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SPI-3 Annex F Proposal

Cable Media Performance Testing

Document 98-219r5

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1. Overview

This normative annex defines the electrical performance requirements for shielded and unshielded cable media. This document specifies the details of the measurement methodology to minimize the error between measurements executed in different laboratories.

Seven parameters are required to specify the electrical requirements: Transmission line impedance (Zo), capacitance, dielectric constant variation, propagation time, propagation time skew, attenuation and near-end cross talk. Some parameters are specified for both single ended and differential applications.

This document also specifies methods for executing the testing for these parameters. Table 1 summarizes the testing requirements.

Table 1 - Cable media test summary

Parameter	Section	measurement domain	test conditions	sample configuration	Active equipment
SE local Zo	2.1	Time	Rise time at 3 ns	(A) tie one wire of each pair & shield together, 3 meters long	TDR i.e. Tektronix 11801 or equiv.
Diff local Zo	2.2	Time	Rise times at 0.5 and 3 ns	(B) all wires + shield floating, 3 meters long	TDR i.e. Tektronix 11801 or equiv.
Diff extended distance (balanced) Zo	0	Frequency	sweep between 1 MHz and 1 GHz	(C) same as (B) with minimum 30 meter length	HP 8753E network anal or equiv.
SE capacitance	3.1	Frequency	100KHz and 1MHz	(D) Sample length 3 meters	LCR meter
Dielectric constant variation with frequency	3.3	Frequency	Sweep between 100KHz and 1 GHz	(E) Sample of one pair approx. 1” in length	Network anal.
Diff capacitance	3.2	Frequency	1 MHz and 120 MHz	(F) Sample Length 3 meters	LCR meter
Diff (Tp) propagation time per meter – Note: Tp is 1/Vp	4	Frequency	An S12 measurement	(G) Sample 30 meters	HP 8753E network anal or equiv.
Diff (Tp) propagation time per meter – Note: Tp is 1/Vp	5	Time	Launched rise time between 0.5 ns to 5 ns -propagation time is measured @ the amplitude mid-point of the STD**	(G) Modified to 3 meters	Signal pulse, (no signal generator) TDR 11801 or Equiv.
Diff propagation time skew	6		Difference between the min. and max Tp of all pairs.		NA
Diff attenuation (balanced)	7	Frequency	low freq. shelf* to 1 GHz	(H) Sample leave all other lines open - long enough to produce at least 1dB at the low freq. shelf (typically > 30 m)	HP 8753E network anal or equiv.
Cross talk NEXT Diff (Balanced)	8	Time	Signal pulse, max legal size, min. signal transition duration time	(I) Sample For freq. option use sample set up (G)	Tektronix 11801 with TDR or equiv.

*Low Frequency Shelf: That range where a 3X change in Frequency produces less than 0.5 dB in attenuation difference.
**STD: Signal Transition Duration.

Methods provided use either frequency or time domain measurements as noted in Table 1. Attempts are made to cover as much of the application as practical. Specifically, both local and extended distance parameters and the range of applicable frequencies are required.

The physical construction details can seriously affect the measured performance parameters. For example, using similar materials a flat discrete construction intrinsically has higher near end cross talk than twisted pair construction. However, properly constructed flat cable media can perform well for SCSI. This annex does not specify any construction requirements but rather relies solely on the measured performance results as the criteria for compliance.

Several test parameters use a per unit length measurement in order to allow concatenation of different lengths of cable without exceeding the performance limits at maximum length.

Cable media provides only part of the electrical path in system applications. The requirements in this annex only apply to cable media performance in nominally uniform media.

Media constructions designed to be non-uniform for purposes of enabling connectorization are not covered in this annex. An example of such media is unshielded round media that has areas where the conductors are constrained to be flat (in a line) for short distances so that an insulation displacement type of connector may be attached. These types of media are considered to be intrinsically part of a cable assembly (where connectors are attached) and the performance cannot be accurately assessed without considering the connectors also.

In system applications effects not specified in this annex, but nevertheless related to cable media, may affect the bus performance. For example, the use of cable media with different impedance values in the same bus should be avoided to minimize discontinuities and signal reflections.

Other effects that may affect the performance of a complete SCSI bus segment:

- spacing of media conductors from other physical structures for non-shielded constructions (e.g. wires in other media, metallic walls, non-metallic surfaces)
- non uniform device loading across all the SCSI signals
- non uniform stub properties
- the population and spacing of devices
- connectors and media disturbances required to attach connectors
- data phase speed

The test methods defined in this annex may or may not be applicable to complete SCSI bus segment performance. This annex does not address performance other than that of media designed to be uniform.

2. Impedance

2.1 Local impedance for single ended transmission

The impedance measurement produces a plot of transmission line impedance as recorded by a time domain reflectometer instrument. There is a direct mapping of the measurements to the physical position within the cable under test. The test shall be performed at the specified signal transition duration time for the signals being used in the end-user application.

The sample length is long enough to ensure no interference from the far end.

2.1.1 Sample preparation

This test requires type A samples prepared in the following way:

1. Cut sample length to 3m ± 0,025 meter
2. Remove 5,0 cm of outer jacket from one end
3. Comb out braid wire strands to form a pigtail
4. Trim filler and tape materials to the base of braid wire
5. Strip 0,5 cm insulation from all conductors
6. Connect one wire from each pair to the shield (for flat type cable, tie every other conductor to ground)

2.1.2 Test fixture and measurement equipment

Figure 1 shows the test configuration for the local single ended impedance test.

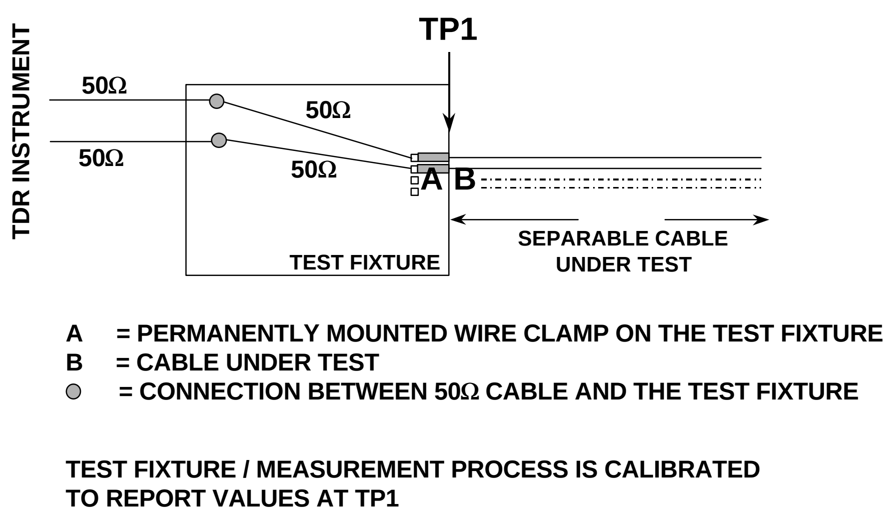

Figure 1 - Test configuration for SE impedance

The test fixture may be constructed of semi-rigid coax, microstrip PCB, or stripline PCB. To be able to see the entire signal transition it is necessary that the length from the TDR to the DUT be long enough to contain the complete transition. For the 3ns STD this minimum length is approximately 1.25m for cables with solid polyethylene dielectric. For other dielectrics this length should be adjusted appropriately.

2.1.3 Calibration and verification procedure

2.1.2.1 Instrument verification

It is not necessary to perform a separate instrument verification for this test. The calibration in the following section includes the instrument.

2.1.2.2 Measurement system (with test fixture) calibration

Connect the 50Ω cable to the test fixture.

In place of “B” in Figure 1,connect a 100Ω ±0.1% (preferred) low inductance chip resistor. Use an unfiltered trace and the TDR cursors to measure the resistance value, R100, approximately 4ns (displayed) after the resistor discontinuity. See Figure 2.

In a similar manner, in place of “B” connect a 50Ω ±0.1% (preferred) low inductance chip resistor. Use an unfiltered trace and use the TDR cursors to measure the resistance value, R50, approximately 4ns (displayed) after the resistor discontinuity.

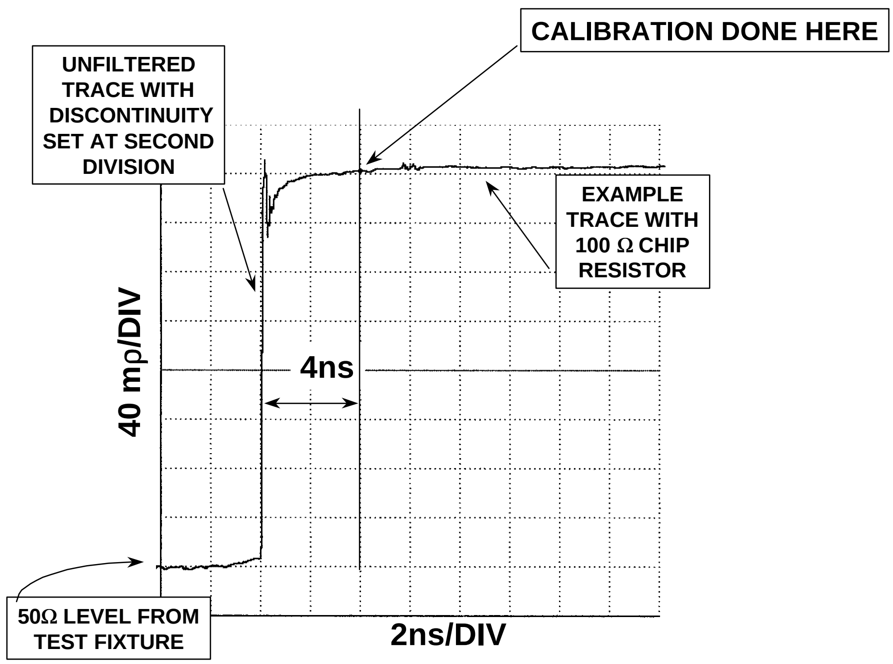

Figure 2 SE impedance calibration

Subtract R50 from R100 producing Delta R.

