Technical Note

Using the Agilent Physical Layer Test System (PLTS) For Acquiring Time Domain Data

Using:
Final Inch® Test/Eval Kit, Differential Pair - No Grounds Configuration, QTE-DP/QSE-DP, 5mm Stack Height (P/N FIK-QxE-04-01)

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Report Revision: 1/12/2006

Series: Final Inch® Test Kit, Differential – No Grounds Configuration, QxE-DP, 5mm Stack Height
Description: Using the Agilent PLTS For Acquiring Time Domain Data

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Introduction

Measured data on passive interconnects (cables, connectors) can be acquired in either the time domain or frequency domain. In principle, data can be transformed into the "other" domain using Fourier transforms. There are two commercial tools currently used by Samtec:

- TDA Systems IConnect TDR and VNA Software (TDA)
  Acquires data in the time domain using a digitizing oscilloscope (Tektronix CSA 8000 with 80E04 sampling module) and can convert to the frequency domain

- Agilent Physical Layer Test Systems version 2.500 (PLTS)
  Acquires data in the frequency domain with a vector network analyzer (Agilent E8364B PNA series network analyzer with N4421B S-parameter test set) and can convert to the time domain

In this report, we compare data taken using TDA and transformed into the frequency domain with data taken in the frequency domain. We will also compare data taken with PLTS and transformed into the time domain with data taken in the time domain.

The Device Under Test (DUT) is a Samtec QTE-DP/QSE-DP QPairs® Final Inch® Test and Evaluation Board.

Conclusions

Correlation in the time domain between the TDA data and the transformed PLTS data was typically within 1 ohm which is within the accuracy of the measurement equipment.

Correlation in the frequency domain between the magnitude of the PLTS data and the transformed TDA data was <0.5 dB for insertion loss and <2dB for return loss. The phase correlation was generally better than 5 degrees except in regions where the phase response had greater structure.

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Samtec QPairs® QTE-DP/QSE-DP Final Inch® Test and Evaluation Board

The Samtec QPairs® QTE-DP/QSE-DP Final Inch® Test and Evaluation Board set (test board) consists of precision SMA launches, controlled impedance stripline traces, and the QTE-DP/QSE-DP high speed connectors (Figure 1). The test boards allow access to 28 different connector pins and are suitable for single ended or differential pair testing.

For this test data, only the J7-J9 pair was used and results are for differential excitation unless noted otherwise. Typically, the test boards are used to empirically measure the performance of a connector or to validate electrical models developed by Samtec. For further information refer to the following Samtec webpage: http://www.samtec.com/signal_integrity/final_inch/test_boards.asp

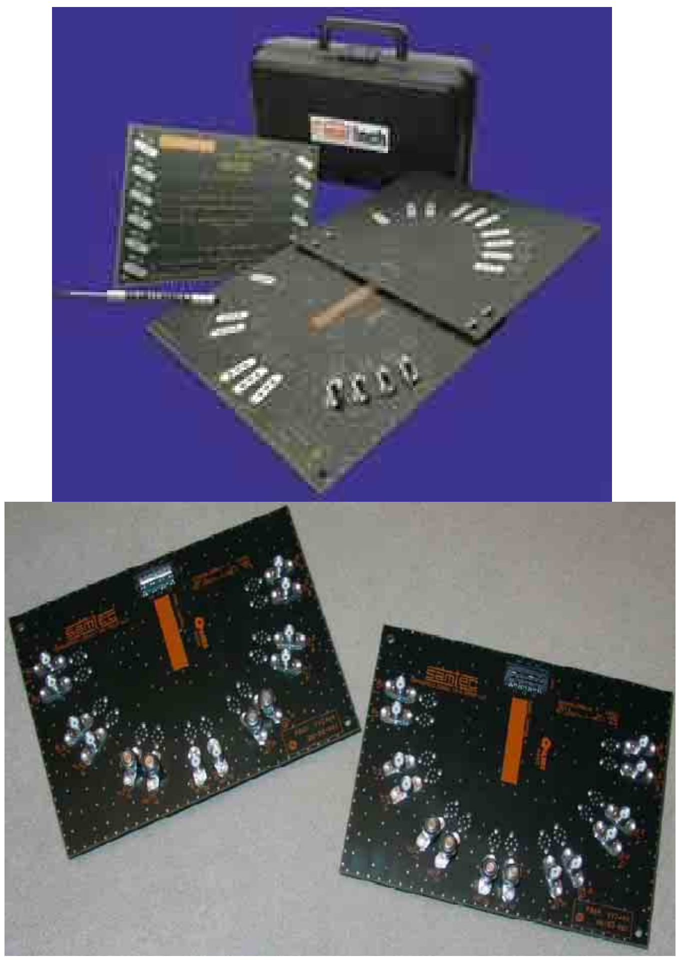

Figure 1: Final Inch® QPairs® Test and Evaluation Board kit (top), QTE-DP/QSE-DP test boards (bottom)

