98-219r1

Prepared by:

Ed Armstrong
Zane Daggett
Bill Ham
Martin Ogbuokiri

Date: 07-24-98
Revised: 09-29-98
Revised again: 10-14-98

1. REQUIREMENTS FOR SPI-3 CABLES

This clause specifies the electrical performance requirements for shielded and unshielded cables.

Five parameters are required to specify the electrical requirements: Transmission line impedance (Zo), capacitance per unit length, propagation velocity, propagation velocity skew, and signal attenuation. Each parameter is specified for both SE and Diff applications.

This clause also specifies methods for executing the testing for extracting these parameters.

Two methods are specified for the transmission line impedance: time domain and frequency domain. The capacitance is extracted from the frequency domain measurements for transmission line impedance. The propagation velocity is based on a time domain measurement. The attenuation is derived from a frequency domain measurement.

1.1 General Notes for Testing

To minimize discontinuities and signal reflections, the use of cables with different impedances in the same bus should be minimized. Implementations may require trade-offs in shielding effectiveness, cable length, the number of loads, transfer rates, and cost to achieve satisfactory system operation. To minimize discontinuities due to local impedance variation, a flat cable should be spaced at least 1,27 mm (0,050 in) from other cables, any other conductor, or the cable itself when the cable is folded. Also, use of 26 AWG wire in 1,27 mm (0,050 in) pitch flat cable will more closely match impedances of many round shielded cables, resulting in fewer impedance discontinuities and therefore, improved signal quality. When mixing devices of different widths, particular care should be taken to not exceed the skew allowances provided by the cable skew delay and the system skew delay. These timing parameters may be lowered by reducing SCSI device input capacitance, SCSI device stub length, and the number of SCSI devices attached to the bus. The same precautions should be taken on busses with single-ended devices using fast synchronous data transfers in order to maintain system integrity.

Parameter	Section	measurement domain	test conditions	sample style	Active equipment
SE Zo	2.1.1.1	time	any within 0.5 to 3 ns rise time	(A) tie all grounds & shield together 6 meters long	TDR
	2.1.1.2	Freq.	sweep between 1 MHz and 100 MHz	(B) same as (A) tune length to eliminate resonance	HP 4291B Z anal
Diff Zo	2.2.1.1	time	any within 0.5 to 3 ns rise time	(C) details TBD 6 meters long	Diff TDR
	2.2.1.2	Freq.	sweep between 1 MHz and 100 MHz	D (almost B) details TBD pick length to eliminate resonance	HP 4291B Z anal
SE C	3.1.1.1	Freq.	sweep between 1MHz and 100 MHz	B	HP 4291B Z anal
Diff C	3.2.1.1	Freq.	sweep between 1 MHz and 100 MHz	D	HP 4291B Z anal
SE Vp	4.1.1.1	time	any within 0.5 to 3 ns rise time	A	TDR
Diff Vp	4.2.1.1	time	any within 0.5 to 3 ns rise time	C	TDR
SE skew	5.1.1.1	time	010101…5.0 ns or less rise time	G same as A with both ends prepped	Signal gen + scope
Diff skew	5.2.1.1	time	010101… 1.0 ns or less rise time	H same as B with both ends prepped	signal gen (with balun possibly) + scope
SE attenuation	6.1.1.1	Freq.	low freq. shelf to 5MHz	E leave all other lines open - long enough to produce at least 6dB at the low freq. shelf	HP 8751A network anal
Diff attenuation	6.2.1.1	Freq.	low freq. shelf to 200 MHz	F leave all other lines open on both ends - same requirements as E	HP 8751A

2. Transmission line impedance (time domain)

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

2.1 SE Impedance

2.1.1 Sample preparation

2.1.1.1 Sample Setup A – Time Measurement Domain

The following procedure prepares the cable sample for the testing of single-end mode impedance.

a) Cut sample cable length to 6 m.
b) Remove 5,0 cm of outer jacket at each end of the cable sample.
c) Comb out braid wire strands to form a pigtail.
d) Trim filler and tape materials.
e) Strip insulation from all conductors at both cable ends 0,6 cm.
f) Tie all grounds and shield together.

2.1.1.2 Sample Setup B – Frequency Measurement Domain

a) Reference Sample Setup A (2.1.1.1)
b) 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 cable physical structure exists not to exceed one inch on either end.

2.1.2 Equipment required:

a) Hewlett Packard 4291B RF Impedance / Material Analyzer or equivalent. Test fixture, balun(cap and Z)

b) Hewlett Packard 8751A Network Analyzer or equivalent, test fixture, balun. (atten)

2.1.3 Cable Measurements

Impedance, TDR, single-ended
Using a time domain reflectometer with a 500 ps maximum rise time, on a 6 m cable sample length, measure the cable impedance between the signal wire of a particular pair and the ground wire of all pairs connected to the shield. The impedance will be averaged between 2 ns and 4 ns from the test fixture/cable interface.