Correction factor for vertical scale and cursor readings $= \frac{\text{Delta R}}{50}$

2.1.2.3 Single ended signal transition duration (STD) calibration

This step ensures that the proper signal transition (STD) time is being presented to the DUT. Place a short on the test fixture where the cable would be attached in place of “B” in Figure 1. Use the filter function on the TDR to set the measured STD (20%-80%) to the desired value according to the detailed procedure described below. It may be desirable to use a separate test fixture that is nominally identical to the actual cable test fixture for this step.

Assuming a falling edge, set up the display on the TDR as shown in Figure 3. This display has the following properties:

> The time scale on the display is 2.0 ns / div for the 3.0 ns STD. Set the horizontal position such that the midpoint of the displayed curve is near the center of the display and the 100% and 0% baselines are clearly visible as shown in Figure 3. The STD is the time between the 20% and 80% values

of the displayed signal amplitude (most instruments can do this calculation automatically).

When the instrument will not automatically measure STD, perform the following steps:

Measure the voltage at 100% (V_{100})
Measure the voltage at 0% (V_0)
The voltage at 20% is { $V_{20} = V_0 + 0.2(V_{100} - V_0)$
The voltage at 80% is { $V_{80} = V_0 + 0.8(V_{100} - V_0)$
Set cursors at V_{20} and V_{80} and measure the time difference

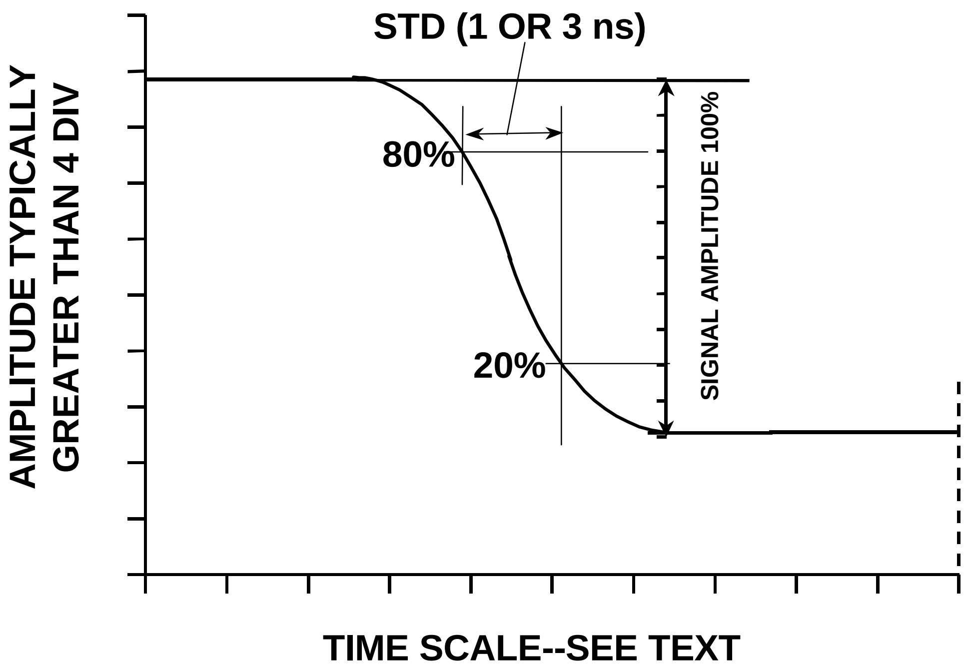

Figure 3 - Signal transition duration calibration

2.1.4 Testing procedure

Connect the DUT to the test fixture wire clamp and record the TDR trace using the method described below.

Figure 4 shows the TDR display setup to use for this measurement.

- Set the time scale to 2 ns /div (total time axis span of 20 ns).
- Set the vertical scale (mρ) to 40 mρ /div.
- With the DUT disconnected turn off the filtering.
- Next, set the horizontal position such that the discontinuity is on the third division from the left.
- Adjust the vertical position to approximately place the 50Ω reference (cable

from fixture to TDR) at the first vertical division from the bottom.

- With the filter turned on to 3ns connect the DUT.
- Note: the DUT shall be suspended in air. No metallic supports should be used.
- Set the TDR cursor to measure min, mean and max ohms with cursors set on the trace as it crosses the 5th and 6th times divisions.

These measurements include a small error factor caused by losses in the cable which varies with gauge size. This error increases the measured impedance slightly.

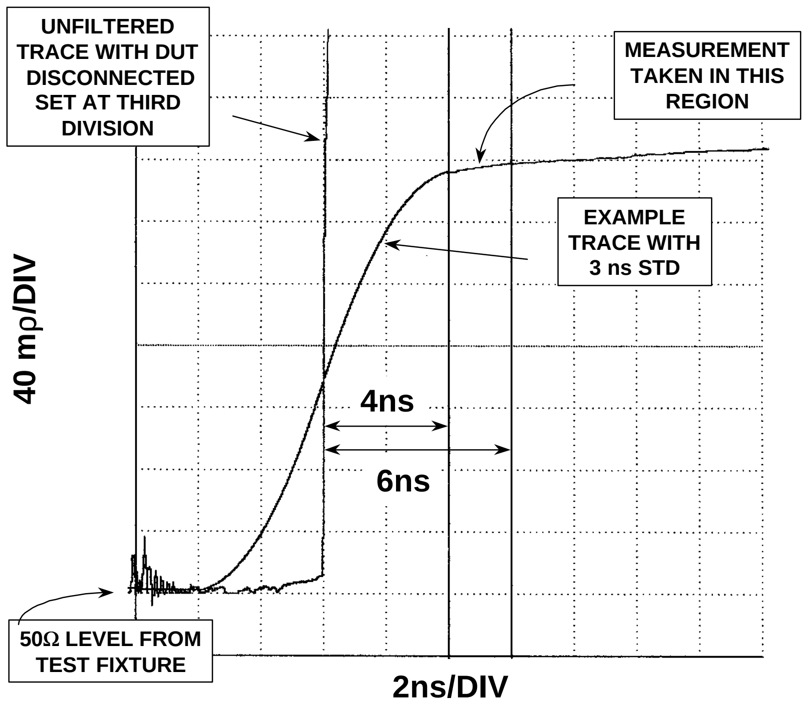

Figure 4 – SE impedance measurement

2.2 Local impedance for Differential transmission

This requirement is necessary to allow the cable media to interface with devices and terminators without inducing excessive signal reflections.

2.2.1 Sample preparation

This test requires type B samples prepared in the following way:

1. Cut sample length to 3m +/- 0,025 meter
2. Remove 5,0 cm of outer jacket from one end
3. Comb out braid wire strands to form a pigtail
4. Trim filler and tape materials to the base of braid wire
5. Strip 0,5 cm insulation from all conductors
6. Select the pair to be measured. Tie all other pairs and the shield together

2.2.2 Test fixture and measurement equipment

Figure 1 shows the test configuration for the local differential impedance test.

2.2.2.1 Calibration and verification procedure

2.2.2.2 Instrument verification

It is not necessary to perform a separate instrument verification for this test. The calibration in the following section includes the instrument.

2.2.2.3 Measurement system (with test fixture) calibration

Connect the 50Ω cable to the test fixture.

In place of “B” in Figure 1, connect a 100Ω ±0.1% (preferred) low inductance chip resistor across the pair. Use a differential unfiltered trace and use TDR cursors to measure the resistance value, R100, approximately 4ns (displayed) after the resistor discontinuity. See Figure 2. The method shown in Figure 2 applies to differential except a 100Ω level from the test fixture will be seen and differential signals are displayed.

In a similar manner, in place of “B” connect a 50Ω ±0.1% (preferred) low inductance chip resistor across the pair. Use a differential unfiltered trace and use the TDR cursors to measure the resistance value, R50, approximately 4ns (displayed) after the resistor discontinuity.

Subtract R50 from R100 producing Delta R.

Correction factor for vertical scale and cursor readings $= \frac{\text{Delta R}}{50}$

2.2.2.4 Differential signal transition duration (STD) calibration

This step ensures that the proper STD is being presented to the DUT. Place a short on the test fixture across the pair where the DUT would be attached (e.g. instead of “B” in Figure 1. Use the filter function on the TDR to set the measured STD (20%-80%) to the desired value according to the detailed procedure described below. It may be desirable to use a separate test fixture that is nominally identical to the actual cable test fixture for this step.

Assuming a falling edge, set up the display on the TDR as shown in Figure 3. This display has the following properties:

> The time scale on the display is 1.0 ns / div for the 1.0 ns STD and 2.0 ns / div for the 3.0 ns STD. Set the horizontal position such that the midpoint of the displayed curve is near the center of the display and the 100% and 0% baselines are clearly visible as shown in Figure 3. The STD is the time between the 20% and 80% values of the displayed signal amplitude (most instruments can do this calculation automatically).

