing the low-frequency jitter test pattern.
2. Connect the DUT's Lane 0 transmitter to the test fixture.
3. Measure the DC common mode output voltage at the V_{com} test point.
4. Repeat steps 2 and 3 for Lanes 1, 2, and 3.

Observable Results:

a. For all lanes, the DC common mode output voltage shall be between -0.4 V and 1.9 V with respect to signal shield.

Possible Problems: None

Test 54.1.3 - Differential Output Amplitude

Purpose: To verify that the differential output amplitude of the DUT transmitter is within the conformance limits.

References:

[1] IEEE Std 802.3ak-2003, subclause 54.6.3 - Transmitter characteristics
[2] Ibid., subclause 54.6.3.4 - Output amplitude
[3] Ibid., subclause 54.6.3.1 - Test fixtures
[4] IEEE Std 802.3ae-2002, Annex 48A.2 - Low-frequency test pattern

Resource Requirements: See Appendix 54.A

Last Modification: November 20, 2003 (Version 1.0)

Discussion:

Reference [1] specifies the transmitter characteristics for 10GBASE-CX4 devices. This specification includes conformance requirements for the differential output amplitude, which are specified in [2].

In this test, the maximum differential peak-to-peak output voltage is measured while the DUT is connected to the test fixture defined in [3], or its functional equivalent. Reference [2] also requires that the DUT be transmitting the low-frequency jitter test pattern defined in [4] during this test.

Test Setup: See Appendix 54.A

Test Procedure:

1. Configure the DUT so that it is sourcing the low-frequency jitter test pattern.
2. Connect the DUT's Lane 0 transmitter to the test fixture.
3. Measure the maximum peak-to-peak differential output voltage.
4. Repeat steps 2 and 3 for Lanes 1, 2, and 3.

Observable Results:

a. For each lane, the maximum differential peak-to-peak output voltage shall be between 800 mV and 1200 mV.
b. The maximum difference between any two lanes' differential peak-to-peak output voltage shall be less than or equal to 150 mV.

Possible Problems: None

Test 54.1.4 - Differential Output Template

Purpose: To verify that the DUT transmitter provides equalization such that the output waveform falls within the specified template

References:

[1] IEEE Std 802.3ak-2003, subclause 54.6.3 - Transmitter characteristics
[2] Ibid., subclause 54.6.3.6 - Differential output template
[3] Ibid., subclause 54.6.3.1 - Test fixtures
[4] IEEE Std 802.3ae-2002, Annex 48A.2 - Low-frequency test pattern

Resource Requirements: See Appendix 54.A

Last Modification: November 20, 2003 (Version 1.0)

Discussion:

Reference [1] specifies the transmitter characteristics for 10GBASE-CX4 devices. This specification includes conformance requirements for the amount of transmitter equalization present on the DUT output signal. This is expressed in terms of a differential output template, which is specified in [2]. This reference also defines the procedure for normalizing and fitting the measured waveform to the template.

In this test, conformance to the differential output template is measured while the DUT is connected to the test fixture defined in [3], or its functional equivalent. Reference [2] also requires that the DUT be transmitting the low-frequency jitter test pattern defined in [4] during this test.

Test Setup: See Appendix 54.A

Test Procedure:

1. Configure the DUT so that it is sourcing the low-frequency jitter test pattern.
2. Connect the DUT's Lane 0 transmitter to the test fixture.
3. Capture, normalize, and fit the output waveform to the differential output template.
4. Repeat steps 2 and 3 for Lanes 1, 2, and 3.

Observable Results:

a. For all lanes, the normalized output waveform shall fit within the specified template.

Possible Problems: None

Test 54.1.5 - Transition Time

Purpose: To verify that the rise/fall transition times of the DUT transmitter are within the conformance limits

References:

[1] IEEE Std 802.3ak-2003, subclause 54.6.3 - Transmitter characteristics
[2] Ibid., subclause 54.6.3.7 - Transition time
[3] Ibid., subclause 54.6.3.1 - Test fixtures
[4] IEEE Std 802.3ae-2002, Annex 48A.1 - High-frequency test pattern

Resource Requirements: See Appendix 54.A

Last Modification: November 20, 2003 (Version 1.0)

Discussion:

Reference [1] specifies the transmitter characteristics for 10GBASE-CX4 devices. This specification includes conformance requirements for the driver rise/fall transition times, which are specified in [2].

In this test, the transition times are measured while the DUT is connected to the test fixture defined in [3], or its functional equivalent. Reference [2] also requires that the DUT be transmitting the high-frequency jitter test pattern defined in [4] during this test.

Test Setup: See Appendix 54.A

Test Procedure:

1. Configure the DUT so that it is sourcing the high-frequency jitter test pattern.
2. Connect the DUT's Lane 0 transmitter to the test fixture.
3. Measure the 20%-80% rising edge transition time.
4. Measure the 80%-20% falling edge transition time.
5. Repeat steps 2 through 4 for Lanes 1, 2, and 3.