Impedance, Impedance Analyzer, single-ended
Using the Equivalent Circuit Model method the Impedance is calculated from the values measured using the open / short measurements at the required frequencies.

2.2 Diff. Impedance

2.2.1 Sample Preparation

2.2.1.1 Sample Setup C

2.2.1.2 Sample Setup D

2.2.2 Cable Measurements

Impedance, TDR, differential
On a 6 m (20 ft) cable sample length, select the pair to be measured. Tie all other wires and the shield together. Using a time domain reflectometer with a 500 ps maximum rise time. The Impedance will be averaged between 2 ns and 4 ns from the test fixture/cable interface.

Impedance, Impedance Analyzer, differential

3. Capacitance

3.1 SE Capacitance

3.1.1 Sample Preparation

3.1.1.1 Refer to Sample setup B (2.1.1.2)

3.2 Diff. Capacitance

3.2.1 Sample Preparation

3.2.1.1 Refer to Sample setup D (2.2.1.2)

4. Velocity of Propagation

4.1 SE Velocity of Propagation

4.1.1 Sample Preparation

4.1.1.1 Refer to Sample setup A (2.1.1.1)

4.2 Diff. Vp

4.2.1 Sample Preparation

4.2.1.1 Refer to Sample setup C (2.2.1.1)

5. Deley Skew

5.1 SE Skew

5.1.1 Sample Preparation

5.1.1.1 Sample Setup G

Same as setup A (2.1.1.1) but both ends prepped.

5.2 Diff. Skew

5.2.1 Sample Preparation

5.2.1.1 Sample Setup H

Same as setup B (2.1.1.2) but both ends prepped.

6. Attenuation

6.1 Attenuation Testing of Balanced Systems Using a Network Analyzer.

The purpose of this paper is to explain the proper methodology for performing attenuation measurements on balanced systems and the restricting issues involved.

6.1.1 Equipment Required.

a) Network Analyzer (HP 87xx Series)
b) Impedance Matching Devices such as Baluns
c) Connectors for interface between cable and baluns
d) Test fixture to mount baluns

6.2 Theory

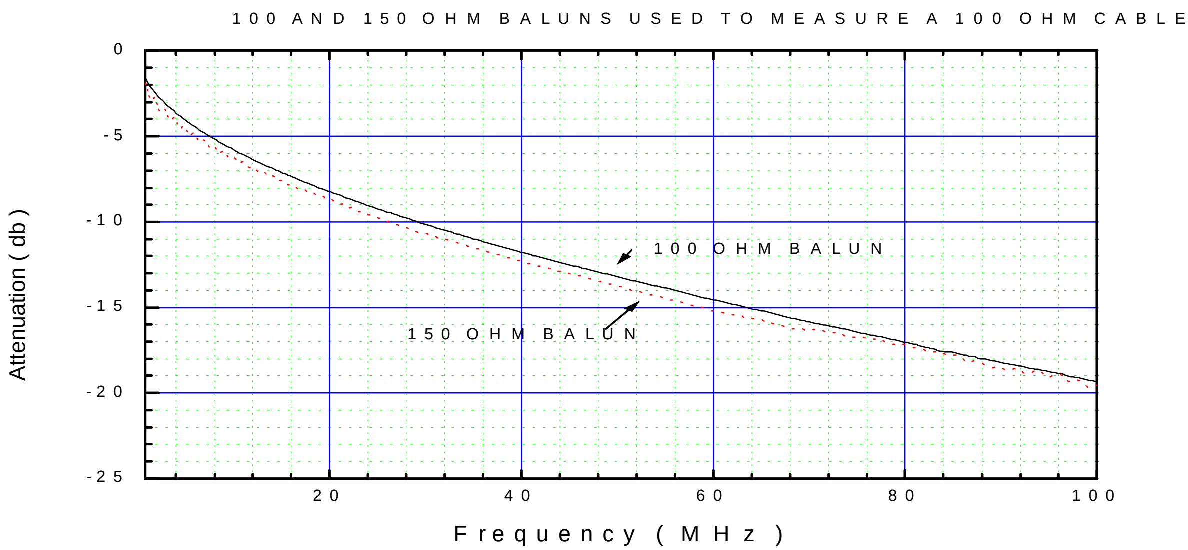
Attenuation is a measurement of the dissipative losses on a balanced transmission line. The series resistive loss of the conductors (copper) and the shunt loss due to the dissipation factor of the dielectric covering the conductors dominate these losses. At higher frequencies, the conductor loss increases due to skin effect. Skin effect is where the current crowds towards the outer “skin” of the conductor and effectively reduces the conductor area that current flows through. The attenuation for a given balanced transmission line will be due to a delicate balance of conductor metal composition and wire 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 impedances are not perfectly matched at either side of the interface. The amount of mismatch loss that will be experienced at each interface is :

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

Balanced transmission lines are also susceptable 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.

