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SPI-3 Annex ___ Proposal

Cable Media Performance Testing

Document 98-219r4

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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.

Six parameters are required to specify the electrical requirements: Transmission line impedance (Zo), capacitance, 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 config	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	2.3	Freq.	sweep between 1 MHz and 1 GHz (30Ω peak to peak swing in impedance values is maximum allowed)	(C) same as (B) with minimum 30 meter length	HP 8753E network anal or Equiv.
SE capacitance	3.1	Freq. (C length #)	100KHz and 1MHz	(D) Sample length 3 meters	LCR meter
	3.2	Freq. (freq. stability of C	Sweep between 100KHz and 1 GHz (1% max change in Capacitance over freq.)	(E) Sample length 1”	Network anal.
Diff capacitance	3.3	Freq. (C length #)	100KHz and 1MHz	(F) Sample Length 3 meters	LCR meter
Diff (Tp) propagation time per meter – Note: Tp is 1/Vp	4	time	Launched rise time between 0.5 ns to 5 ns -propagation time is measured @ the amplitude mid-point of the STD**	(G) Sample 30 Meters	Signal pulse, (no signal generator) TDR 11801 or Equiv.
Diff propagation time skew	5	time	Difference between the min. and max Tp of all pairs.		NA
Diff attenuation (balanced)	6	Freq.	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)	7	Time (Diagnostic option using freq.)	Signal pulse, max legal size, min. signal transition duration time	(I) Sample For freq. option use sample set up (G)	TDR 11801 or Equiv. (For Freq. HP 8753B Network Analyzer or Equiv.)

*Low Frequency Shelf: That range where a 3X change in Frequency produces less than ½ 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 constriction 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 system applications effects not 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 to consider when executing the test in this document include spacing of media conductors from other metallic structures (including wires in other media), non uniform device loading across all the SCSI signals, non uniform stub properties, the population and spacing of devices, and the actual data phase speed of interest.

The bus performance may or may not be quantified by the media requirements in this annex.

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.

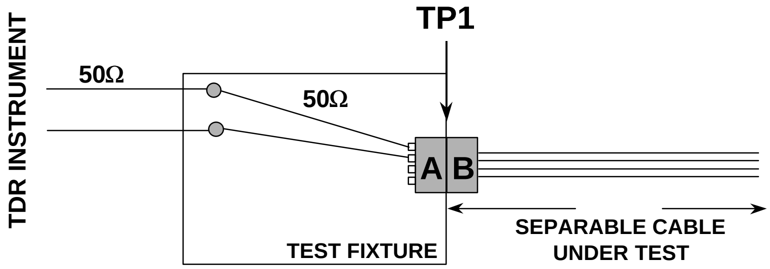
2.1.1 Sample preparation

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

1. Cut sample length to 3m +- 0.1 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. Tie one wire from each pair and the shield together

2.1.2 Test fixture and measurement equipment

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



A = PERMANENTLY MOUNTED WIRE CLAMP ON THE TEST FIXTURE
B = PART OF THE SEPARABLE CABLE UNDER TEST
● = CONNECTION BETWEEN 50Ω CABLE AND THE TEST FIXTURE

TEST FIXTURE / MEASUREMENT PROCESS IS CALIBRATED
TO REPORT VALUES AT TP1

Figure 1 - Test configuration for SE impedance

The test fixture may be constructed of semi rigid coax, microstrip PCB, or stripline PCB. The test fixture must be at least three signal transition lengths long on the side of the wire clamp near the instrumentation and have a section where there are no non-uniformities such as vias. This section is used as an aid in calibrating the TDR for SE transmission line impedance.

2.1.3 Calibration and verification procedure

2.1.3.1 Instrument calibration

Connect a known separate 50Ω±1% SMA load to the end of the SMA 50Ω cable attached to the TDR that will be used to connect to the test fixture. The impedance recorded at the end of the cable should be 50Ω. This calibration will account for the losses in the cable and validates the instrument calibration.

2.1.3.2 Test fixture verification

Connect the 50Ω cable to the test fixture. In place of “B” in Figure 1 connect one of three known low inductance chip resistors whose values are:
A) on the low end of the tolerance level
B) on the high end of the tolerance level
C) at the ideal value of 50 ohms

Compare the measured resistance value for each chip resistor against “C” the ideal value. The measured deviation from the ideal value for the ideal value resistor is the test bias for the fixture. The measurements with high and low value chip resistors should track quantitatively. If this tracking is not achieved the test fixture shall be repaired.

2.1.3.3 Single ended signal transition duration calibration

This step ensures that the proper signal transition time is being presented to the cable under test. 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 signal transition duration (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 5. This display has the following properties:

- The span of the time scale on the display is approximately twice the nominal bit period for the data rate being used. Ten divisions are used on the time axis. Table 1 specifically shows the time scales to use.
- The vertical axis is set at 75 mV per division
- Move the displayed curve to the right and adjust the vertical position such that the flat portion of the curve (flat for at least time divisions) passes through the ninth division from the bottom
- Set the horizontal position such that the displayed curve passes through the third division on the time axis and the seventh division on the vertical axis
- Use the peak to peak function on the TDR to find the signal amplitude of the displayed portion of the trace as shown in Figure 5. This amplitude may also be read directly off the display. This signal amplitude of the displayed trace may or may not accurately represent the asymptotic signal levels that may exist at times not displayed.
- The signal transition duration (STD) is the time between the 20% and 80% values of the displayed signal amplitude

Table 2 - Scale to be used for STD calibrations

Bit rate * (Mbits/s)	Time axis scale (ps/div)
20 ST	5000
40 ST	2500
40 DT	5000
80 ST	1250
80 DT	2500
100 DT	2000
200 DT	1000
400 DT	500
800 DT	250
1062.5	200
1250	200
1600	100
2125	100
2500	100
3200	50
4250	50
5000	50
* ST = single transition clocking DT = double transition clocking	

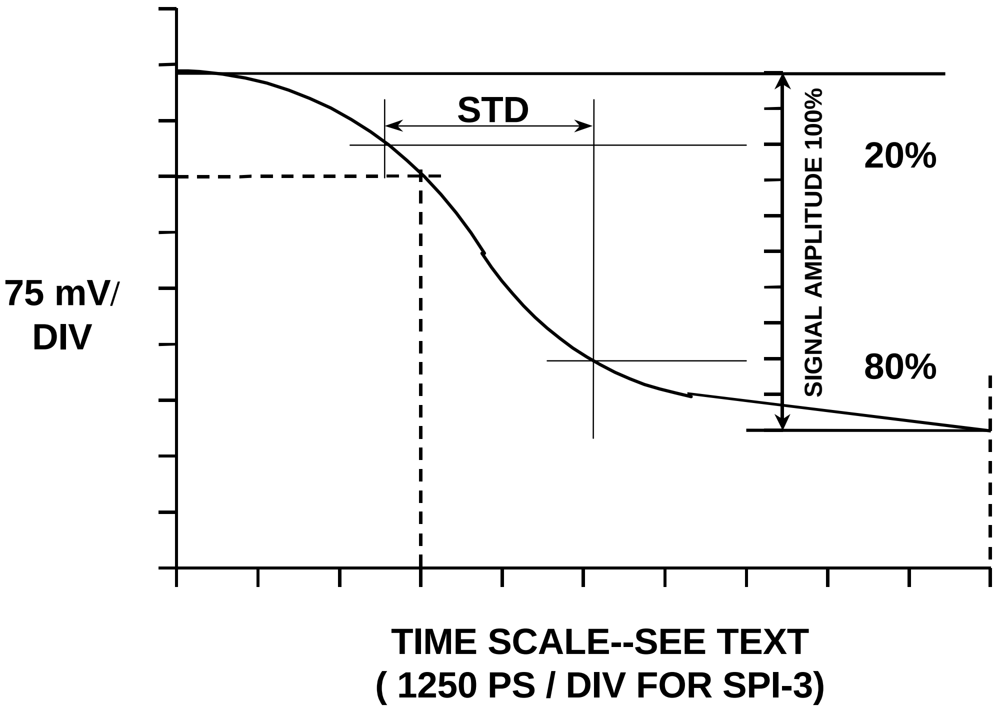


Figure 2 - Signal transition duration calibration

For a rising edge signal the STD measurement is the same as for the falling edge with the changes noted in Figure 6.

