FPD-Link Transmission Channel Test Procedure

- For Channel Requirement, PCB and cable assembly budget, please refer to the Channel Requirements of the SER-DES chipset

Version 1.2
Aug 14, 2017

Revision History

Version	Date	Descriptions
1.0	March 23, 2017	Initial release.
1.1	April 6, 2017	Add prelim channel info for DS90UH94xA, add f_{MIN} to tables
1.2	Aug 14, 2017	Updated. Split document into Channel Compliant Test Procedure (this document), with reference to separate Channel Requirement for individual FPD-Link III SER-DES chipset.

Introduction

The transmission channel refers to the transmission medium that connects a FPD-Link III Serializer (SER) to a de-serializer (DES). It consists of the printed circuit board (PCB) structures and components on the SER and DES boards, along with the cable assembly between the two boards. The transmission channel is designed to be compatible to the SER and DES chipset's operating frequency range and signal integrity capability.

Figure 1 and 2 illustrate the transmission channels for a single-end transmission topology and a differential signaling topology. For single-end topology, the transmission channel is made up of single-end PCB traces, connectors and coaxial cable with 50 Ω characteristic impedances. For differential signaling topology, the transmission channel is made up of coupled differential PCB traces, connectors, and shielded twisted pair (STP) or shielded quad-twisted (STQ) cable with 100 Ω differential impedances.

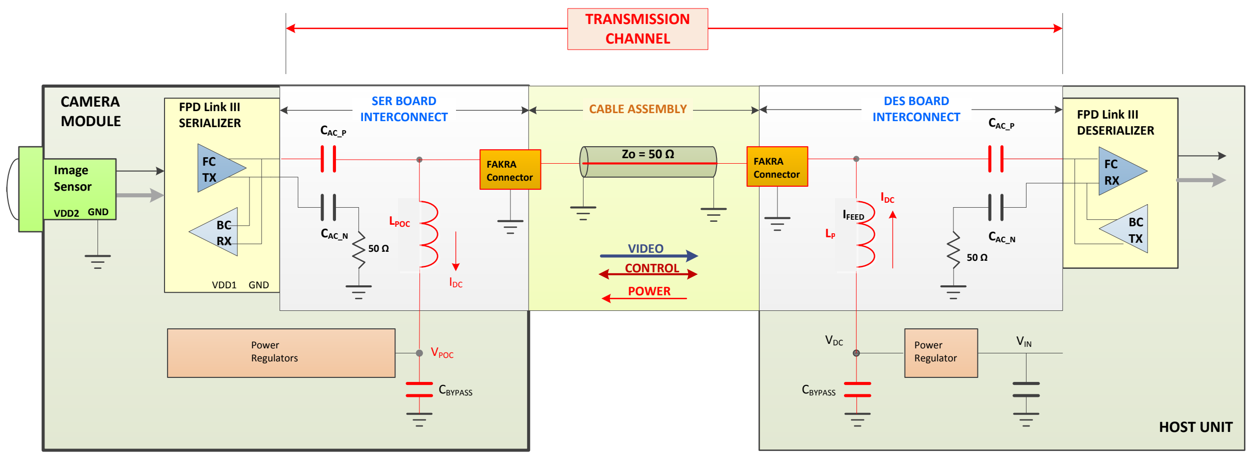

Figure 1. Transmission channel for a single-end transmission topology

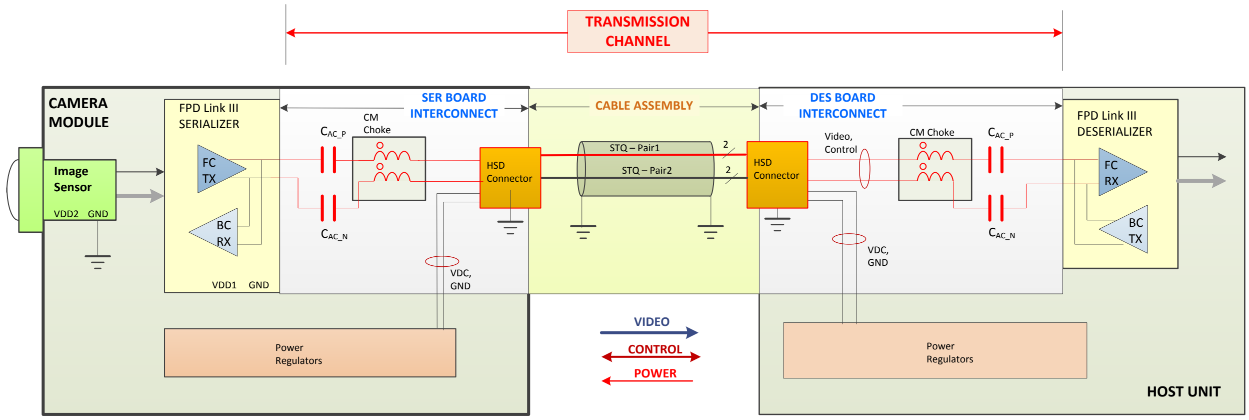

Figure 2. Transmission channel for a differential signaling topology

Figures 3 and 4 illustrate the differential insertion loss and return loss of the transmission channel compare with its board and cable contributions. Depends on the trace length, the SER and DES board has small contribution to the channel's insertion loss. Depends on the trace impedance and components used on the board, the SER and DES board also affect the channel's return loss.

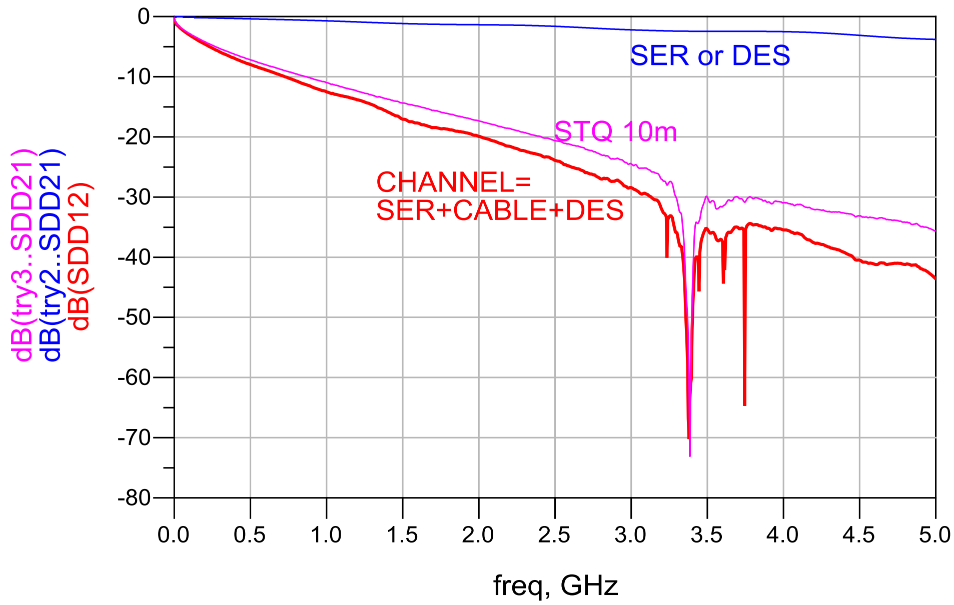

Figure 3. Differential insertion loss of the transmission channel comparing with that of cable and PCB

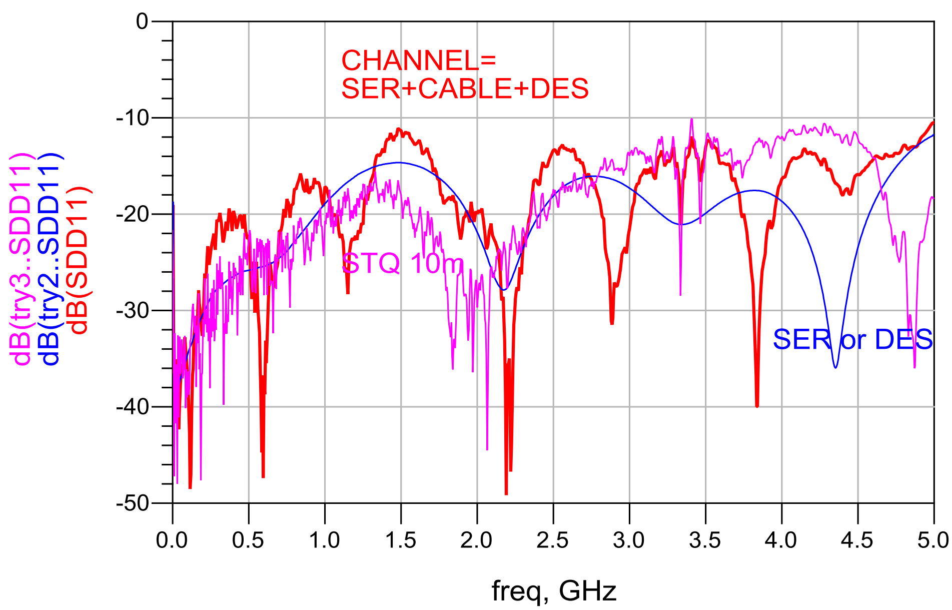

Figure 4. Differential return loss of the transmission channel comparing with that of cable and PCB

How to use this document

The frequency range of the transmission channel depends on the operating mode of the chosen SER-DES chipset, determined by the forward channel Nyquist frequency (data rate divided by 2), and the minimum pulse frequency of the back channel signal. The transmission channel's insertion loss is primarily dependable on the DES receive equalization, echo cancelation as well as the clock and data recovery circuit's jitter tolerance capability. It is secondary dependent on the SER's output jitter and the transferred jitter from the pixel clock.

This document describes the ***Transmission Channel Test Procedure*** that applies to the SER-board, cable assembly, the DES-board, or the total transmission channel (SER-board + cable assembly + DES-board). A separate document ***Channel Requirement*** covers the detail requirements on the transmission channel, PCB and cable budget specific to the chosen SER and DES chipset.

	SER	DES
Channel Requirement for DS90UB953-954/960	DS90UB953	DS90UB954 DS90UB960

Compliant Test Lab

The University of New Hampshire InterOperability Laboratory is a third party test lab capable to run these channel compliant testing for a fee.

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Key Channel Parameters

The transmission channel is described by a set of parameters that defines the channel's transmission characteristics, which affect the channel's ability to satisfactorily inter-operate with the chosen SER and DES chipset.

The channel characteristics are described by the following parameters:

Characteristic impedance – defines the channel's impedance matching to the terminations of the SER and DES.

Impedance mis-match – defines the allowable impedance variations caused by connectors or PCB structures.

Return loss - defines the channel's impedance matching and indicative of its ability to support a bi-directional full-duplex link. The return loss includes the effect of on-board components such as PoC network or common mode choke, as well as any in-line connectors used in the cable assembly.

Insertion loss - includes that of SER-board, cable assembly and DES-board. The channel's insertion loss should be within the range supported by the SER-DES chipset. A longer PCB trace introduces higher insertion loss for the board, and thus reduce the insertion loss (and the length) of the cable assembly. Below the Nyquist frequency, the transmission channel should be free of resonance that creates sharp drops in insertion loss and abrupt changes in the channel's group delay that will impact the SER-DES chipset's timing margin. The maximum insertion loss of the channel is dependent on the drive capability of the SER, and the receiver capability of the DES.

Intra-pair skew - for differential signaling only; skew between the positive and negative signals within the pair; excessive intra-pair skew affects signal integrity of the DES. A common mode choke placed at the input of the DES reduces the amount of intra-pair skew caused by an un-balanced cable assembly, but also add small amount of insertion loss.

Inter-pair skew - for multi FPD-Link applications only; defines the maximum allowable lane-to-lane skew for adjacent FPD-Link channels used in a DES.

Cross-talk – for multi FPD-Link applications; excessive crosstalk affects the signal integrity for the SER and DES by reducing the signal-to-noise ratio. Cross-talk appears in a cable with more than one signal lane that share one connector, for example, a HSD STQ cable if both pairs are used for FPD-Link, or four coaxial cables that connect to a quad-mini-FAKRA connector.

Aging and Mechanical Stress – define the amount of changes in the cable assembly after temperature cycle test and mechanical stress test that provide the basis to predict the cable's characteristics over the cable's life time in a vehicle. Aging usually introduce increase in insertion loss, while mechanical stress usually introduce degradation in the cable's characteristic impedance and return loss. Aging and mechanical stress tests should be performed in according to automotive OEM requirements to ensure the cable assembly continues to meet the channel requirement specifications of the SER-DES chipset.

The effect of aging and stress depend on the cable's construction. Figure 5 shows an example of a coaxial cable after aging test. In this example, the cable's insertion loss increases by about 10% at 2 GHz.

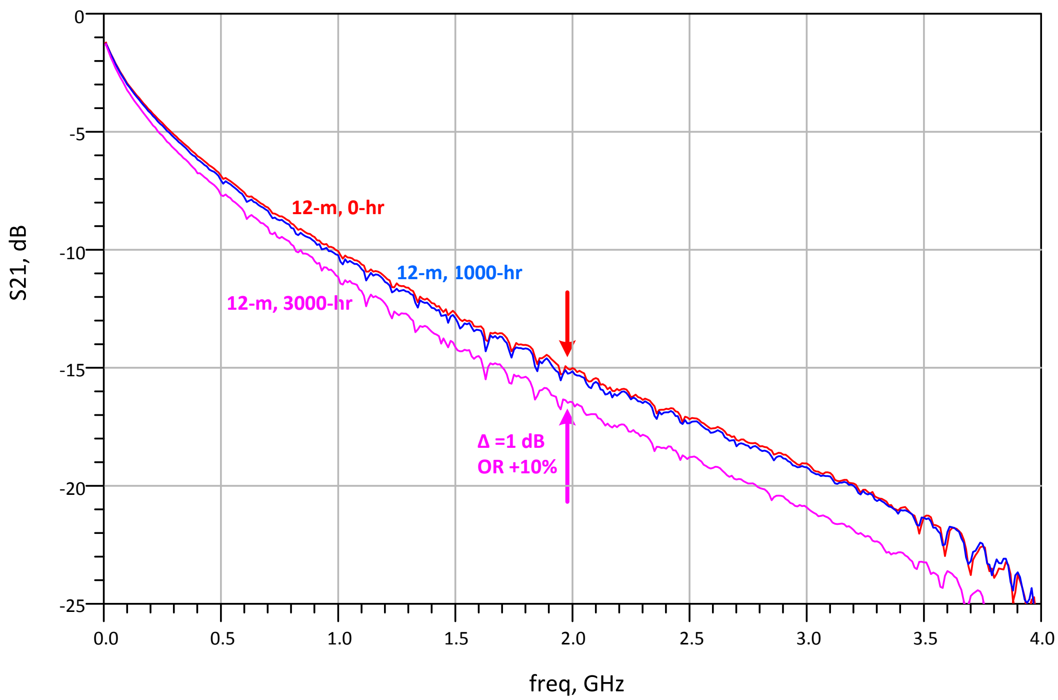

Figure 5. Insertion loss of a coaxial cable before and after 3000-hour temperature stress test

Shielding Effectiveness – defines the effectiveness of the shield braid in attenuating EMI radiation or EMC pick-up. Shielding effectiveness is dependent on the braid's density and the connector's contact ground impedance. Contact cable suppliers on shielding effectiveness.

Board Elements

Figure 6 and 7 illustrate the PCB circuit elements for single-end transmission topology and differential transmission topology. To minimize the board's insertion loss contribution, it is recommended to place the connector close to the SER or DES integrated circuit.

In setting up insertion loss budget for SER-board, cable assembly, and DES-board, a 2-inch budget is assumed for the SER-board or the DES-board. With this assumption, insertion loss budget is allocated to the SER-board, DES-board, and cable assembly. The transmission channel's insertion loss is the sum of the SER-board, cable assembly and DES-board. If a longer trace is used, the insertion loss of the cable assembly is correspondingly reduced, such that the total transmission loss of the channel remains the same.

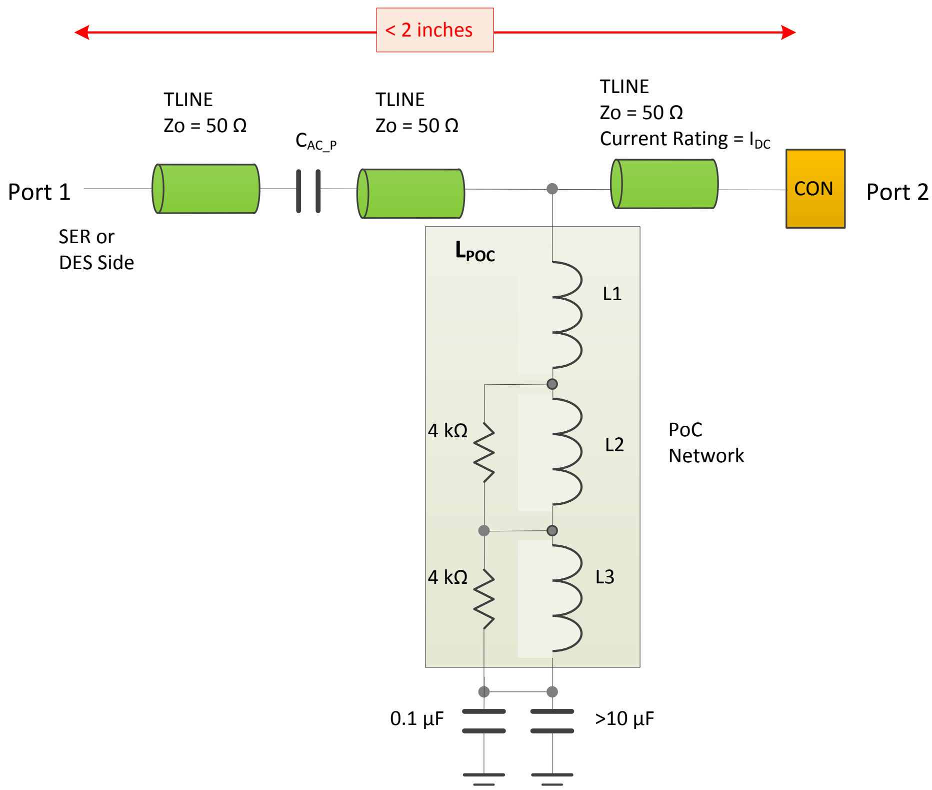

Figure 6. PCB circuit elements for single-end transmission topology with PoC

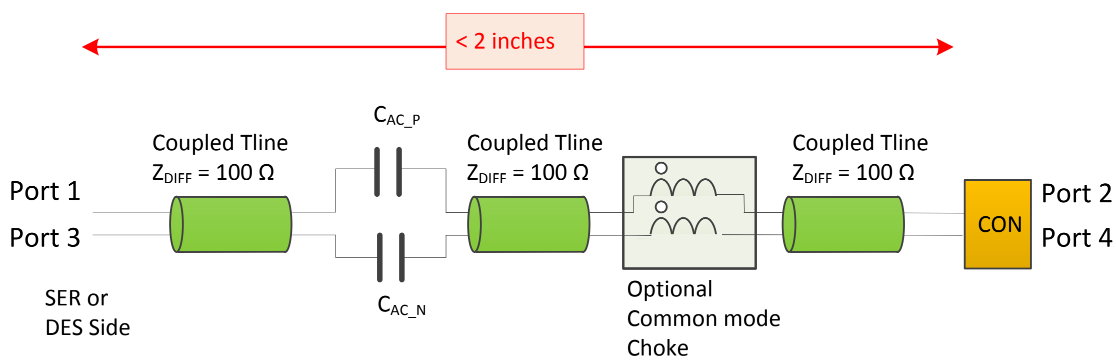

Figure 7. PCB circuit elements for differential transmission topology

Use of Common Mode Choke

Common mode choke is commonly used in the SER board as a means to mitigate EMI. In some cases, it is used in the DES board to reduce the intra-pair skew caused by an unbalanced differential cable. Select a suitable common mode choke that offers the lowest differential insertion loss at Nyquist frequency, good differential return loss and high common mode attenuation. Figures 8-10 show the differential insertion loss, return loss and common mode attenuation characteristics of a common mode choke suitable for 4 Gbps use (*Murata DLW21SN121HQ2 or its equivalent automotive grade common mode choke*).

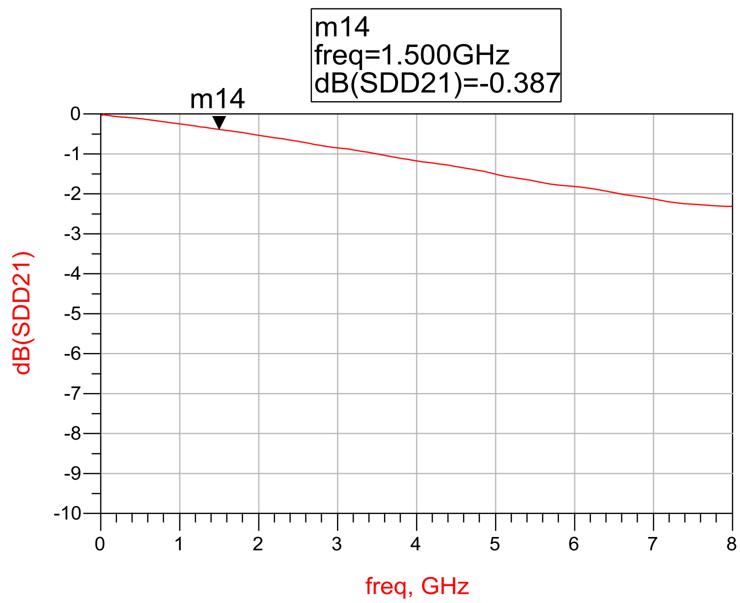

Figure 8. Select a CM choke with the lowest insertion loss at Nyquist frequency

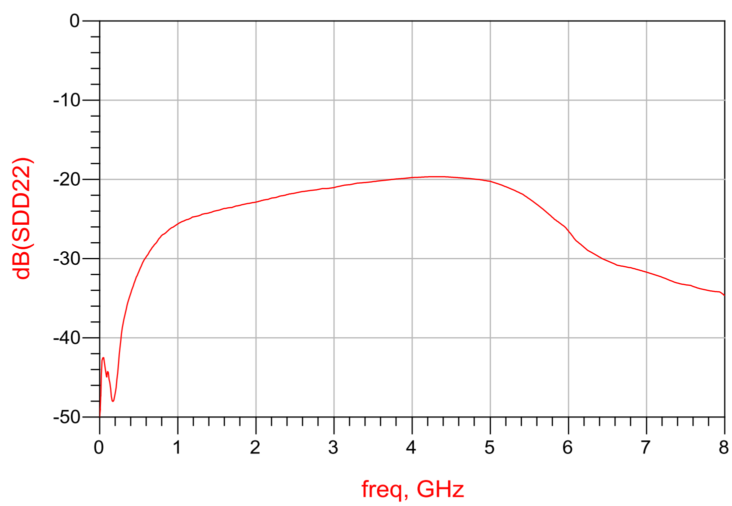

Figure 9. Select a CM choke with good differential return loss

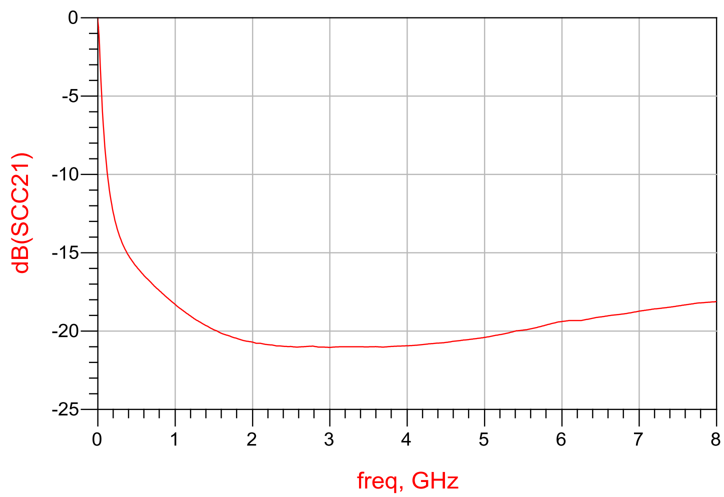

Figure 10. Select a CM choke with good common mode attenuation

Validating the Total Transmission Channel from SER-board to DES-board

Validating the total transmission channel follows similar test methodology as validating the cable assembly. The evaluation signal path starts from the landing pads of the SER IC (with IC removed), through the SER-board, cable assembly, the DES-board, and ends at the landing pads of the DES IC (with IC removed). A probe station is needed for securing the SER- and DES-boards on a flat and stable platform, such that RF probes can be reliably landed on the IC landing pads for measurements(1).

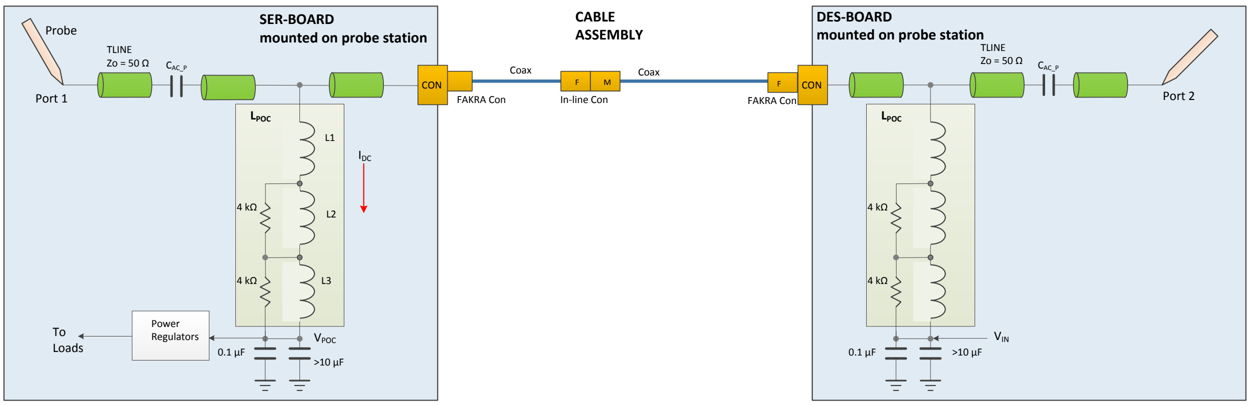

Figure 11. Validating the total transmission channel from SER to DES, with PoC at full load

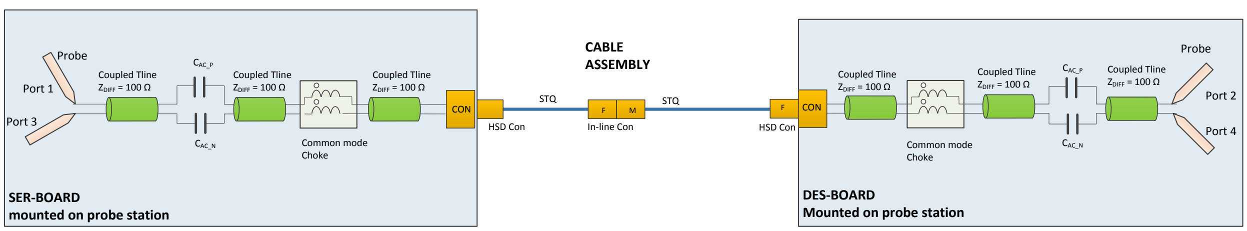

Figure 12. Validating the total transmission channel from SER to DES

Note 1: In the absence of a probe station, suitable RF probes or calibration kit, 3rd party test lab, such as GigaTest Lab, can help to run VNA or TDR testings with a fee.

Validating the SER- or DES-board

Similar methods can be used to evaluate the SER- or DES-board with the use of a probe station. This is illustrated in Figure 13. If a probe station is not available, the return loss S22 or SDD22 at the connector can be measured with the IC removed and replaced by 50-Ω terminations. The board's impedance profile can also be measured with the use of a TDR. These measurement capabilities are illustrated in Figure 14.

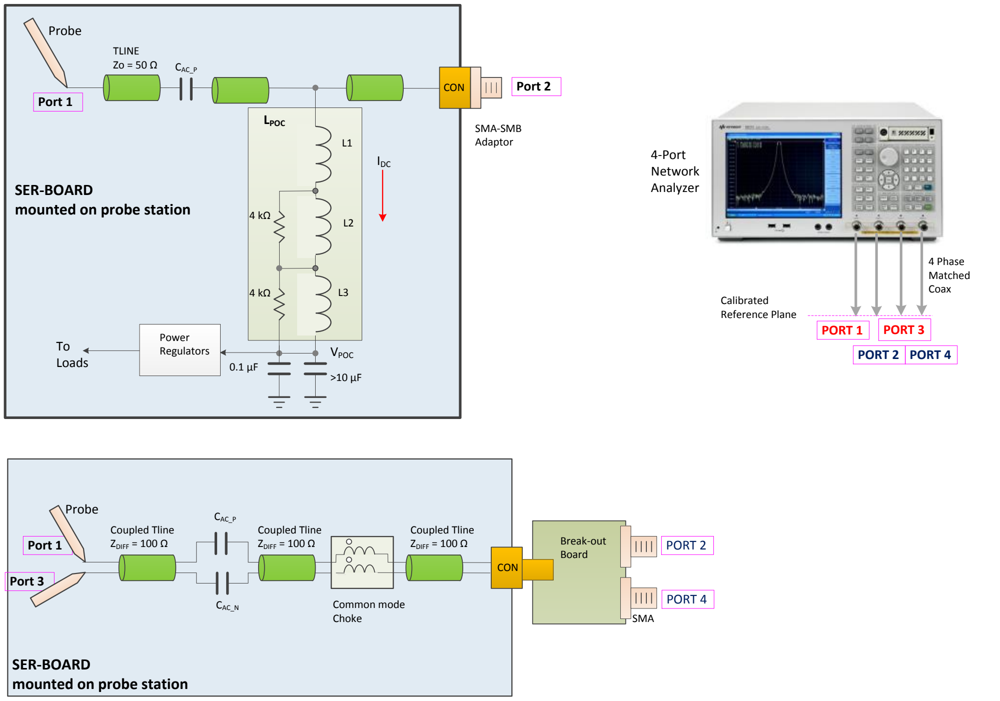

Figure 13. Validating the SER- or DES-boards with the use of a probe station

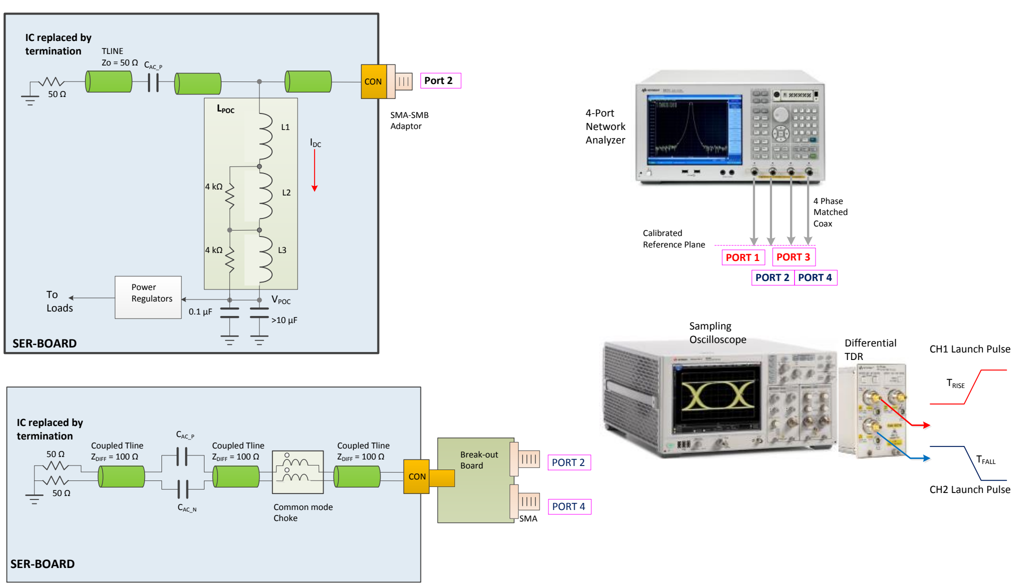

Figure 14. Validating the impedance and return loss of the SER- or DES-boards

Test Cable Assembly

Test cable assembly replicates the final cable harness used in a vehicle, built with the same cable type, number of in-line connectors and lengths. The use of cable assembly provides a means to validate the SER- and DES-equipment during board bring-up. It helps to ensure high confidence of interoperability and acceptable link performance when the SER-board, cable harness and the DES-board are installed in a vehicle.

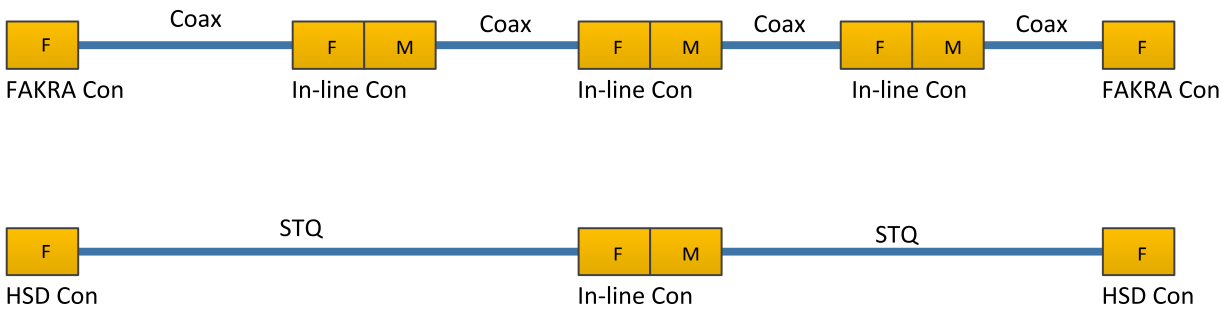

Figure 15. Test cable assemblies – coax and Quad-twisted STQ with in-line connectors

Validating Link Performance of cable assembly

Before the final cable harness is available, system link tests with SER board and DES board can be done with the use of a test cable that replicates similar length and construction as the final cable harness.

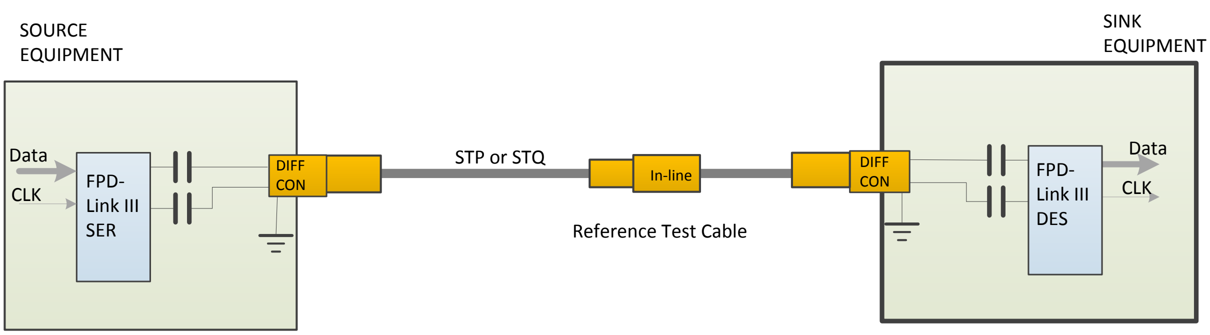

Figure 16. System Link test with SER-cable-DES

Compliant testing for Transmission Channel (cable assembly, PCB or total transmission channel)

Table 1 shows a list of compliant tests for cable assembly. Similar test methods are used to validate the SER-board, DES-board or the total transmission channel (SER board + cable + DES board), with the use of a probe station (see Figures 11-13).

Test ID	Cable Compliance Test Methods
Cable – Electrical Parametric Tests (Coax)	
1.1	Coax cable - impedance
1.3	Coax cable - return loss
1.5	Coax cable – insertion loss
Cable – Electrical Parametric Tests (STP or STQ cable)	
1.2	Differential cable – impedance
1.4	Differential cable – return loss
1.6	Differential cable – insertion loss
1.8	Differential cable – Intra-pair skew
1.10	Differential cable – Inter-pair skew
1.12	Differential cable - crosstalk

Table 1. Cable Compliant Test List

Test ID 1.1: Coax Cable – impedance

Reference	Requirement
Coax cable - impedance	Meets the impedance requirement for coax cable. Meets the impedance tolerance requirement for the connector area.

Test Objective:
Confirm meeting the impedance requirement for the cable and connector area of the cable assembly.

Test Diagram:

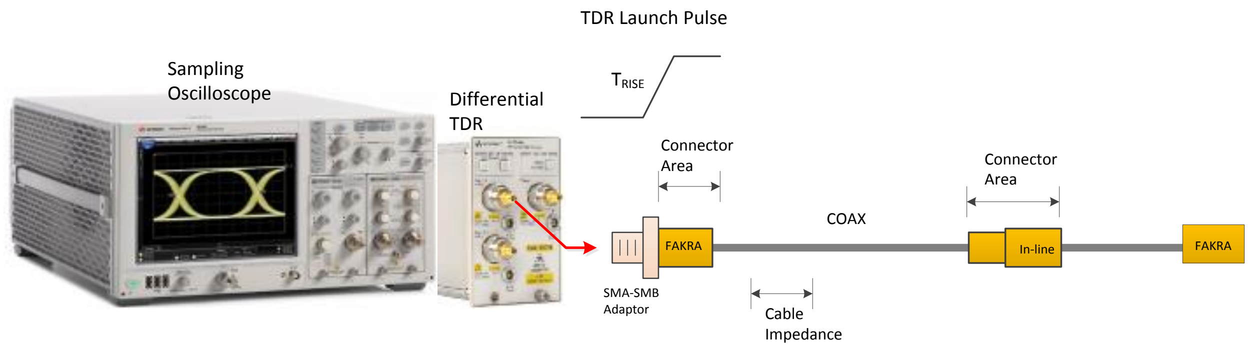

Figure 1.1-1. Measure the cable impedance with a Time Domain Reflectometer (TDR)

Test Method:

1. Configure a high speed sampling oscilloscope in the TDR mode.
2. Follow the calibration procedure of the TDR and normalize the oscilloscope's TDR response to the target transition time T_{RISE}. T_{RISE} is chosen to be the nominal edge rate of the Serializer output.
3. Connect one end of the Cable DUT to the TDR channel through a SMA-SMB adaptor.
4. Position two markers at electrical lengths of about 150 and 900 ps (approximately 1-inch and 6-inch) from the connector to form a measurement window. Measure the minimum and maximum impedance within this window. Note the TDR round-trip delay for the window is 300 and 1800 ps.
5. Verify that the minimum and maximum impedances are within the cable impedance requirement.
6. Position the markers to the connector area. Measure the minimum and maximum impedance within the connector area.
7. Verify that the minimum and maximum impedances of the connector area are within the tolerance of the connector requirement.
8. Figure 1.1-2 illustrates an example of a coaxial cable's impedance measured with a hardware or software TDR.

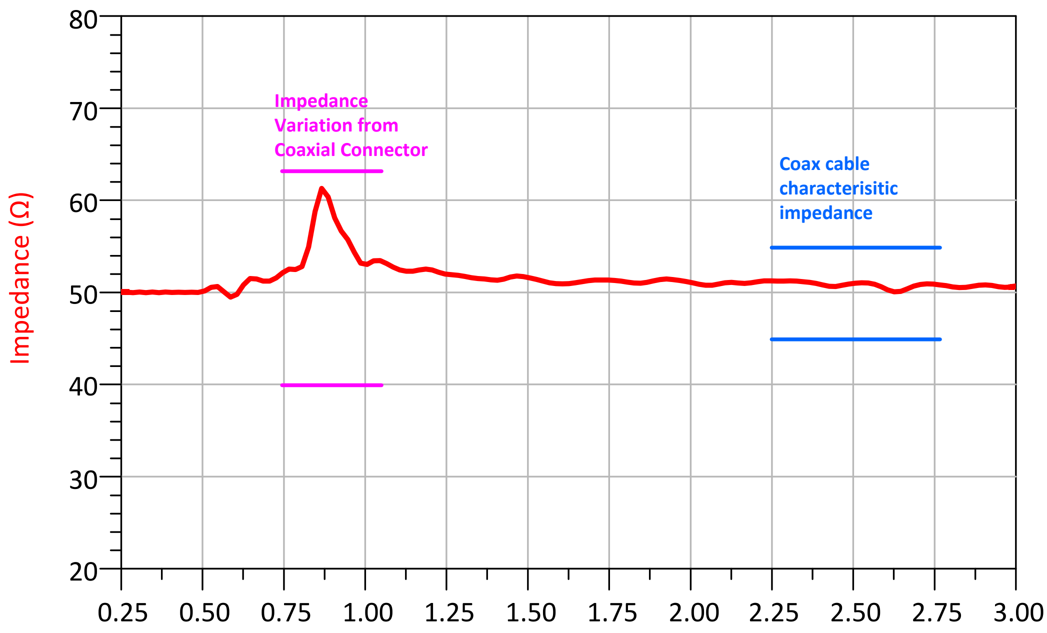

Figure 1.1-2. Impedance plot of a coaxial cable

Test ID 1.2: Differential Cable – impedance

Reference	Requirement
Differential Cable - impedance	Meets the differential impedance requirement for a STP or STQ cable. Meets the differential impedance tolerance requirement for the connector area.

Test Objective:

Confirm meeting the differential impedance requirement for the cable and connector area of the STP or STQ cable assembly.

Test Diagram:

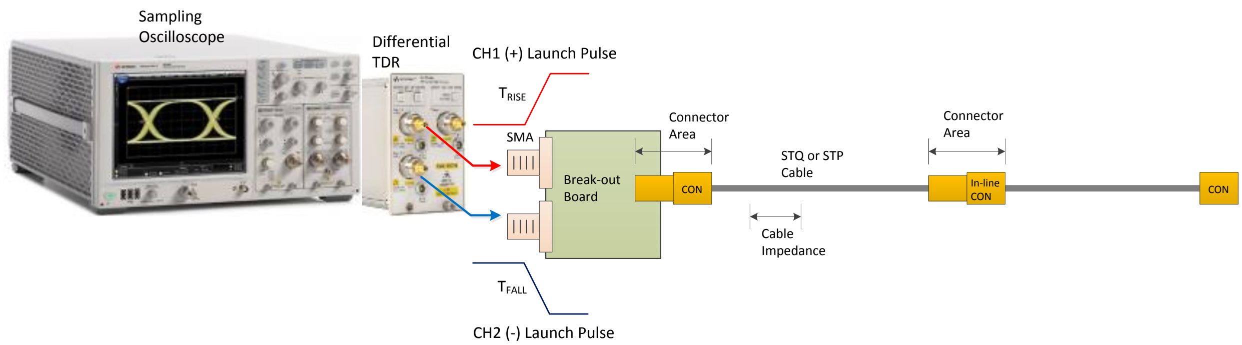

Figure 1.2.1. Measure the cable impedance with a differential Time Domain Reflectometer (TDR)

Test Method:

1. Configure a high speed sampling oscilloscope in the differential TDR mode.
2. Follow the calibration procedure of the TDR and normalize the oscilloscope's TDR response to the target transition time T_{RISE}. T_{RISE} is chosen to be the nominal edge rate of the Serializer output.
3. Follow the skew adjustment procedure of the TDR to ensure the TDR launch pulses at Channel 1 (CH1) and Channel 2 (CH2) are aligned.
4. Connect one end of the Cable DUT to the differential TDR CH1 and CH2 through a SMA-connector break-out board.
5. Configure the oscilloscope to display the differential impedance by using the oscilloscope's math-function CH1-CH2. Normalized display should be used with the target transition time $T_{RISE.}$
6. Position two markers at electrical length of about 150 and 900 ps (approximately 1-inch to 6-inch) from the connector to form a measurement window. Measure the minimum and maximum differential impedance within this window. Note the TDR round-trip delay for the window is 300 and 1800 ps.
7. Verify that the minimum and maximum differential impedances are within the cable impedance requirement.

8. Position the markers to the connector area. Measure the minimum and maximum differential impedance within the connector area.
9. Verify that the minimum and maximum differential impedances of the connector area are within the tolerance of the cable connector requirement.
10. Figure 1.2-2 illustrates an example of a cable's differential impedance measured with a hardware or software TDR.

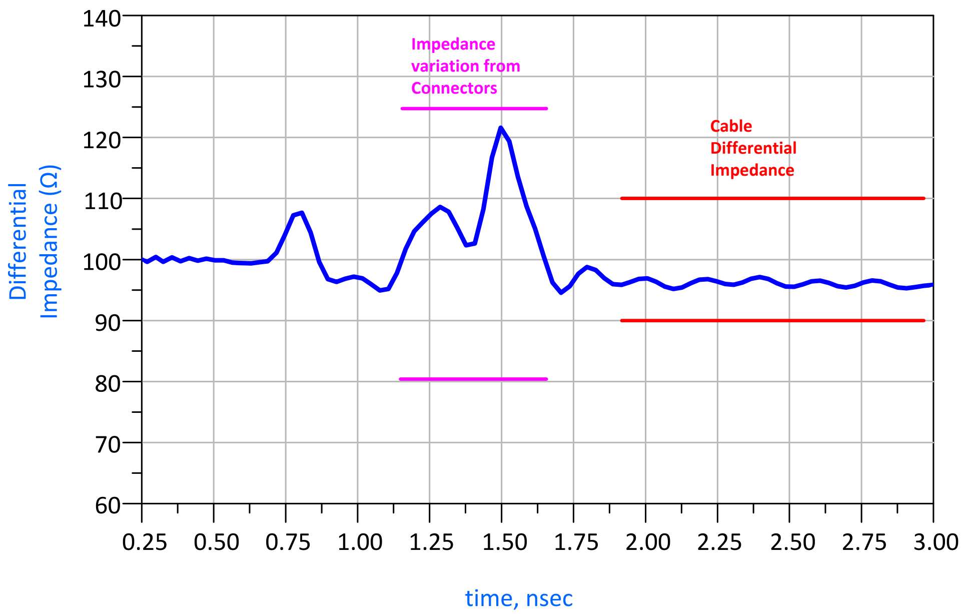

Figure 1.2-2. Impedance plot of a differential cable

Test ID 1.3: Coax cable – return loss

Reference	Requirement
Coax cable - return loss	Meets the return loss requirement for coax cable.

Test Objective:
Confirm meeting or exceeding the requirement for the cable return loss reference to 50 Ω.

Test Diagram:

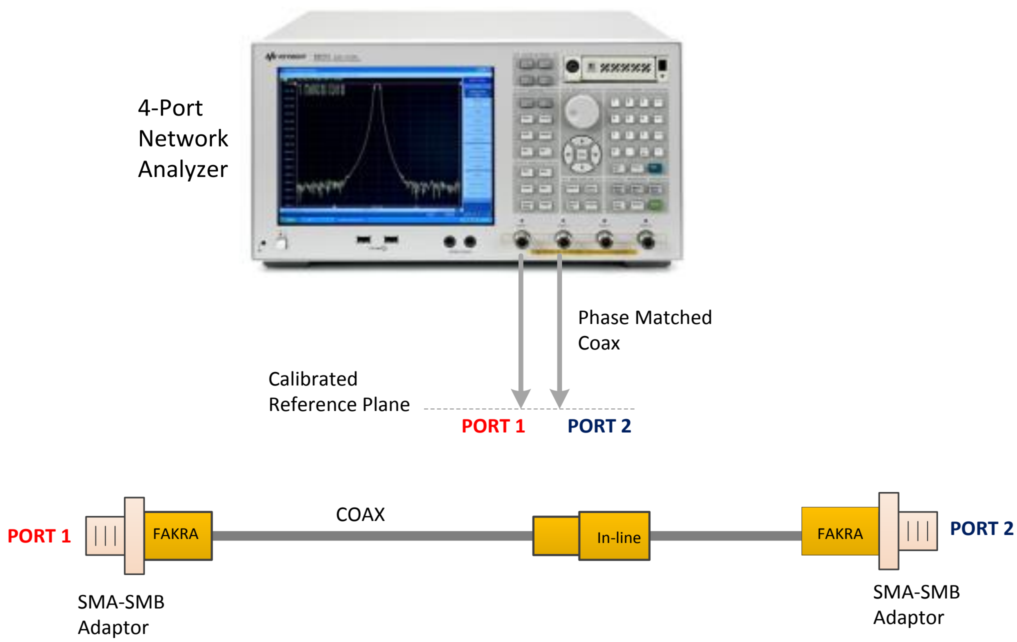

Figure 1.3-1. Measure the return loss of the coax cable with a network analyzer

Test Method:
1. Configure a 2-port (or 4-port) network analyzer (NA) with measurement frequency range of 100 KHz to 5 GHz, power level of 0 dBm, log sweep.
2. Follow the calibration procedure of the NA using an automatic or manual calibration kit.
3. Connect the Cable DUT to Port 1 and Port 2 of the NA through SMA-SMB adaptors
4. Configure the NA to measure S11 and S22 with display format set to magnitude dB.
5. Compare the measured S11 and S22 to the cable return loss requirement.

Test ID 1.4: Differential Cable – return loss

Reference	Requirement
Differential cable – differential return loss	Meets the differential return loss requirement for the STP or STQ cable.

Test Objective:

Confirm meeting or exceeding the requirement for the STP or STQ cable's differential return loss reference to 100 Ω.

Test Diagram:

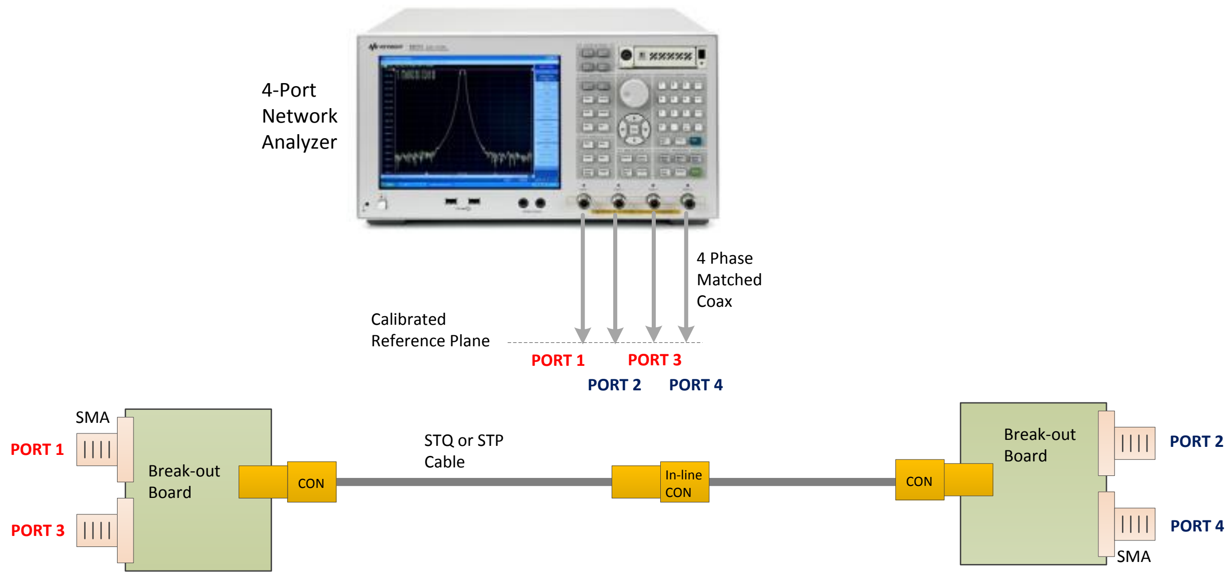

Figure 1.4-1. Measure the differential return loss of the STP or STQ cable with a 4-port network analyzer

Test Method:

1. Configure a 4-port network analyzer (NA) with measurement frequency range of 100 KHz to 5 GHz, power level of 0 dBm, log sweep.
2. Follow the 4-port calibration procedure of the NA using an automatic or manual calibration kit.
3. Connect the one end of the Cable DUT to Ports 1-3 and the other end to Ports 2-4 of the NA through two SMA-connector break-out boards. The un-used SMA of the break-out boards should be terminated by 50 Ω.
4. Configure the NA to measure SDD11 and SDD22 with display format set to magnitude dB.
5. Compare the measured SDD11 and SDD22 to the cable return loss requirement.

Test ID 1.5: Coax cable – insertion loss

Reference	Requirement
Coax cable – insertion loss	Meets the insertion loss requirement for coax cable.

Test Objective:
Confirm meeting or exceeding the coax cable insertion loss requirement.

Test Diagram:

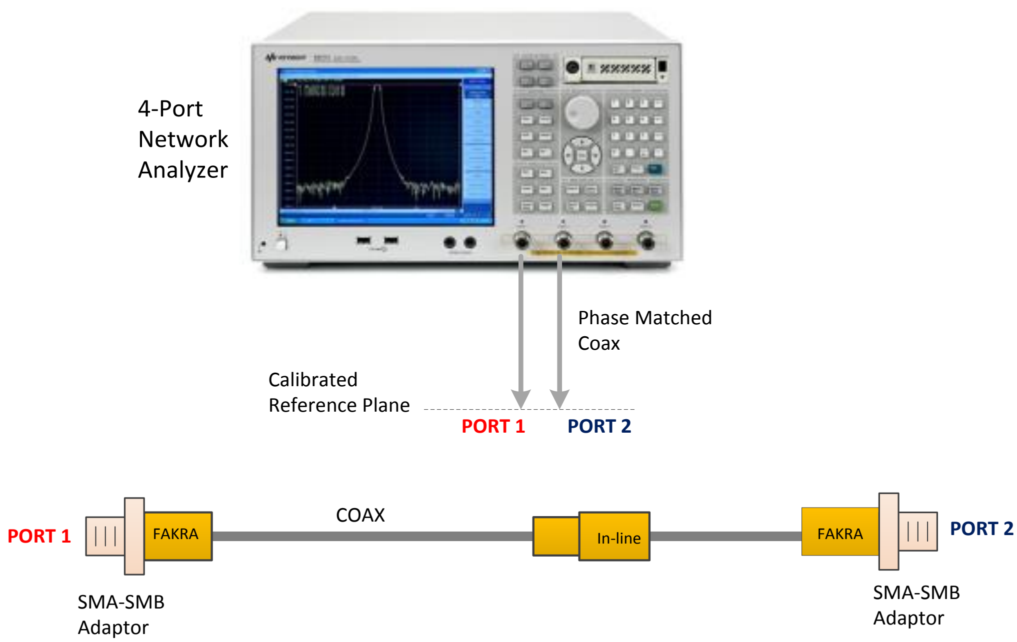

Figure 1.5-1. Measure the insertion loss of the coax cable with a network analyzer

Test Method:

1. Configure a 2-port (or 4-port) network analyzer (NA) with measurement frequency range 100 KHz to 5 GHz, power level of 0 dBm, log sweep.
2. Follow the calibration procedure of the NA using an automatic or manual calibration kit.
3. Connect the Cable DUT to Port 1 and Port 2 of the NA through SMA-SMB adaptors
4. Configure the NA to measure S21 or S12 with display format set to magnitude dB.
5. Compare the measured S21 and S12 to the cable insertion loss requirement.
6. Verify that there is no "dip" or sign of resonance in the S21 plot at frequency below 1.2x Nyquist frequency.

Test ID 1.6: Differential cable – insertion loss

Reference	Requirement
Differential cable – insertion loss	Meets the differential insertion loss requirement for STP or STQ cable

Test Objective:
Confirm meeting or exceeding the differential insertion loss requirement for the STP or STQ cable.

Test Diagram:

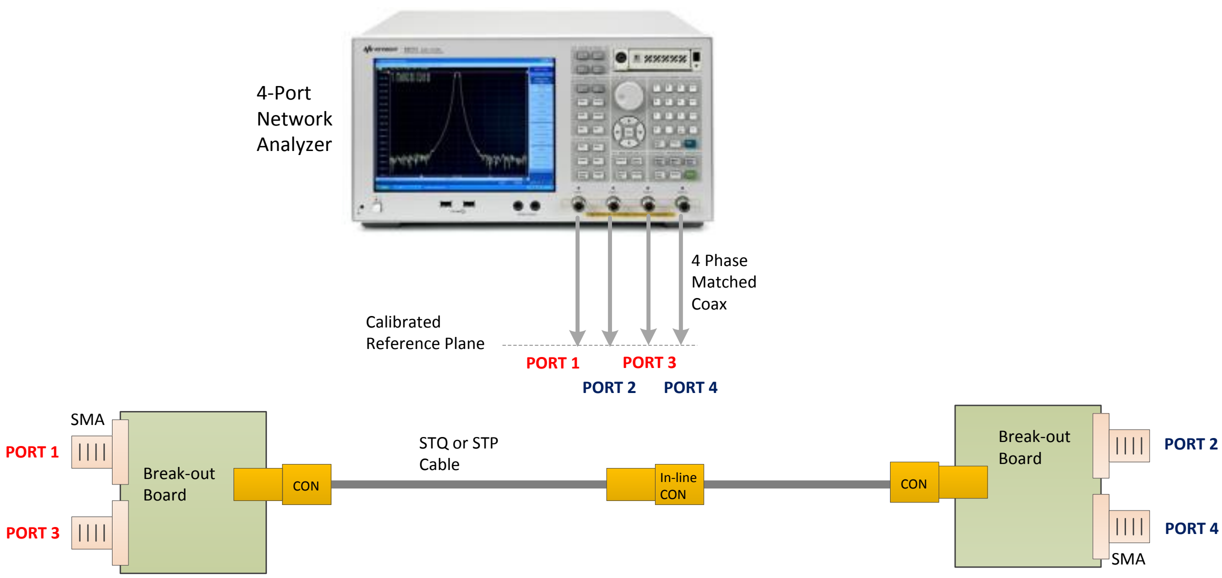

Figure 1.6-1. Measure the insertion loss of the STP or STQ cable with a network analyzer

Test Method:
1. Configure a 4-port network analyzer (NA) with measurement frequency range 100 KHz to 5 GHz, power level of 0 dBm, log sweep.
2. Follow the 4-port calibration procedure of the NA using an automatic or manual calibration kit.
3. Connect one end of the Cable DUT to Ports 1-3 and the other end to Ports 2-4 of the NA through two SMA-connector break-out boards. The un-used SMA of the break-out boards should be terminated by 50Ω.
4. Configure the NA to measure SDD21 and SDD12 with display format set to magnitude dB.
5. Compare the measured SDD21 and SDD12 to the cable's insertion loss requirement.
6. Verify that there is no "dip" or sign of resonance in the SDD21 plot at frequency below 1.2x Nyquist frequency.

Test ID 1.8: Differential Cable – intra-pair skew

Reference	Requirement
Differential cable – intra-pair skew	Meets the intra-pair skew requirement for STP or STQ cable.

Test Objective:

Confirm meeting or exceeding the intra-pair skew requirement for the STP or STQ cable

Test Diagram:

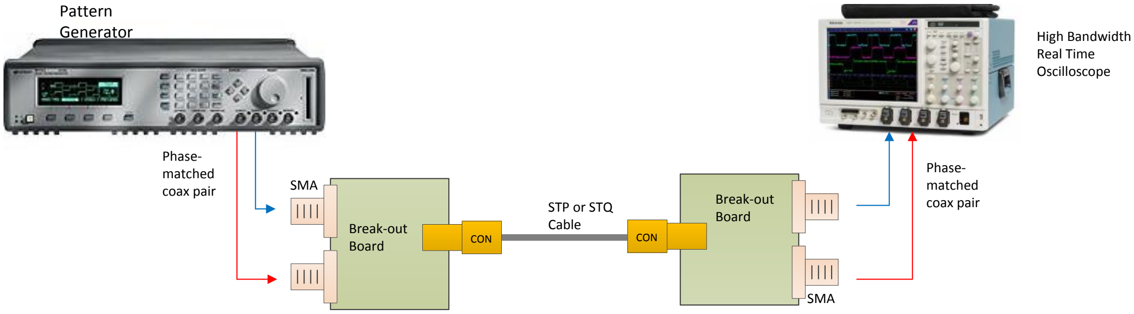

Figure 1.8-1. Measure the intra-pair skew of the STP or STQ cable

Test Method:

1. Configure a pattern generator to output a differential serial bit stream of clock-like 1-0 pattern at the desired data rate DR, differential amplitude of 0.5Vpp. The measurement frequency is data rate DR/2 GHz.
2. Use 4 equal-length SMA coax cables, with two pairs of phase matched for connections to DUT cable.
3. Connect the pulse generator to the oscilloscope with the two pairs of coax cables through a pair of SMA-SMA thru-adaptors.
4. Position one marker at the rising edge of the waveform at CH1 (+), and another marker at the corresponding falling edge of the waveform at CH2 (-).
5. Perform a de-skew procedure at the oscilloscope between CH1 and CH2.
6. Connect one end of the Cable DUT to the Pulse Generator differential output through a SMA-connector break-out board.
7. Connect the other end of the Cable DUT to the Oscilloscope: CH1 (+) and CH2 (-) through a SMA-connector break-out board.
8. Position one marker at the rising edge of the waveform at CH1 (+), and another marker at the corresponding falling edge of the waveform at CH2 (-). Measure the delta time between the two markers. The delta time measurement is the intra-pair skew.
9. Verify that the measured intra-pair skew at the measurement frequency is meeting the cable's intra-pair skew requirement.

Test ID 1.10: Differential cable – inter-pair skew

Reference	Requirement
Differential cable – inter-pair skew	Meets the inter-pair skew requirement for STP or STQ cable. Applies to differential cables for multi-lane use only.

Test Objective:

Confirm meeting or exceeding the inter-pair skew requirement for the STP or STQ cable used in multi-lane applications.

Test Diagram:

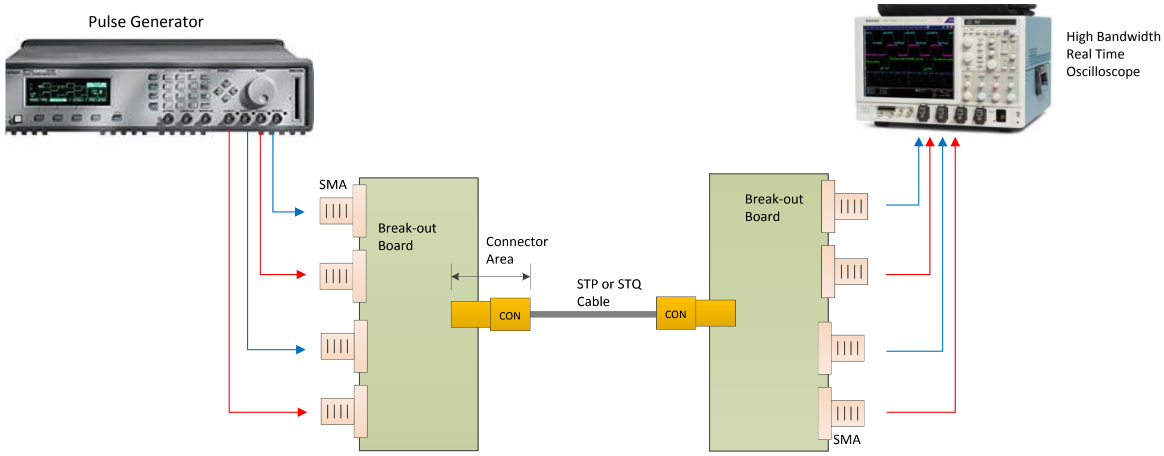

Figure 1.10-1. Measure the inter-pair skew of the STP or STQ cable

Test Method:

1. Configure a pattern generator to output a differential serial bit stream of clock-like 1-0 pattern at the maximum data rate DR, differential amplitude of 0.5Vpp.
2. Use 8 equal-length SMA coax cables, with four pairs of phase matched for connections to DUT cable.
3. Connect the pulse generator to the oscilloscope with the four pairs of coax cables through SMA-SMA thru-adaptors.
4. Position one marker at the rising edge of the waveform at CH1 (pair1+), and another marker at the corresponding falling edge of the waveform at CH2 (pair1-).
5. Position one marker at the rising edge of the waveform at CH3 (pair2+), and another marker at the corresponding falling edge of the waveform at CH4 (pair2-).
6. Perform a de-skew procedure at the oscilloscope among CH1, CH2, CH3 and CH4.
7. Configure the oscilloscope to display Math functions M1=CH1-CH2, M2=CH3-CH4. They represent the differential signals for the cable's pair1 and pair2.
8. Check that the rising edges of M1 and M2 are aligned.
9. Connect one end of the Cable DUT to the Pulse Generator differential output through a SMA-connector break-out board.

10. Connect the other end of the Cable DUT to the Oscilloscope: CH1 (pair1+), CH2 (pair1-), CH3 (pair2+), and CH4 (pair2-) through a SMA-connector break-out board.
11. Any un-used SMA of the break-out boards should be terminated by 50 Ω.
12. Position one marker at the rising edge of the M1 waveform (differential signal for pair1), and another marker at the corresponding rising edge of the M2 waveform (differential signal for pair2). Measure the delta time between the two markers. The delta time measurement is the inter-pair skew.
13. Verify that the measured inter-pair skew is meeting the cable's intra-pair skew requirement.

Test ID 1.12: Differential cable – crosstalk

Reference	Requirement
Differential cable – crosstalk	Meets the crosstalk requirement for STP or STQ cable. Applies to differential cable with more than one lane.

Test Objective:

Confirm meeting or exceeding the crosstalk requirement for multi-pair STP or STQ cable.

Test Diagram:

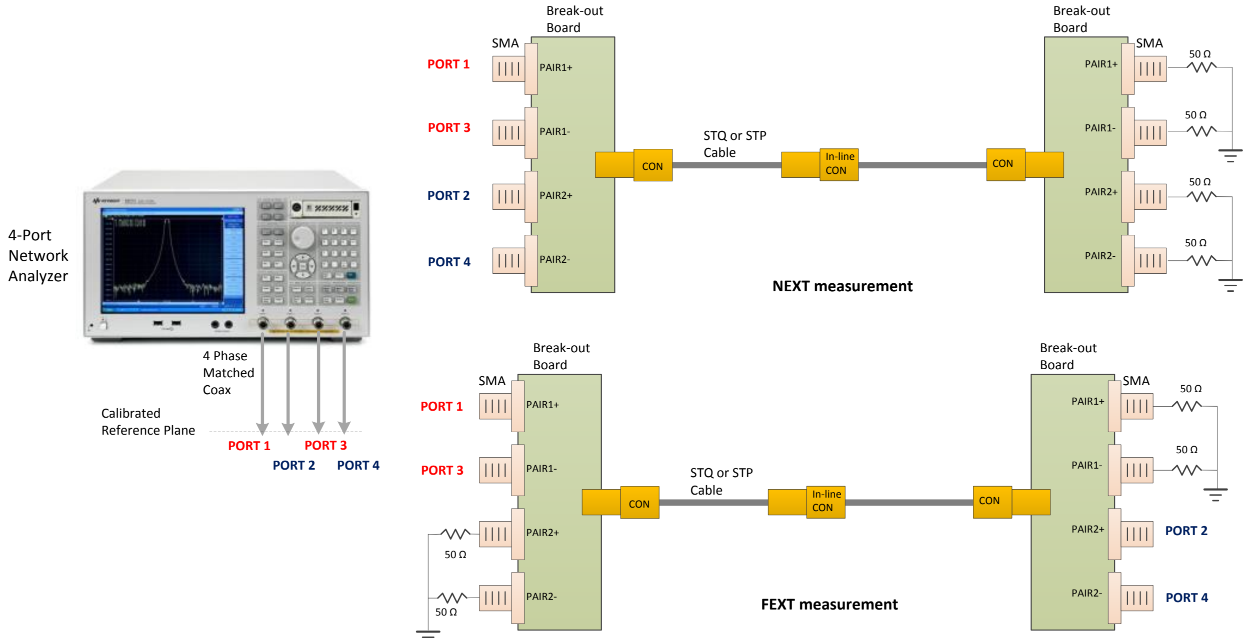

Figure 1.12-1. Measure FEXT or NEXT of the STP or STQ cable

Test Method:

1. Configure a 4-port network analyzer (NA) with measurement frequency range 100 KHz to 5 GHz, power level of 0 dBm, log sweep.
2. Follow the 4-port calibration procedure of the NA using an automatic or manual calibration kit.
3. Follow the connection for FEXT or NEXT measurement as shown in the Test Diagram.
4. For FEXT measurement, follow the connection shown in the Test diagram. Connect Ports 1-3 of NA to one end of the Cable DUT – Pair1, and Ports 2-4 to the other end of the Cable DUT – Pair2 through two SMA-connector break-out boards. The un-used SMA of the break-out boards are terminated by 50 Ω.
5. For NEXT measurement, follow the connection shown in the Test diagram. Connect Ports 1-3 of NA to one end of the Cable DUT – Pair1, and Ports 2-4 to the same end of the Cable DUT – Pair2 through two SMA-connector break-out boards. The un-used SMA of the break-out boards are terminated by 50 Ω.

6. Configure the NA to measure SDD21 with display format set to magnitude dB. The SDD21 is the corresponding cross-talk measurement.
7. Compare the measured SDD21 cross-talk attenuation to the cable requirement.

Appendix 1

S-parameter Measurement for use in Time-domain simulation

The transmission channel's characteristics measured by a network analyzer, is commonly stored in a touch-stone format called s-parameter. It is a text file that describes the channel's frequency responses. The s-parameter file is commonly used in circuit simulator to predict the time-domain waveform and timing analysis. To support such use on jitter analysis, fine time-steps used in simulator requires the s-parameter measurements performed with linear frequency sweep and with data points to higher frequencies with fine frequency steps. The table below shows the recommended NA settings for s-parameter models used in high data rate forward channel and lower data rate back-channel simulations. For cable aging and stress testing, it is recommended to have an s-parameter model that is capable to support circuit simulations for predicting the effect of the aged and stressed cable to the link's performance.

	PARAMETER	VALUE	UNIT
Forward Channel s-parameter model for simulation use			
	Start frequency	10	MHz
	Stop frequency	20.01	GHz
	Step frequency	10	MHz
	Number of data points	2001	
	Frequency sweep	Linear	
Back Channel s-parameter model for simulation use			
	Start frequency	0.1	MHz
	Stop frequency	500.1	MHz
	Step frequency	0.2	MHz
	Number of data points	2501	
	Frequency sweep	Linear	

Port Assignments for S-parameter measurements