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Agilent PLTS

The Agilent PLTS is broadly classified as a 4 Port Vector Network Analyzer (VNA). It has become popular in characterizing passive interconnect structures for high speed digital applications. Connectors, coupled stripline traces, and cable assemblies can be characterized with the PLTS. The bandwidth used for these measurements is from 10 MHz to 20 GHz.

Calibration

Calibration of the VNA using well defined standards can be complex, but it is critical to achieve accurate measurements. For the data presented in this report, a Short, Open, Load, Thru (SOLT) calibration was performed prior to performing any measurements. The calibration was from 10 MHz to 20 GHz with a step frequency of 10 MHz. Precision 2.4mm cables and a 2.4mm-3.5mm adapter connect the VNA to the test boards. As with any measurement, it is wise to validate the calibration by measuring a known device and verifying that the magnitude and phase response are reasonable.

TDA IConnect

TDA IConnect was used to acquire the time domain waveform from the Tektronix CSA 8000 Oscilloscope. 80E04 sampling heads were used which have an output risetime of approximately 30 ps (10%-90%). IConnect can compute insertion loss and return loss provided a reference waveform is obtained. The reference waveform establishes the reference plane and can account for imperfections in the fixturing. For the return loss computations, an open calibration standard was used. This established the reference plane for the return loss measurement at the SMA interface at the end of the test cable. Differential loss measurements were performed by acquiring differential waveforms from the oscilloscope and processed within TDA using the “compute S-parameter” feature. For the insertion loss computations, a short (~.400”) SMA female-SMA female adapter was used. Because this barrel was used, we would expect a phase off set of approximately 50 ps or 200 degrees at 10 GHz compared to the PLTS data.

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Time Domain Comparison

The Agilent PLTS software has several parameters which can be adjusted that can affect the computed time domain response from the measured frequency domain data. For the purpose of this report, a nominal time domain window was used. This feature is found under the "Tools" menu and adjusts the windowing filter bandwidth.

Impedance

The Agilent PLTS software will export a CSV file for T11 which is the reflected voltage from port 1. For the data shown in Figures 6.1.1, port 1 equates to J7. To compute the impedance profile from the reflected voltage, we use the following equation:

$$Z = Z_0\left(\frac{1+\rho}{1-\rho}\right)$$

where ρ is the coefficient of reflection and Z0 is the reference impedance. This calculation was included in the Excel spreadsheet used to process the data in Figure 2 and 3.