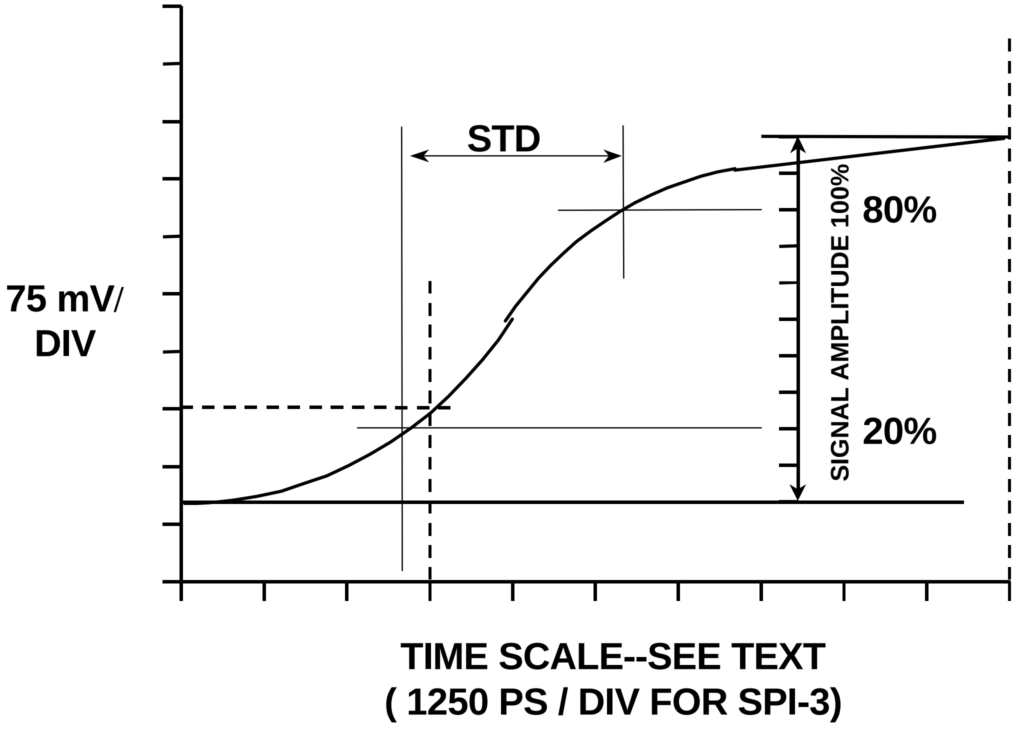


Figure 3 - Signal transition duration calibration

Adjust the TDR filter so that the desired STD is achieved. Note that there will usually be two values of STD required: one for each extreme of the specification. For SPI-3, the extremes are 500 ps to 3 ns. The value of the filter setting required to achieve these STD conditions should be used during the impedance measurement

2.1.4 Testing procedure

Connect the separable cable under test 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 1.25 ns /div (total time axis span of 12.5 ns).
- Set the vertical scale (mρ) to 40 mρ /div
- Adjust the vertical position to approximately center the trace on the display
- Adjust the horizontal position such that the first discontinuity is on the first division.
- Set the TDR cursor to read ohms
- Use the cursor to measure the minimum and maximum values in ohms near the left side of the trace that shows the disturbances from the wire clamp.
- Disconnect the cable under test from the test fixture and note the time position of the wire clamp interface, t_{inf}.
- Reconnect the cable under test and extrapolate the linear portion of the trace on the right side of the display to t_{inf} (see Figure 4)
- Use the cursor (in ohms) to read the value of extrapolation to t_{inf}. This is the media transmission line impedance.

Execute the test with both extremes of transition time allowed (e.g. 500 ps and 3 ns for SPI-3) using the above method to record the trace. Note: a separate calibration and verification should have been done at these STD extremes.

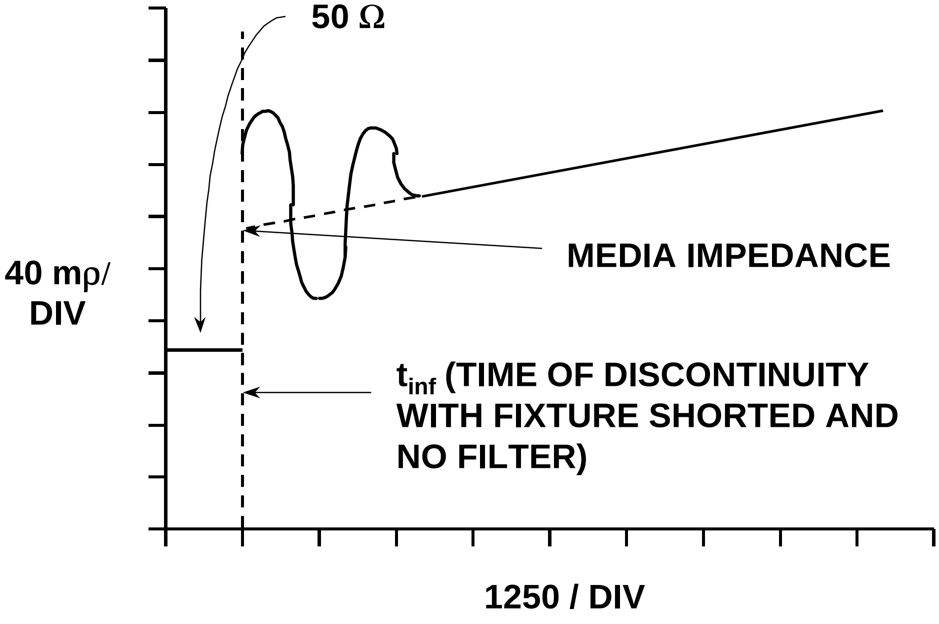


Figure 4 - Extrapolation to find media impedance

2.1.4 Acceptable ranges

The media impedance is measured at a maximum of 4 ns from the wire clamp interface (well into the cable media). The measurement at 4 ns is adjusted for cable attenuation by using a linear fit as shown in Figure 4.

Table 3 - Allowed ranges for transmission line impedance

	Local SE transmission line impedance **		Local DIFF transmission line impedance **	
	Min	Max	Min	Max
Flat, Twisted Flat, Round jacketed unshielded cables	84	96	115	140
Round Shielded cables	78*	96	110	135

All values are measured by time domain reflectometry
* If SCSI loads attached to round shielded cables, are separated by less than 1.0 m, this value is 84 Ohms.
** Ideally one design will meet both SE and DIFF criteria

2.2 Differential transmission line impedance

This requirement is necessary to allow the cable media to interface to 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 +- 0.1 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

2.2.2 Test fixture and measurement equipment

Figure 1 shows the test configuration for the differential transmission line impedance tests.

