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BACKPLANE ETHERNET CONSORTIUM

Clause 72
10GBASE-KR PMD Test Suite
Version 1.1

Technical Document

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MODIFICATION RECORD

March 22, 2011 Version 1.1

Jon Beckwith: Fixed references in 72.1.6.
Removed references to training (coefficient decrement/increment text) in 72.1.6.

Nick Rainsford: For test 72.1.1, in procedure step one instead of requiring test pattern 2/3, it is listed now that a high frequency test pattern is needed.
For test 72.1.2, in procedure step one instead of requiring test pattern 2/3, it is listed now that a high frequency test pattern is needed.
For test 72.1.3, in procedure step one instead of requiring test pattern 2/3, it is listed now that a high frequency 1010, test pattern is needed.
Changed all of the 802.3ap-2007 references to 802.3-2008 instead.
Added setup diagrams of the two testing setups, with a general description.

February 1, 2008 Version 1.0

Adam Sayer: Clean-up and formal initial release.

December 5, 2007 Version 0.1

Adam Sayer: Informal preliminary draft. Internal IOL use only.

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ACKNOWLEDGMENTS

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-KR products.

These tests are designed to determine if a product conforms to specifications defined in Clause 72 of the IEEE 802.3-2008 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-KR 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 72 of IEEE 802.3-2008.

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Test 72.1.1 – Signaling Speed

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

References:
       [1] IEEE Std. 802.3-2008, subclause 72.7.1 – Transmitter Electrical Characteristics
       [2] IEEE Std. 802.3-2008, subclause 72.7.1.3 – Signaling Speed
       [3] IEEE Std. 802.3-2008, subclause 72.7.1.1 – Test fixtures

Resource Requirements: See Appendix 72.A

Last Modification: June 10, 2011

Discussion:
       Reference [1] specifies the transmitter characteristics for 10GBASE-KR devices. This specification includes conformance requirements for the signaling speed, which is specified in [2].

       Reference [2] states that the 10GBASE-KR signaling speed shall be 10.3125 Gbaud +/- 100 ppm. This translates to 10.3125 Gbaud +/- 1.03125 Mbaud, with a nominal Unit Interval (UI) of 97 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-KR signal, however a 1010 (high frequency) pattern will be used, primarily out of convenience, as this pattern is also used for several other tests in this group.

Test Setup: See Appendix 72.A

Test Procedure:
       1. Configure the DUT to send a high frequency test pattern.
       2. Connect the DUT's transmitter to the test fixture.
       3. Measure the average TX signaling speed.

Observable Results:
       a. The signaling speed shall be within 10.3125 Gbaud +/- 1.03125 Mbaud

Possible Problems: None.

Test 72.1.2 – 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. 802.3-2008, subclause 72.7.1 – Transmitter characteristics
[2] IEEE Std. 802.3-2008, subclause 72.7.1.4 – Output amplitude
[3] IEEE Std. 802.3-2008, subclause 72.7.1.1 – Test fixtures
[4] IEEE Std. 802.3-2005, subclause 52.9.1.1 – Test-pattern definition

Resource Requirements: See Appendix 72.A

Last Modification: June 10, 2011

Discussion:
Reference [1] specifies the transmitter characteristics for 10GBASE-KR devices. This specification includes conformance requirements for the common mode output voltage defined 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-KR signal, however the test pattern 3 (PRBS31) 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 72.A

Test Procedure:
1. Configure the DUT to send PRBS31
2. Connect the DUT's transmitter to the test fixture.
3. Measure the common mode output voltage of SL<p> and SL<n> at the V_{com} test point.
4. For enhanced accuracy, repeat step 3 multiple times and average the voltages measured at each point.

Observable Results:
a. The common mode output voltage shall be between 0 V and 1.9 V with respect to the signal shield.

Possible Problems: None

Test 72.1.3 – Differential Output Amplitude

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

References:
[1] IEEE Std. 802.3-2008, subclause 72.7.1 – Transmitter characteristics
[2] IEEE Std. 802.3-2008, subclause 72.7.1.4 – Output amplitude
[3] IEEE Std. 802.3-2008, subclause 72.7.1.1 – Test fixtures

Resource Requirements: See Appendix 72.A

Last Modification: June 10, 2011

Discussion:
Reference [1] specifies the transmitter characteristics for 10GBASE-KR devices. This specification includes conformance requirements for the differential output amplitude defined 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. The signal being transmitted by the DUT may be any valid 10GBASE-KR signal consisting of no fewer than eight symbols of alternating polarity. However a 1010 (high frequency) pattern will be used, as the requirement for amplitude is on a 1010 pattern.