When the instrument will not automatically measure STD, perform the following steps:

Measure the voltage at 100% (V_{100})
Measure the voltage at 0% (V_0)
The voltage at 20% is { $V_{20} = V_0 + 0.2(V_{100} - V_0)$
The voltage at 80% is { $V_{80} = V_0 + 0.8(V_{100} - V_0)$
Set cursors at V_{20} and V_{80} and measure the time difference

Adjust the TDR filter so that the desired STD is achieved.

2.2.3 Testing procedure

Connect the DUT to the test fixture wire clamp and record the TDR trace using the method described below.

Figure 5 shows the TDR display setup to use for this measurement.

- Set the time scale to 2 ns /div (total time axis span of 20 ns).
- Set the vertical scale (mρ) to 40 mρ /div.
- With the DUT disconnected turn off the filtering.
- Next, set the horizontal position such that the discontinuity is on the third division from the left.
- Adjust the vertical position to approximately place the 100Ω reference (cable from fixture to TDR) at the fifth vertical division from the bottom.
- With the filter turned on to 1ns connect the DUT.
- Note: the DUT shall be suspended in air. No metallic supports should be used.
- Set the TDR cursor to measure min, mean and max ohms with cursors set on the trace as it crosses the 5th and 6th times divisions.
- Set the filter to 3ns.
- Set the TDR cursor to measure min, mean and max ohms with cursors set on the trace as it crosses the 5th and 6th times divisions.

These measurements include a small error factor caused by losses in the cable which varies with gauge size. This error increases the measured impedance slightly.

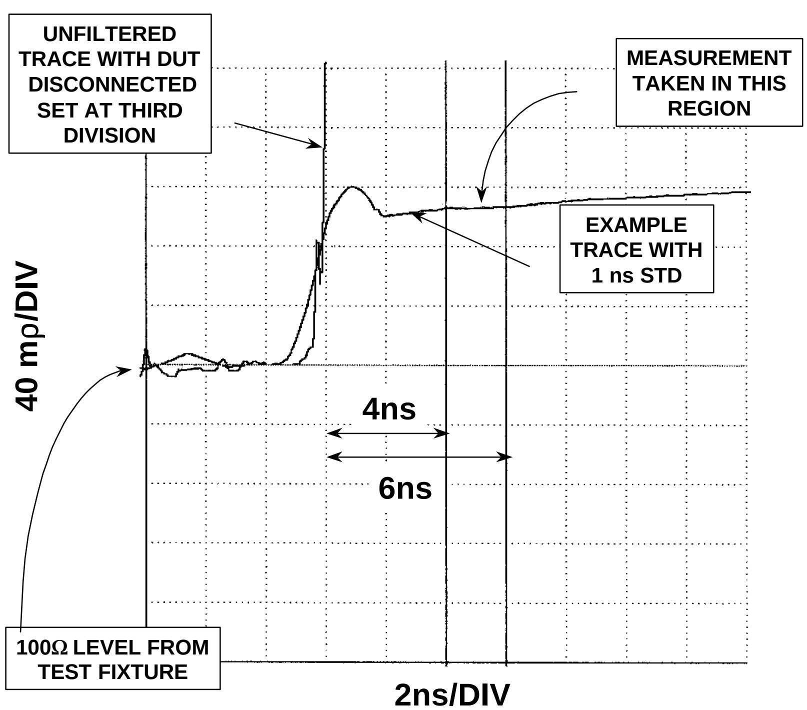

Figure 5 – Differential impedance test

2.3 Differential extended distance (balanced) impedance (frequency domain)

2.3.1 Sample preparation

This test requires type C samples prepared in the following way:

1. First the cable sample shall be cut to a length such that resonance does not occur. (Approximately 30 meters or greater.)
2. Remove 5,0 cm of outer jacket from one end
3. Comb out braid wire strands to form a pigtail
4. Trim filler and tape materials to the base of braid wire
5. Strip 0,5 cm insulation from all conductors

2.3.2 Test Fixture for differential extended distance impedance

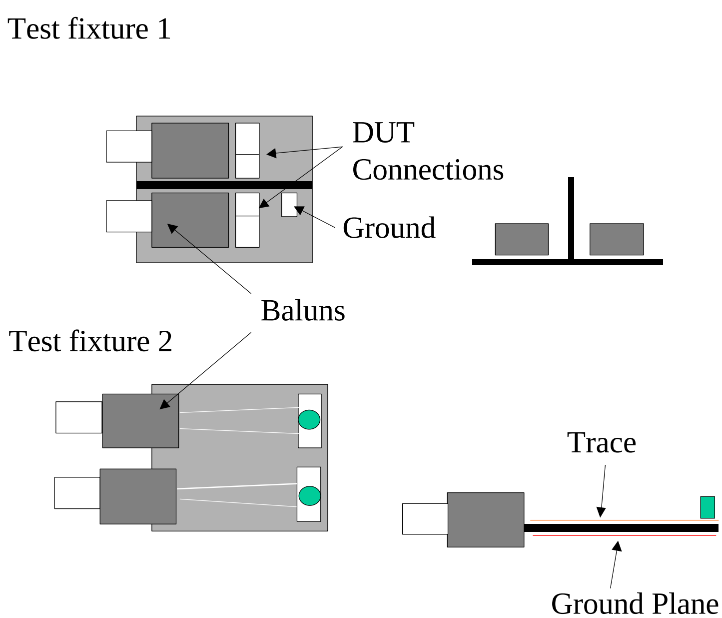

Figure 6 – Test fixtures for differential extended distance impedance profile

Figure 6 shows the test configuration for the differential extended distance impedance tests.

2.3.2.1 Scope and objective

Two types of test fixtures are described in order to provide sufficient flexibility in constructing fixtures required in measuring cable characteristics in the frequency domain environment. The two types of fixtures are closely related.

The first type is constructed using two baluns mounted on aluminum base and electrically isolated from each other by aluminum screen **(test fixture 1).**

The second type uses high speed PCB with microstrip construction. Two baluns are mounted at one edge of the board with sufficient separation to reduce mutual coupling by a minimum of 20dB. The interconnect traces of the signal pairs are further separated from each other in a radial form and the signal traces run at 61 ohms to ground for each differential line **(test fixture 2).**

2.3.2.2 Test equipment

A scalar or vector network analyzer instrument measures the reflection and transmission characteristics of the DUT (device-under-test). With the appropriate calibration and error correction techniques, a high degree of accuracy is possible. The analyzer can be used both as the source of the test signal and as a means of measuring the DUT’s characteristics.

Two precision coax cables whose transmission line impedance matches the impedance of the network analyzer system are used to connect the test fixture to the test analyzer system.

2.3.2.3 Test Fixtures

For the aluminum base test fixture (test fixture 1), the transmission line is provided by the baluns as the signal paths and the aluminum base as the current return path. The baluns provide a 50 to 61 ohm impedance matching between the test instrument system and the DUT, as well as provide differential signals. The aluminum screen provides electric field isolation between the two baluns. The DUT connects to the fixture via a mechanical clamp system. The DUT should self terminate given its length.

For the PCB test fixture, the test fixture consist of a printed circuit board incorporating controlled impedance trace construction of 61 ohms (refer to test fixture 2). The transmission line is provided by the connected baluns and PCB traces for the signal paths and the ground plane of the board for the return current path. A coaxial cable (same transmission line impedance as the test instrument) connects one end of the cable to the instrument test port through the baluns and the PCB fixture trace combination. The baluns provide a 50 to 61 ohm impedance matching between the test instrument system and the DUT, as well as provide differential signals. The separation of the baluns and the signal lines provide electric field isolation between the two baluns and the signal lines. The DUT connects to the fixture via a mechanical clamp system. The DUT should self terminate given its length.

Note: the baluns required for this test are high frequency (~500MHz) precision types.

A stand is recommended for mounting fixture board and to support the DUT. It is recommended that the stand keep the fixture board at least 7cm from the top of the lab bench to minimize coupling.

2.3.2.4 Fixture board design requirements (test fixture 2):

Traces are constructed on the PCB to conform with the differential transmission scheme. The fixture shall be through hole or surface mount PCB. The signal traces are connected to the balun’s differential pins using microstrip construction with controlled characteristic impedance of 61 ohms. The length of the connections shall permit the board to operate at the desired frequencies and accommodate the required number of signal lines, including sufficient separation to reduce mutual coupling by a minimum of 20dB. It is recommended that the bandwidth of the board be at least twice the bandwidth of the fifth harmonics of DUT. Board impedance shall be tightly controlled to within +/- 5% of the impedance of the environment.

The fixture board shall include calibration traces for measuring the effects of the test fixturing on the measurement data. This board construction is useful for other frequency domain measurements but is not designed to accommodate time domain.

2.3.3 Calibration Procedure

Set the analyzer to perform an S11 measurement with the source power set at a minimum of 6dbm, the number of points set to a minimum of 401 and the band width at a maximum of 200HZ (averaging at a minimum of 2 averages). Start and stop frequencies are 1MHz and 1GHz respectively. The calibration is for the open, short and load method, keeping the leads as short as possible on the load standards. The load standard will match the impedance of the secondary balun and have a maximum tolerance of 1%.

2.3.4 Measurement Procedure

Using either

a) Hewlett Packard 4291B RF Impedance / Material Analyzer or equivalent. Test fixture and an impedance matching balun unbalanced to balanced, or

b) Hewlett Packard 8753E Network Analyzer or equivalent test fixture and an impedance matching balun unbalanced to balanced.

