UNH IOL 10 GIGABIT ETHERNET CONSORTIUM

High Speed Cable
Test Suite
Version 0.2

Technical Document

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MODIFICATION RECORD

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Andy Baldman: Misc formatting edits.

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Jeff Lapak: Initial internal draft release.

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Jeff Lapak	UNH InterOperability Lab
Andy Baldman	UNH InterOperability Lab

INTRODUCTION

Overview

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 suite of tests has been developed to help implementers evaluate the functioning of their Clause 28 Auto-Negotiation based products. The tests do not determine if a product conforms to the IEEE 802.3 Standard, nor are they purely interoperability tests. Rather, they provide one method to isolate problems within an auto-negotiating device. Successful completion of all tests contained in this suite does not guarantee that the tested device will operate with other auto-negotiating 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 well in most auto-negotiating 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 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

The references section lists cross-references to the IEEE 802.3 standards and other documentation that might be helpful in understanding and evaluating the test and results.

Resource Requirements

The requirements section specifies the hardware, and test equipment that will be needed to perform the test. The items contained in this section are special test devices or other facilities, which may not be available on all devices.

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 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 step-by-step instructions for carrying out the test. It provides a cookbook approach to testing, and may be interspersed with observable results.

Observable Results

The observable results section lists observations that can be examined by the tester to verify that the DUT is operating properly. When multiple values are possible for an observable, this section provides a short discussion on how to interpret them. The determination of a pass or fail for a certain 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.

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GROUP 1: Frequency Domain Based Measurements

Scope: The following tests cover cable testing based in the frequency domain. Typically these measurements would traditionally be taken with a Network Analyzer.

Overview: These tests are designed to verify Insertion Loss, Return Loss, and Crosstalk effects.

Test #1.1: Insertion Loss

Purpose: To verify that the cable meets the required Insertion loss over the defined frequency range.

References:

[1] IEEE Std. 802.3ak: subclause 54.7.2, Equation 54-3
[2] InfiniBand Architecture Specification Volume 2, Release 1.1: subclause 7.9.2, Table 30
[3] American National Standard Project T10/1601-D, Revision 7: subclause 5.3.9, Table 34
[4] Serial ATA, Revision 1.0a: subclause 6.3.9.1, Table 4

Resource Requirements:

- Network Analyzer

Last Modification: December 15, 2004

Discussion: In order for two end devices to communicate properly it is necessary for the interconnect to effect the signaling in a marginal way. Loss of power in the interconnect is one of the major factors in a system being able to meet a required bit error rate.

Test Setup: Using a high quality adaptor, connect the cable under test to the Network Analyzer.

Technology	Curve or Points
10GBASE-CX4	$IL \leq (0.2629 \times \sqrt{f}) + (0.0034 \times f) + (12.76 \div \sqrt{f})$ with f in MHz
InfiniBand	10dB for f $\leq$ 1.25 GHz
Serial Attached SCSI	6dB for f $\leq$ 1.5 or 3.0 GHz
Serial ATA	6dB for 10 $\leq$ f $\leq$ 4500 MHz

Procedure:

1. Sweep the Network Analyzer over the defined frequency band for the technology at the required power and IF bandwidth.

Observable Results:

a. The insertion loss measured should be less than the defined curve or points defined for the technology.

Possible Problems: Since most cables are not terminated to an interface compatible with most Network Analyzers it is necessary to use an adaptor. This adaptor must be properly designed to have a marginal effect on the testing, this includes the need for the adaptor to use high quality connectors and impedance controlled low loss interconnects.

Test #1.2: Return Loss

Purpose: To verify that the cable meets the required return loss over the defined frequency range.

References:
[1] IEEE Std. 802.3ak: subclause 54.7.3, Equations 54-4 and 54-5

Resource Requirements:
- Network Analyzer

Last Modification: December 15, 2004

Discussion: In order for two end devices to communicate properly it is necessary for the interconnect to effect the signaling in a marginal way. Reflections in the cable can effect the performance of a transmitter as well as generating more near end crosstalk.