The test fixture may be constructed of semi rigid coax, microstrip PCB, or stripline PCB. The test fixture must be at least three signal transition lengths long on the side of the wire clamp near the instrumentation and have a section where there are no non-uniformities such as vias. This section is used as an aid in calibrating the TDR for Diff transmission line impedance.

2.2.2.1 Calibration and verification procedure

2.2.2.2 Instrument calibration

Connect a known separate 50Ω resistor at the far end of each of the 50Ω cables attached to the TDR that will be used to connect to the test fixture. The impedance recorded at the end of each cable should be 50Ω. This calibration will account for the losses in the cable and validates the instrument calibration.

2.2.2.3 Test fixture verification

Connect the 50Ω cables to the test fixture. In place of "B" in Figure 1 connect one of three known low inductance chip resistors whose values are:
A) on the low end of the tolerance level
B) on the high end of the tolerance level
C) at the ideal value 100 ohm

Compare the measured resistance value for each chip resistor against "C" the ideal value. The measured deviation from the ideal value for the ideal value resistor is the test bias for the fixture. The measurements with high and low value chip resistors should track quantitatively. If this tracking is not achieved the test fixture shall be repaired.

2.2.2.4 Differential signal transition duration calibration

This ensures that the proper signal transition duration is being presented to the cable under test. Place a short on the test fixture where the cable under test would be attached (e.g. instead of "B" in Figure 1. Use the filter function on the TDR to set the measured signal transition duration (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 5. This display has the following properties:

- The span of the time scale on the display is approximately twice the nominal bit period for the data rate being used. Ten divisions are used on the time axis. Table 1 specifically shows the time scales to use.
- The vertical axis is set at 75 mV per division
- Move the displayed curve to the right and adjust the vertical position such that the flat portion of the curve (flat for at least time divisions) passes through the ninth division from the bottom.
- Set the horizontal position such that the displayed curve passes through the third division on the time axis and the seventh division on the vertical axis
- Use the peak to peak function on the TDR to find the signal amplitude of the displayed portion of the trace as shown in Figure 5. This amplitude may also be read directly off the display. This signal amplitude of the displayed trace may or may not accurately represent the asymptotic signal levels that may exist at times not displayed.
- The signal transition duration (STD) is the time between the 20% and 80% values of the displayed signal amplitude

Table 4 - Scale to be used for STD calibrations

Bit rate * (Mbits/s)	Time axis scale (ps/div)
20 ST	5000
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400 DT	500
800 DT	250
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1250	200
1600	100
2125	100
2500	100
3200	50
4250	50
5000	50
* ST = single transition clocking DT = double transition clocking	

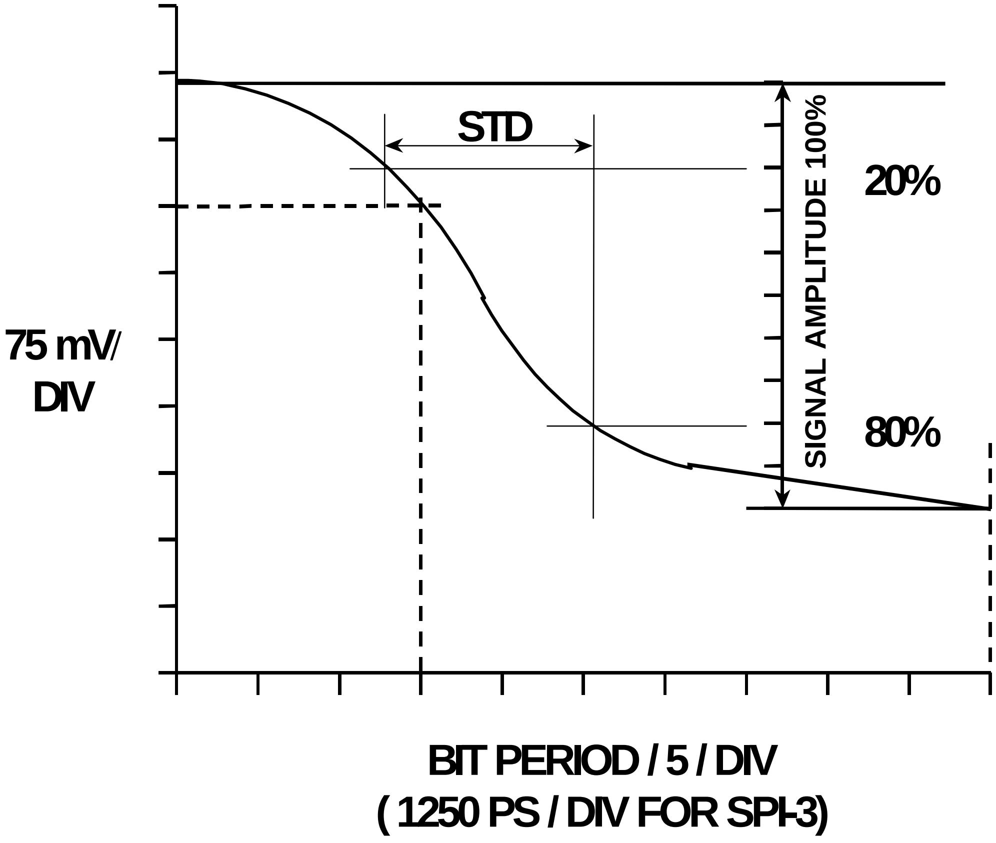


Figure 5 - Signal transition duration calibration

For a rising edge signal the STD measurement is the same as for the falling edge with the changes noted in Figure 6.