Connect the near end of the sample to the output balun on the test fixture, keeping the leads as short as possible to eliminate inductance problems and terminate the far end of the sample in the impedance of the cable. Perform a sweep test from 1MHz through 1GHz.

3. Capacitance

3.1 Single ended capacitance

3.1.1 Sample preparation

This test requires type D samples prepared in the following way:

For Flat cables:

1. Cut sample length to 3 meters
2. Separate conductors at one end
3. Strip 0,5cm insulation from all conductors

For Round Cables Shield connected:

1. Cut sample length to 3 meters
2. Remove 5,0 cm of outer jacket from one end
3. Comb out braid wire strands to form a pig tail
4. Trim filler and tape materials to the base of braid wire.
5. Strip 0,5 cm insulation from all conductors

6. Connect one (1) conductor of each pair to the shield

For Round Cables Shield floating:

1. Cut sample length to 3 meters
2. Remove 5,0 cm of outer jacket from one end
3. Cut braid wire back to jacket
4. Trim filler and tape materials to the base of braid wire.
5. Strip 0,5 cm insulation from all conductors

3.1.2 Test fixture for SE capacitance

shows the test configuration to use for this test procedure.

3.1.3 Calibration Procedure

If using an HP4263A Bridge, calibration shall be as follows:

1. Connect fixture to meter and perform open calibration as specified by HP.
2. Connect a wire (short) to the sockets of the test fixture and perform a “short” calibration as specified by HP.

For other manufacture’s equipment, follow the calibration procedures specified by the manufacturer of the LCR bridge for reliable results.

3.1.4 Measurement Procedure

3.1.2.1 Flat cables – G-S

With the Bridge set at the desired frequency, connect the pair to the test fixture and record the capacitance

3.1.2.2 Flat cables – G-S-G

With the Bridge set at the desired frequency, connect the two grounds together on one side of the test fixture and the signal to the other side of the test fixture, record the capacitance.

3.1.2.3 Round cables – shielded

With the Bridge set at the desired frequency, connect one half of the twisted pair to one side of the test fixture and the other half of the twisted pair to the shield and to the other side of the test fixture. Record the capacitance.

3.1.2.4 Round Cables – floating shield

With the Bridge set at the desired frequency, connect the twisted pair to the test fixture. Record the capacitance.

3.2 Differential Unbalanced Capacitance

3.2.1 Sample Preparation

This test requires type F sample prepared in the following way:

For Flat cables:

1. Cut sample to a length that eliminates resonance
2. Separate conductors at both ends
3. Strip 0,5cm insulation from all conductors

For Round Cables Shield connected:

1. Cut sample to a length that eliminates resonance
2. Remove 5,0 cm of outer jacket from both ends
3. Comb out braid wire strands to form a pig tail
4. Trim filler and tape materials to the base of braid wire.
5. Strip 0,5 cm insulation from all conductors
6. Connect one (1) conductor of each pair to the shield

For Round Cables Shield floating:

1. Cut sample to a length that eliminates resonance
2. Remove 5,0 cm of outer jacket from both ends
3. Cut braid wire back to jacket
4. Trim filler and tape materials to the base of braid wire.
5. Strip 0,5 cm insulation from all conductors

3.2.2 Test fixture for differential capacitance

Refer to for the proper test configuration.

3.2.3 Calibration Procedure

If using an Impedance/material Analyzer Model #4291B from H.P, calibration shall be as follows:

3.2.2.1 Calibration set up procedure

1. Set up Bandwidth
2. Set Start and stop frequencies
3. Set for impedance magnitude for measurement type
4. Number of points is equal to 401
5. Minimum average points shall be two (2)
6. You shall receive a linear measurement

3.2.2.2 Calibration

1. Connect Fixture to test head and perform open circuit calibration
2. Connect wire (short) to test fixture head and perform “short” circuit calibration
3. Connect a 50Ω resistor to the test fixture and perform load calibration

For other manufacture’s equipment, follow the calibration procedures specified by the manufacturer for reliable results.

3.2.4 Measurement Procedure

The measurement will be performed using the equivalent circuit method adjusting the open and short values of the capacitance and inductance so that the traces over lay as closely as absolutely possible across the entire bandwidth.

Note Impedance values could be measured and recorded at this time.
Note: Fixture should be measured for functionality through Bandwidth of interest.

3.3 Dielectric constant variation with frequency

Selection of this test method is on underway.

4. Propagation time (differential frequency mode)

4.1 Sample preparation

This test requires type G samples prepared in the following way:

1. Cut sample length to 30m +/- 0.1 meter
2. Remove 5,0 cm of outer jacket from both ends
3. Comb out braid wire strands to form a pigtail at both ends
4. Trim filler and tape materials to base of braid wire at both ends
5. Strip 0,5 cm insulation from all conductors
6. Each pair under test shall be terminated with a 100 Ω resistor at the far end of the cable.

4.2 Test fixture for propagation time (differential frequency mode)
Reference: 2.2.2 for appropriate test fixtures

4.3 Calibration Procedure
The analyzer shall be set to perform a S12 measurement with the power set at a minimum of 6dbm, the number of points set to a minimum of 401, the band width at a maximum of 200HZ, averaging at a minimum of 2 averages, and the start / stop frequencies per the table. Perform a transmission calibration using a sample of the cable to be tested keeping the sample as short as possible.

4.4 Measurement Procedure
With the analyzer set up in the delay mode, connect one end of the sample to the balun on the output port and the opposite end to the balun on the input port with the markers turned on record the minimum and maximum delay across the band width as listed in the table.

5. Propagation time (differential - time domain mode)

5.1 Sample preparation
This test requires type D sample prepared in the following way:

For flat cables:
1. Cut sample length to 6 meters
2. Separate conductors at one end

3. Strip 0,5cm insulation from all conductors

For round cables shield connected:
4. Cut sample length to 6 meters
5. Remove 5,0 cm of outer jacket from one end
6. Comb out braid wire strands to form a pig tail
7. Trim filler and tape materials to the base of braid wire.
8. Strip 0,5 cm insulation from all conductors

5.2 Test fixture for propagation time (differential - time domain mode)

shows the test configuration for propagation time (differential mode)

5.3 Test configuration calibration procedure

If using an HP TDR scope such as an HP54750, calibration shall be as follows:

1. Leave channel 1 and 2 open
2. Default setup
3. Setup, stimulus, differential
4. Preset TDR/TDT
5. Select time base – set to 100 ps/div.
6. Select position – move trace to approximately center of screen
7. Select acquisition - change average to 4.
8. Delta time – Channel 1 minus Channel 2
9. Connect test fixture
10. Press time base – select position
11. Adjust position of fixture
12. Select right most channel
13. Select calibrate
14. Select skew
15. Reduce imbalance by half
16. Select TDR skew – adjust until difference between the two channels is approximately zero
17. Clear markers
18. Select TDR/TDT setup
19. Establish reference plane
20. Calibrate channel one
    1. Connect a wire (short) to the sockets of the test fixture and perform a “short” calibration as specified by HP.
    2. Connect a 50Ω precision resistor to the test fixture and perform load calibration.
21. Calibrate channel two
    1. Connect a wire (short) to the sockets of the test fixture and perform a “short” calibration as specified by HP.
    2. Connect a 50Ω precision resistor to the test fixture and perform load calibration.
22. For other manufacture’s equipment, use the same procedure adapted for that instrument.

At this point calibration is complete

23. Select TDR response 1
24. Select differential
25. Vertical resolution shall be set to display the full dynamic range of the response.
26. Turn off channel 1
27. Turn off channel 2
28. The differential response will be displayed
29. Markers

Set + source to response 1
Set x source to response 1
30. Adjust markers so they are on the trace

5.4 Measurement Procedure

1. Select TDR response 1
2. Select differential
3. Turn off channel 1
4. Turn off channel 2
5. The differential response will be displayed
6. Adjust both markers so that they track the response trace
7. Connect the DUT to the test fixture
8. Vertical resolution shall be set to display the full dynamic range of the response.
9. Adjust time base scale so that both the launch and the end of cable are on the screen
10. Set the + marker to the temporal position at the midpoint of the launch step (signal transition)
11. Set the x marker to the temporal position at the midpoint of the end step
12. Set horizontal unit to seconds
13. Take the time delta between markers and divide by twice the cable length. This will provide the propagation time.

6. Propagation time skew (differential)

6.1 Measurement procedure

Maximum propagation time minus the minimum propagation time renders the overall propagation time skew of the pair under test.

7. Attenuation

7.1 Differential attenuation

Attenuation is calculated from the ratio of output signal level to input signal level through the DUT and is a measure of the losses experienced when transmitting a signal through the DUT. Higher attenuation means less signal at the output or equivalently a gain of less than unity. A sinusoidal signal is used to eliminate the need for complex descriptions of real pulses and square or trapezoidal signals in terms of Fourier components. A complete attenuation specification requires examining all frequencies of interest to the application. A spectral description is recommended. The basic formula for attenuation in decibels is:

Attenuation (dB) = 20 $\log_{10}$ (input signal / output signal).

Note that this formula gives the attenuation as a positive number since the argument of the log is greater than unity. Sometimes attenuation is casually reported as a negative number when the gain is really the intended mathematical statement. In any case the magnitude is the same for both gain and attenuation. The following formula expresses gain in decibels.