Test Setup: Using a high quality adaptor, connect the cable under test to the Network Analyzer.

Technology	Curve or Points
10GBASE-CX4	$RL \leq 22.35 - 17.19 \times \log(f \div 100)$ for $100 \leq f \leq 400$ and $RL \leq 12$ dB for $400 \leq f \leq 2000$; for f in MHz

Procedure:
1. Sweep the Network Analyzer over the defined frequency band for the technology at the required power and IF bandwidth.

Observable Results:
a. The return loss measured should be less than the defined curve or points defined for the technology.

Possible Problems: Since most cables are not terminated to an interface compatible with most Network Analyzers it is necessary to use an adaptor. This adaptor must be properly designed to have a marginal effect on the testing, this includes the need for the adaptor to use high quality connectors and impedance controlled low loss interconnects.

Test #1.3: Near End Crosstalk

Purpose: To verify that the cable meets the required crosstalk levels over the defined frequency range.

References:
[1] IEEE Std. 802.3ak: subclause 54.7.4, Equation 54-6
[2] American National Standard Project T10/1601-D, Revision 7: subclause 5.3.9, Table 34
[3] Serial ATA, Revision 1.0a: subclause 6.3.9.1, Table 4

Resource Requirements:
- Network Analyzer

Last Modification: December 15, 2004

Discussion: In order for two end devices to communicate properly it is necessary for the interconnect to effect the signaling in a marginal way. Near end crosstalk, energy coupled from a transmitter on the same end of an interconnect as the receiver, can seriously degrade the ability of a receiver to properly decode data coming from the remote device. It is important to verify that this induced crosstalk is lower than the budgeted margin.

Test Setup: Using a high quality adaptor, connect the cable under test to the Network Analyzer.

Technology	Curve or Points
10GBASE-CX4	$NEXT(f) \geq 30 - 17 \times \log(f \div 2000)$
Serial Attached SCSI	33dB for f $\leq$ 1.5 or 3.0 GHz
Serial ATA	26dB for 10 $\leq$ f $\leq$ 4500 MHz

Procedure:
a. Sweep the Network Analyzer over the defined frequency band for the technology at the required power and IF bandwidth.

Observable Results:
a. The Crosstalk measured should be less than the defined curve or points defined for the technology.

Possible Problems: Since most cables are not terminated to an interface compatible with most Network Analyzers it is necessary to use an adaptor. This adaptor must be properly designed to have a marginal effect on the testing, this includes the need for the adaptor to use high quality connectors and impedance controlled low loss interconnects.

Test #1.4: Far End Crosstalk

Purpose: To verify that the cable meets the required crosstalk levels over the defined frequency range.

References:
[1] IEEE Std. 802.3ak: subclause 54.7.5, Equation 54-9

Resource Requirements:
- Network Analyzer

Last Modification: December 15, 2004

Discussion: In order for two end devices to communicate properly it is necessary for the interconnect to effect the signaling in a marginal way. Far end crosstalk, energy coupled from a transmitter on the opposite end of an interconnect as the receiver, can seriously degrade the ability of a receiver to properly decode data coming from the remote device. It is important to verify that this induced crosstalk is lower than the budgeted margin. In the case of CX-4 cabling ELFEXT measurements are made rather than typical FEXT measurements, where ELFEXT is equal to FEXT minus the insertion loss of the disturbed lane.

Test Setup: Using a high quality adaptor, connect the cable under test to the Network Analyzer.

Technology	Curve or Points
10GBASE-CX4	$ELFEXT(f) \geq 21 - 20 \times \log(f \div 2000)$

Procedure:
1. Sweep the Network Analyzer over the defined frequency band for the technology at the required power and IF bandwidth.

Observable Results:
a. The Crosstalk measured should be less than the defined curve or points defined for the technology.