Test Setup: See Appendix 72.A

Test Procedure:
1. Configure the DUT to send a high frequency test pattern consisting of a 1010 pattern.
2. Connect the DUT's transmitter to the test fixture.
3. Measure the maximum peak-to-peak differential output voltage.
4. Disable the transmitter and measure the peak-to-peak output voltage.
5. For enhanced accuracy, repeat steps 3 and 4 multiple times and average the voltages measured at each point.

Observable Results:
a. The maximum differential peak-to-peak output voltage shall be less than 1200 mV, regardless of equalization setting.
b. The transmitter output voltage shall be less than 30 mV peak-to-peak when disabled.

Possible Problems: None

Test 72.1.4 – Transition Time

Purpose: To verify that the rising and falling edge transition times are within the conformance limits.

References:
[1] IEEE Std. 802.3-2008, subclause 72.7.1 – Transmitter characteristics
[2] IEEE Std. 802.3-2008, subclause 72.7.1.7 – Transition time
[3] IEEE Std. 802.3-2008, subclause 72.7.1.1 – Test fixtures
[4] IEEE Std. 802.3-2008, subclause 72.7.1.11 – Transmitter output waveform requirements
[5] IEEE Std. 802.3-2005, subclause 52.9.1.2 – Test-pattern definition

Resource Requirements: See Appendix 72.A

Last Modification: January 15, 2008

Discussion:
Reference [1] specifies the transmitter characteristics for 10GBASE-KR devices. This specification includes conformance requirements for the rising and falling edge transition times defined in [2].

In this test, the transition time is measured while the DUT is connected to the test fixture defined in [3] or its functional equivalent. The transition times are to be measured at the 20% and 80% levels referenced to v_2 and v_5 as defined in [4]. Reference [2] also requires that the measurement be done using the square wave test pattern defined in [5], with no equalization and a run of at least eight consecutive ones.

Test Setup: See Appendix 72.A

Test Procedure:
1. Configure the DUT so that it is sourcing the square wave (low frequency) test pattern, with no equalization.
2. Connect the DUT's transmitter to the test fixture.
3. Capture a run of at least eight consecutive ones.
4. Measure the rising and falling edge transition times.

Observable Results:
a. The rising and falling edge transition times shall be between 24 ps and 47 ps.

Possible Problems: None

Test 72.1.5 – Transmit Jitter

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

References:
        [1] IEEE Std. 802.3-2008, subclause 72.1.1 – Transmitter characteristics
        [2] IEEE Std. 802.3-2008, subclause 72.7.1.8 – Transmit jitter
        [3] IEEE Std. 802.3-2008, subclause 72.7.1.9 – Transmit jitter test requirements
        [4] IEEE Std. 802.3-2008, subclause 72.7.1.1 – Test fixtures
        [5] IEEE Std. 802.3-2005, subclause 52.9.1.1 – Test-pattern definition

Resource Requirements: See Appendix 72.A

Last Modification: January 15, 2008

Discussion:
        Reference [1] specifies the transmitter characteristics for 10GBASE-KR devices. This specification includes conformance requirements for the peak-to-peak transmit jitter defined 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 test pattern 2 or 3 as defined in [5] during this test.

Test Setup: See Appendix 72.A

Test Procedure:
        1. Configure the DUT so that it is sourcing test pattern 2 or 3.
        2. Connect the DUT's transmitter to the test fixture.
        3. Measure the random jitter, deterministic jitter, duty cycle distortion, and total transmit jitter.

Observable Results:
        a. The Random Jitter value shall not exceed 0.15 UI.
        b. The Deterministic Jitter value shall not exceed 0.15 UI.
        c. The Duty Cycle Distortion value shall not exceed 0.035 UI.
        d. The Total Jitter value shall not exceed 0.28 UI.

Possible Problems: None

Test 72.1.6 – Transmitter Output Waveform Requirements Related to Coefficient Update

Purpose: To verify that the transmitter output waveform of the DUT is within the conformance limits with respect to the coefficient update process.

References:
- [1] IEEE Std. 802.3-2008, subclause 72.7.1 – Transmitter characteristics
- [2] IEEE Std. 802.3-2008, subclause 72.7.1.11 – Transmitter output waveform requirements
- [3] IEEE Std. 802.3-2008, subclause 72.7.1.1 – Test fixtures
- [4] IEEE Std. 802.3-2005, subclause 52.9.1.2 – Test-pattern definition
- [5] IEEE Std. 802.3-2008, Figure 72-12 – Transmitter output waveform
- [6] IEEE Std. 802.3-2008, Table 72-7 – Transmitter output waveform requirements related to coefficient update

Resource Requirements: See Appendix 72.A

Last Modification: January 15, 2008

Discussion:
Reference [1] specifies the transmitter characteristics for 10GBASE-KR devices. This specification includes conformance requirements for the transmitter output waveform related to coefficient update defined in [2].