Gain (dB) = 20 $\log_{10}$ (output signal / input signal)

Since the argument of the log is less than unity the gain is a negative number.

This document requires that attenuation be expressed as a positive number unless there is active gain in the path from active circuits. Therefore a typical attenuation plot has the form shown in Figure 7.

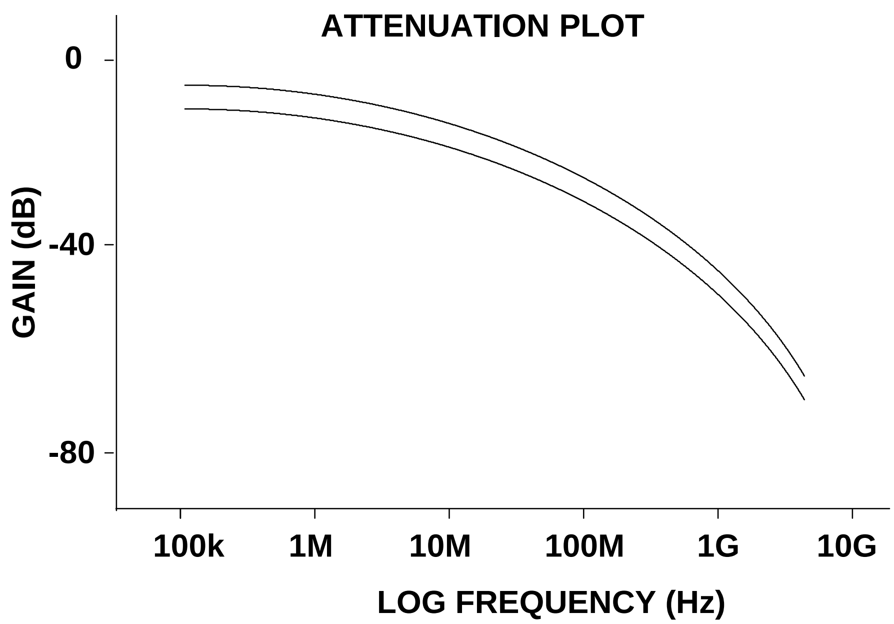

Figure 7 - Form of attenuation plots

Attenuation is a measurement of the dissipative losses on a balanced transmission line. The series resistive loss of the conductors (copper) and the shunt loss due to the dissipation factor of the dielectric covering the conductors dominate these losses. At higher frequencies, the conductor loss increases due to skin effect. Skin effect is where the current become increasing confined in the outer “skin” of the conductor as the frequency increases. This effectively reduces the conductor area available for current flow. The attenuation for a given balanced transmission line will be affected by the conductor metal composition and size, and the composition, uniformity, and thickness of the dielectric that surrounds the conductors.

Attenuation can only be measured directly with an ideal test system that is perfectly matched to the balanced transmission line to be tested. In a practical test system, the quantity that is actually measured is insertion loss. Insertion loss is comprised of a component due to the attenuation of the balanced transmission line, a component due to the mismatch loss at the input or near end side of the transmission line and a component due to the mismatch loss at the output or far end side of the transmission line.

There will be a mismatch loss component at any interface where the transmission line impedance is not perfectly matched on both sides of the interface. The amount of mismatch loss that will be experienced at each interface is :

$$\text{Mismatch Loss (dB)} = (-10 \, LOG_{10} \, (1 - |\Gamma|^2)) \, dB$$

Balanced transmission lines are also susceptible to measurement errors when measuring high values of attenuation (>50 dB) due to radiated energy coupling into the transmission line. The largest source of this error is due to direct coupling of the near end side of the test system to the far end side of the test system. This coupled signal will combine with the test signal passing through the transmission line under test and cause a significant ripple error in the insertion loss measurements at the higher frequencies where the attenuation of the transmission line under test is the largest.

Since the test instruments are single ended and the DUT is balanced a coupling device called a balun is required to connect the DUT to the test equipment.

Balun Selection. The impedance on the primary side of the balun must match the impedance of the test equipment, normally a network analyzer. The impedance on the secondary side of the balun must be matched as closely as possible to the nominal impedance of the DUT in the balanced state to minimize reflections. If reflections are present they will skew the data by introducing a mismatch loss ripple component.

Figure 8 shows the effect of different baluns on a very long cable (approximately 300 meters). There are no reflections visible because they are attenuated to insignificant levels by the long length. Another very important benefit to using long cables for these tests is the elimination of resonance effects for the same reason that reflections are not a problem. The main effect of using relatively serious mismatched baluns on very long cables is a small error in the attenuation reported (less than 1 dB in the example shown).

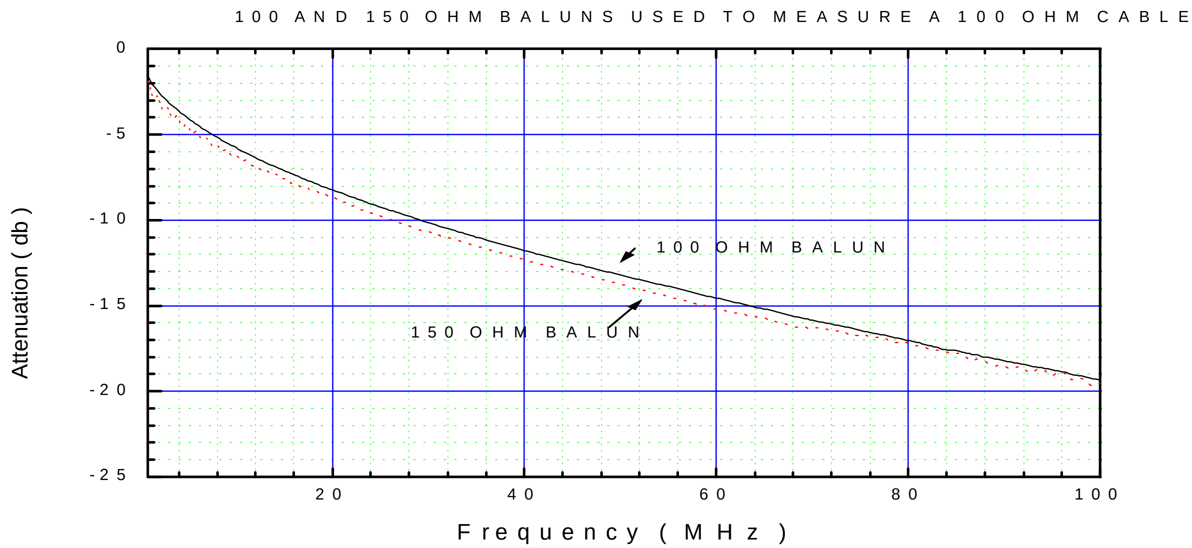

Figure 8 - Effect of balun selection on measured attenuation for very long cables

Sample Length. The optimum sample length is such that there is at least ~ 1db of one way attenuation at the lowest frequency of interest. This will guarantee that there will be at least 2 dB of additional loss experienced by that portion of the test signal that reflects from the far end.

This will reduce the uncertainty caused by multiple reflections due to the far end and will result in acceptable resolution / ripple. The resulting measurements will be accurate and repeatable. If a sample is used that yields an attenuation of less than 1dB the mismatch ripple from the near end combined with the mismatch ripple from the far end can approach the same or greater magnitude than the attenuation at the lowest frequency. For example in the unmatched balun case:

Case 1 :
Near End Balun Z = 100 Ohm
Far End Balun Z = 100 Ohm
Nominal Balanced Cable Z = 150 Ohm
Balanced Cable loss at lowest test frequency = 0.5 dB = 0.94406

In case 1 there is only 0.5dB attenuation in the presence of a ripple that will add anywhere from 0.354 dB to 0.6972dB of measurement error as shown in Figure 9.

GAIN (dB)

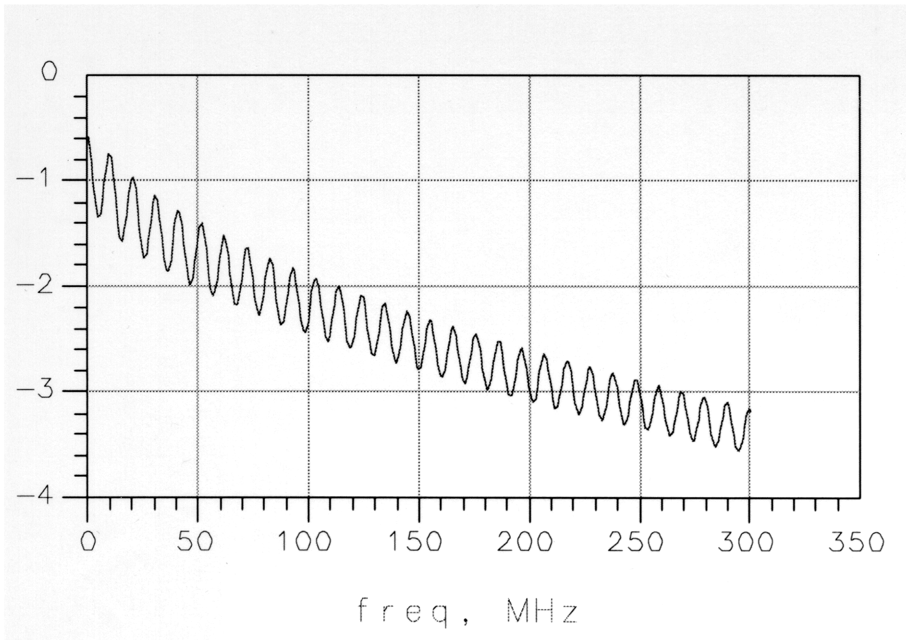

Figure 9 - Effects of mismatched baluns in a short DUT

For the matched case otherwise identical to case 1:

Case 2 :

Near End Balun Z = 150 Ohm
Far End Balun Z = 150 Ohm
Nominal Balanced Cable Z = 150 Ohm
Balanced Cable loss at lowest test frequency = .5 dB = .94406

The insertion loss equals the desired attenuation result and there is no ripple to cause measurement uncertainty as shown in Figure 10.