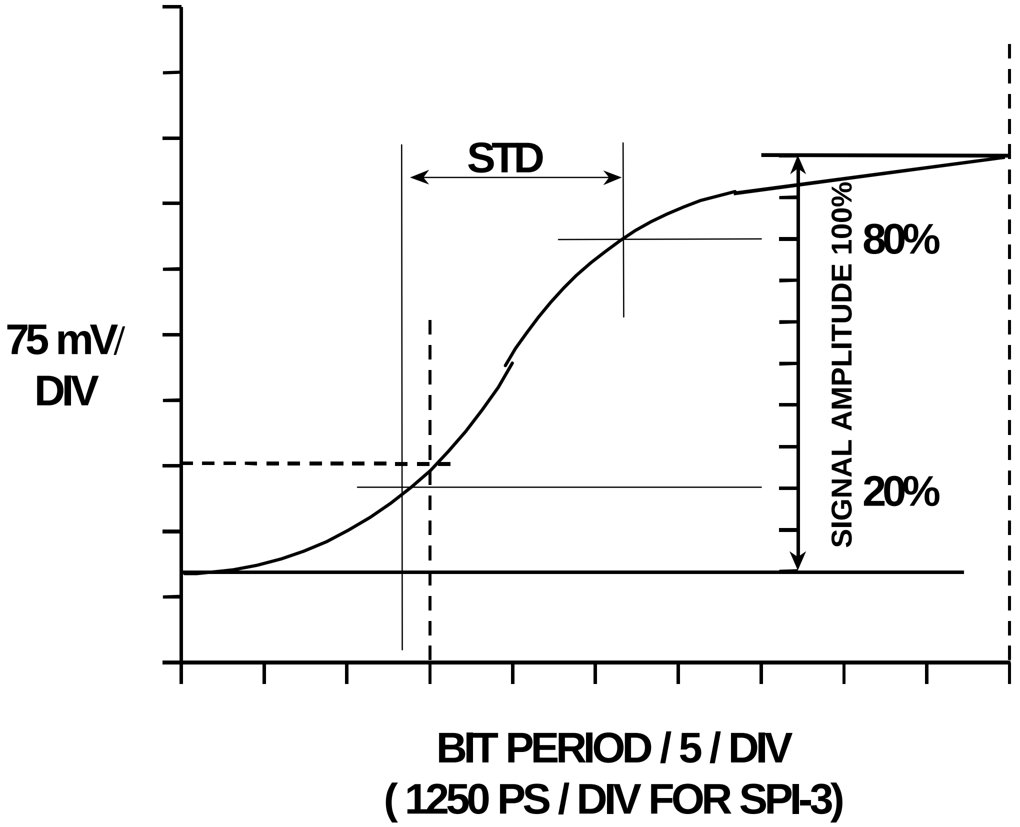


Figure 6 - Signal transition duration calibration

Adjust the TDR filter so that the desired STD is achieved. Note that there will usually be two values of STD required: one for each extreme of the specification. For SPI-3, the extremes are 500 ps to 3 ns. The value of the filter setting required to achieve these STD conditions should be used during the impedance measurement

2.2.3 Testing procedure

Connect the separable cable under test to the test fixture wire clamp. Figure 7 shows the TDR display setup to use for this measurement.

- Set the time scale to 1.25 ns /div (total time axis span of 12.50 ns).
- Set the vertical scale (mρ) to 40 mρ /div
- Adjust the vertical position to approximately center the trace on the display
- Adjust the horizontal position such that the first discontinuity is on the first division.
- Set the TDR cursor to read ohms
- Use the cursor to measure the minimum and maximum values in ohms near the left side of the trace that shows the disturbances from the wire clamp.
- Disconnect the cable under test from the test fixture, disable the software filtering, and note the time position of the wire clamp interface, t_{inf}.
- Reconnect the cable under test, turn the software filtering back on and extrapolate the linear portion of the trace on the right side of the display to t_{inf} (see Figure 7).
- Use the cursor (in ohms) to read the value of extrapolation to t_{inf}. This is

the media transmission line impedance.

Execute the test with both extremes of transition time allowed (e.g. 500 ps and 3 ns for SPI-3) using the above method to record the trace. Note: a separate calibration and verification should have been done at these STD extremes.

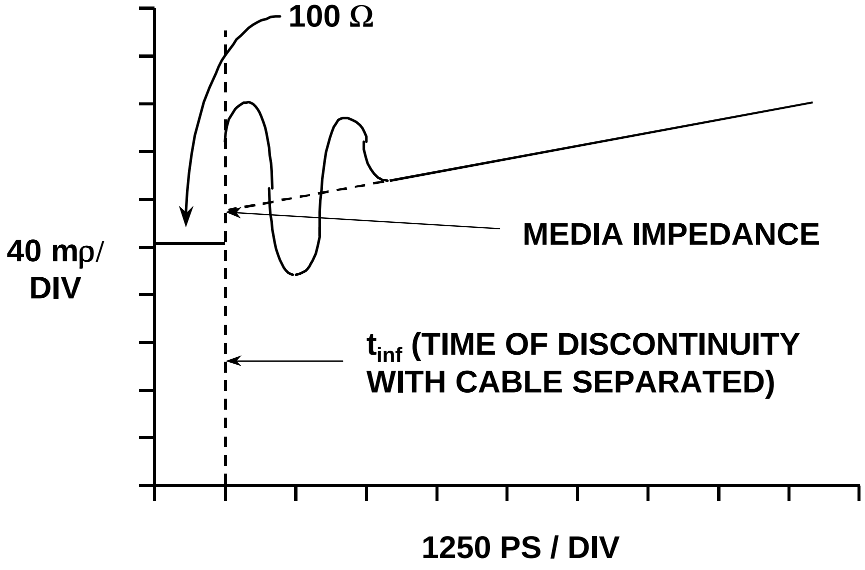


Figure 7 - Extrapolation to find media impedance

2.2.3 Acceptable ranges

The trace within the close proximity electrical neighborhood should be within in the range shown in Table 3 for all signal transition times allowed for the application. The media impedance is measured at a maximum of 4 ns from the wire clamp interface (well into the cable media). The measurement at 4 ns is adjusted for cable attenuation by using a linear fit as shown in Figure 7).

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:

First the cable sample shall be cut to a length such that resonance does not occur. The ends shall be prepared in such a manner that as little disturbance as possible to the original cables physical structure exists not to exceed one inch on either end.

2.3.2 Test Fixture

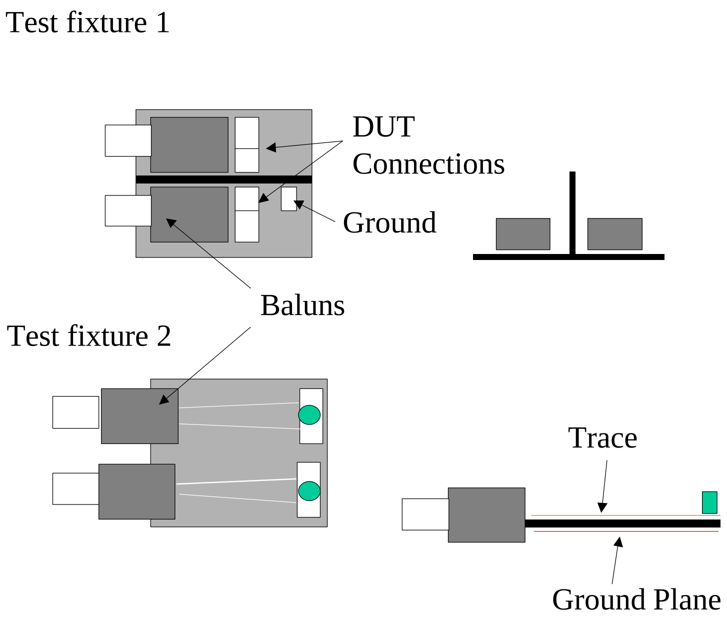


Figure 8 – Test configuration for differential extended distance impedance profile

Figure 8 shows the test configuration for the differential extended distance impedance tests.

2.3.1.1 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. 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 figure 2).**

2.3.1.2 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 very 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 cable characteristics.

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

2.3.1.3 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 device-under-test, as well as provide differential signals. The aluminum screen provides electrical isolation between the two baluns. The DUT (cable -under -test) connects to the fixture via a mechanical clamp system. The DUT is terminated by connecting the far end of the cable to the second Balun on the same fixture or by a direct resistive termination across signal lines.

For the PCB test fixture, the test fixture consist of a printed circuit board incorporating controlled characteristic 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 current return path. A coaxial cable (same characteristic impedance as the test instrument) connects one end of the cable to the instrument test port through the baluns and the PC board fixture trace combination. The baluns provide a 50 to 61 ohm impedance matching between the test instrument system and the device-under-test, as well as provide differential signals. The separation of the baluns and the signal lines provide electrical isolation between the two baluns and the signal lines. The DUT connects to the fixture via a mechanical clamp system. The DUT is terminated by connecting the far end of the DUT to the second Balun on the same fixture or by a direct resistive termination across signal lines.

Fixture board stand is recommended for mounting fixture board and preventing the device under test (dut) from dangling around. It is recommended that the fixture stand keep the fixture board at distances of at least 3 inches from the top of the lab bench to prevent coupling to grounded bench tops.