Possible Problems: Since most cables are not terminated to an interface compatible with most Network Analyzers it is necessary to use an adaptor. This adaptor must be properly designed to have a marginal effect on the testing, this includes the need for the adaptor to use high quality connectors and impedance controlled low loss interconnects.

Test #1.5: Multiple Disturber NEXT

Purpose: To verify that the cable meets the required crosstalk levels over the defined frequency range.

References:
[1] IEEE Std. 802.3ak: subclause 54.7.4.2, Equations 54-7 and 54-8

Resource Requirements:
- Network Analyzer

Last Modification: December 15, 2004

Discussion: In order for two end devices to communicate properly it is necessary for the interconnect to effect the signaling in a marginal way. Near end crosstalk, energy coupled from a transmitter on the same end of an interconnect as the receiver, can seriously degrade the ability of a receiver to properly decode data coming from the remote device. It is important to verify that this induced crosstalk is lower than the budgeted margin. In certain technologies multiple transmitters and receivers are used, in this case it is important to examine how a single signal path is effected by all of the nearby transmitters.

Test Setup: Using a high quality adaptor, connect the cable under test to the Network Analyzer.

Technology	Curve or Points
10GBASE-CX4	$MDNEXT(f) \geq 28 - 17 \times \log(f \div 2000)$

Procedure:
1. Sweep the Network Analyzer over the defined frequency band for the technology at the required power and IF bandwidth.
2. Repeat 1 for all adjacent lanes
3. Sum the power of these measurements

Observable Results:
a. The Crosstalk measured should be less than the defined curve or points defined for the technology.

Possible Problems: Since most cables are not terminated to an interface compatible with most Network Analyzers it is necessary to use an adaptor. This adaptor must be properly designed to have a marginal effect on the testing, this includes the need for the adaptor to use high quality connectors and impedance controlled low loss interconnects.

Test #1.6: Multiple Disturber FEXT

Purpose: To verify that the cable meets the required crosstalk levels over the defined frequency range.

References:
[1] IEEE Std. 802.3ak: subclause 54.7.5.2, Equations 54-10 and 54-11

Resource Requirements:
- Network Analyzer

Last Modification: December 15, 2004

Discussion: In order for two end devices to communicate properly it is necessary for the interconnect to effect the signaling in a marginal way. Far end crosstalk, energy coupled from a transmitter on the opposite end of an interconnect as the receiver, can seriously degrade the ability of a receiver to properly decode data coming from the remote device. It is important to verify that this induced crosstalk is lower than the budgeted margin. In certain technologies multiple transmitters and receivers are used, in this case it is important to examine how a single signal path is effected by all of the nearby transmitters. In the case of CX-4 cabling ELFEXT measurements are made rather than typical FEXT measurements, where ELFEXT is equal to FEXT minus the insertion loss of the disturbed lane.

Test Setup: Using a high quality adaptor, connect the cable under test to the Network Analyzer.

Technology	Curve or Points
10GBASE-CX4	$MDELFEXT(f) \geq 19 - 20 \times \log(f \div 2000)$

Procedure:
1. Sweep the Network Analyzer over the defined frequency band for the technology at the required power and IF bandwidth.
2. Repeat 1 for all adjacent lanes
3. Sum the power of these measurements

Observable Results:
a. The Crosstalk measured should be less than the defined curve or points defined for the technology.

Possible Problems: Since most cables are not terminated to an interface compatible with most Network Analyzers it is necessary to use an adaptor. This adaptor must be properly designed to have a marginal effect on the testing, this includes the need for the adaptor to use high quality connectors and impedance controlled low loss interconnects.

GROUP 2: Time Domain Based Measurements

Scope: The following tests cover cable testing based in the Time domain. Typically these measurements would traditionally be taken using Time Domain Reflectronomy.

Overview: These tests are designed to verify Return Loss, Skew and Impedance values.