Observable Results:

a. The rising edge transition time shall be between 60 and 130 ps.
b. The falling edge transition time shall be between 60 and 130 ps.

Possible Problems: None

Test 54.1.6 - Transmit Jitter

Purpose: To verify that the peak-to-peak transmit jitter of the DUT is within the conformance limits

References:

[1] IEEE Std 802.3ak-2003, subclause 54.6.3 - Transmitter characteristics
[2] Ibid., subclause 54.6.3.8 - Transmit jitter
[3] Ibid., subclause 54.6.3.9 - Transmit jitter test requirements
[4] Ibid., subclause 54.6.3.1 - Test fixtures
[5] IEEE Std 802.3ae-2002, Annex 48A.5 - Continuous jitter test pattern (CJPAT)

Resource Requirements: See Appendix 54.A

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Discussion:

Reference [1] specifies the transmitter characteristics for 10GBASE-CX4 devices. This specification includes conformance requirements for the peak-to-peak transmit jitter, which are specified in [2] and [3].

In this test, the peak-to-peak transmit jitter is measured while the DUT is connected to the test fixture defined in [4], or its functional equivalent. Reference [3] also requires that the DUT be transmitting the continuous jitter test pattern (CJPAT) defined in [5] during this test.

Test Setup: See Appendix 54.A

Test Procedure:

1. Configure the DUT so that it is sourcing the CJPAT test pattern.
2. Connect the DUT's Lane 0 transmitter to the test fixture.
3. Measure the random, deterministic, and total transmit jitter.
4. Repeat steps 2 and 3 for Lanes 1, 2, and 3.

Observable Results:

a. For all lanes, the Random Jitter value shall not exceed 0.27 UI.
b. For all lanes, the Deterministic Jitter value shall not exceed 0.17 UI.
c. For all lanes, the Total Jitter value shall not exceed 0.35 UI.

Possible Problems: None

GROUP 2: IMPEDANCE REQUIREMENTS

Overview:

The tests defined in this section verify the impedance characteristics of the Physical Medium Dependent (PMD) layer defined in Clause 54 of IEEE 802.3ak.

Test 54.2.1 - Output Return Loss

Purpose: To verify that the differential output return loss of the DUT is within the conformance limits

References:
[1] IEEE Std 802.3ak-2003, subclause 54.6.3 - Transmitter characteristics
[2] Ibid., subclause 54.6.3.5 - Output return loss

Resource Requirements: See Appendix 54.A

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Discussion:
Reference [1] specifies the transmitter characteristics for 10GBASE-CX4 devices. This specification includes conformance requirements for the differential output return loss, which are specified in [2].

For the purpose of this test, the differential output return loss is defined as the magnitude of the reflection coefficient expressed in decibels. The reflection coefficient is the ratio of the voltage in the reflected wave to the voltage in the incident wave. Note that this is also known as the S_{DD22} scattering parameter (s-parameter). For frequencies from 100 MHz to 2.0 GHz, the differential return loss of the driver shall exceed Equation 54.1 and 54.2:

ReturnLoss(f) >= 10 dB (for 100 MHz <= f < 625 MHz) (EQ. 54.1)

ReturnLoss(f) >= 10 - 10log(f/625) dB (for 625 MHz <= f <= 2.0 GHz) (EQ. 54.2)

This value is to be verified for each of the four DUT TX lanes, which are identified as Lane 0, Lane 1, Lane 2, and Lane 3.

Test Setup: See Appendix 54.A

Test Procedure:
1. Calibrate the VNA to remove the effects of the coaxial cables.
2. Configure the DUT so that it is sourcing normal IDLE signaling.
3. Connect the DUT's Lane 0 transmitter to the VNA.
4. Measure the reflection coefficient at the DUT transmitter from 100 MHz to 2.0 GHz.
5. Compute the return loss from the reflection coefficient values.
6. Repeat steps 3 through 5 for Lanes 1, 2, and 3.

Observable Results:
a. For all lanes, the differential return loss shall exceed the limits described by Equations 54.1 and 54.2.

Possible Problems: None

Test 54.2.2 - Input Return Loss

Purpose: To verify that the differential input return loss of the DUT is within the conformance limits

References:

[1] IEEE Std 802.3ak-2003, subclause 54.6.4 - Receiver characteristics
[2] Ibid., subclause 54.6.4.5 - Input return loss

Resource Requirements: See Appendix 54.A

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Discussion:

Reference [1] specifies the receiver characteristics for 10GBASE-CX4 devices. This specification includes conformance requirements for the differential input return loss, which are specified in [2].

Note that because the same conformance limits are used in both the input and output return loss specifications, this test is almost identical to Test 54.2.1 (Output Return Loss), except the measurement is now performed on the DUT receiver instead of the transmitter.