2.3.1.4 Fixture board design requirements (test fixture 2):

Traces are constructed on the PC board to conform with the differential transmission scheme. The fixture shall be through hole or surface mount PC board. The signal traces are connected to the baluns 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 the required signal separation for isolation.. It is recommended that the bandwidth of the board be at least twice the bandwidth of the fifth harmonics of cable-under-test. 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. The board construction will provide a set of transmission traces that will enable the inductance, the capacitance, the electrical lengths, and the noise contributions of the fixture boards to be measured.

2.3.3 Calibration Procedure

Set the equipment up as recommended by the manufacturer and calibrate using the appropriate calibration standard kit.

The analyzer will be set to perform a S11 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. The calibration will be of the open, short, load method keeping the leads as short as possible on the standards. The load standard will match the impedance of the secondary balun and have a maximum tolerance of 1%.

2.3.4 Measurement Procedure

Set the equipment up as recommended by the manufacturer and calibrate using the appropriate calibration standard kit.

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

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

c) Connect the near end of the sample to the output balun on the test fixture using 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 swept test for the bandwidth as required by table.

2.3.5 Acceptable Values

A maximum of 30 Ohms peak to peak is acceptable for this test condition.

3. Capacitance

3.1 SE Capacitance

3.1.1 Sample preparation

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

1. Cut sample length to 3m +- 0.1 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

3.1.1 Calibration Procedure

Calibration method specified by the manufacturer of the LCR Bridge will be followed for reliable results.

3.1.2 Measurement Procedure

With the bridge set at the desired frequency, connect the pair and record the capacitance.

3.1.3 Acceptable Values

Cable shall not exhibit more than 20pF/ft or more than 66pF/m.

3.2 SE variation of capacitance with frequency

3.2.1 Sample preparation

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

3.2.2 Calibration Procedure

3.2.4 Measurement Procedure

Sweep fixture with no sample then sweep with sample in place. Take difference B-A= c(f)

3.2.5 Acceptable Values

SE 20 pF/ft or more than 66pF/m max at 100 kHz and 1 MHz.

3.3 Differential Capacitance

3.3.1 Sample preparation

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

3.3.2 Test Fixture

Reference: Figure 1 for appropriate test fixture

3.3.3 Calibration Procedure

Reference 2.3.3 for requirements

3.3.4 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.

3.3.5 Acceptable Values

Cable shall not exhibit more than 14pF/ft or more than 50pF/m at 100 kHz and 1 MHz

4. Propagation time (differential)

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

Reference: 2.3.3 for appropriate test fixtures

4.3 Calibration Procedure

The analyzer will 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 out put 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.

4.5 Acceptable Values

Cable shall not exhibit more than 1.65 ns per foot or 5.4 ns per meter

5. Propagation time skew (differential)

5.1 Measurement procedure

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

5.2 Acceptable values

Maximum skew shall not exceed 25 ps/ft or 82 ps/m.

6. Attenuation

6.1 Differential attenuation

Attenuation is calculated from the ratio of output signal level to input signal level through the PUT and is a measure of the losses experienced when transmitting a signal through the interconnect. 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 trapeziodal 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 9.

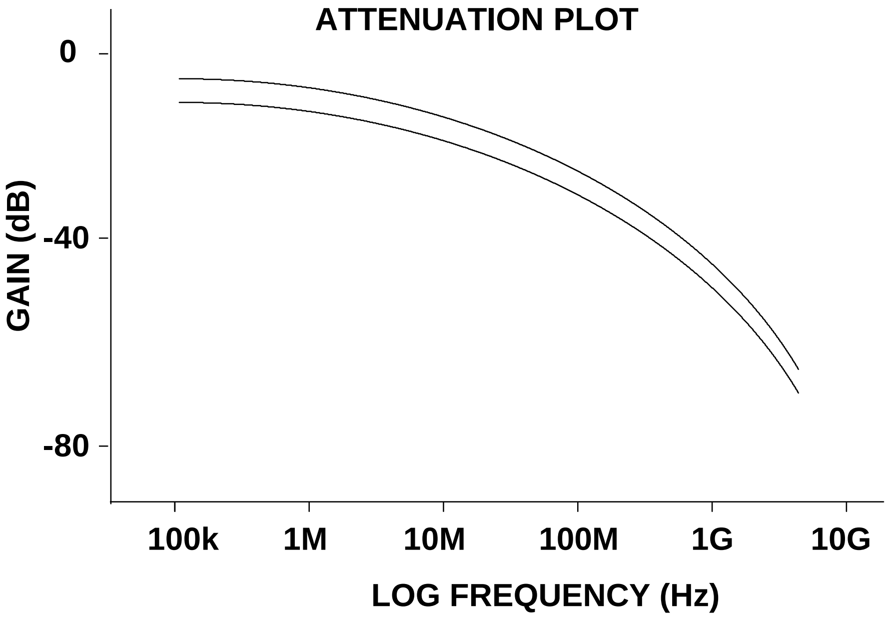


Figure 9 - Form of attenuation plots

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 :

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

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 IUT is balanced a coupling device called a balun is required to connect the IUT 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 IUT in the balanced state to minimize reflections. If reflections are present they will skew the data by introducing a mismatch loss ripple component.

Figure 10 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 seriously mismatched baluns on very long cables is a small error in the attenuation reported (less than 1 dB in the example shown).

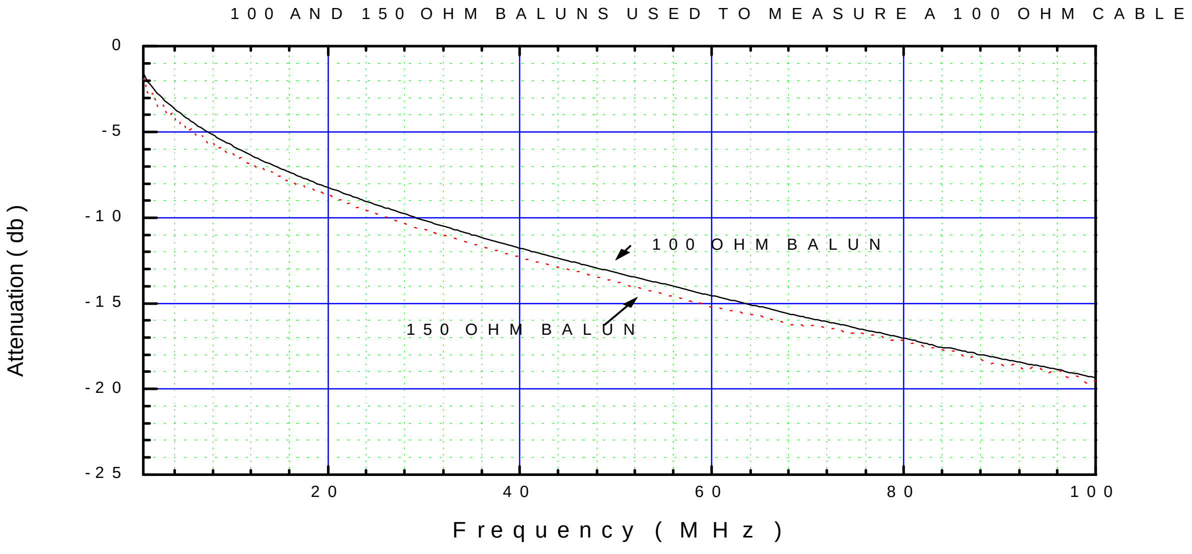


Figure 10 - Effect of balun selection on measured attenuation for very long cables

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 11.