6.3 Balun Selection. The impedance on the primary side of the balun must match the impedance of the network analyzer. The impedance on the secondary side of the balun must be matched as closely as possible to the nominal impedance of the cable in the balanced state to minimize reflections, which will skew the data by introducing a mismatch loss ripple component.



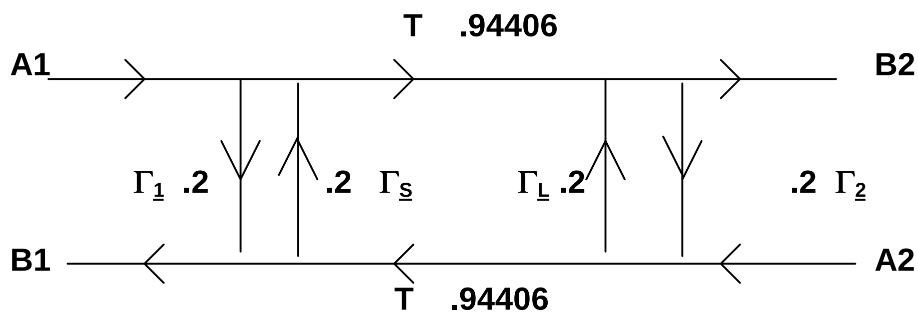
6.4 Sample Length. The optimum sample length is such that you have at least ~ 6db of one way attenuation at the lowest frequency of interest. This will guarantee that there will be at least 12 dB of additional loss experienced by that portion of the test signal that reflects from the far end.

This will minimize the uncertainty caused by multiple reflections due to the far end and will result in acceptable resolution / ripple. The resultant measurements will be accurate and repeatable measurements. If you use a sample that yields an attenuation of less than 6db 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:

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 = .5 dB = .94406

$|\Gamma|$ Near End = .2 VSWR Near End = 1. 5 : 1
$|\Gamma|$ Far End = .2 VSWR Far End = 1. 5 : 1
Near End Worse case Mismatch Loss = $-10 \, LOG_{10} (1 - |\Gamma|^2) = .177$ dB
Far End Worse case Mismatch Loss = $-10 \, LOG_{10} (1 - |\Gamma|^2) = .177$ dB

The resultant flow graph :



Worse Case Mismatch Loss Error dB =

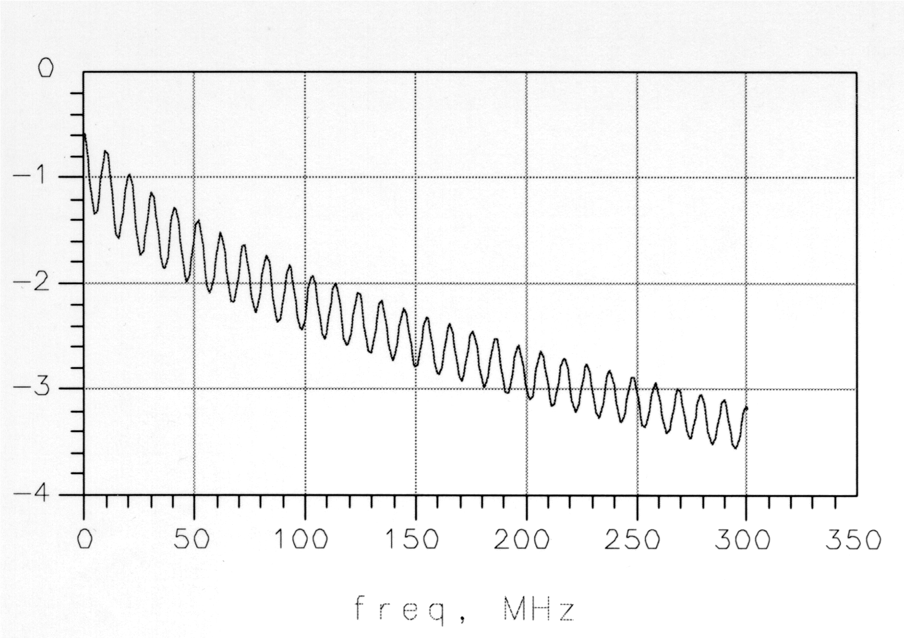
$$20 \, LOG_{10} \left| \frac{1 - |\Gamma_s| * |\Gamma_L|)}{(1 - (|\Gamma_s| * |\Gamma_1|) - (|\Gamma_2| * |\Gamma_L|) - ((T)^2 (|\Gamma_s| * |\Gamma_L|) + (|\Gamma_s| * |\Gamma_L|| \Gamma_1| * |\Gamma_2|)} \right|$$

Worse Case Mismatch Loss Error dB =

$$20 \, LOG_{10} \left| \frac{1 - (.2 * .2)}{(1 - (.2 * .2) - (.2 * .2) - ((.94406)^2 (.2 * .2) + (.2 * .2 * .2 * .2)} \right|$$

= .6972 dB

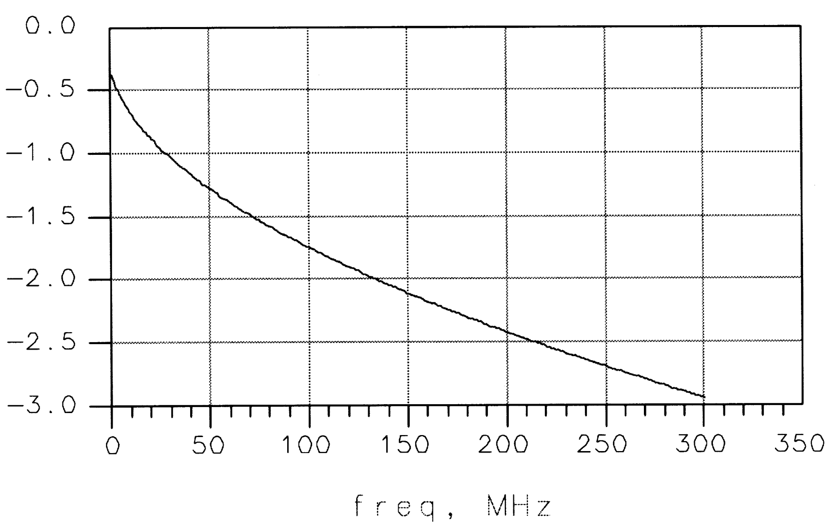
Therefore, we will be trying to measure .5dB attenuation in the presence of a ripple that will add anywhere from .354 dB to .6972dB of measurement error.



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

Under a matched condition, the insertion loss equals the attenuation and there is no ripple to cause measurement uncertainty.

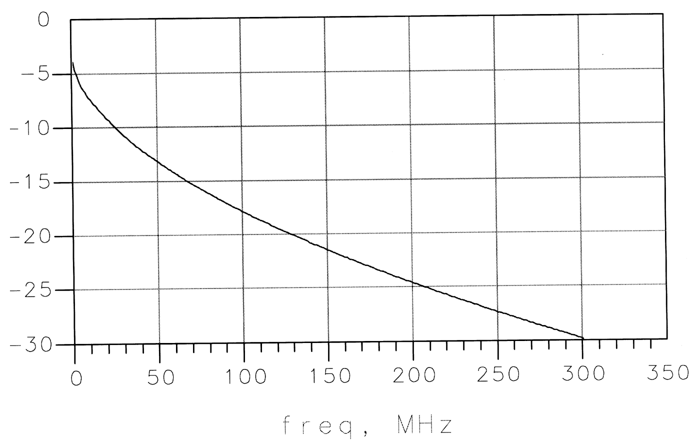


Case 3 :

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

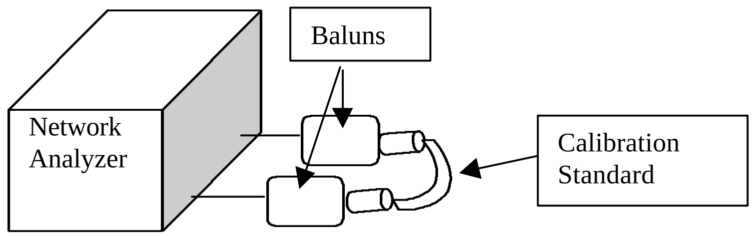
Under a mismatched condition, the insertion loss equals the attenuation plus the mismatch loss at the near end and at the far end. However, in this case, there is sufficient attenuation in the cable at the lowest frequency to make multiple reflections inconsequential, so there is no ripple component of measurement uncertainty. The mismatch loss error is still present, but it is ~ .3 dB out of a measured insertion loss of ~ 6 dB.



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 you introduce an additional uncertainty because you are trying to separate a small value (cable attenuation) from a large value, (attenuator attenuation) and you will face dynamic range issues.

6.5 Calibration Standard.For calibration purposes you shall use a length of the cable you are actually measuring. This length of cable must be kept as short as possible and still be terminated to the secondary side of the Impedance Matching Devices connected to the Network Analyzer.

Note: *If connectors are to be used to perform the measurement, they must also be used on the calibration sample.*



7.0 Measuring The Cable.

amount of the conductors are exposed from the jacket, install connectors if required,
connect the cable to the baluns and perform the tests as required. It is important to either separate or shield the

the frequency is above approximately 150 MHz, potential direct coupling from the near end to the far end balun

measurement uncertainty.