In this test, the transmitter output waveform voltage is measured at test point TP1 while the DUT is connected to the test fixture defined in [3] or its functional equivalent. The signal being transmitted by the DUT is the square wave test pattern defined in [4], with a run of at least eight consecutive ones. Voltage levels v_1, v_2, and v_3, as defined in [5], are measured both before and after a coefficient update specified in [6]. The differences in the pre- and post-update voltage levels are then compared to the requirements for that particular coefficient update, as defined in [6].

Test Setup: See Appendix 72.A

Test Procedure:
1. Configure the DUT to source square wave test pattern, with a run of at least eight consecutive zeros.
2. Connect the DUT's transmitter to the test fixture.
3. Measure the voltages v_1 through v_6, Δv_2, and Δv_5, as defined in [2].
4. Perform the coefficient update specified in the first row of [6].
5. Measure the voltages v_1 through v_6, Δv_2, and Δv_5, as defined in [2], for the updated waveform.
6. For enhanced accuracy, repeat step 3 and 5 multiple times and average the voltages measured at each point.
7. Repeat steps 1 through 5 for all other rows of [6].

Observable Results:
a. The pre- and post-update voltage levels shall conform to the requirements specified in [6].
b. For any coefficient update, the magnitudes of the changes in v_1, v_2, and v_3 shall be within 5 mV of each other.
c. The quantities Δv_2 and Δv_5 shall not exceed 40 mV peak-to-peak.
d. The quantity v_2 shall be greater than or equal to 40 mV.
e. The magnitude of the voltages shall match such that each of the quantities $(v_1+v_4)/v_1$, $(v_2+v_5)/v_2$, and $(v_3+v_6)/v_3$ does not exceed 0.05.

Possible Problems: None

Test 72.1.7 – Transmitter Output Waveform Requirements Related to Coefficient Status

Purpose: To verify that the transmitter output waveform of the DUT is within the conformance limits with respect to the coefficient status.

References:
> [1] IEEE Std. 802.3-2008, subclause 72.7.1 – Transmitter characteristics
> [2] IEEE Std. 802.3-2008, subclause 72.7.1.11 – Transmitter output waveform requirements
> [3] IEEE Std. 802.3-2008, subclause 72.7.1.1 – Test fixtures
> [4] IEEE Std. 802.3-2005, subclause 52.9.1.2 –Test-pattern definition
> [5] IEEE Std. 802.3-2008, Figure 72-12 – Transmitter output waveform
> [6] IEEE Std. 802.3-2008, Table 72-8 – Transmitter output waveform requirements related to coefficient status

Resource Requirements: See Appendix 72.A

Last Modification: January 15, 2008

Discussion:
Reference [1] specifies the transmitter characteristics for 10GBASE-KR devices. This specification includes conformance requirements for the transmitter output waveform related to coefficient status, which is specified in [2].

In this test, the transmitter output waveform voltage is measured at test point TP1 while the DUT is connected to the test fixture defined in [3] or its functional equivalent. The signal being transmitted by the DUT is the square wave test pattern defined in [4], with a run of at least eight consecutive ones. Voltage levels v_1, v_2, and v_3, as defined in [5], are measured after observing the coefficient status specified in [6]. From these voltages, pre- and post-cursor equalization ratios R_{pre} and R_{pst} are derived using Equation (72-8) and Equation (72-9).

$$R_{pre} = \frac{v_3}{v_2} \tag{72-8}$$

$$R_{pre} = \frac{v_1}{v_2} \tag{72-9}$$

Test Setup: See Appendix 72.A

Test Procedure:
> 1. Configure the DUT to source square wave test pattern, with a run of at least eight consecutive zeros.
> 2. Connect the DUT's transmitter to the test fixture.
> 3. Perform coefficient updates on the DUT until a status specified in [6] is achieved.
> 4. Measure voltages v_1, v_2, and v_3 and calculate R_{pre} and $R_{pst.}$
> 5. For enhanced accuracy, repeat step 4 multiple times and average the voltages measured at each point.
> 6. Repeat steps 1 through 4 for all other rows of [6].

Observable Results:
> a. R_{pre}, R_{pst}, and v_2 shall conform to the requirements specified in [6].

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 72 of IEEE 802.3ap.