GAIN (dB)

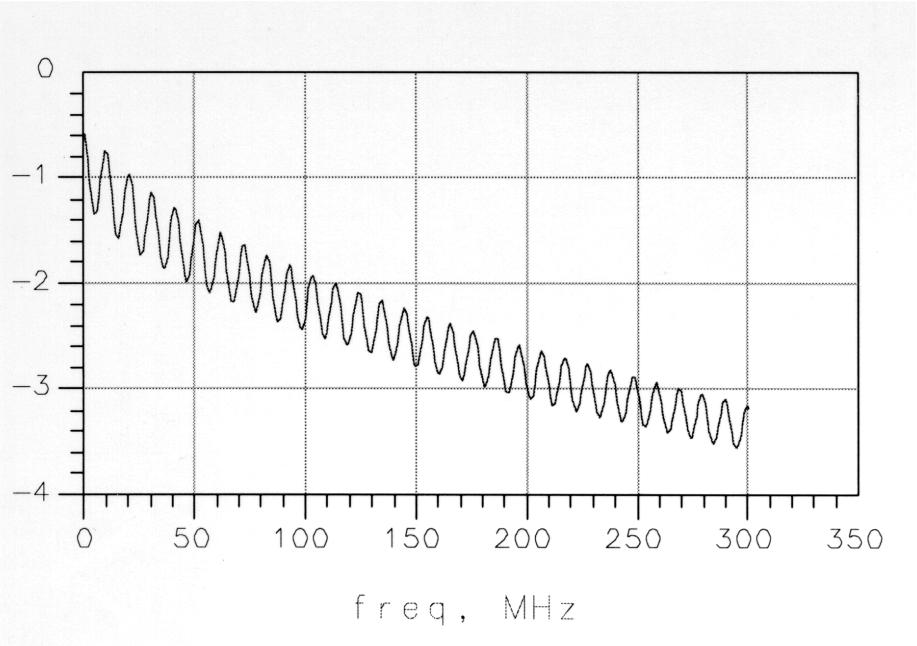


Figure 11 - Effects of mismatched baluns in a short IUT

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 12.

GAIN (dB)

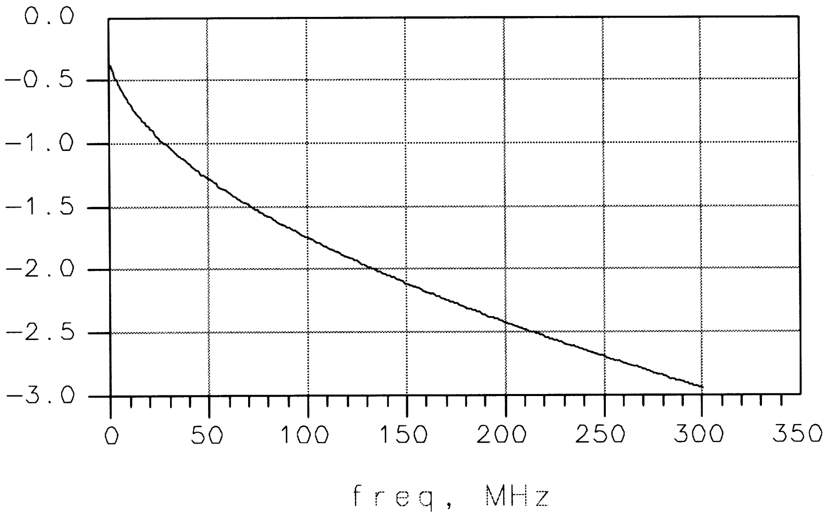


Figure 12 - Effect of matched baluns on a short sample

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.

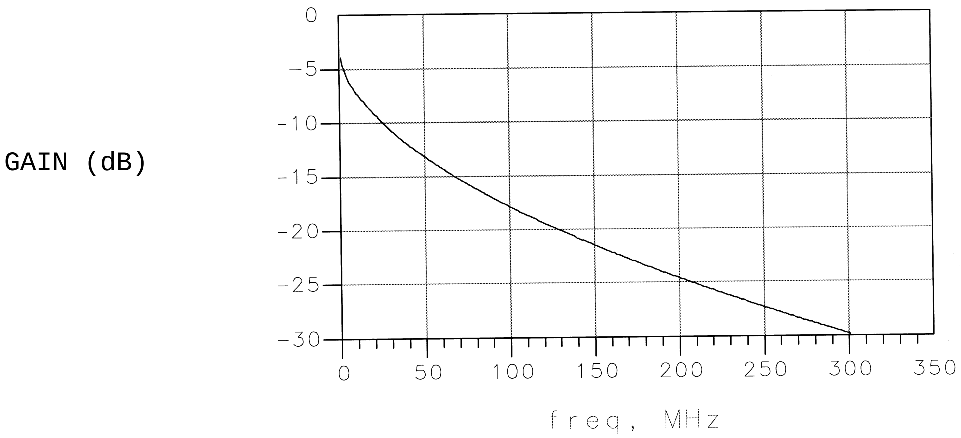


Figure 13 - Effects of mismatched baluns with 6 dB LF attenuation

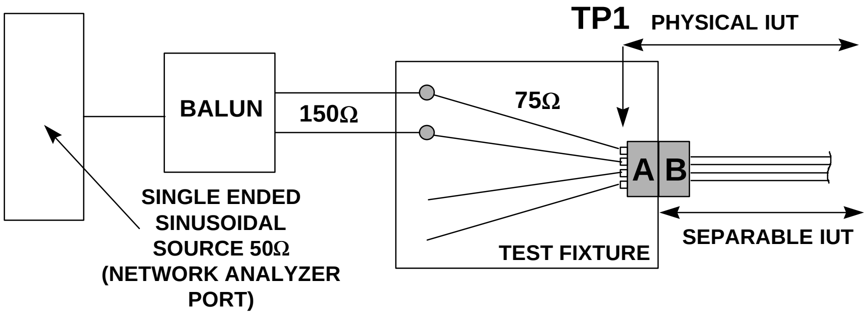
Note: The use of an attenuator for measuring shorter lengths is not acceptable because there is still mismatch loss uncertainty due to the fact that the attenuator does not have any better match than the far end test port. Also an *additional uncertainty is introduced because a small value (cable attenuation)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

6.1.1 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 14 and Figure 15 an calibrated as shown in Figure 16. This test fixture may be exactly the same as used for the impedance tests in Section 2.1.

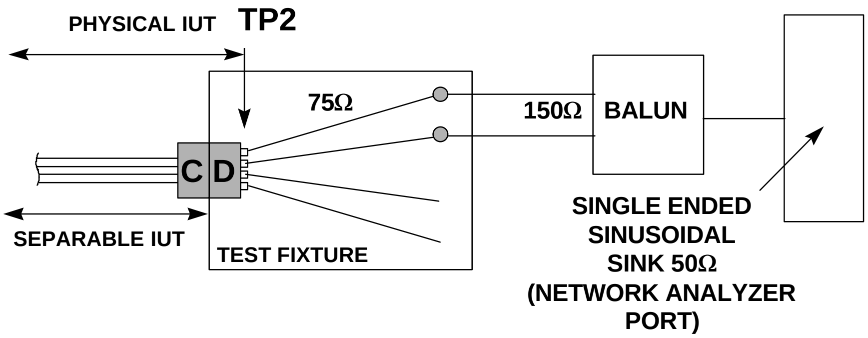


A = PERMANENTLY MOUNTED CONNECTOR ON THE TEST FIXTURE
B = PART OF THE SEPARABLE INTERCONNECT UNDER TEST
● = CONNECTOR

TEST FIXTURE / MEASUREMENT PROCESS IS CALIBRATED
TO REPORT AT TP1

Figure 14 - Source-end test fixture for attenuation tests

The balun shown in Figure 14 is 50 Ω single ended to 150 Ω differential.