Test #2.1: Insertion Loss

Purpose: To verify that the cable meets the required Insertion loss over the defined frequency range.

References:
[1] IEEE Std. 802.3ak: subclause 54.7.2, Equation 54-3
[2] InfiniBand Architecture Specification Volume 2, Release 1.1: subclause 7.9.2, Table 30
[3] American National Standard Project T10/1601-D, Revision 7: subclause 5.3.9, Table 34
[4] Serial ATA, Revision 1.0a: subclause 6.3.9.1, Table 4

Resource Requirements:
- Network Analyzer

Last Modification: December 15, 2004

Discussion: In order for two end devices to communicate properly it is necessary for the interconnect to effect the signaling in a marginal way. Loss of power in the interconnect is one of the major factors in a system being able to meet a required bit error rate.

Test Setup: Using a high quality adaptor, connect the cable under test to a TDR system.

Technology	Curve or Points
10GBASE-CX4	$IL \leq (0.2629 \times \sqrt{f}) + (0.0034 \times f) + (12.76 \div \sqrt{f})$ with f in MHz
InfiniBand	10dB for f $\leq$ 1.25 GHz
Serial Attached SCSI	6dB for f $\leq$ 1.5 or 3.0 GHz
Serial ATA	6dB for 10 $\leq$ f $\leq$ 4500 MHz

Procedure:
1. Using a TDR, transmit a pulse and calculate the frequency domain response over the defined frequency band for the technology.

Observable Results:
a. The insertion loss measured should be less than the defined curve or points defined for the technology.

Possible Problems: Since most cables are not terminated to an interface compatible with most Network Analyzers or TDR systems it is necessary to use an adaptor. This adaptor must be properly designed to have a marginal effect on the testing, this includes the need for the adaptor to use high quality connectors and impedance controlled low loss interconnects.

Test #2.2: Return Loss

Purpose: To verify that the cable meets the required Return loss over the defined frequency range.

References:
[1] IEEE Std. 802.3ak: subclause 54.7.3, Equations 54-4 and 54-5

Resource Requirements:
- Network Analyzer

Last Modification: December 15, 2004

Discussion: In order for two end devices to communicate properly it is necessary for the interconnect to effect the signaling in a marginal way. Loss of power in the interconnect is one of the major factors in a system being able to meet a required bit error rate.

Test Setup: Using a high quality adaptor, connect the cable under test to the Network Analyzer.

Technology	Curve or Points
10GBASE-CX4	$RL \leq 22.35 - 17.19 \times \log(f \div 100)$ for $100 \leq f \leq 400$ and $RL \leq 12$ dB for $400 \leq f \leq 2000$; for f in MHz with f in MHz

Procedure:
1. Using a TDR, transmit a pulse and calculate the frequency domain response over the defined frequency band for the technology.

Observable Results:
a. The return loss measured should be less than the defined curve or points defined for the technology.

Possible Problems: Since most cables are not terminated to an interface compatible with most Network Analyzers or TDR systems it is necessary to use an adaptor. This adaptor must be properly designed to have a marginal effect on the testing, this includes the need for the adaptor to use high quality connectors and impedance controlled low loss interconnects.

Test #2.3: Skew

Purpose: To verify that the cable has been designed to limit skew between pairs or lanes.

References:
[1] InfiniBand Architecture Specification Volume 2, Release 1.1: subclause 7.9.2, Table 30
[2] American National Standard Project T10/1601-D, Revision 7: subclause 5.3.9, Table 34
[3] Serial ATA, Revision 1.0a: subclause 6.3.9.1, Table 4

Resource Requirements:
- Network Analyzer

Last Modification: December 15, 2004

Discussion: In order for two end devices to communicate properly it is necessary for the interconnect to effect the signaling in a marginal way. Differential skew causes a phase shift between the positive and negative values of the same signal, this can severely degrade the ability of a receiver to correctly decode an incoming waveform. Pair to pair skew can lead to a multi-lane signal to arrive at the receiver at different times, this degrades the ability of a receiver to align the lanes properly.