Test 72.2.1 – Differential Output Return Loss

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

References:
[1] IEEE Std. 802.3-2008, subclause 72.7.1 – Transmitter characteristics
[2] IEEE Std. 802.3-2008, subclause 72.7.1.5 – Differential output return loss

Resource Requirements: See Appendix 72.A

Last Modification: January 15, 2008 (Version 1.0)

Discussion:
Reference [1] specifies the transmitter characteristics for 10GBASE-KR 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 50 MHz to 7.5 GHz, the differential return loss of the driver shall exceed Equation 72-4 and 72-5:

$$\text{ReturnLoss}(f) \geq 9 \text{ dB} \qquad \text{(for 50 MHz} \leq f < 2500 \text{ MHz)} \qquad \text{(EQ. 72-4)}$$

$$\text{ReturnLoss}(f) \geq 9 - 12\log(f/2500E6) \text{ dB} \quad \text{(for 2500 MHz} \leq f \leq 7500 \text{ MHz)} \qquad \text{(EQ. 72-5)}$$

Test Setup: See Appendix 72.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 transmitter to the VNA.
4. Measure the reflection coefficient at the DUT transmitter from 50 MHz to 7.5 GHz.
5. Compute the return loss from the reflection coefficient values.

Observable Results:
a. The differential output return loss shall exceed the limits described by Equations 72-4 and 72-5.

Possible Problems: None

Test 72.2.2 – Common-Mode Output Return Loss

Purpose: To verify that the common-mode output return loss of the DUT is within the conformance limits

References:
      [1] IEEE Std. 802.3-2008, subclause 72.7.1 – Transmitter characteristics
      [2] IEEE Std. 802.3-2008, subclause 72.7.1.6 – Common-mode output return loss

Resource Requirements: See Appendix 72.A

Last Modification: January 15, 2008 (Version 1.0)

Discussion:
      Reference [1] specifies the transmitter characteristics for 10GBASE-KR devices. This specification includes conformance requirements for the common-mode output return loss defined in [2].

      For the purpose of this test, the common-mode 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_{CC22} scattering parameter (s-parameter). For frequencies from 50 MHz to 7.5 GHz, the common-mode return loss of the driver shall exceed Equation 72-6 and 72-7. The reference impedance for common-mode return loss measurements is 25 Ω.

$$ReturnLoss(f) >= 6 \text{ dB} \quad\quad (for\ 50\ MHz <= f < 2500\ MHz) \quad\quad (EQ.\ 72\text{-}6)$$

$$ReturnLoss(f) >= 6 - 12log(f/2500E6) \text{ dB} \quad (for\ 2500\ MHz <= f <= 7500\ MHz) \quad (EQ.\ 72\text{-}7)$$

Test Setup: See Appendix 72.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 transmitter to the VNA.
      4. Measure the reflection coefficient at the DUT transmitter from 50 MHz to 7.5 GHz.
      5. Compute the return loss from the reflection coefficient values.

Observable Results:
      a. The common-mode output return loss shall exceed the limits described by Equations 72-6 and 72-7.

Possible Problems: None

Test 72.2.3 – Differential Input Return Loss

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

References:
[1] IEEE Std. 802.3-2008, subclause 72.7.2 – Receiver characteristics
[2] IEEE Std. 802.3-2008, subclause 72.7.2.5 – Differential Input return loss

Resource Requirements: See Appendix 72.A

Last Modification: January 15, 2008

Discussion:
Reference [1] specifies the receiver characteristics for 10GBASE-KR devices. This specification includes conformance requirements for the differential input return loss defined 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 72.2.1 (Differential Output Return Loss), except the measurement is now performed on the DUT's receiver instead of the transmitter.

Test Setup: See Appendix 72.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 receiver to the VNA.
4. Measure the reflection coefficient at the DUT receiver from 50 MHz to 7.5 GHz.
5. Compute the return loss from the reflection coefficient values.

Observable Results:
a. The differential return loss shall exceed the limits described by Equations 72-4 and 72-5 (see test 72.2.1).

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 72.A - Test Fixtures and Setups

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

References:
 [1] IEEE Std. 802.3-2008, subclause 72.7.1.1 – Test Fixtures

Last Modification: January 15, 2008

Discussion:

The reader will need the following in order to perform tests in Group 1.