A = PERMANENTLY MOUNTED CONNECTOR ON THE TEST FIXTURE
B = PART OF THE SEPARABLE INTERCONNECT UNDER TEST
● = CONNECTOR

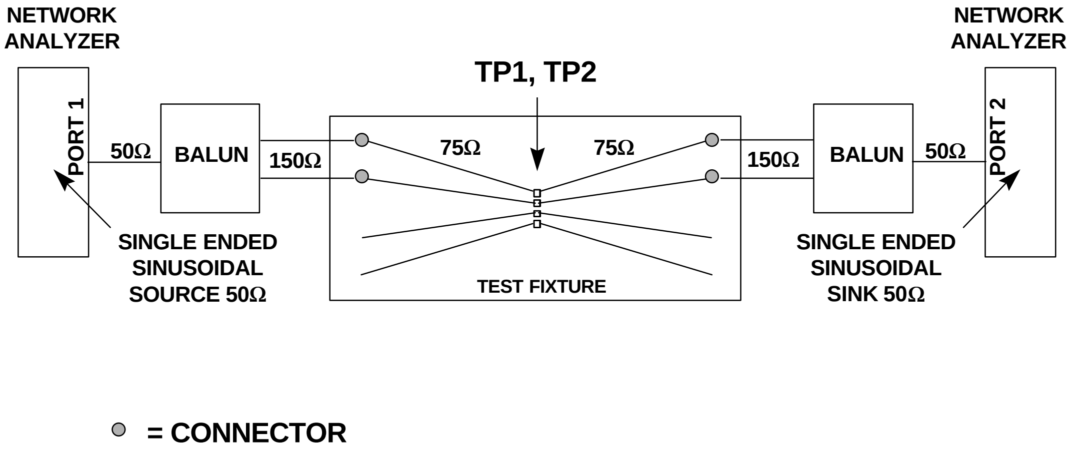
TEST FIXTURE / MEASUREMENT PROCESS IS CALIBRATED
TO REPORT VALUES AT TP2

Figure 15 - Sink end test fixture for attenuation tests

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

6.1.2 Calibration procedure

A special “through” test fixture is used for the signal calibration process which is exactly like the test fixture in Figure 14 and Figure 15 except that there are no IUT connectors (A, D). See Figure 16.



TEST FIXTURE / MEASUREMENT PROCESS IS CALIBRATED TO REPORT VALUES AT IUT CONNECTION POINT (TP1, TP2)

Figure 16 - Calibration configuration for attenuation tests

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

6.1.3 Testing procedure

Connect the IUT to the test fixtures shown in Figure 14 and Figure 15 (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 17 and Figure 18 show the effects of balun isolation.

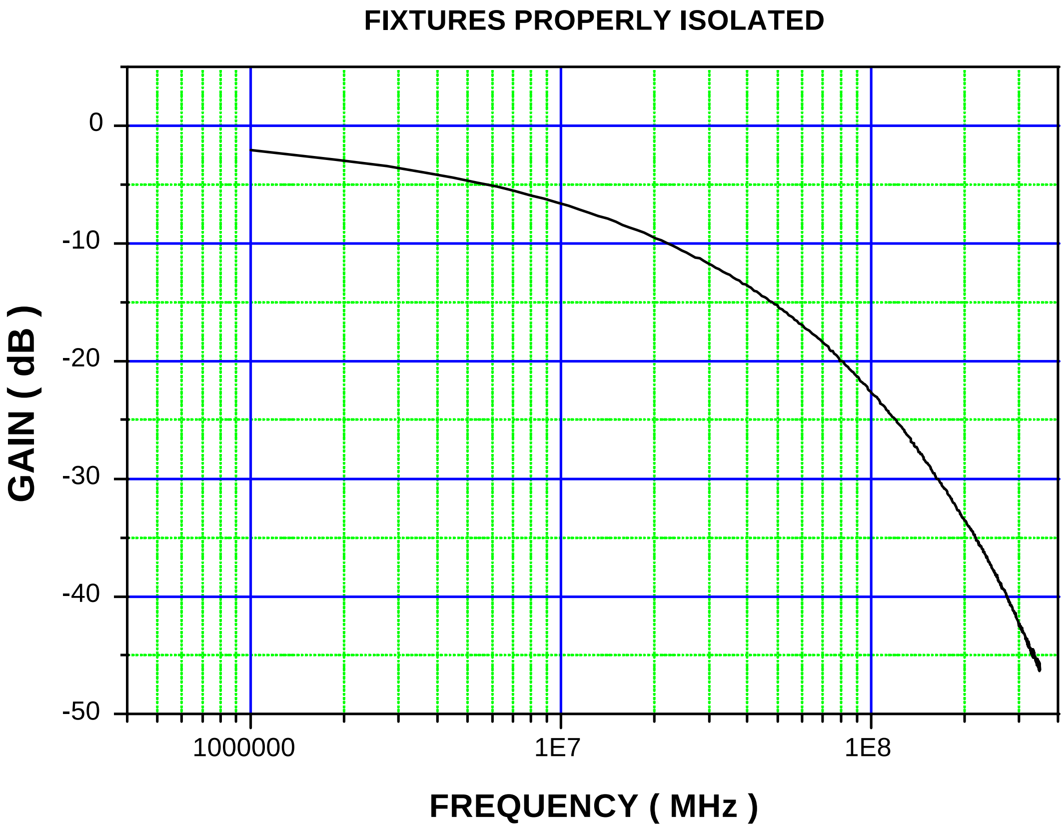


Figure 17 - Attenuation scan with proper balun isolation

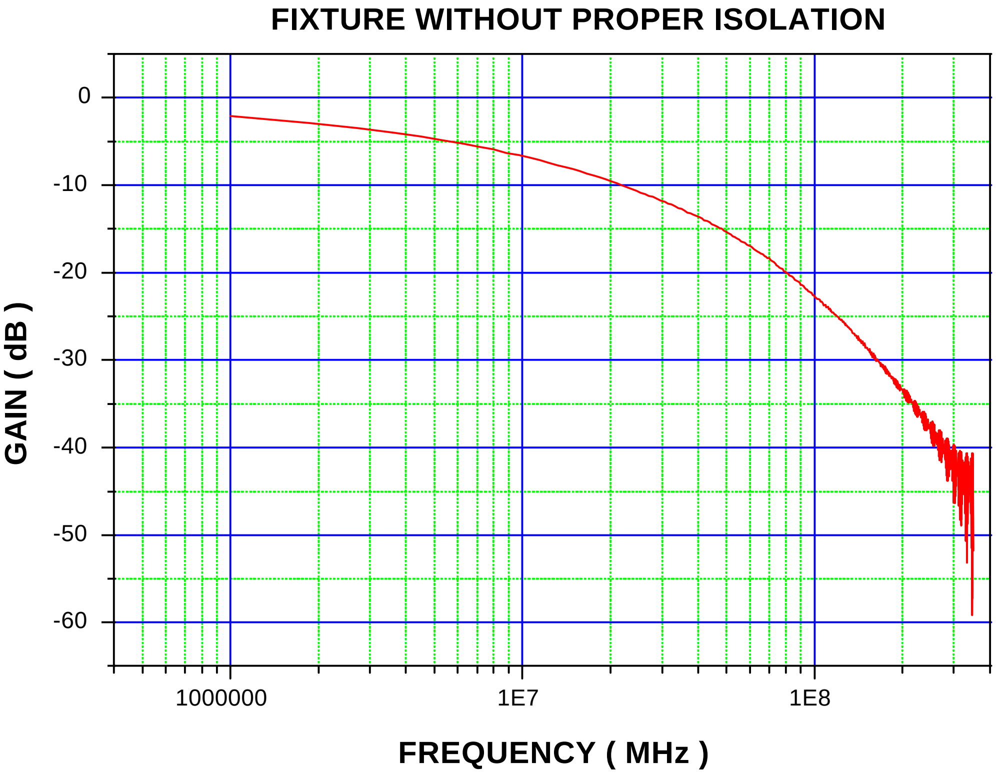


Figure 18 - Attenuation scan without good balun isolation

6.1.4 Acceptable ranges

From terminator to terminator at 200 MHz attenuation shall be either:

(1) no greater than 6 dB producing 0.5 dB max per meter up to 12m (consistent with 30 AWG solid copper at 12 meters) or,
(2) no greater than 10dB producing 0.4 dB max per meter at ≤ 25m and > 12m (consistent with 28 AWG stranded copper at 25 meters).

7. Near end cross talk (quiescent noise)

This test is limited to a single option: the single applied pulse method. In this method pulses with maximum differential amplitude, maximum and minimum STD signal are applied to the cable under test on one pair and the signal induced on all other pairs is measured. The pair with the applied pulse is the aggressor pair and a pair with the induced noise is the victim pair.

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.

Another important point is the value of the recorded disturbance in the victim line. Should the peak, peak to peak or some other feature of the induced noise be used? This document requires that the differential peak value of the induced noise at a time position within the cable under test be used.

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. (This is another reason why the pulse technique is desirable.)

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.

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 and the results added to yield the total cross talk.

7.1 Sample preparation

This test requires type B samples as described in section 2.2.1

7.2 Test fixture and measurement equipment

The same basic test fixture is used as for the impedance tests. See Figure 1.

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.

7.3 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 IUT for STD and reference time calibration).

Noting the time position of the short establishes a reference time for determining the parts of the tests 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 19.

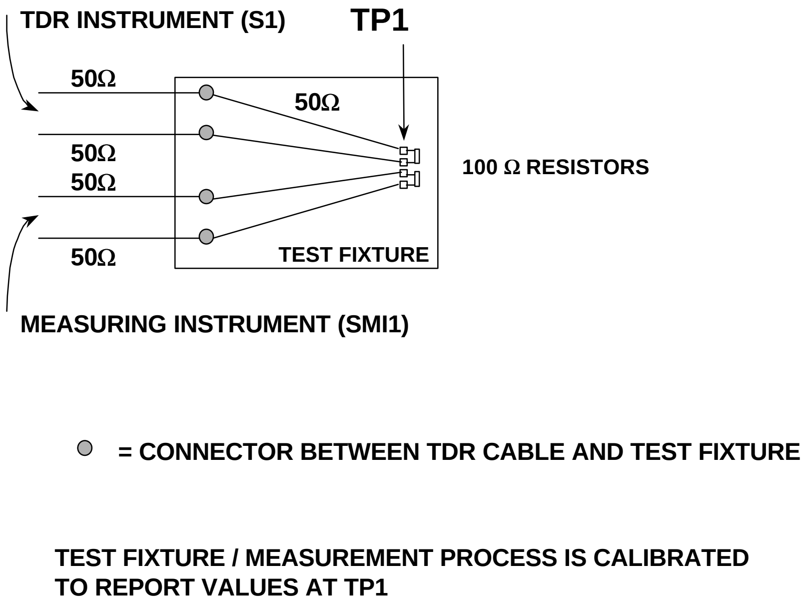


Figure 19 - Calibration system for NEXT

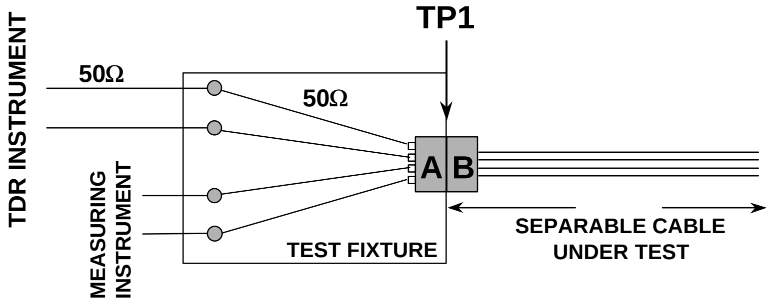
The amplitude calibration is the same as for the impedance tests in section 2.2.2.4. Use the 100% differential amplitude as defined in Figure 5.

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

7.3.1 Testing procedure

Using the test setup shown in Figure 20 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.



A = PERMANENTLY MOUNTED WIRE CLAMP ON THE TEST FIXTURE
B = PART OF THE SEPARABLE CABLE UNDER TEST
● = CONNECTION BETWEEN 50Ω CABLE AND THE TEST FIXTURE

TEST FIXTURE / MEASUREMENT PROCESS IS CALIBRATED TO REPORT VALUES AT TP1

Figure 20 - 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.

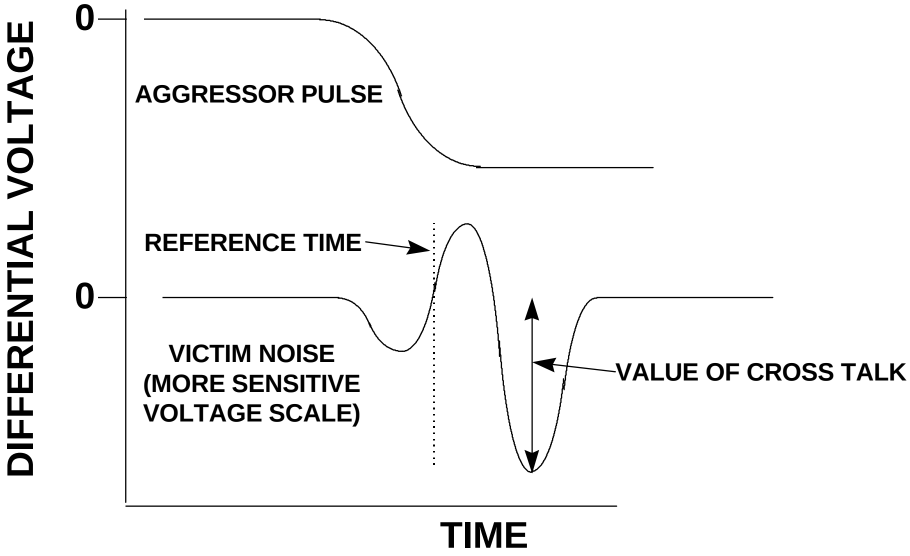


Figure 21 - Example of cross talk measurement

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:

$$\%NEXT = \frac{\text{Arithmetic Sum of peak differential victim voltages}}{\text{peak to peak differential aggressor voltage}}$$

Note: Software filtering is not allowed for this test – hardware filters are required to produce the rise time required. *This issue is still under review.*

7.3.2 Acceptable ranges

The allowed limit for the total cross talk is 3.0% of the aggressor signal amplitude at 0.5 ns rise time.