GAIN (dB)

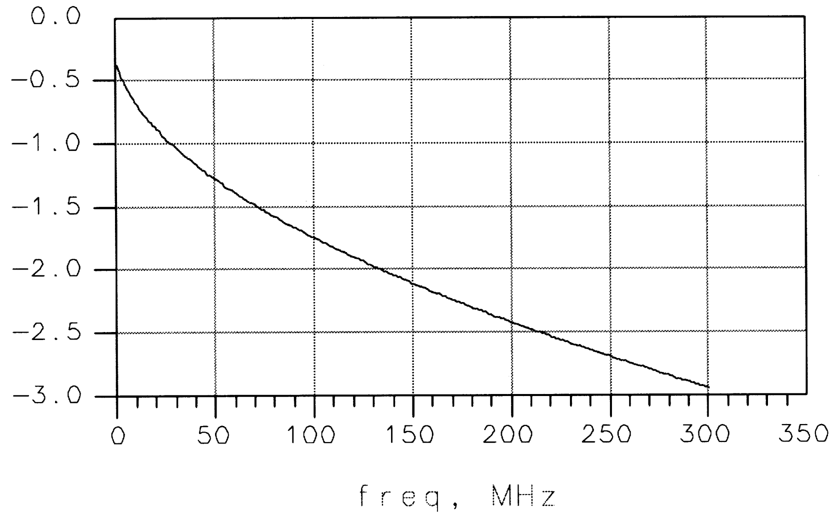

Figure 10 - Effect of matched baluns on a short sample

Finally, for the case of at least 6 dB of low frequency attenuation the results are achieved without requiring a closely matched balun:

Case 3 :

Near End Balun Z = 100 Ohm
Far End Balun Z = 100 Ohm
Nominal Balanced Cable Z = 150 Ohm
Balanced Cable loss at lowest test frequency ~ 6 dB

Under a mismatched condition, the insertion loss equals the attenuation plus the mismatch loss at the near end and at the far end. However, in this case, there is sufficient attenuation in the cable at the lowest frequency to make multiple reflections inconsequential, so there is no ripple component of measurement uncertainty. The mismatch loss error is still present, but it is ~ 0.3 dB out of a measured insertion loss of ~ 6 dB.

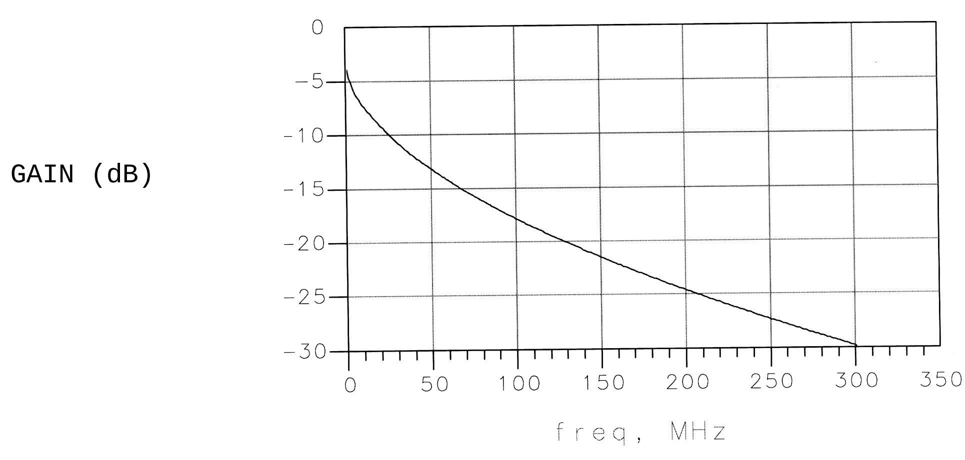

Figure 11 - Effects of mismatched baluns with 6 dB LF attenuation

Note: The use of an attenuator for measuring shorter lengths is not acceptable because there is still mismatch loss uncertainty due to the fact that the attenuator does not have any better match than the far end test port. Also an *additional uncertainty is introduced because a small value (cable attenuation) is being subtracted from a large value, (attenuator attenuation). There are also dynamic range issues for the instrumentation.*

7.1.1 Measurement test fixture and measurement equipment

An instrument capable of supplying a sinusoidal signal is used as the signal source and an instrument capable of detecting the amplitude of a sinusoidal signal is used as the signal sink. Two measurement test fixtures are required: one for the source end and one for the sink end. Since most source and sink instruments capable of using variable frequency sinusoidal signals are single ended, a balun [Picosecond Pulse Labs] or a hybrid [Picosecond Pulse Labs, Minicircuits] may be used between the instruments and the test fixtures. If a source or sink is used that is capable of sourcing or sinking differential signals then no balun is required for the differential source or sink.

Equipment Required: Network Analyzer (HP 87xx Series)

A test fixture having 75Ω single ended paths for each signal line is used for the measurement as shown in Figure 12 and Figure 13 and calibrated as shown in Figure 14. This test fixture may be exactly the same as used for the impedance tests in Section 2.1.

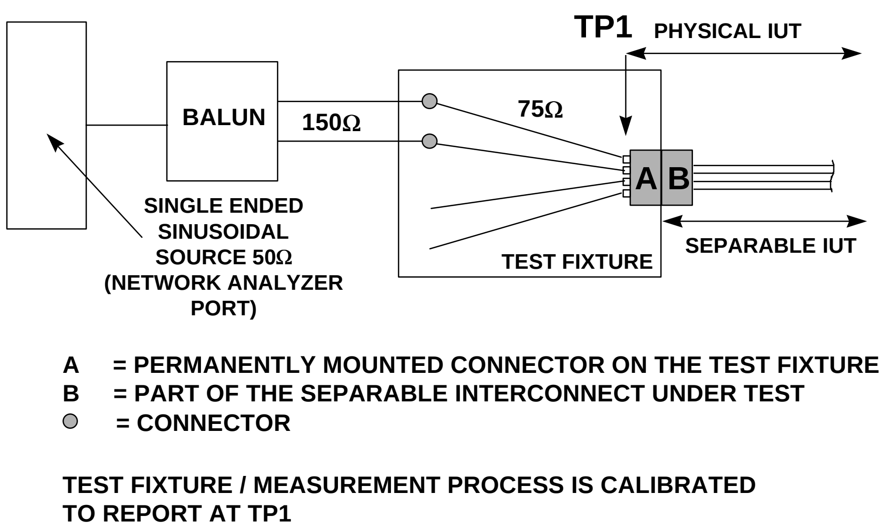

Figure 12 - Source-end test fixture for attenuation tests

The balun shown in Figure 12 is 50 Ω single ended to 150 Ω differential.

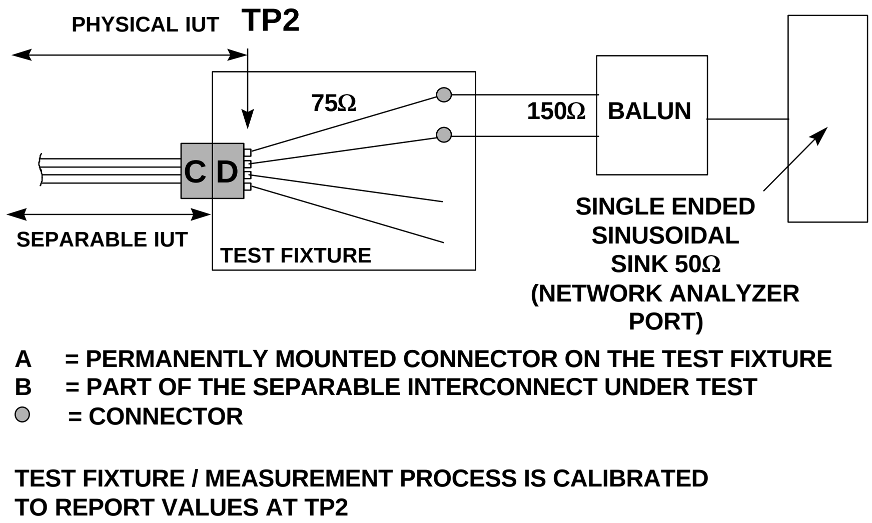

Figure 13 - Sink end test fixture for attenuation tests

The separable DUT is connected between the source and sink test fixtures.

7.1.2 Calibration procedure

A special “through” test fixture is used for the signal calibration process which is exactly like the test fixture in Figure 12 and Figure 13 except that there are no DUT connectors (A, D). See Figure 14.