Test Setup: Using a high quality adaptor, connect the cable under test to the Network Analyzer.

Technology	Curve or Points
InfiniBand	500ps (pair to pair)
Serial Attached SCSI	10ps (intra-pair)
Serial ATA	10ps (intra-pair)

Procedure:
1. Using a TDR, transmit a pulse and measure the propagation delay between the pairs or lanes.

Observable Results:
a. The skew should between pairs or intra-pair should be less than the defined maximum value.

Possible Problems: Since most cables are not terminated to an interface compatible with most Network Analyzers or TDR systems it is necessary to use an adaptor. This adaptor must be properly designed to have a marginal effect on the testing, this includes the need for the adaptor to use high quality connectors and impedance controlled low loss interconnects.

Test #2.4: Impedance profile (Differential Mode)

Purpose: To verify that the cable meets the required impedance defined for each differential pair.

References:
[1] InfiniBand Architecture Specification Volume 2, Release 1.1: subclause 7.9.2, Table 30
[2] American National Standard Project T10/1601-D, Revision 7: subclause 5.3.9, Table 34
[3] Serial ATA, Revision 1.0a: subclause 6.3.9.1, Table 4

Resource Requirements:
- Network Analyzer

Last Modification: December 15, 2004

Discussion: In order for two end devices to communicate properly it is necessary for the interconnect to effect the signaling in a marginal way. Discontinuities in the cable due to impedance mismatches cause reflections which can not only affect the transmitter but also cause a loss in the power received at the receiver. This test is designed to insure that the cables meet the defined impedance profile for a given technology.

Test Setup: Using a high quality adaptor, connect the cable under test to the Network Analyzer.

Technology	Curve or Points
InfiniBand	95 to 155 ohms mean value, with no more than 5 ohms variance from the mean
Serial Attached SCSI	100 +- 15 ohms and no more than 5 ohms variance intra-pair
Serial ATA	100 +- 15 ohms and no more than 5 ohms variance intra-pair

Procedure:
1. Using a TDR, transmit a pulse and measure impedance of the channel.

Observable Results:
a. The impedance of the cable should be within the defined allowable range.

Possible Problems: Since most cables are not terminated to an interface compatible with most Network Analyzers or TDR systems it is necessary to use an adaptor. This adaptor must be properly designed to have a marginal effect on the testing, this includes the need for the adaptor to use high quality connectors and impedance controlled low loss interconnects.

Test #2.5: Impedance profile (Common Mode)

Purpose: To verify that the cable meets the required impedance defined for each differential pair.

References:
[1] American National Standard Project T10/1601-D, Revision 7: subclause 5.3.9, Table 34
[2] Serial ATA, Revision 1.0a: subclause 6.3.9.1, Table 4

Resource Requirements:
- Network Analyzer

Last Modification: December 15, 2004

Discussion: In order for two end devices to communicate properly it is necessary for the interconnect to effect the signaling in a marginal way. Discontinuities in the cable due to impedance mismatches cause reflections which can not only affect the transmitter but also cause a loss in the power received at the receiver. This test is designed to insure that the cables meet the defined impedance profile for a given technology.

Test Setup: Using a high quality adaptor, connect the cable under test to the Network Analyzer.

Technology	Curve or Points
Serial Attached SCSI	32.5 +- 7.5 Ohms
Serial ATA	25 to 40 Ohms

Procedure:
1. Using a TDR, transmit a pulse and measure impedance of the channel.

Observable Results:
a. The impedance of the cable should be within the defined allowable range.

Possible Problems: Since most cables are not terminated to an interface compatible with most Network Analyzers or TDR systems it is necessary to use an adaptor. This adaptor must be properly designed to have a marginal effect on the testing, this includes the need for the adaptor to use high quality connectors and impedance controlled low loss interconnects.