1. Digital Storage Oscilloscope, 20 GHz bandwidth (minimum)
2. Transmitter Test Fixture
3. Post Processing
4. Digital Multi-meter
5. SMA cables

72.A-1: example test setup for tests 72.1.1 through 72.1.7
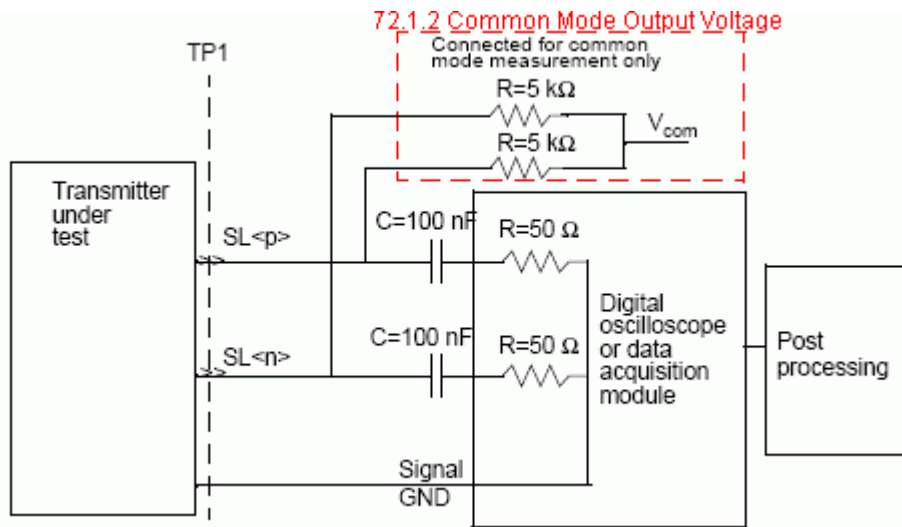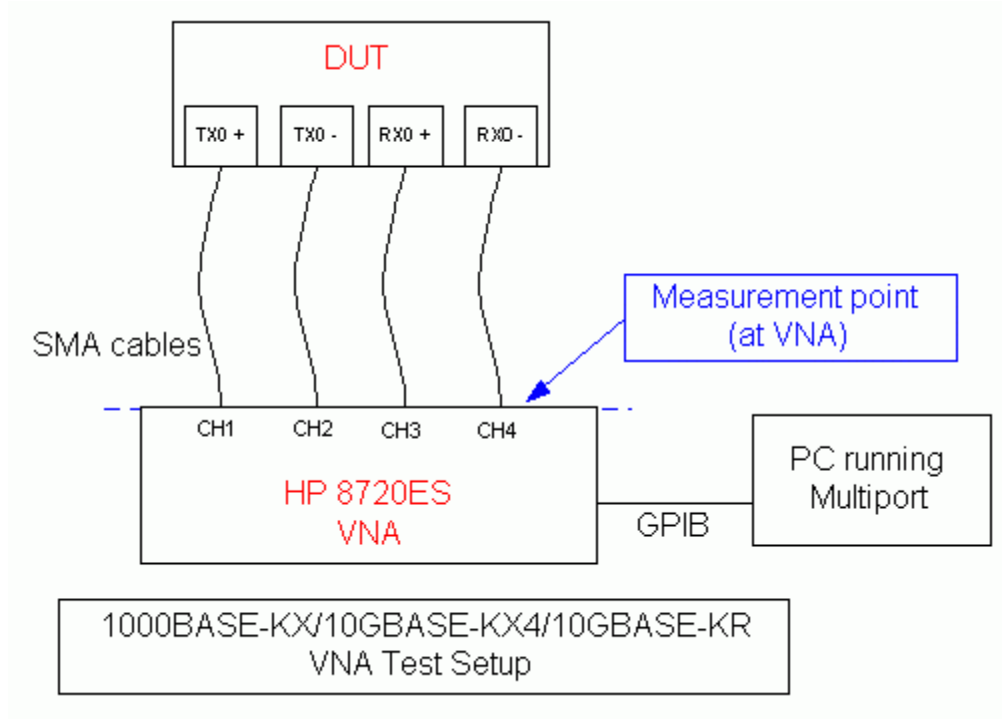
Explanation of 72.A-1:

For test, 72.1.2(Common Mode Output Voltage), the DSO is not used to perform the test. For 72.1.2 the portion of the diagram above outlined in red will be used. Vcom in this diagram will be a DMM, set to measure voltage.

For the other six tests (72.1.1-72.1.6, excluding 72.1.2), The DSO will be used. The DUT should be connected to the DSO as depicted in the above diagram through the channel slots on the DSO with SMA cables. The DSO is connected to a computer for post processing through a GPIB cable.

The reader will need the following in order to perform tests in Group 1.

1. Vector Network Analyzer
2. SMA cables
3. Post Processing

72.A-2: example test setup for tests 72.2.1 through 72.2.3

Explanation of 72.A-2:

For tests, 72.2.1 through 72.2.3 connect the DUT to the VNA with SMA cables according to the 72A-2 setup diagram. For post processing, connect the VNA to the PC with a GPIB cable.