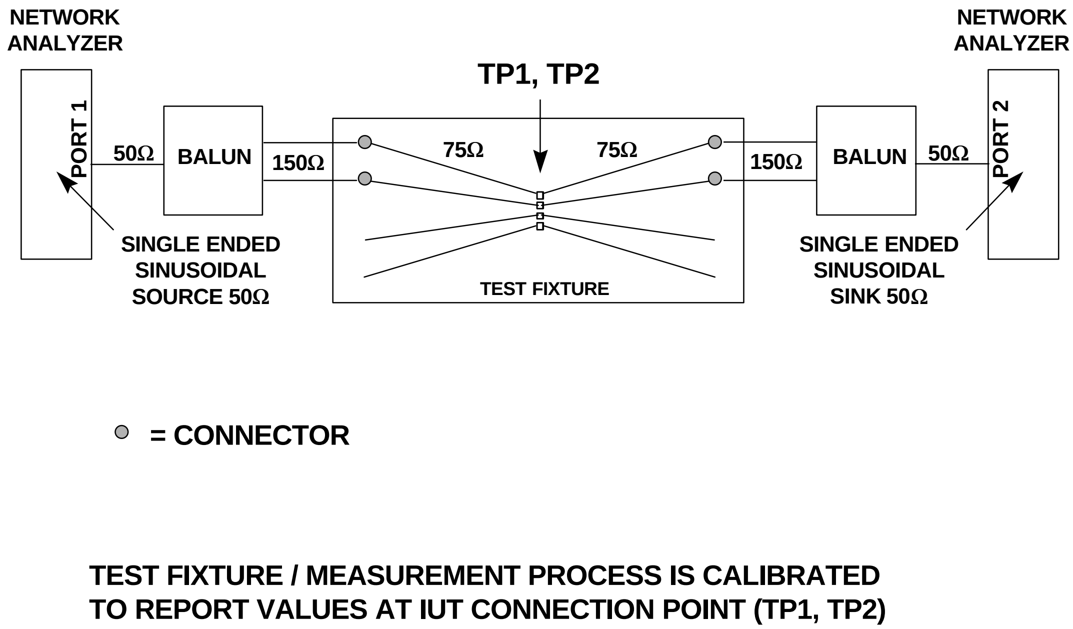

Figure 14 - Calibration configuration for attenuation tests

Using the instructions from the network analyzer perform a calibration scan over the frequency of interest.

7.1.3 Testing procedure

Connect the DUT to the test fixtures shown in Figure 12 and Figure 13 (including the board mounted connectors).

Using the instructions from the network analyzer perform an attenuation scan over the frequency range of interest. The instrument automatically accounts for the attenuation found in the calibration scan.

It is important to either separate or shield the baluns from each other when measuring long cable samples. When the attenuation of the cable exceeds ~50 dB or the frequency is above approximately 150 MHz, potential direct coupling from the near end to the far end balun will create an increasingly large ripple in the attenuation measurement that can cause a significant amount of measurement uncertainty.

Figure 15 and Figure 16 show the effects of balun isolation.

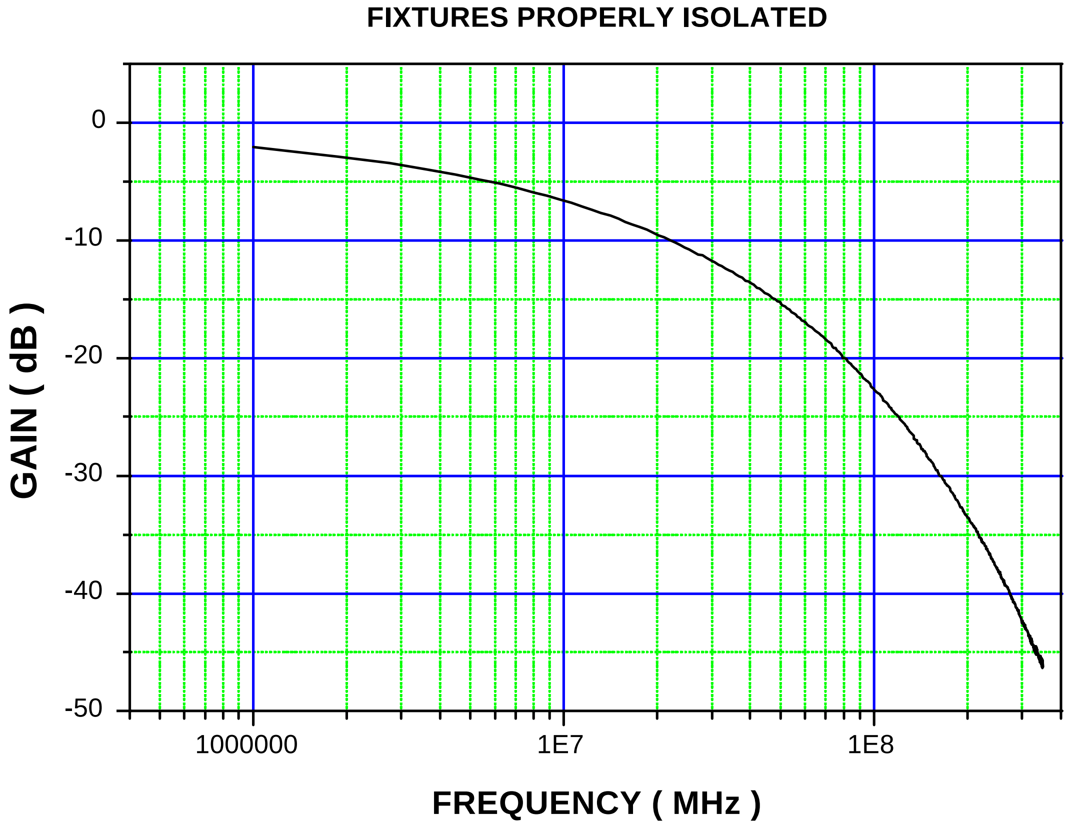

Figure 15 - Attenuation scan with proper balun isolation

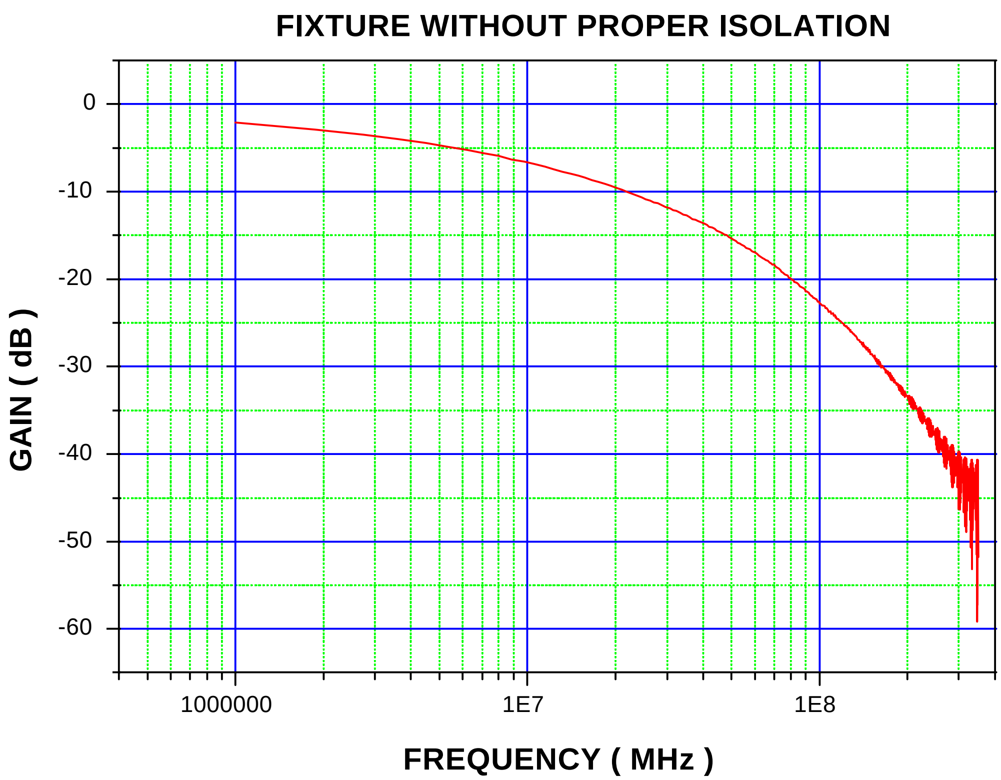

Figure 16 - Attenuation scan without good balun isolation

8. Near end cross talk (quiescent noise)

This test is limited to a single option: the single applied pulse method. The sum of the noise produced by all pairs on the REQ or ACK pair is the cross talk. In this method pulses with maximum differential amplitude, maximum and minimum STD signal are applied to one pair at a time in the DUT, and the signal induced on the REQ or ACK pair is measured. The pair with the applied pulse is the aggressor pair and a pair with the induced noise is the victim pair. If the REQ is the victim pair then the ACK pair is included as an aggressor pair. If ACK is the victim pair then the REQ pair is included as an aggressor pair. The sum of the noise from the aggressor pairs on the victim pair IS the cross talk.

Single pulse tests eliminate the effects of resonance, are very deterministic in the causes of the induced noise (due to the mapping of the time and space as in the TDR tests), and produce the worst case results. It is necessary to reverse the polarity of the aggressor signal to ensure that unintended compensation from the imperfections in the applied signal is not occurring.

The aggressor pulses are of the same type used for the impedance test: start with single ended signals: + signal at +/- 250 mV and the - signal at -/+ 250 mV. The + signal and - signal pulses initiate in opposite directions to form a collapsing differential aggressor pulse ending at differential zero.