GROUP 3: Eye Diagram Based Measurements

Scope: The following tests cover cable testing based on lab measured stimulus and response. Typically these measurements would traditionally be taken using a digital storage oscilloscope.

Overview: These tests are designed to verify Jitter induced by the cable.

Test #3.1: Jitter

Purpose: To verify that a cable introduces a limited amount of jitter to the overall system.

References:
[1] InfiniBand Architecture Specification Volume 2, Release 1.1: subclause 7.9.2, Table 30

Resource Requirements:
- Network Analyzer

Last Modification: December 15, 2004

Discussion: Jitter (timing error) can be caused by many sources. The ability for a device to properly decode a signal depends strongly on the ability to recover the clock from the signal. Large amounts of jitter can make the re-creation of a reference clock extremely difficult. Some cable specifications call for a specified maximum jitter induced by the cable assemble. For a measurement of this kind, it is extremely important to use highly calibrated sources and scopes to properly ensure that the extra jitter measured is not being induced by sources, but is strictly a measure of the jitter induced by the cable.

Test Setup: Using a high quality adaptor, connect the cable under test to the signal sources and oscilloscope. Measure the eye opening as specified and determine the jitter in the box etc.

Technology	Curve or Points
InfiniBand	0.25 UI

Procedure:
1. Connect the test stimulus (Fibre Channel CJPAT at 1 Vpp operating at 2.5 Gb/s) to the channel under test and the two most adjacent pairs to an asynchronous crosstalk source at 1.6 Vpp differential amplitude operating at a speed of no less than 1.3Gb/s.
2. Using a 20mV high jitter box until 1000 hits are observed, calculate the minimum horizontal eye opening.

Observable Results:
a. The worst case jitter observed should be less than 0.25 UI.

Possible Problems: Since most cables are not terminated to an interface compatible with most Network Analyzers or TDR systems it is necessary to use an adaptor. This adaptor must be properly designed to have a marginal effect on the testing, this includes the need for the adaptor to use high quality connectors and impedance controlled low loss interconnects.

Test #3.2: Eye Opening

Purpose: To verify that a cable introduces a limited amount of jitter to the overall system.

References:
[1] InfiniBand Architecture Specification Volume 2, Release 1.1: subclause 7.9.2, Table 30

Resource Requirements:
- Network Analyzer

Last Modification: December 15, 2004

Discussion: Jitter (timing error) can be caused by many sources. The ability for a device to properly decode a signal depends strongly on the ability to recover the clock from the signal. Large amounts of jitter can make the re-creation of a reference clock extremely difficult. Some cable specifications call for a specified maximum jitter induced by the cable assemble. For a measurement of this kind, it is extremely important to use highly calibrated sources and scopes to properly ensure that the extra jitter measured is not being induced by sources, but is strictly a measure of the jitter induced by the cable.

Test Setup: Using a high quality adaptor, connect the cable under test to the signal sources and oscilloscope. Measure the eye opening as specified and determine the jitter in the box etc.

Technology	Curve or Points
InfiniBand	316 mV

Procedure:
1. Calibrate the test stimulus and crosstalk sources according to the Infiniband Trade Association TD: Eye jitter test setup procedure.
2. Connect the test stimulus (Fibre Channel CJPAT at 1 Vpp operating at 2.5 Gb/s) to the channel under test and the two most adjacent pairs to an asynchronous crosstalk source at 1.6 Vpp differential amplitude operating at a speed of no less than 1.3Gb/s.
3. Using a 20mV high jitter box until 1000 hits are observed, calculate the minimum vertical eye opening.

Observable Results:
a. The minimum peak to peak voltage at the center of the eye should be greater than 316 mV.

Possible Problems: Since most cables are not terminated to an interface compatible with most Network Analyzers or TDR systems it is necessary to use an adaptor. This adaptor must be properly designed to have a marginal effect on the testing, this includes the need for the adaptor to use high quality connectors and impedance controlled low loss interconnects.