Test Setup: See Appendix 54.A

Test Procedure:

1. Calibrate the VNA to remove the effects of the coaxial cables.
2. Configure the DUT so that it is sourcing normal IDLE signaling.
3. Connect the DUT's Lane 0 receiver to the VNA.
4. Measure the reflection coefficient at the DUT receiver from 100 MHz to 2.0 GHz.
5. Compute the return loss from the reflection coefficient values.
6. Repeat steps 3 through 5 for Lanes 1, 2, and 3.

Observable Results:

a. For all lanes, the differential return loss shall exceed the limits described by Equations 54.1 and 54.2 (see previous test, 54.2.1).

Possible Problems: None

GROUP 3: RECEIVER PERFORMANCE REQUIREMENTS

Overview:

The tests defined in this section verify the receiver performance characteristics of the Physical Medium Dependent (PMD) layer defined in Clause 54 of IEEE 802.3ak.

Test 54.3.1 - Bit Error Ratio

Purpose: To verify that the Bit Error Ratio of the DUT exceeds the minimum conformance limit

References:

[1] IEEE Std 802.3ak-2003, subclause 54.6.4 - Receiver characteristics
[2] Ibid., subclause 54.6.4.1 - Bit Error Ratio
[3] Ibid., subclause 54.6.4.2 - Signaling speed range
[4] Ibid., subclause 54.6.4.4 - Input signal amplitude
[5] Ibid., subclause 54.7 - Cable assembly characteristics

Resource Requirements:

- Minimum length 10GBASE-CX4 cable (0.5m)
- Maximum length 10GBASE-CX4 cable (15m)
- Compliant 10GBASE-CX4 transmitter (link partner)

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Discussion:

Reference [1] specifies the receiver characteristics for 10GBASE-CX4 devices. This specification includes conformance requirements for the Bit Error Ratio (BER), which are specified in [2].

Reference [2] simply states that the receiver, *"shall operate with a BER of better than 1E-12 when receiving a compliant transmit signal, as defined in 54.6.3, through a compliant cable assembly as defined in 54.7."* An additional note is stated, which reads, *"NOTE - The BER should be met with a worst-case insertion loss, long cable, as well as a low loss, short cable. The low loss cable may be a more stringent requirement on the system due to higher reflections and crosstalk than with the long cables."*

Note that this specification is relatively loose, as it does not mandate that a worst-case compliant transmit signal or worst-case cable assembly be used. (Note the word *should*, not shall, is used with respect to the worst-case insertion loss cable.) There is also no specification for receiver jitter tolerance. From a purely literal interpretation of [2], successful operation at a BER of 1E-12 with *any* compliant transmitter over *any* compliant channel would be sufficient to demonstrate conformance. The short/long cable cases are recommended, but not required for conformance.

As it turns out, the short/long cable cases are effectively what the UNH IOL uses when performing a typical interoperability test. Thus, the receiver BER specification in [2] is effectively equivalent to the IOL's definition of an interoperability test. Since the UNH IOL also currently lacks the capability to generate a formal stressed-receiver tolerance test environment, the easiest practical alternative for verifying the target BER is to simply use an actual 10GBASE-CX4 link partner, and a test channel consisting of real cable. In this case, the goal would be to use a cable that is as close to worst-case as possible, in conjunction with a reference transmitter that is also as close to worst-case as possible. Note that technically the specification of [2] can be somewhat misleading, as references [3] and [4] additionally require that the BER specification of [2] be maintained over the entire conformant range of signaling speed and amplitude values, respectively. This is feasible to accomplish, given a reference transmitter device that provides amplitude adjustment control, and the ability to be driven by an external adjustable clock source.

Test Setup: See test procedure (below)

Test Procedure:

1. Calibrate reference transmitter (link partner) to minimum amplitude and slowest signaling speed values.
2. Connect reference transmitter to the DUT using the minimum length 10GBASE-CX4 cable.
3. Transmit a sufficient number of bits to verify a BER of 1E-12.
4. Repeat step 3, varying reference transmitter amplitude and signaling speed across conformance ranges.
5. Repeat steps 1 through 4, using the maximum length 10GBASE-CX4 cable.

Observable Results:

a. In all cases, the DUT shall maintain a BER of 1E-12 or lower.

Possible Problems: None

APPENDICES

Overview:

Test suite appendices are intended to provide additional low-level technical detail pertinent to specific tests contained in this test suite. These appendices often cover topics that are outside of the scope of the standard, and are specific to the methodologies used for performing the measurements in this test suite. Appendix topics may also include discussion regarding a specific interpretation of the standard (for the purposes of this test suite), for cases where a particular specification may appear unclear or otherwise open to multiple interpretations.

Scope:

Test suite appendices are considered informative supplements, and pertain solely to the test definitions and procedures contained in this test suite.

Appendix 54.A - Test Fixtures and Setups

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

References:

[1] IEEE Std 802.3ak-2003, subclause 54.6.4 - Receiver characteristics
[2] Ibid., subclause 54.6.4.5 - Input return loss

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Discussion: