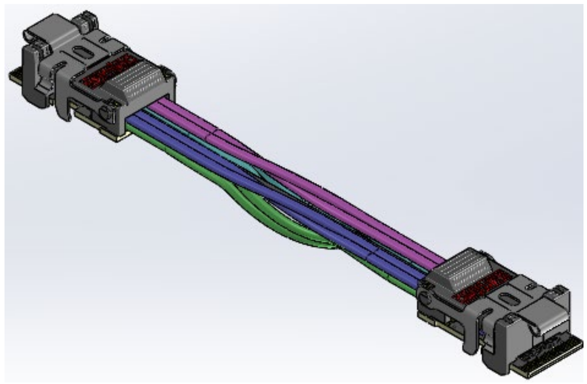
High Speed Characterization Report

PCUE-G4-04-XXX-FF



Mated with:

UEC5-109-2-X-D-RA-2

Description:

PCIe®-Over-FireFly™ Copper Cable Assembly

Samtec Inc.
520 Park East Blvd.
New Albany IN 47151-1147 USA

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Report Revision: 6/3/2021

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Cable Assembly Overview

PCUE is PCIe®-Over-FireFly™ copper (twinax) cable assembly. This cable assembly uses 34 AWG twinax cable. It is x4 duplex system, data connection is taken "off board" for easier routing and meets PCIe® 3.0 (8 GTps) and 4.0 (16 GTps) specifications. The cable assembly mates with the same 2-piece connector system as other FireFly™ systems.

The test sample consists of 8 discrete high-speed micro twinax cable pairs and two low speed sideband signal connections. At each end of the cable there is a connector that is terminated to a small transition PCB. Each UEC5-2 connector is soldered to its respective PCB. The connector terminals are on 0.5 mm centers. The cable assembly is wired to facilitate a Pin A1 to Pin A19 mapping between the cable terminations.

The PCUE cable assemblies were tested by mating to UEC5-2 at both ends. One sample of each length assembly was tested. The actual part numbers that were tested are shown in Table 1, which also identifies End 1 and End 2 of each assembly. A relative sample picture is shown in Figure1. Eight pairs of each assembly type were tested. They are identified as J1_ A2,A3 to J2_A15,A14; J1_ A5,A6 to J2_A18,A17; J1_ A14,A15 to J2_A3,A2; J1_ A17,A18 to J2_A6,A5; J1_ B2,B3 to J2_B14,B15; J1_ B5,B6 to J2_B17,B18; J1_ B14,B15 to J2_B2,B3; J1_ B17,B18 to J2_B5,B6.

Length	Part Number	End 1	End 2
10 cm	PCUE-G4-04-010-FF	J1	J2
30 cm	PCUE-G4-04-030-FF	J1	J2
50 cm	PCUE-G4-04-050-FF	J1	J2

Table 1: Sample Description

Figure 1: Test Sample

Series: PCUE-G4
Description: PCIe®-Over-FireFly™ Copper Cable Assembly

Frequency Domain Data Summary

Bandwidth Chart – Differential Insertion Loss

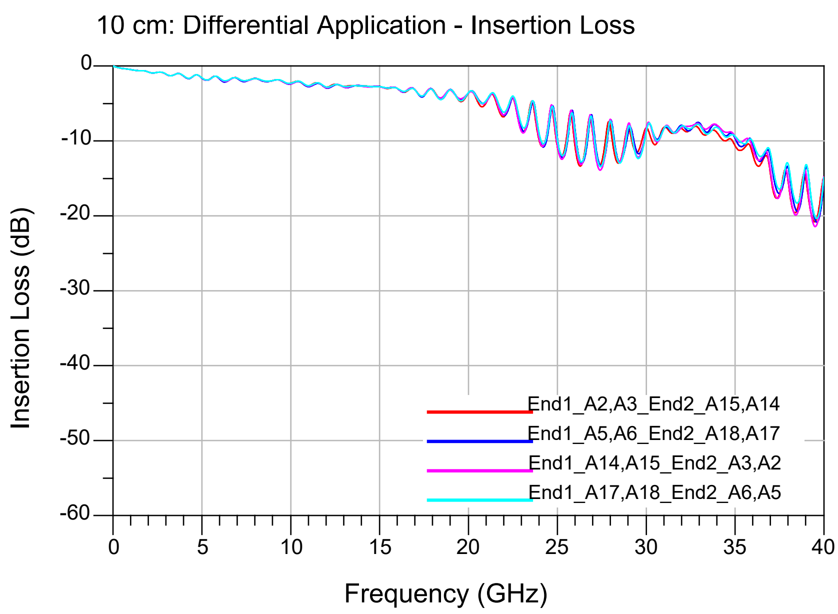

Figure 2

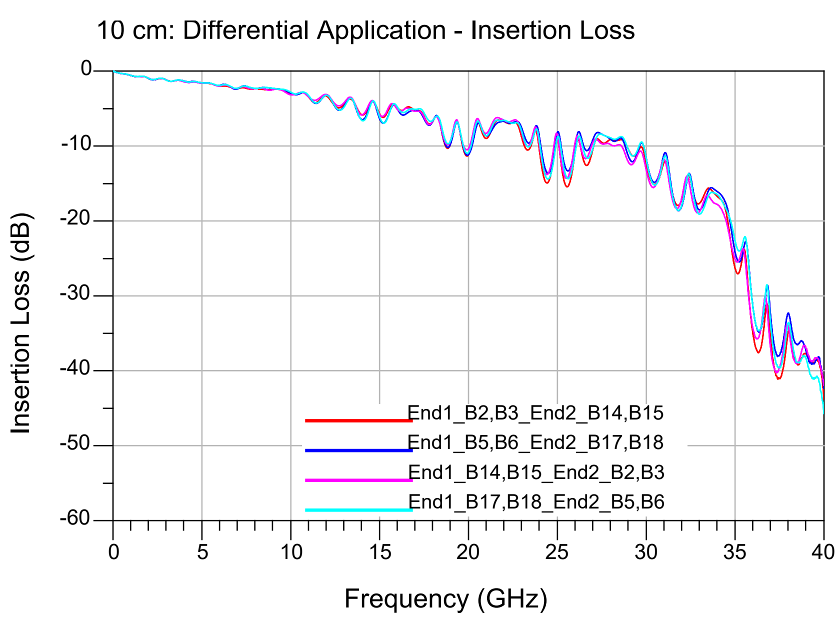

Figure 3

Series: PCUE-G4
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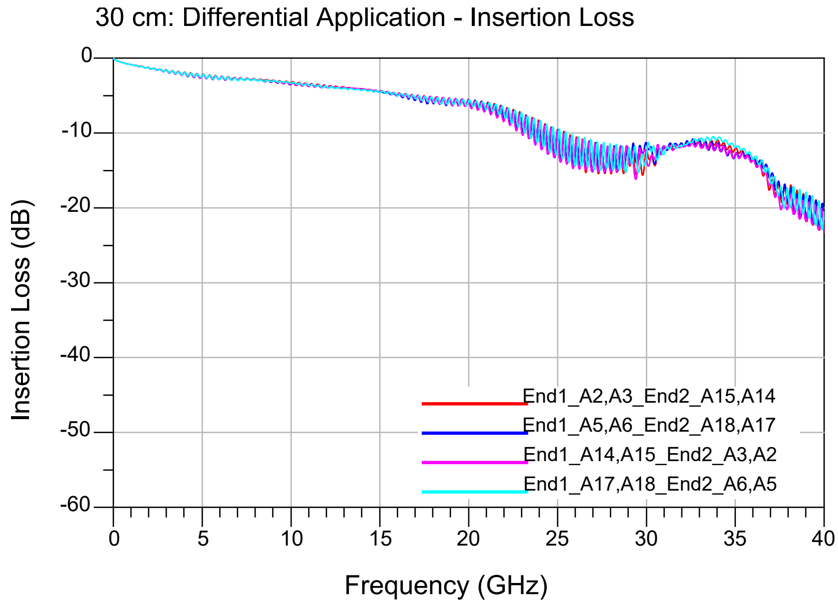

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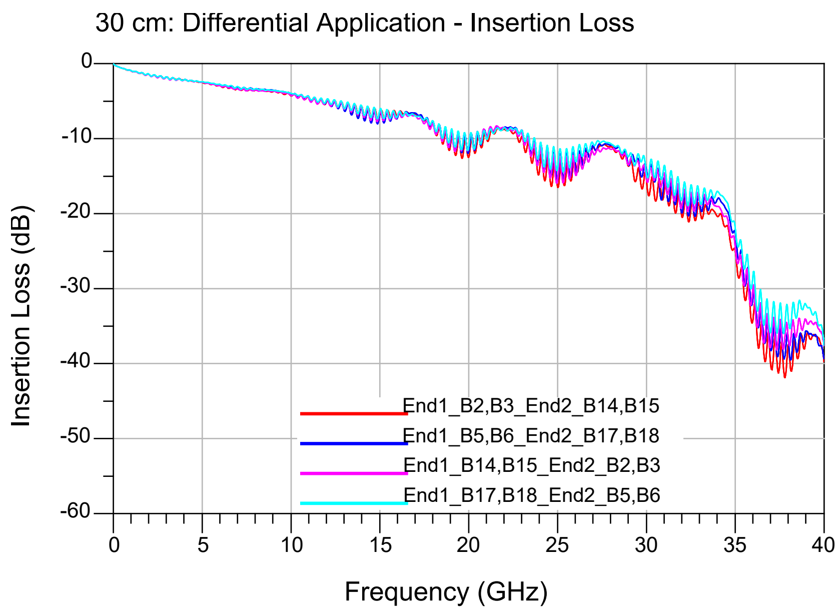

Figure 5

Series: PCUE-G4
Description: PCIe®-Over-FireFly™ Copper Cable Assembly

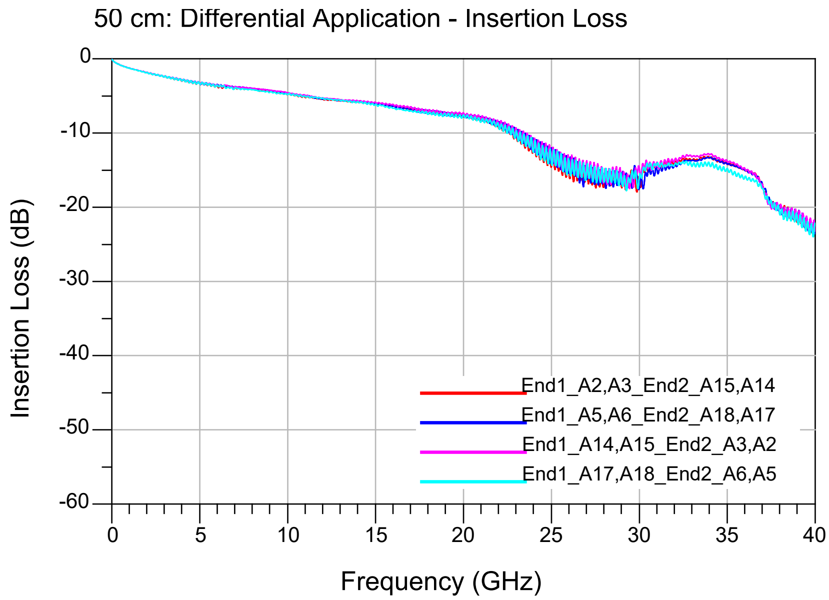

Figure 6

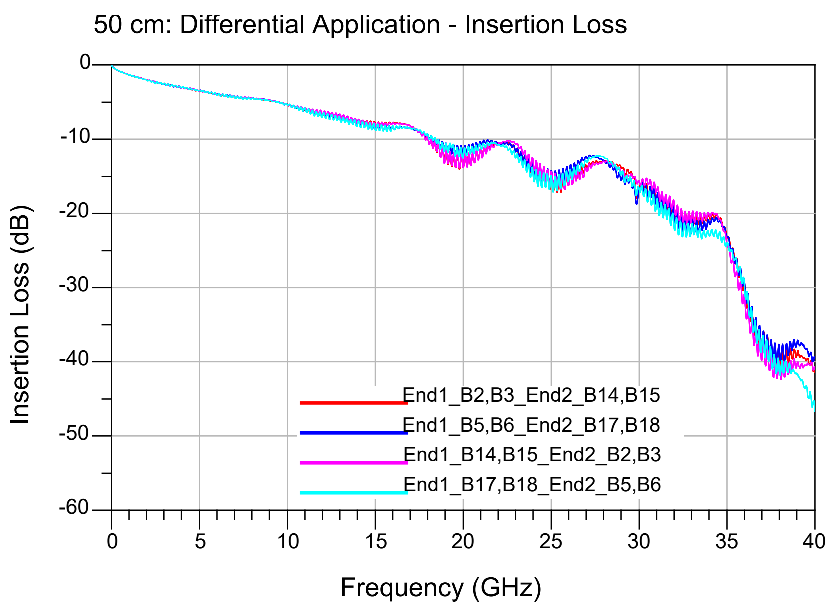

Figure 7

Series: PCUE-G4
Description: PCIe®-Over-FireFly™ Copper Cable Assembly

Time Domain Data Summary

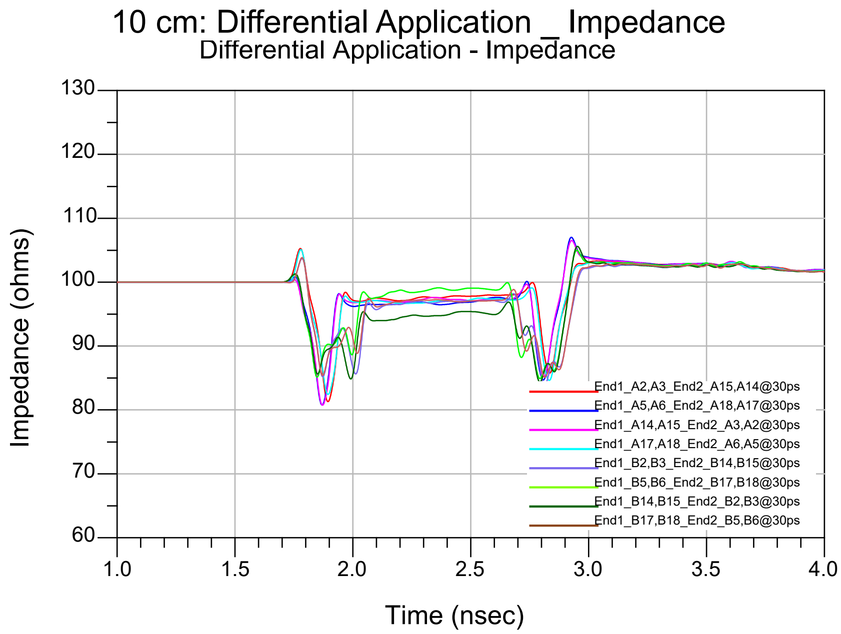

Figure 8

Because the same type of cable is used in the cable assemblies with different lengths, only the impedance profile of 10 cm cable assembly is reported.

Table 2 - Propagation Delay (Cable Assembly)

Driver	Receiver	10cm	30cm	50cm
J1_ A2,A3	J2_A15,A14	0.606 ns	1.563 ns	2.518 ns
J1_ A5,A6	J2_A18,A17	0.603 ns	1.562 ns	2.504 ns
J1_ A14,A15	J2_A3,A2	0.604 ns	1.563 ns	2.515 ns
J1_ A17,A18	J2_A6,A5	0.604 ns	1.557 ns	2.513 ns
J1_ B2,B3	J2_B14,B15	0.618 ns	1.571 ns	2.523 ns
J1_ B5,B6	J2_B17,B18	0.617 ns	1.572 ns	2.523 ns
J1_ B14,B15	J2_B2,B3	0.619 ns	1.575 ns	2.523 ns
J1_ B17,B18	J2_B5,B6	0.616 ns	1.573 ns	2.525 ns

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Characterization Details

This report presents data that characterizes the signal integrity response of a cable assembly in a controlled printed circuit board (PCB) environment. All efforts are made to reveal typical best-case responses inherent to the system under test (SUT).

In this report, the SUT includes the mating connectors, cable assembly, and footprint effects on a typical multi-layer PCB. PCB effects (trace loss) are de-embedded from test data. Board related effects, such as pad-to-ground capacitance, are included in the data presented in this report.

Additionally, intermediate test signal connections can mask the cable assembly's true performance. Such connection effects are minimized by using high performance test cables and adapters. Where appropriate, calibration and de-embedding routines are also used to reduce residual effects.

Differential and Single-Ended Data

Most Samtec cable assemblies can be used successfully in both differential and single-ended applications. However, electrical performance will differ depending on the signal drive type. In this report, data is presented for "GSSG" differential drive configuration only.

Cable assembly Signal to Ground Ratio

Samtec cable assemblies are most often designed for generic applications and can be implemented using various signal and ground pin assignments. In high-speed systems, provisions must be made in the interconnect for signal return currents. Such paths are often referred to as "ground". In some cable assemblies, a ground plane or blade, or an outer shield, is used as the signal return, while in others, cable assembly pins are used as signal returns. Various combinations of signal pins, ground blades, and shields can also be utilized. Electrical performance can vary significantly depending upon the number and location of ground pins.

In general, the more pins dedicated to ground, the better electrical performance will be. But dedicating pins to ground reduces signal density of a cable assembly. Therefore, care must be taken when choosing signal/ground ratios in cost or density-sensitive applications.

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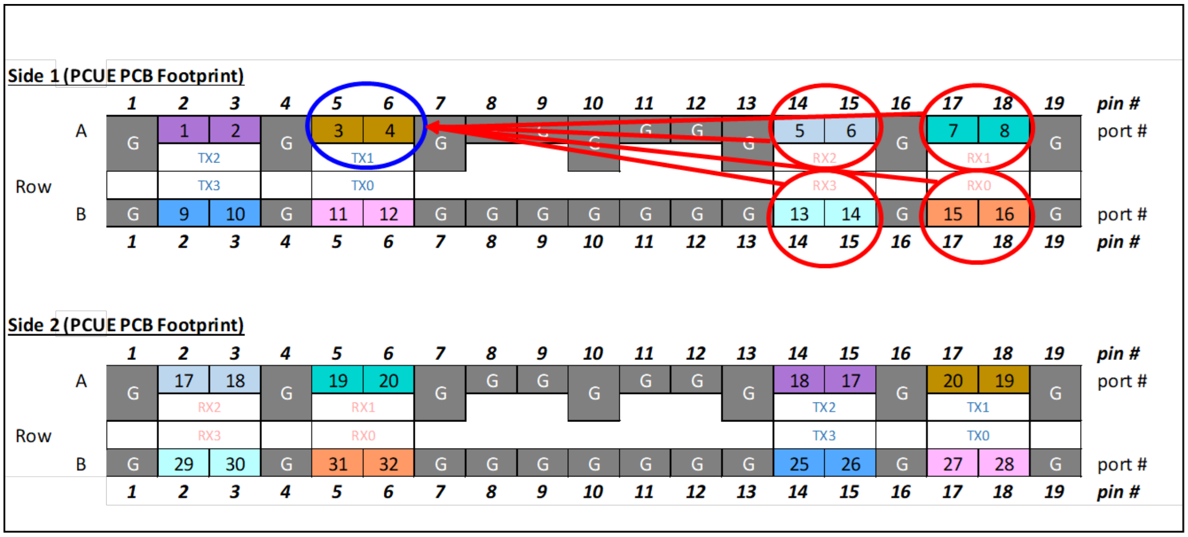
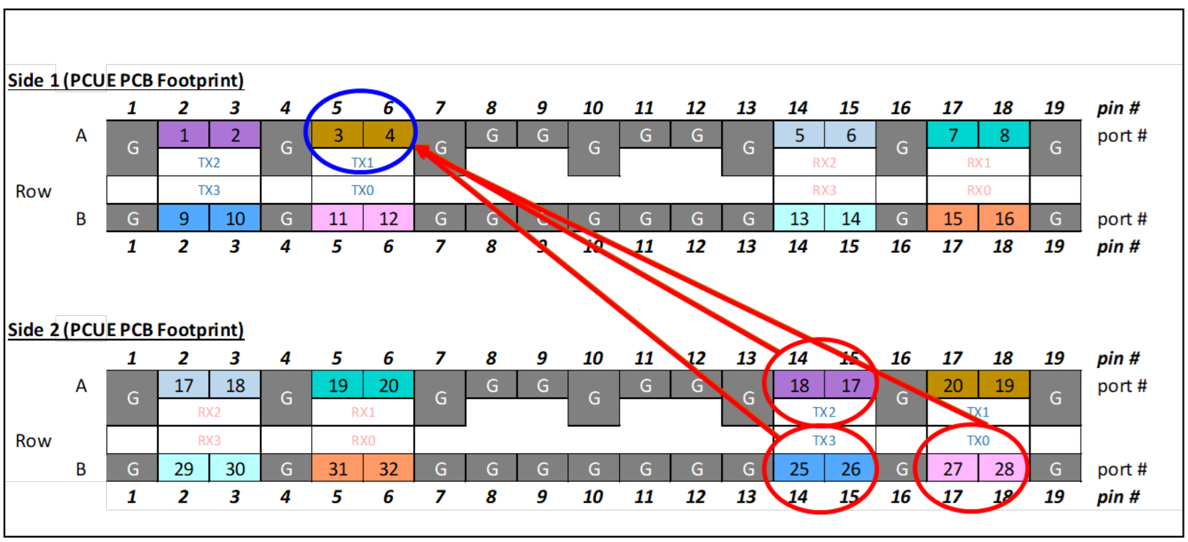
For this cable assembly, the following configurations were evaluated:



NEXT Pin Mapping



FEXT Pin Mapping

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In a real system environment, active signals might be located at the outer edges of the signal contacts of concern, as opposed to the ground signals utilized in laboratory testing. For example, in a single-ended system, a pin-out of “SSSS”, or four adjacent single ended signals might be encountered as opposed to the “GSG” and “GSSG” configurations tested in the laboratory. Electrical characteristics in such applications could vary slightly from laboratory results. But in most applications, performance can safely be considered equivalent.

Signal Edge Speed (Rise Time)
In pulse signaling applications, the perceived performance of the interconnect can vary significantly depending on the edge rate or rise time of the exciting signal. For this report, the fastest rise time used was 30 ps. Generally, this should demonstrate worst-case performance.

In many systems, the signal edge rate will be significantly slower at the cable assembly than at the driver launch point. To estimate interconnect performance at other edge rates, data is provided for several rise times between 30ps and 100ps.

Unless otherwise stated, measured rise times were at 20%-80% signal levels.

Frequency Domain Data
Frequency Domain parameters are helpful in evaluating the cable assembly system’s signal loss and crosstalk characteristics across a range of sinusoidal frequencies. In this report, parameters presented in the Frequency Domain are Insertion Loss, Return Loss, Near-End and Far-End Crosstalk, and Mode Conversion. Other parameters or formats, such as VSWR or S-Parameters, may be available upon request. Please contact our Signal Integrity Group at sig@samtec.com for more information.

Frequency performance characteristics for the SUT are generated directly from network analyzer measurements.

Time Domain Data
Mathematically, Frequency Domain data can be transformed to obtain a Time Domain response. Perfect transformation requires Frequency Domain data from DC to infinity Hz. Fortunately, a very accurate Time Domain response can be obtained with bandwidth-limited data, such as measured with modern network analyzer.

The Time Domain responses were generated using Keysight ADS 2017 update 1. This tool has a transient convolution simulator, which can generate a Time Domain response directly from measured S-Parameters. An example of a similar methodology is provided in the Samtec Technical Note on domain transformation.

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http://suddendocs.samtec.com/notesandwhitepapers/tech-note_using-plts-for-time-domain-data_web.pdf

The measured S-Parameters from the network analyzer are post-processed using Keysight ADS to obtain the time domain response for signal propagation time. The Time Domain procedure is provided in Appendix D of this report. Parameters or formats not included in this report may be available upon request. Please contact our Signal Integrity Group at sig@samtec.com for more information.

In this report, propagation delay is defined as the signal propagation time through the cable assembly, mating connectors, and connector footprint. It also includes 3 or 5.2 mm of PCB trace on each connector side for row A and 4.1 or 6.2 mm of PCB trace on each connector side for row B. Delay is measured at 100 picoseconds signal rise-time. Delay is calculated as the difference in time measured between the 50% amplitude levels of the input and output pulses.

Data for other configurations may be available. Please contact our Signal Integrity Group at sig@samtec.com for further information.

Additional information concerning test conditions and procedures is in the appendices of this report. Further information may be obtained by contacting our Signal Integrity Group at sig@samtec.com.

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Appendix A – Frequency Domain Response Graphs

Differential Application – Insertion Loss

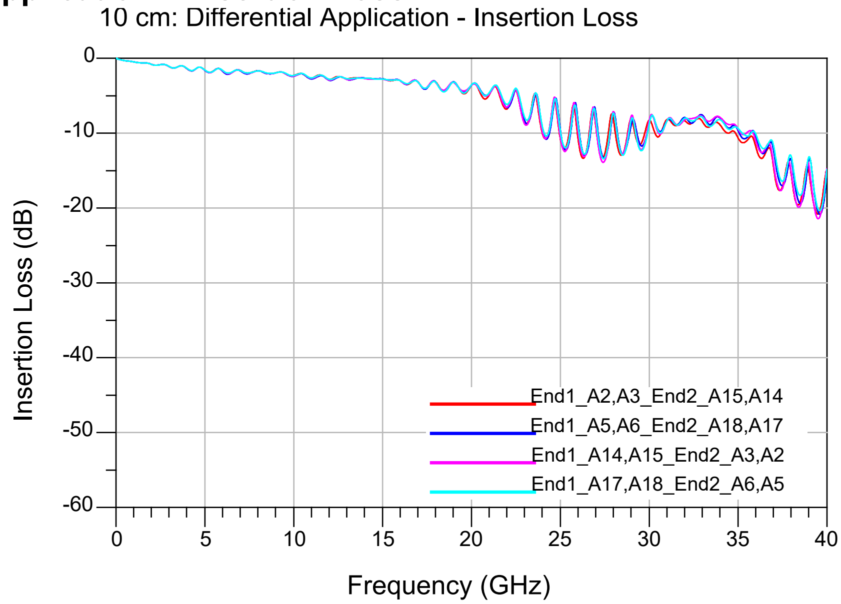

Figure 9

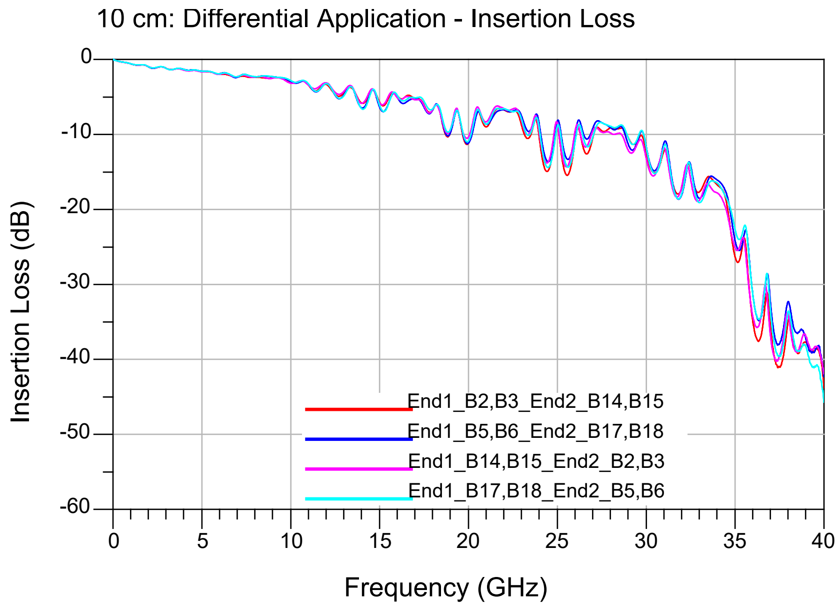

Figure 10

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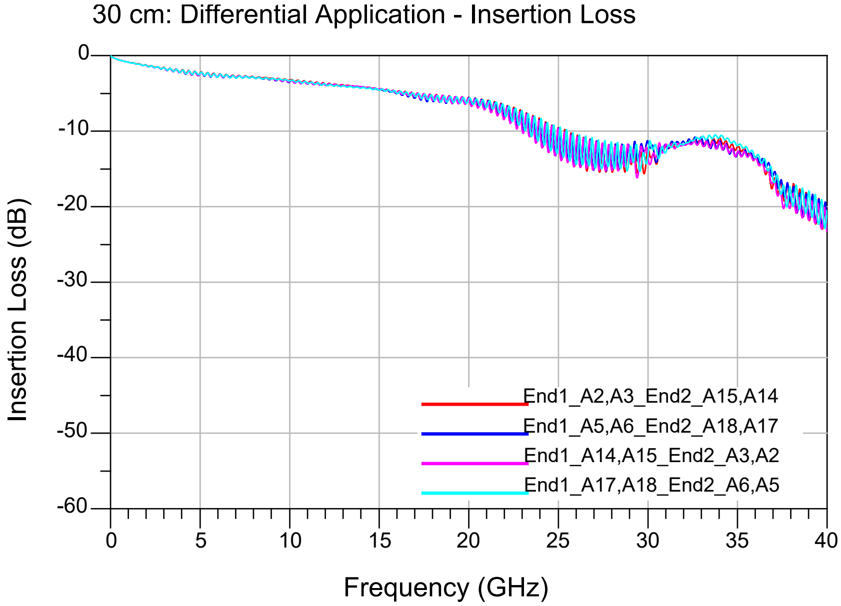

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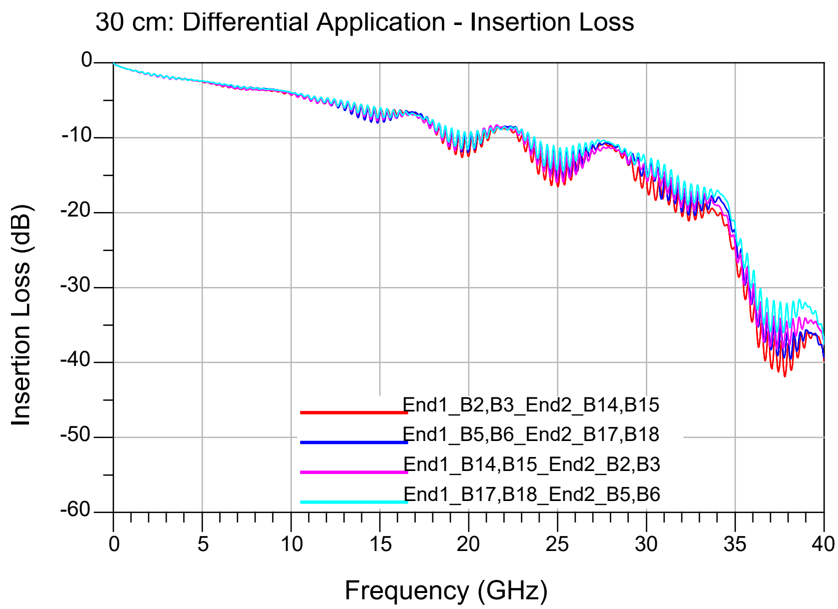

Figure 12

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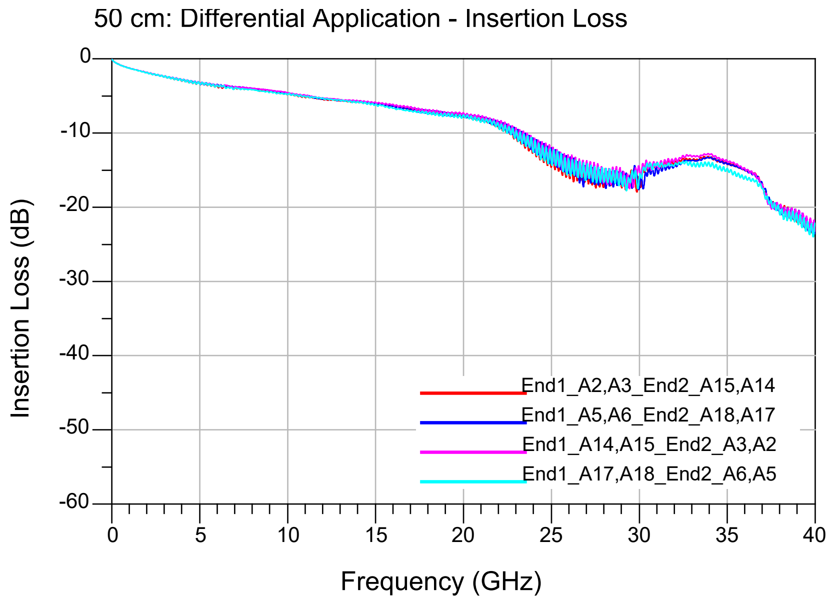

Figure 13

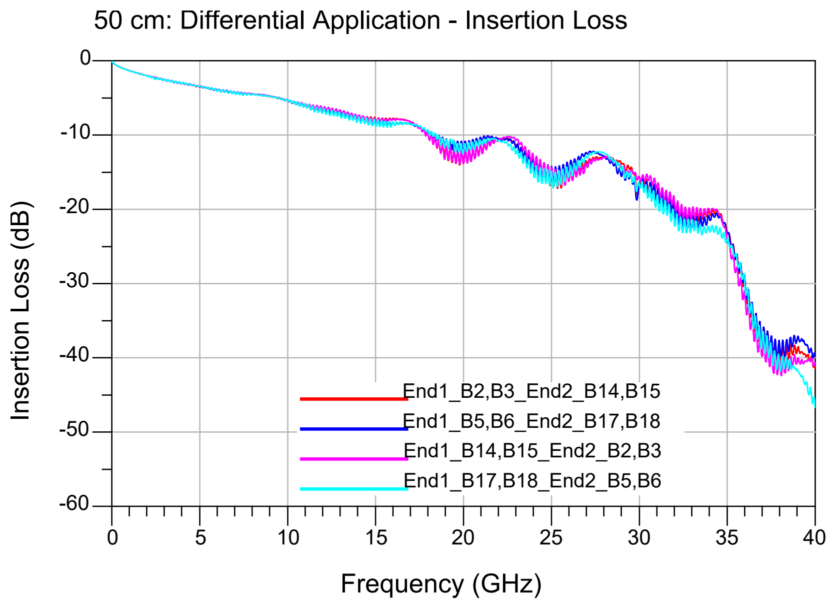

Figure 14

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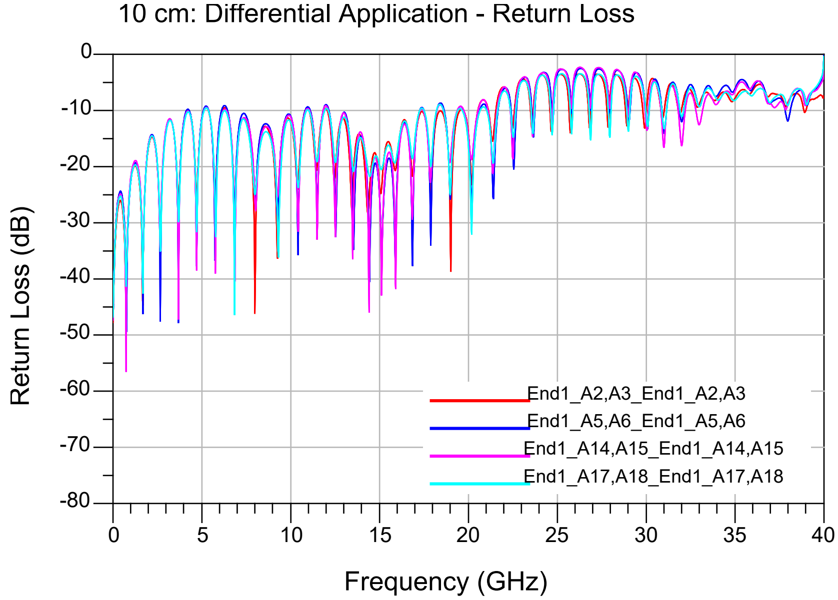
Differential Application – Return Loss



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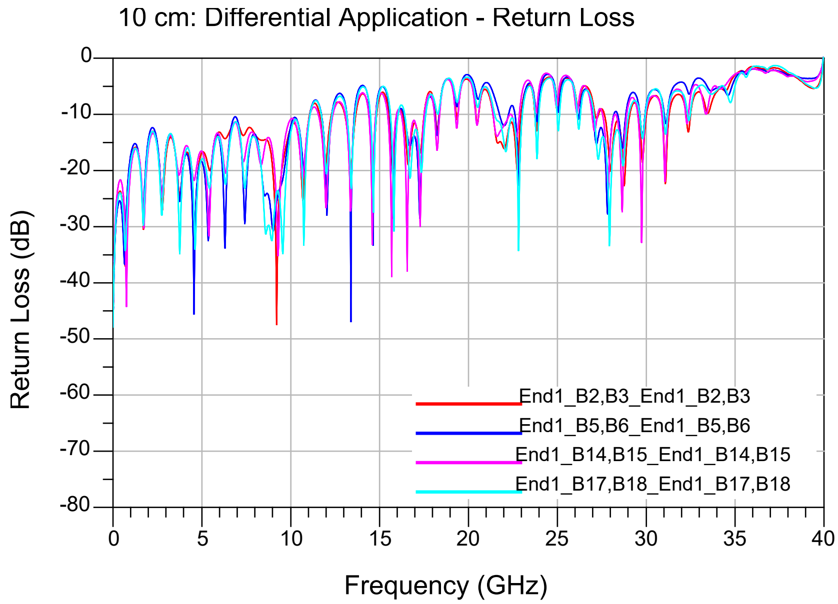

Figure 16

Series: PCUE-G4
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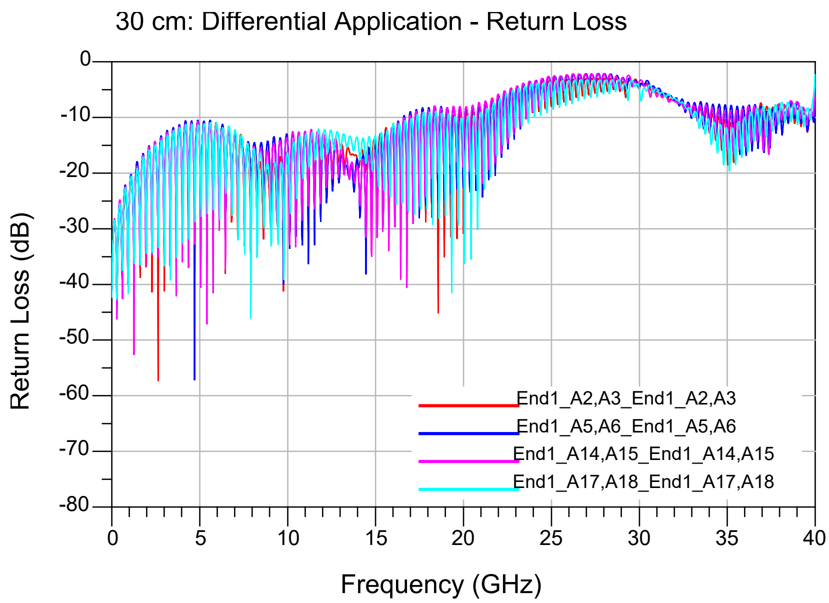

Figure 17

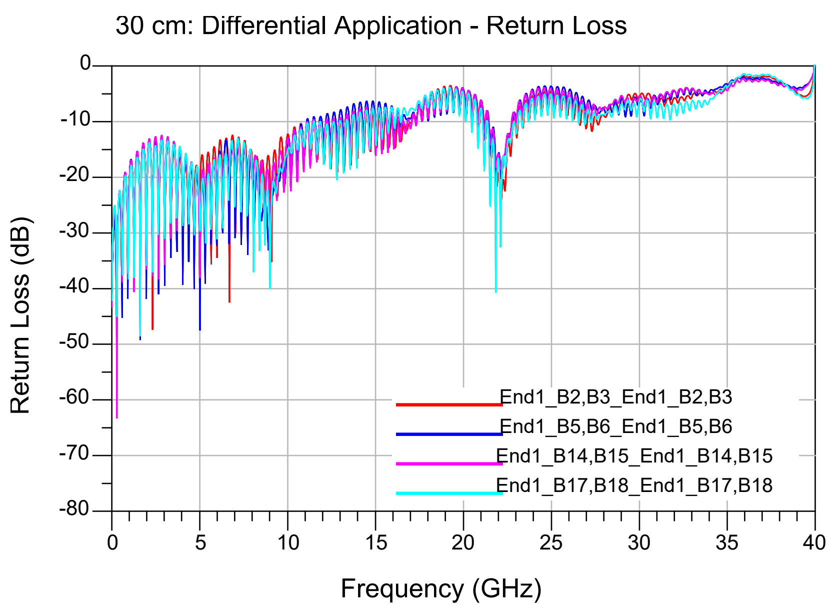

Figure 18

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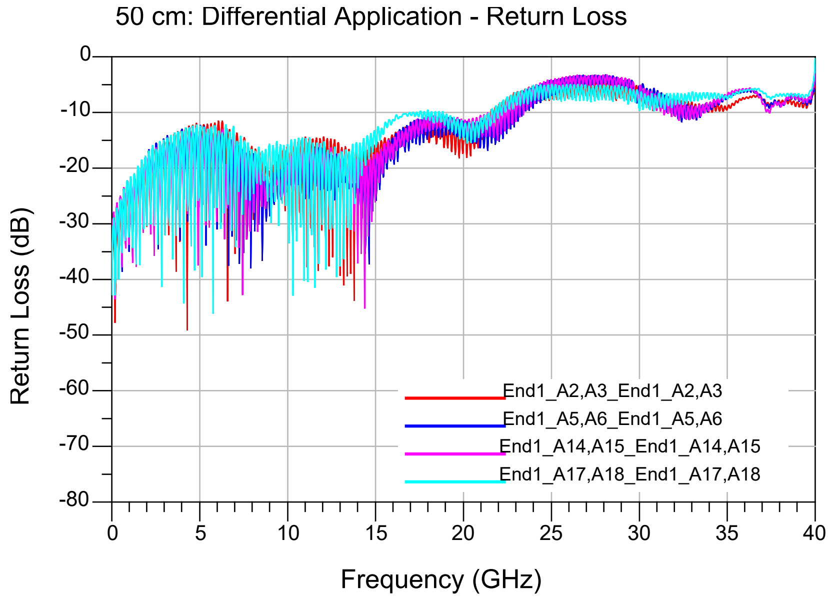

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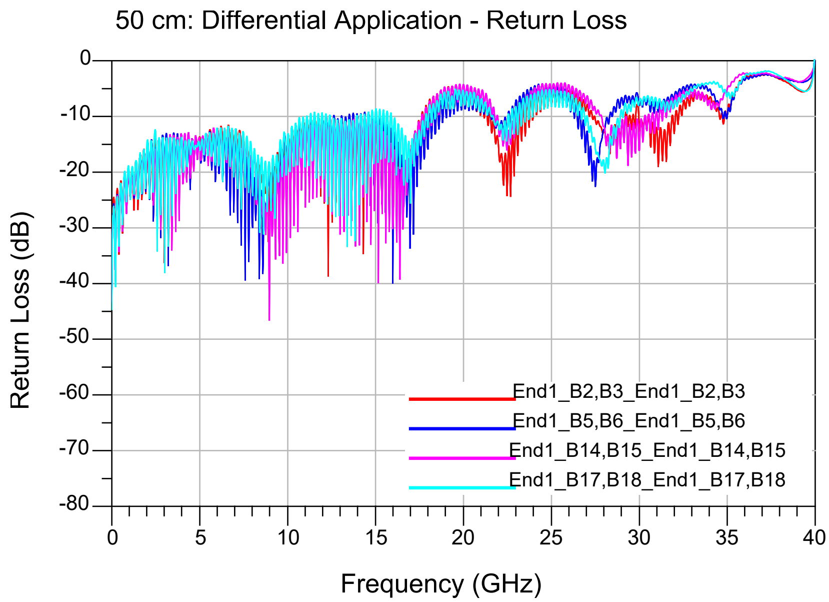

Figure 20

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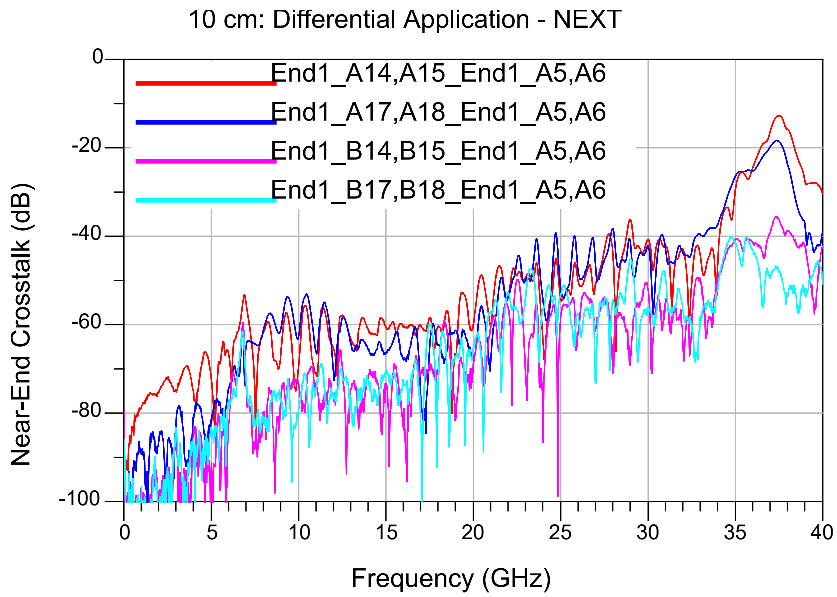
Differential Application – NEXT Configurations



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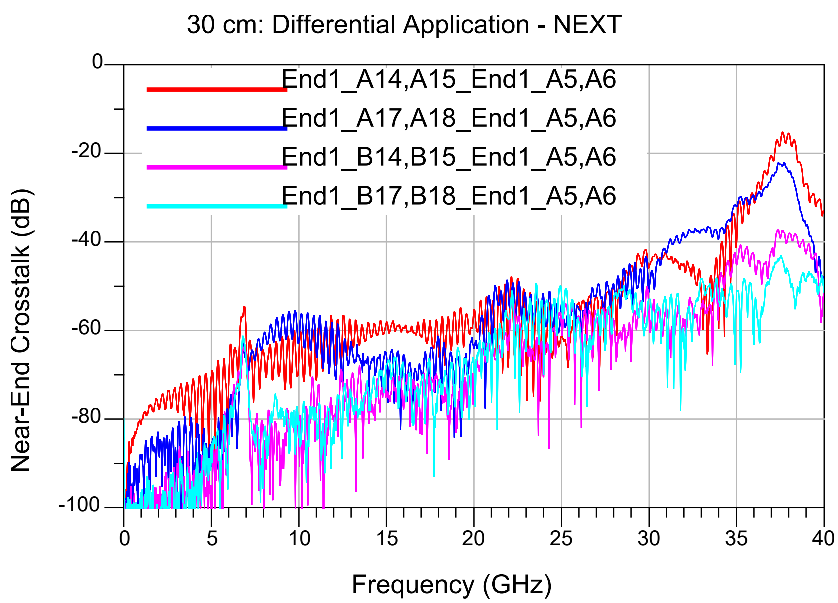

Figure 22

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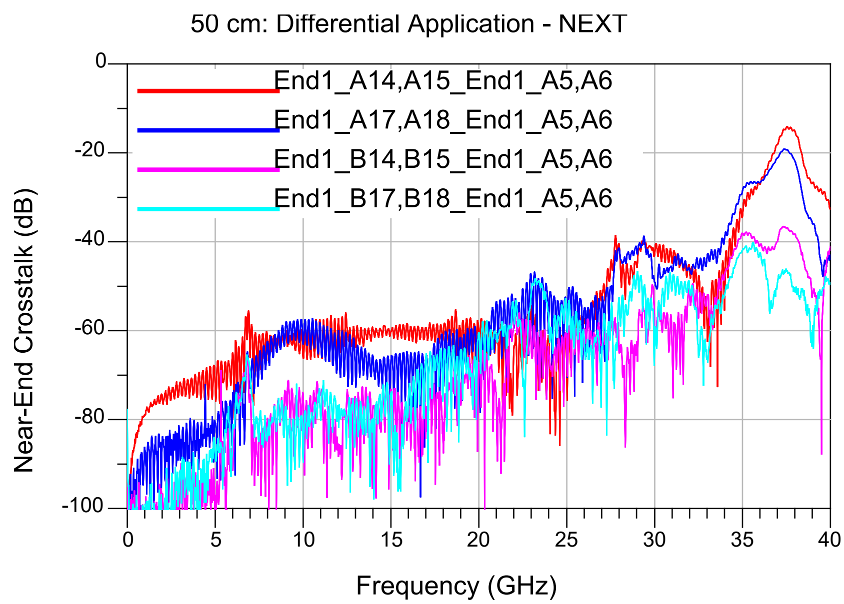

Figure 23

Differential Application – FEXT Configurations

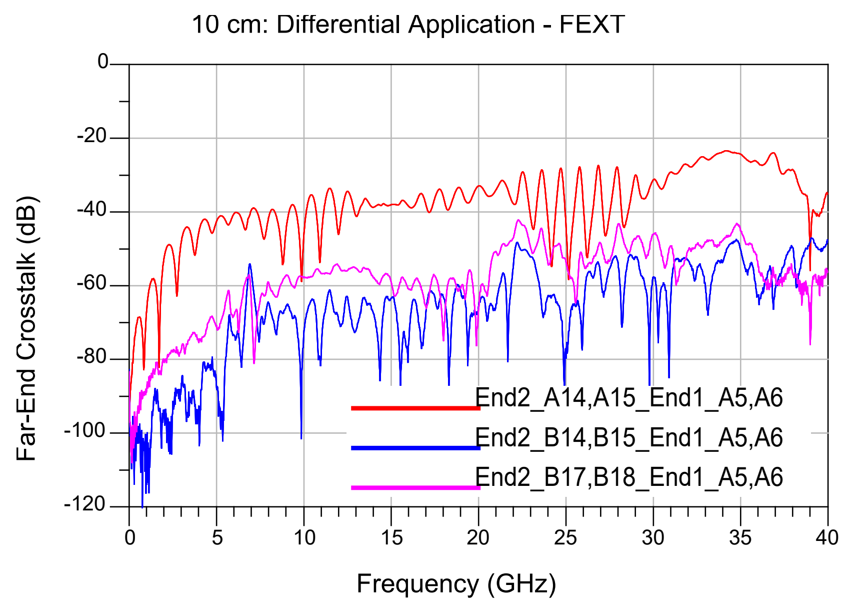

Figure 24

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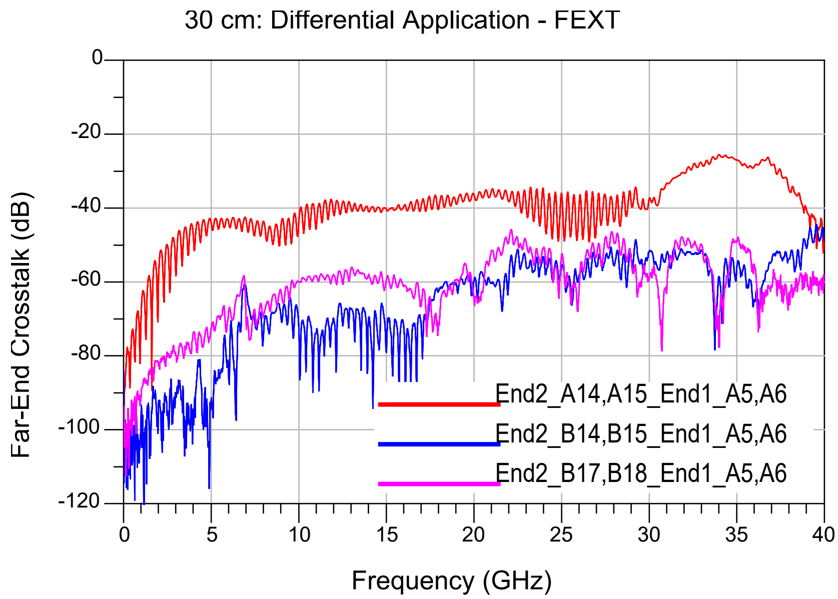

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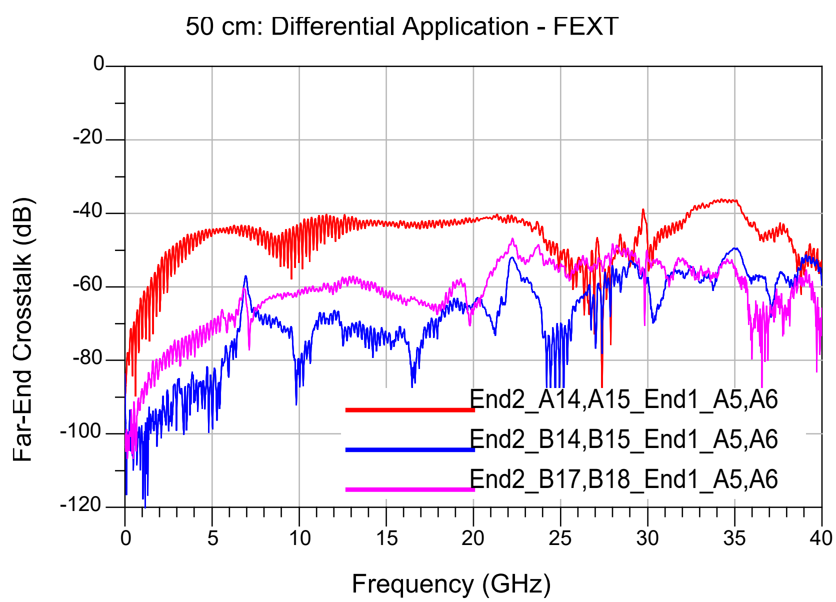

Figure 26

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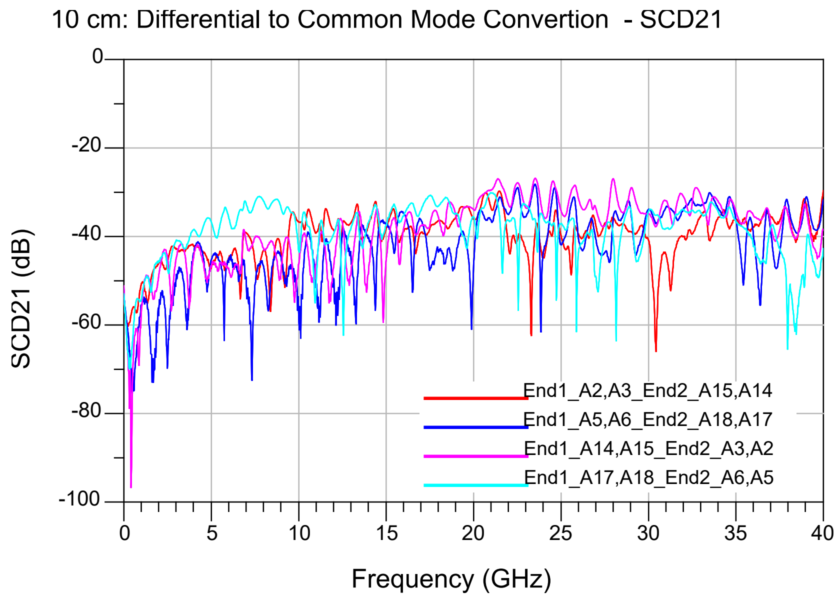
Differential Application – Differential to Common Mode Conversion



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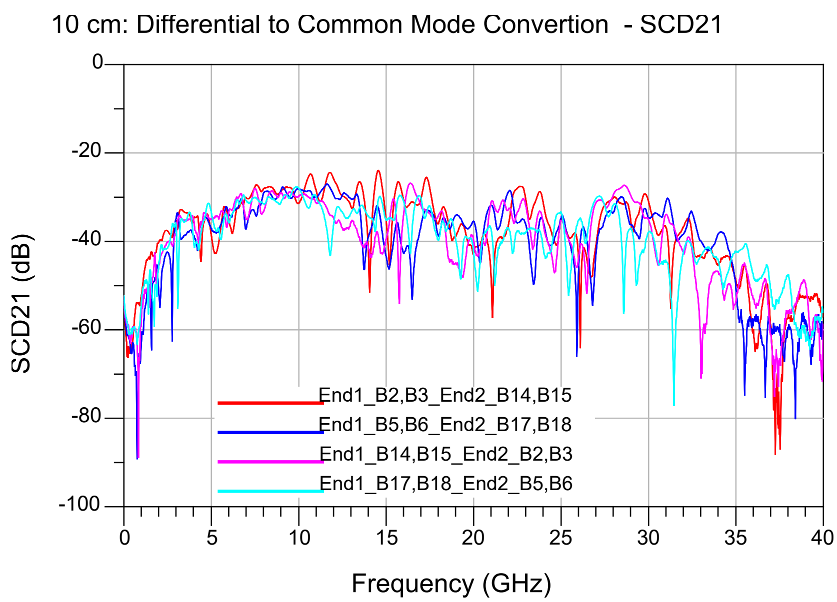

Figure 28

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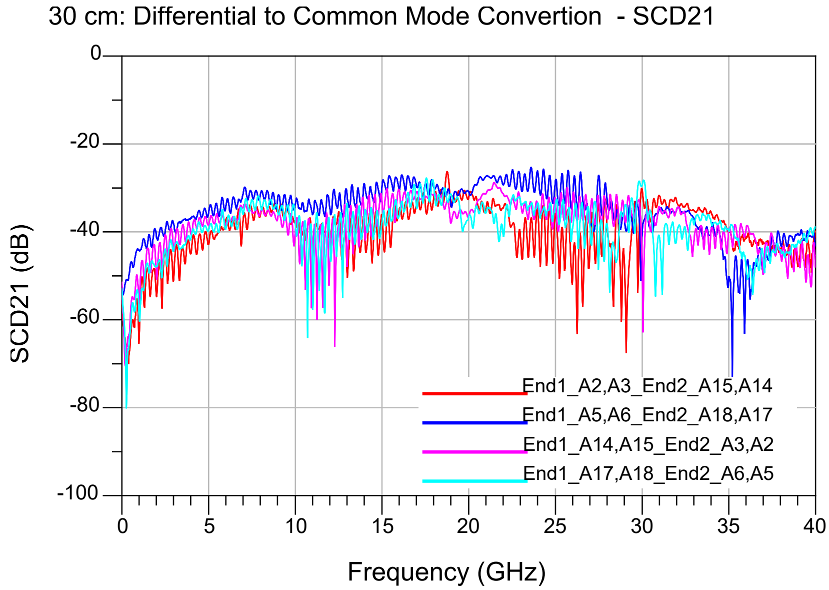

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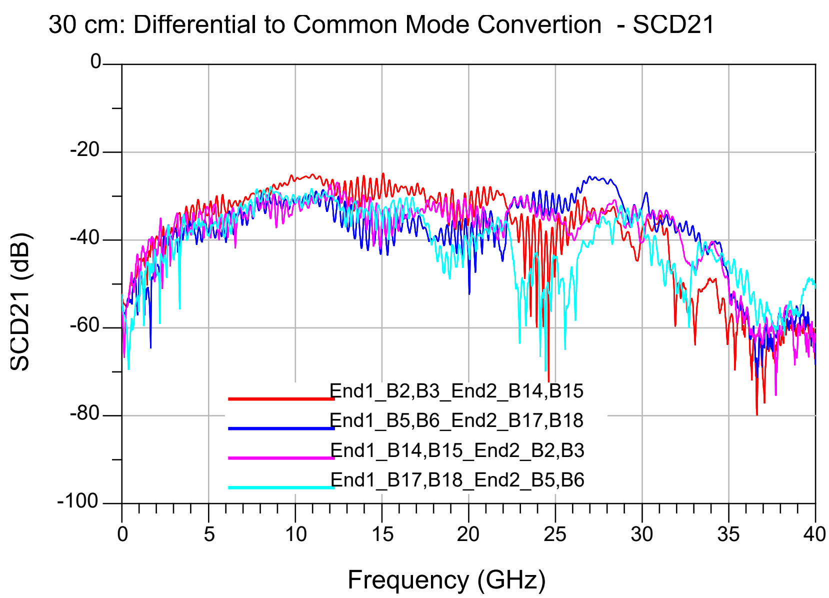

Figure 30

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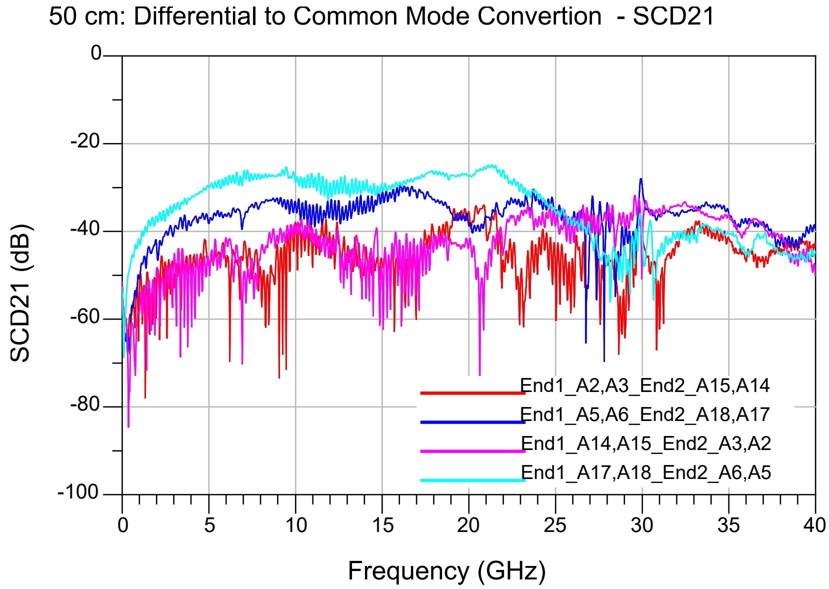

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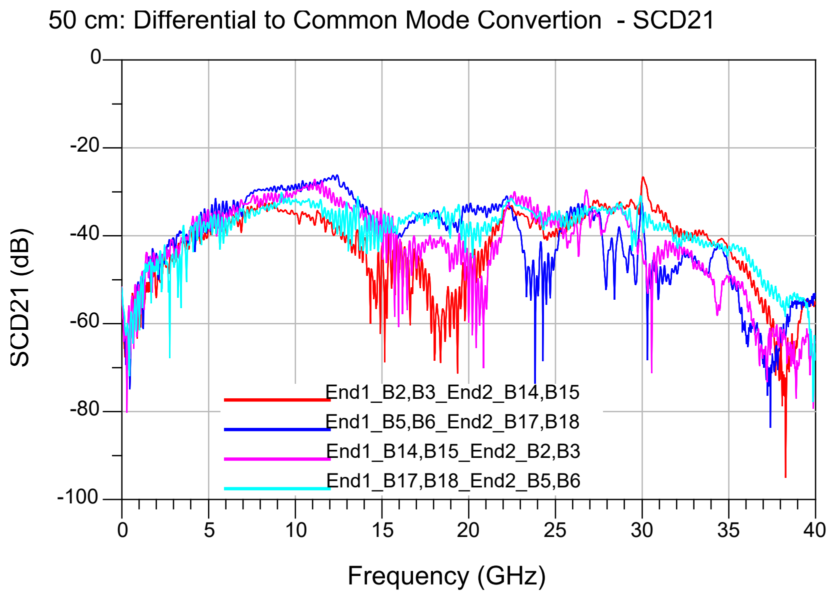

Figure 32

Series: PCUE-G4
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Appendix B – Time Domain Response Graphs

Differential Application – Input Pulse

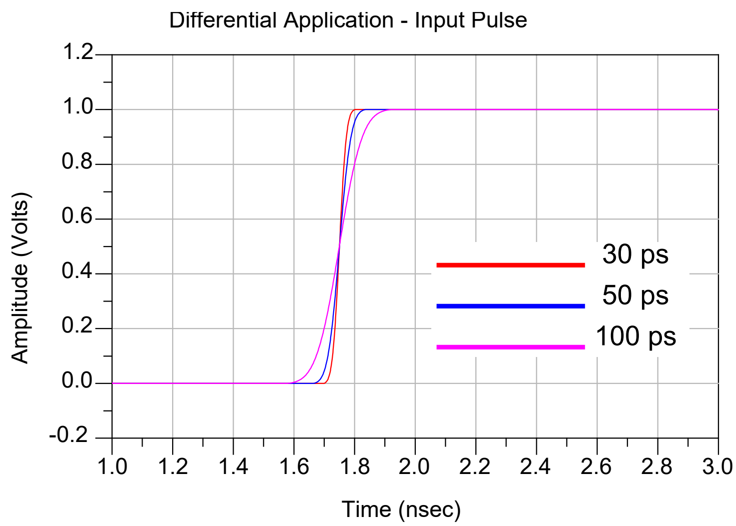

Figure 33

Series: PCUE-G4
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Differential Application – Cable assembly Impedance

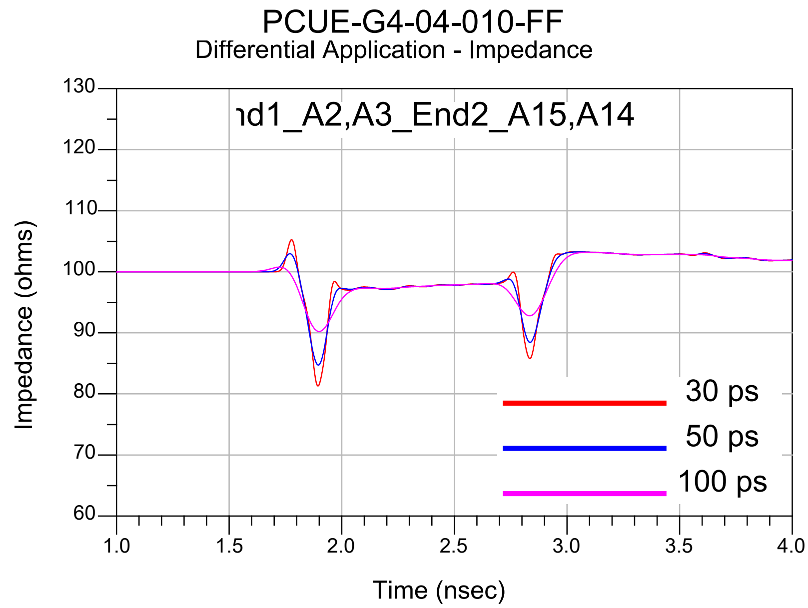

Figure 34

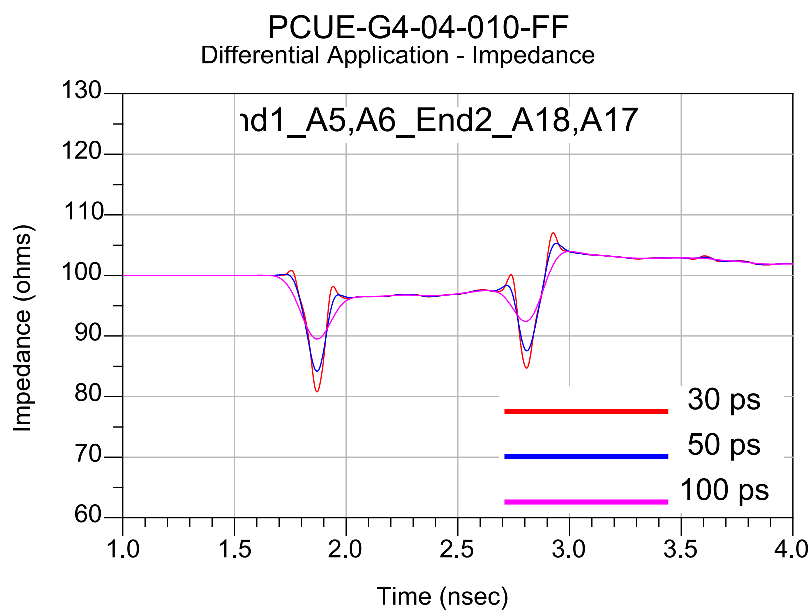

Figure 35

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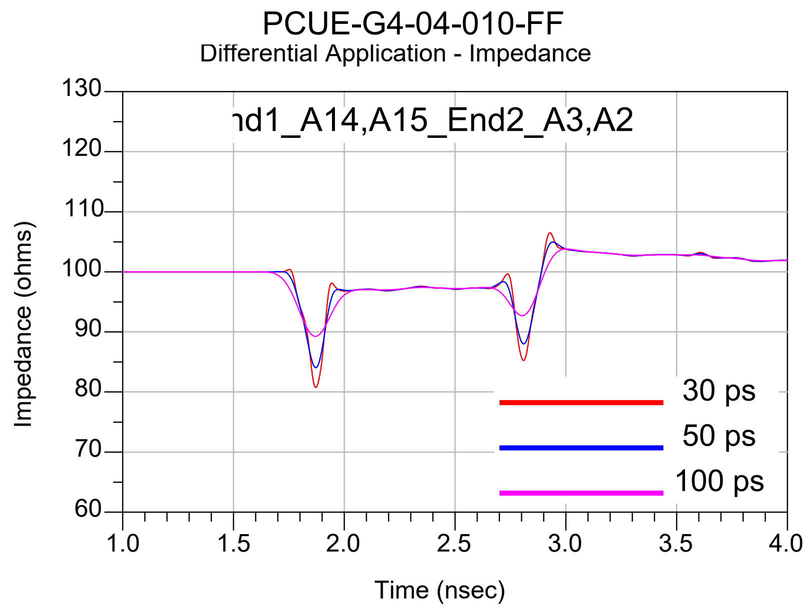

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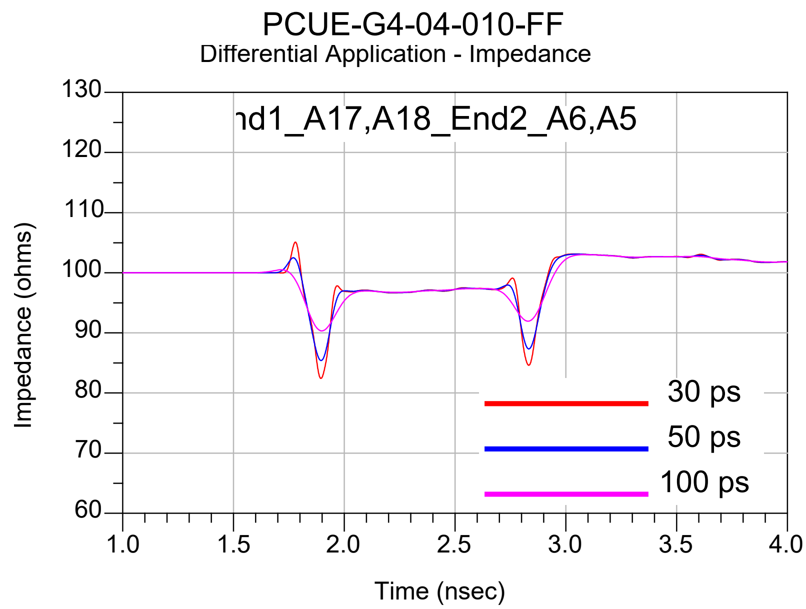

Figure 37

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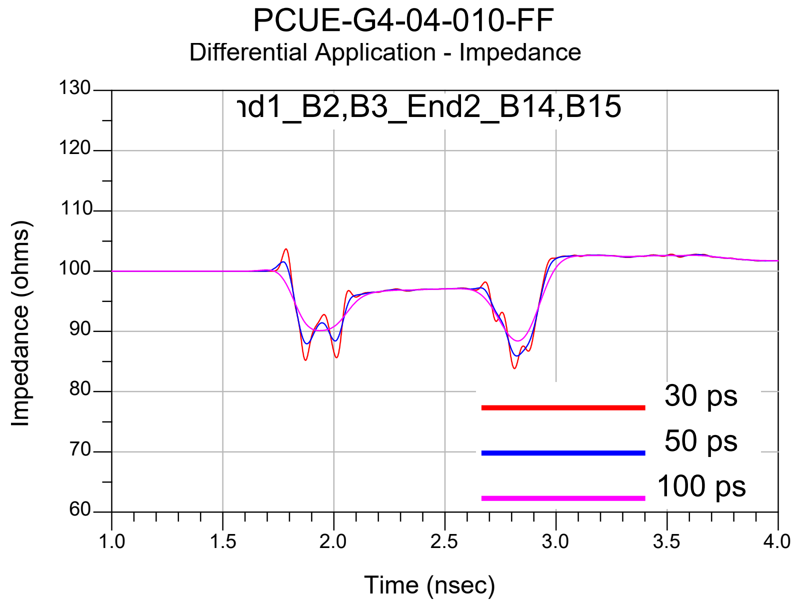

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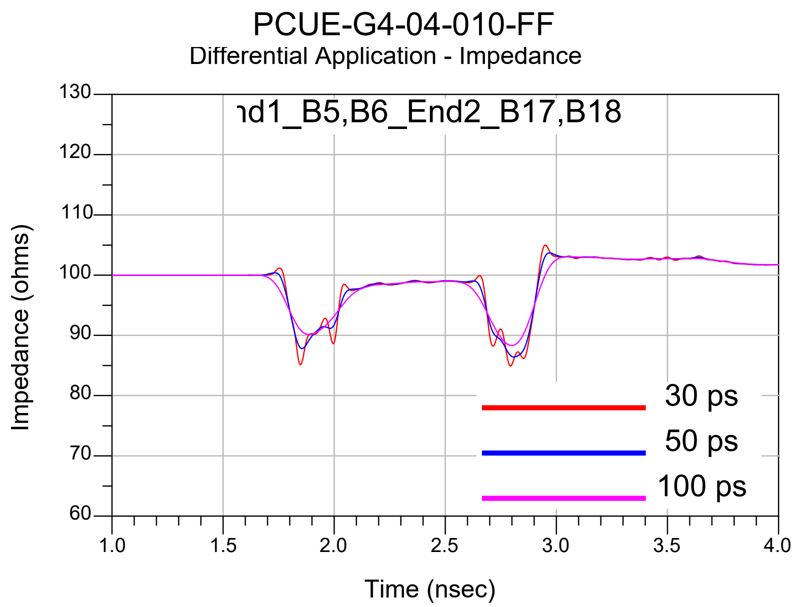

Figure 39

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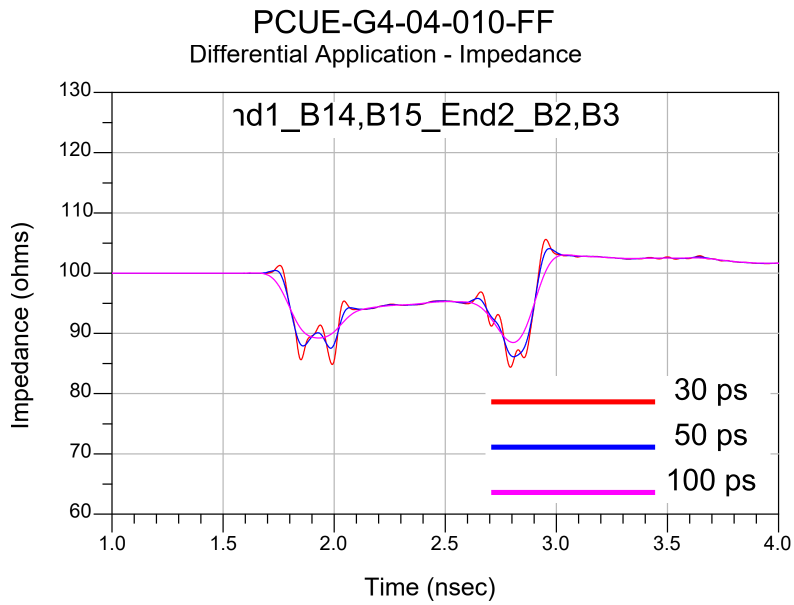

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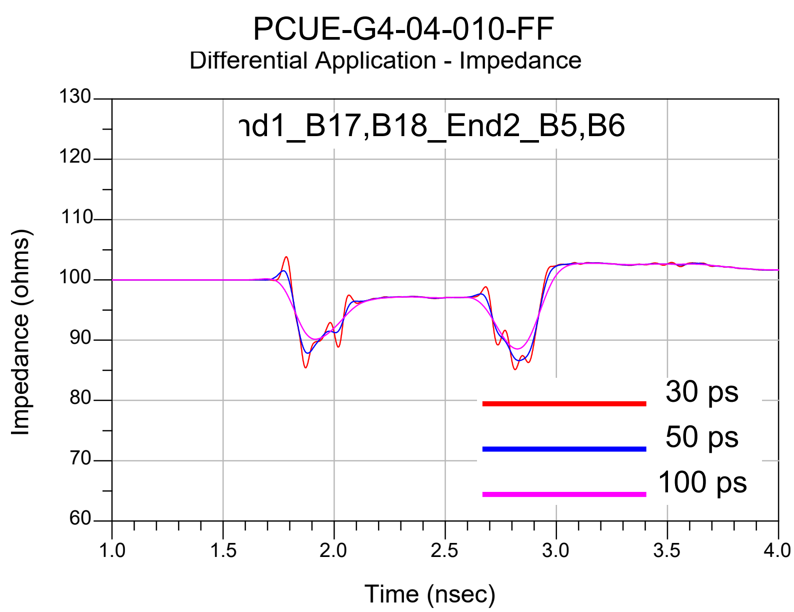

Figure 41

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Differential Application – Propagation Delay

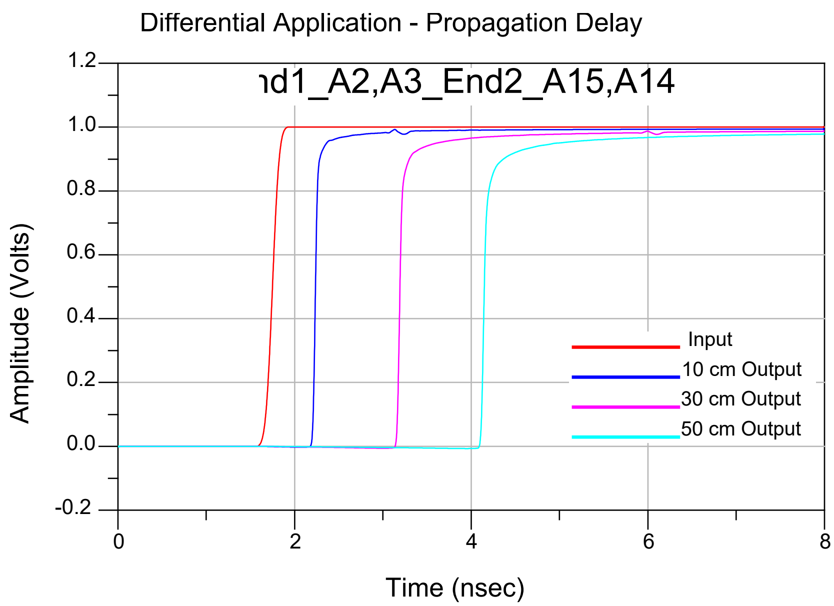

Figure 42

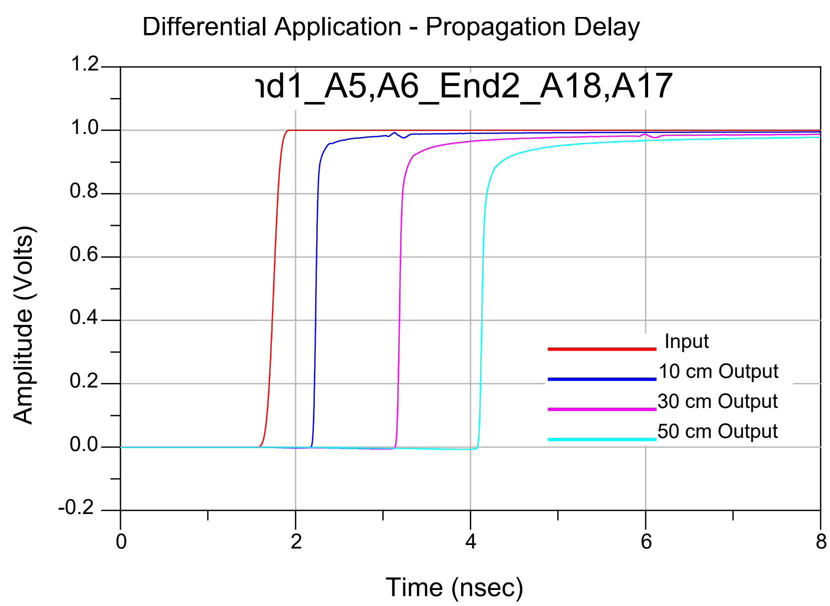

Figure 43

Series: PCUE-G4
Description: PCIe®-Over-FireFly™ Copper Cable Assembly

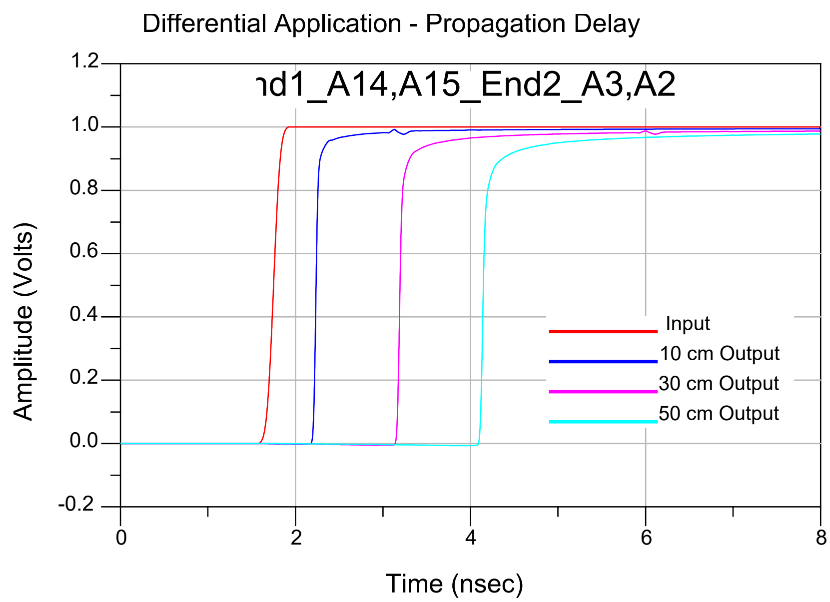

Figure 44

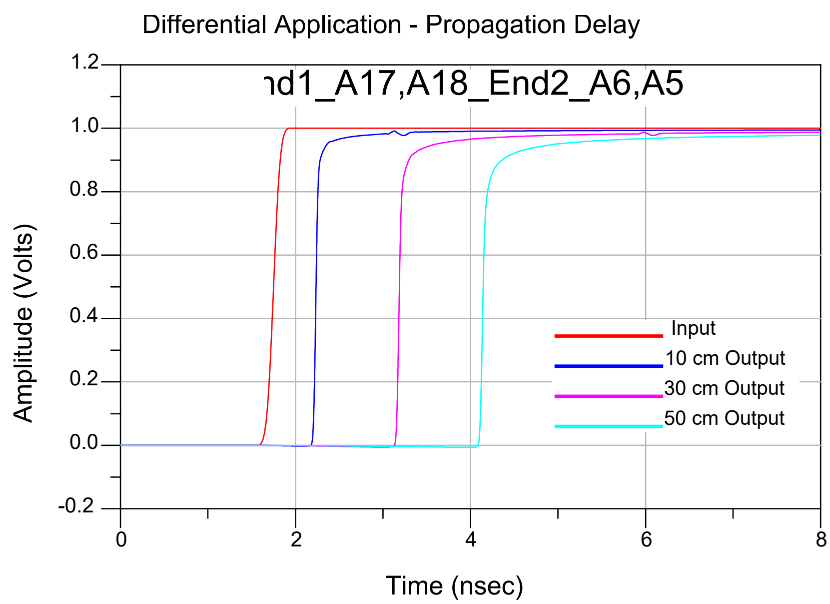

Figure 45

Series: PCUE-G4
Description: PCIe®-Over-FireFly™ Copper Cable Assembly

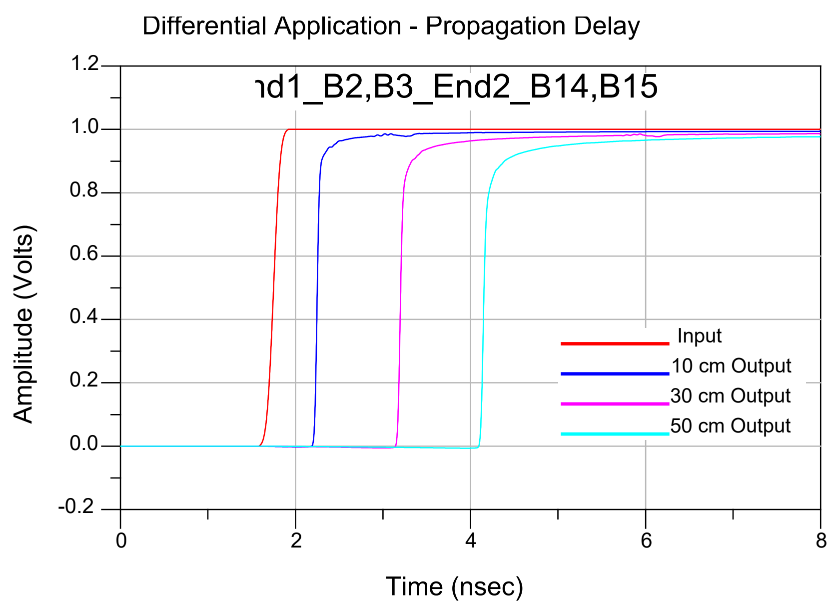

Figure 46

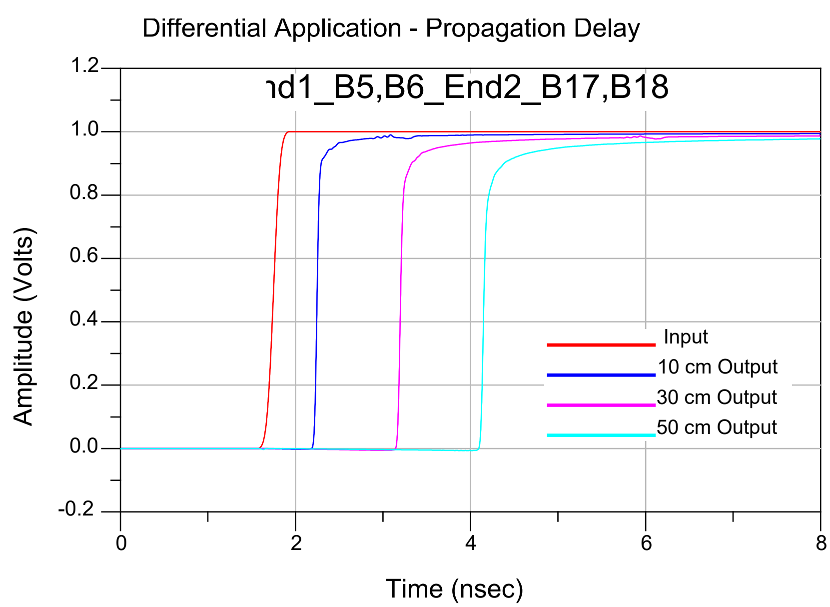

Figure 47

Series: PCUE-G4
Description: PCIe®-Over-FireFly™ Copper Cable Assembly

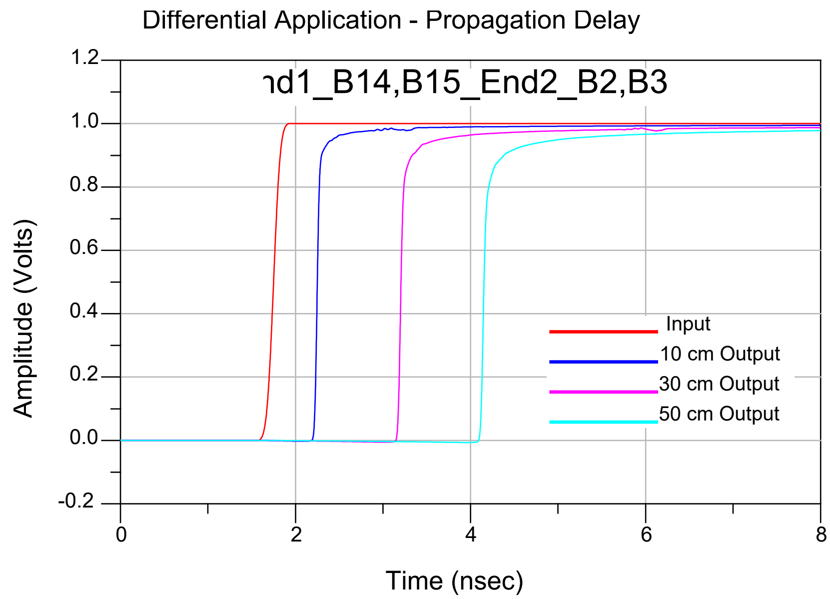

Figure 48

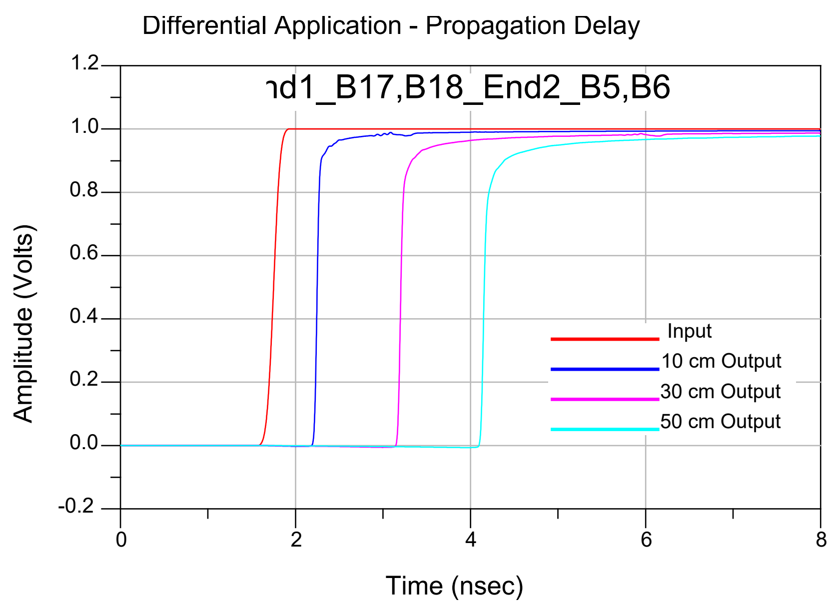

Figure 49

Series: PCUE-G4
Description: PCIe®-Over-FireFly™ Copper Cable Assembly

Appendix C – Product and Test System Descriptions

Product Description

Product test samples are PCIe® Twinax Flyover Cable Assemblies. The part numbers are PCUE-G4-04-010-FF, PCUE-G4-04-030-FF and PCUE-G4-04-050-FF. They mate with UEC5-019-2-X-D-RA-2. A photo of the mated test article mounted to SI test boards is shown below.

The cable assembly terminations had a particular signal line configuration. The respective signal line numbers are shown in Table 3 below. There are a total of 8 pairs.

SIGNAL MAPPING

J1	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19
NAME	G	Tx2N	Tx2P	G	Tx1N	Tx1P	G	DIFF PAIR		G	NC	NC	G	Rx2P	Rx2N	G	Rx1P	Rx1N	G
TYPE		S	S		S	S		D	D					S	S		S	S	
J2	A19	A15	A14	A16	A18	A17	A13	A8	A9	A10	A11	A12	A7	A3	A2	A4	A6	A5	A1

J1	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19
NAME	G	Tx3N	Tx3P	G	Tx0N	Tx0P	G	NC	NC	G	NC	NC	G	Rx3N	Rx3P	G	Rx0N	Rx0P	
TYPE		S	S		S	S								S	S		0N	0P	G
J2	B19	B14	B15	B16	B17	B18	B13	B12	B11	B10	B9	B8	B7	B2	B3	B4	B5	B6	B1

J1	01	02	03	04	05	06	07	08	09	10	UCC8 PADS
NAME	NC	NC	G	NC	RESET	PRESENT	NC	NC	NC	NC	SIDEBANDS
TYPE					S	S					
J2	01	02	03	04	05	06	07	08	09	10	UCC8 PADS

ALL GROUNDS "G" ARE COMMON AND TIED TO CABLE SHIELD AND UCC8 PAD 3
ALL UEC5 "S" SIGNALS HAVE 220nF CAPACITORS IN-LINE
ALL UEC5 "D" AUXILIARY SIGNALS HAVE 0 OHM RESISTORS
ALL UCC8 "S" SIDEBANDS CONNECTED TO NON-SHIELD INSULATED WIRE

Table 3: Respective signal line numbers

Test System Description

The test fixtures are composed of six-layer PSR-4000-BN material with 50Ω signal trace and pad configurations designed for the electrical characterization of Samtec high speed cable assembly products. A PCB mount 2.4mm connector is used to interface the PNA test cables to the test fixtures. Optimization of the 2.4mm launch was performed using full wave simulation tools to minimize reflections. The test fixtures and calibration kit are specific to the PCUE-G4 cable assembly and identified by part number PCB-109194-SIG-01.

PCB-109194-SIG-01 Test Fixtures

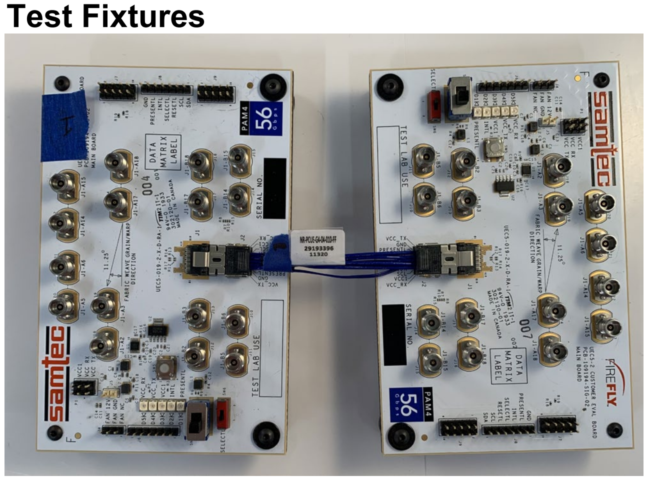

Figure 50

Series: PCUE-G4
Description: PCIe®-Over-FireFly™ Copper Cable Assembly

Artwork of the PCB design is shown below.

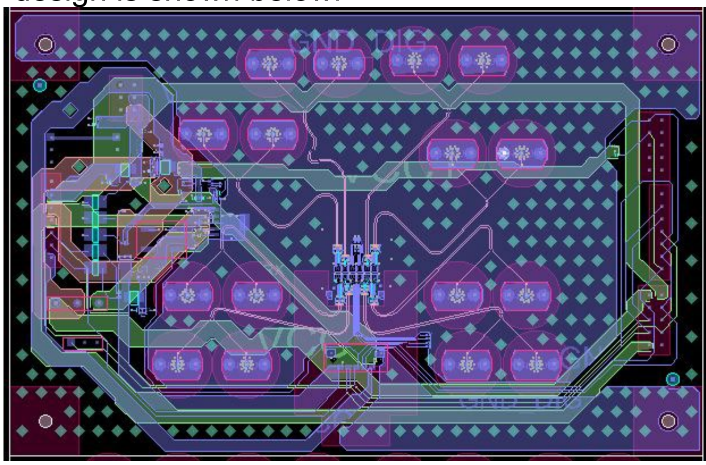

Figure 51

PCB Fixtures

The test fixtures used are as follows:

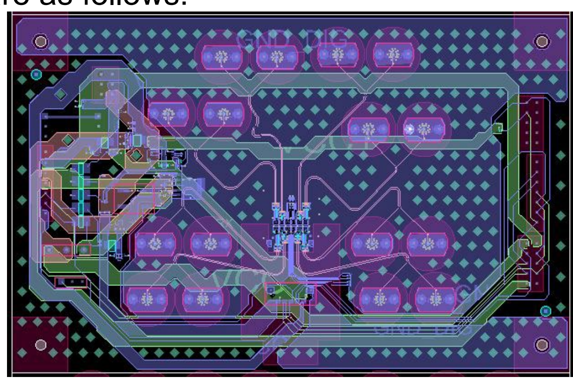

Figure 52

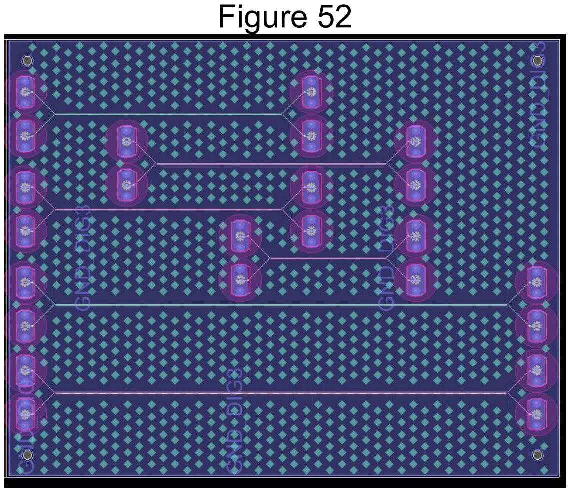

Figure 53

Series: PCUE-G4
Description: PCIe®-Over-FireFly™ Copper Cable Assembly

Appendix D – Test and Measurement Setup

For frequency domain measurements, the test instrument is the Keysight N5225B PNA-L network analyzer. Frequency domain data and graphs are extracted from the instrument by AFR application. Post-processed time domain data and graphs are generated using convolution algorithms within Keysight ADS. The network analyzer is configured as follows:

Start Frequency – 10 MHz
Stop Frequency – 40 GHz
Number of points - 4000
IFBW – 1 KHz

With these settings, the measurement time is approximately 30 seconds.

N5225B Measurement Setup

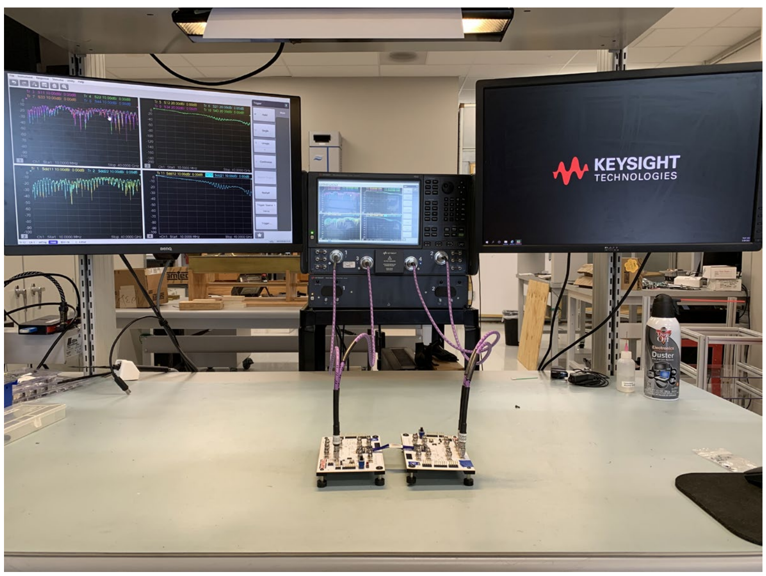

Figure 54

Test Instruments

QTY	Description
1	Keysight N5225B PNA-L Network Analyzer (10 MHz to 40 GHz)
1	Agilent N4694-60003 ECAL Module (10 MHz to 67 GHz)

Test Cables & Adapters

QTY	Description
4	1 m Junkosha 2.4mm male to female cables

Series: PCUE-G4
Description: PCIe®-Over-FireFly™ Copper Cable Assembly

Appendix E - Frequency and Time Domain Measurements

Frequency (S-Parameter) Domain Procedures

The quality of any data taken with a network analyzer is directly related to the quality of the calibration standards and the use of proper test procedures. For this reason, extreme care is taken in the design of the AFR calibration standards, the SI test boards, and the selection of the PCB vendor.

A coaxial SOLT calibration is performed using a N4694-60003 ECAL module. Then DUT measurements are performed under SOLT calibration. The measurements include the effect of test fixture. The measurements of the 2X THRU line standards are required to remove the test fixture effect.

Time Domain Procedures

Mathematically, Frequency Domain data can be transformed to obtain a Time Domain response. Perfect transformation requires Frequency Domain data from DC to infinity Hz. Fortunately, a very accurate Time Domain response can be obtained with bandwidth-limited data, such as measured with modern network analyzer.

The Time Domain responses were generated using Keysight ADS 2017 update 1. This tool has a transient convolution simulator, which can generate a Time Domain response directly from measured S-Parameters. An example of a similar methodology is provided in the Samtec Technical Note on domain transformation.
http://suddendocs.samtec.com/notesandwhitepapers/tech-note_using-plts-for-time-domain-data_web.pdf

Propagation Delay (TDT)

The Propagation Delay is a measure of the Time Domain delay through the cable assembly and footprint. A step pulse is applied to the touchstone model of the cable assembly and the transmitted voltage is monitored. The same pulse is also applied to a reference channel with zero loss, and the Time Domain pulses are plotted on the same figure.
The difference in time, measured at the 50% point of the step voltage is the propagation delay.

Series: PCUE-G4
Description: PCIe®-Over-FireFly™ Copper Cable Assembly

Impedance (TDR)

Measurements involving digital pulses are performed using either Time Domain Reflectometer (TDR) or Time Domain Transmission (TDT) methods. The TDR method is used for the impedance measurements in this report.

The signal line(s) of the SUT's is energized with a TDR pulse and the far-end of the energized signal line is terminated in the test systems characteristic impedance (e.g.; 50Ω or 100Ω terminations). By terminating the adjacent signal lines in the test systems characteristic impedance, the effects on the resultant impedance shape of the waveform are limited.

Series: PCUE-G4
Description: PCIe®-Over-FireFly™ Copper Cable Assembly

Appendix F – Glossary of Terms

ADS – Keysight Advanced Design System
AFR – Automatic Fixture Removal
PCB – Printed Circuit Board
SUT – System Under Test
SOLT – acronym used to define Short, Open, Load & Thru Calibration Standards
TDR – Time Domain Reflectometry
TDT – Time Domain Transmission