The use of actual worst case data patterns on the aggressor lines has been extensively debated and considered. This is the natural excitation that is initially considered. Extensive testing has shown that resonance conditions and effects of test fixtures can severely distort the measured results when using real data patterns. Sometimes these effects improve the cross talk performance and other times they exacerbate it. It is very difficult to diagnose the intensity and cause of resonance and fixture effects when using a real data pattern. The single pulse eliminates these effects and gives a worst case result that can be attributed to as much of the system as desired. For example, if connector termination techniques are causing the cross talk then that can be revealed by examining the time points associated with the termination points.

The value of the recorded disturbance in the victim line is the differential peak value of the induced noise at a time position within the DUT.

This requirement may appear contrary to logic that says the maximum disturbance occurs with the maximum signal swing and that occurs with a peak to peak measurement. The reason that the peak measurement is the important parameter is that receivers measure the differential signal from a differential zero position. Even if the intensity of the cross talk signal is greater with a peak to peak measurement the receiver will only be affected by that portion that deviates from the zero differential level (i.e the peak level).

Since the cross talk is a linear function of amplitude it is not required that the actual aggressor signal be the maximum differential amplitude. A scaling technique is used to compensate for equipment that is not capable of launching maximum amplitude signals.

Although cross talk is generally more intense with shorter STD aggressor signals, both the maximum and minimum STD signals are required to be used. This is to cover the case where physical imperfections may extend over longer distances and therefore could yield a more intense cross talk with longer STD aggressor signals. Cross talk does not necessarily scale linearly with STD. Therefore, the specific STD requirements shall be used.

In a SCSI cable aggressor signals on each of the DATA, PARITY, and REQ or ACK pair induces noise on the ACK or REQ pair respectively. Each DATA, PARITY, and REQ or ACK pair shall be separately excited. The induced absolute peak noise (deviation from zero differential) on the ACK or REQ pair measured at a time position not associated with the test fixture is recorded as the cross talk contribution from that aggressor signal. The results from each aggressor signal are added to yield the total cross talk.

8.1 Sample preparation

This test requires type B samples as described in section 2.2.1

8.2 Test fixture and measurement equipment

The same basic test fixture is used as for the impedance tests. See .

The measurement equipment is also the same as for the impedance tests except that a separate receiving head is used for SMI1.

The length and properties of the 50 ohm leads connecting the aggressor signal and the victim measurement instrument to the test fixture should be the same length.

8.3 Calibration procedure

The STD and time reference calibration is done using the same test fixture and nearly the same procedure as for the TDR tests in section 2.2.2 (using a short in place of the DUT for STD and reference time calibration).

Noting the time position of the short establishes a reference time for determining the parts of the test configuration that are causing the cross talk.

A second calibration fixture configuration is used to verify that the fixture is not causing excessive cross talk and to verify the time position of the TP1. This second fixture is identical to that described in section 2.2.2 but with 100 ohm resistors added instead of shorts. The second calibration setup is shown in Figure 17.

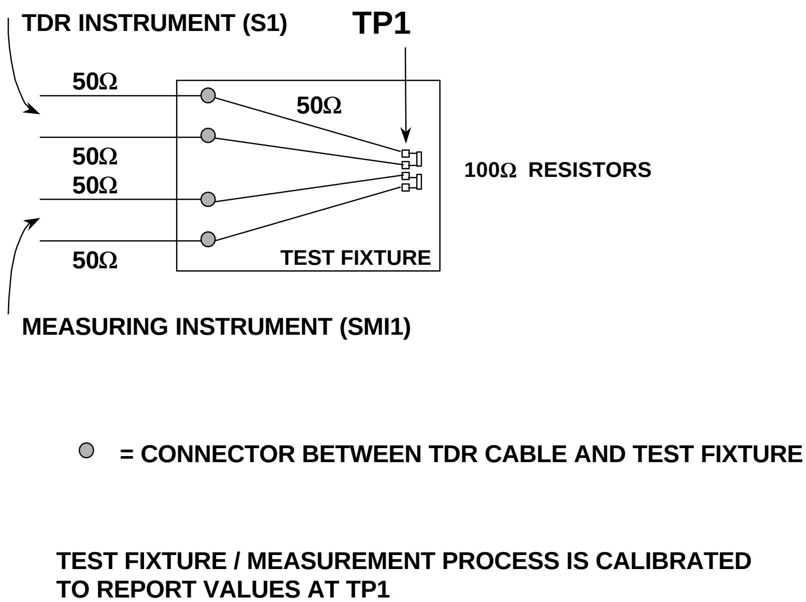

Figure 17 - Calibration system for NEXT

The amplitude calibration is the same as for the impedance tests in section 2.2.2.4. Use the 100% differential amplitude as defined in **Error! Reference source not found.**.

Note the exact settings used for both the minimum and maximum STD conditions as these will be reused when doing the actual measurement.

8.4 Testing procedure

Using the test setup shown in Figure 18 apply the calibrated aggressor pulse for the minimum STD to the aggressor line, S1, and measure the induced noise on the victim line at SMI1.

Repeat the test exactly except with the polarity of the leads to S1 reversed.

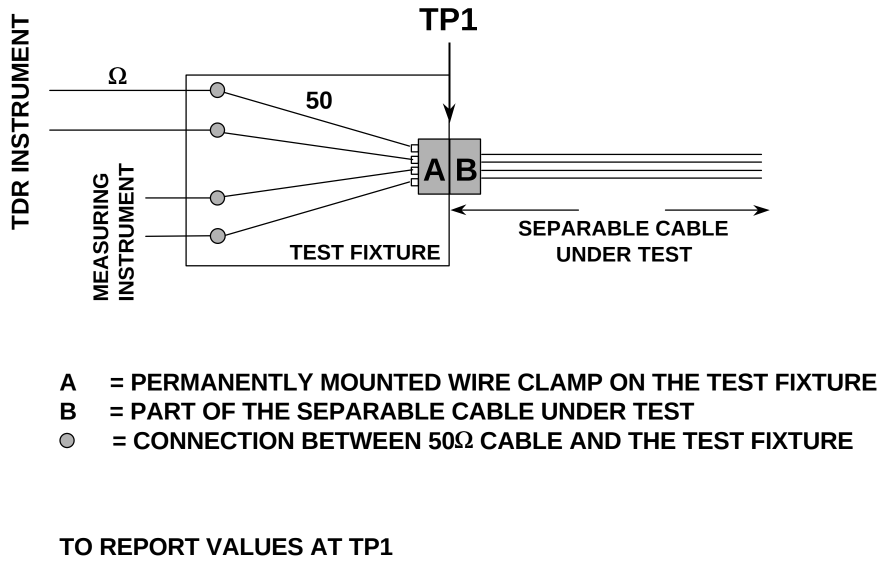

Figure 18 - Test configuration for NEXT

Note the largest peak (i.e. largest deviation from zero differential) on the victim line at a time position farther from S1 than the time position of the short determined in the calibration. This largest peak from either polarity is the value of the induced signal for that STD. Note that a peak to peak value is NOT used. Both the absolute value of the induced signal peak and its percentage with respect to the amplitude of the aggressor signal are recorded.

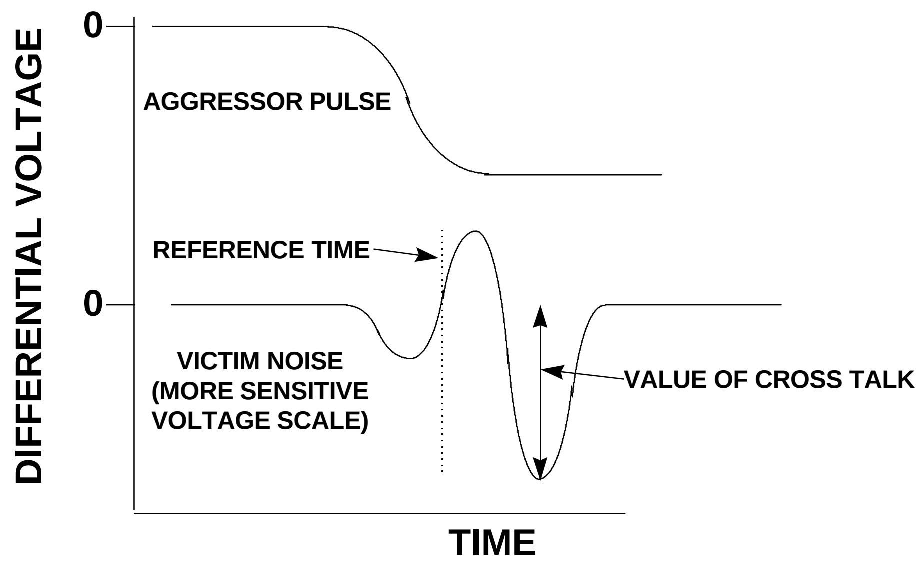

Figure 19 - Example of cross talk measurement

Repeat the tests for both polarity of lead attachment to S1 with the maximum STD aggressor signal.

The absolute value cross talk is scaled to account for the actual amplitude of the aggressor signal. For example if the actual aggressor signal is 500 mV peak and the maximum allowed aggressor signal is 1000 mV then the measured absolute cross talk result would be multiplied by 2.0.

The percentage result does not need to be scaled.

Cross talk percent is calculated as follows:

$$\%NEXT = \frac{\Sigma \text{ peak absolute differential induced voltages on REQ or ACK}}{\text{peak to peak differential aggressor voltage}}$$

Note: Software filtering is not allowed for this test – hardware filters are required to produce the rise time required.