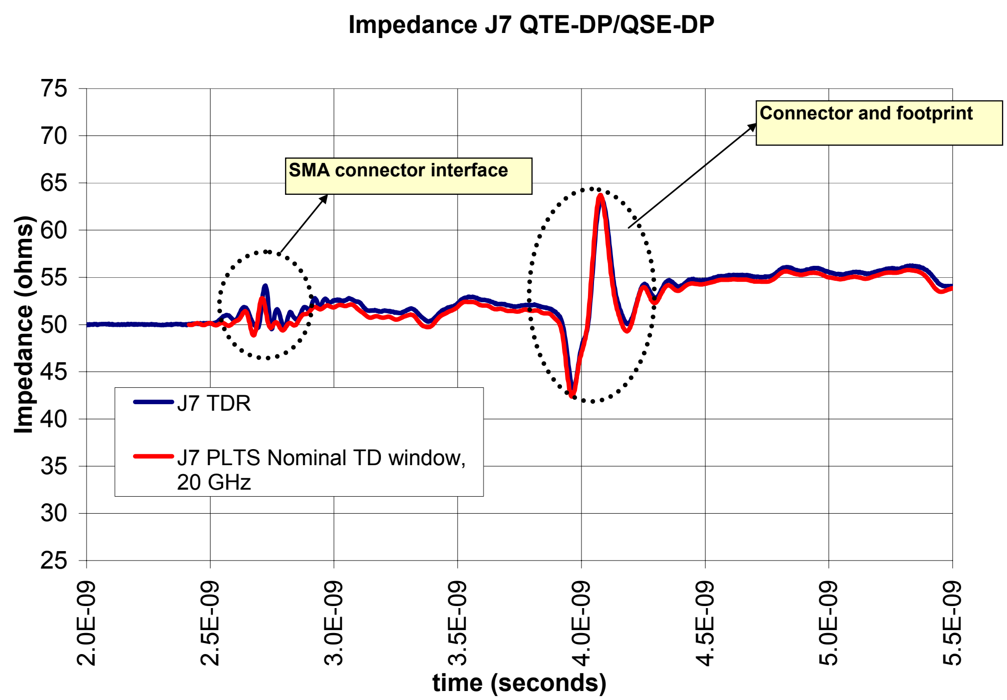

Figure 2: Comparison of Single-Ended Impedance Profiles

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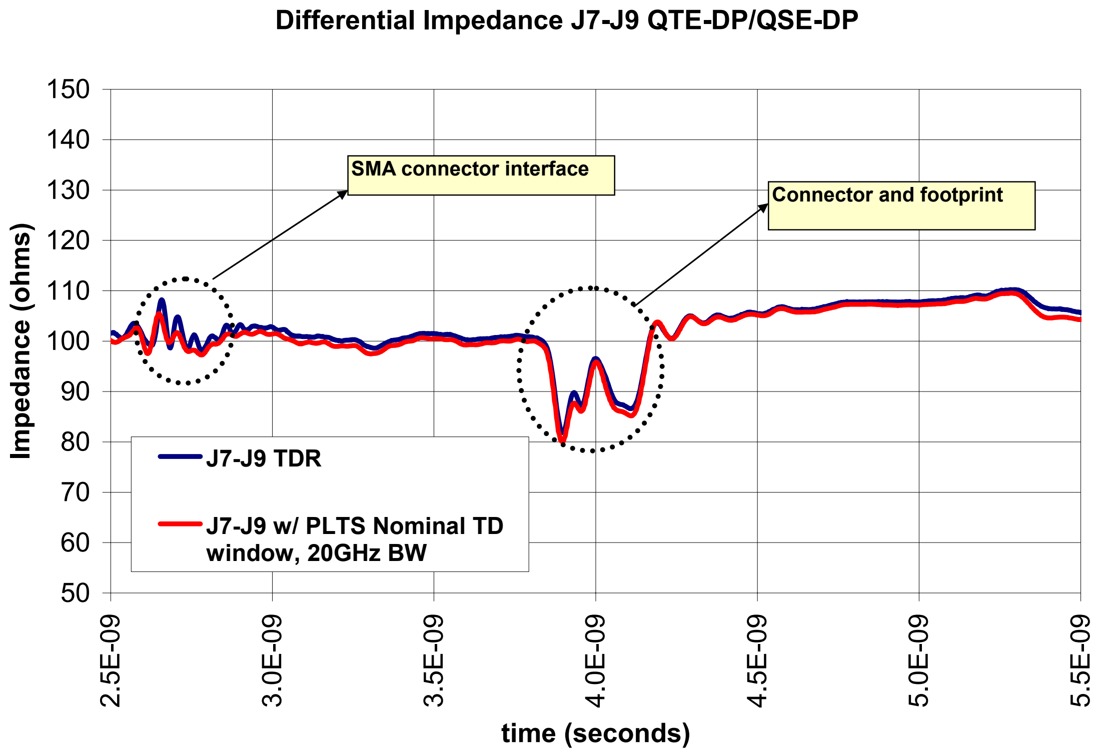

Figure 3: Comparison of Differential Impedance Profiles

The correlation between the time domain data taken with TDA closely matches the frequency domain data taken with the PLTS system which was transformed into the time domain.

Time Domain Transmission (TDT)

The PLTS software exports a CSV file of T21 (TDT) which can be read into Excel. To get the time scales to line up, an offset time needs to be added to the PLTS time vector. The PLTS software exports the TDT voltage with an amplitude of 1 volt. To get the single-ended voltage scales to line up, the voltage vector was multiplied by a factor of 0.25 to mimic the 250 mVp step voltage used by TDA. This voltage vector factor is 0.5 for the differential data in Figure 5

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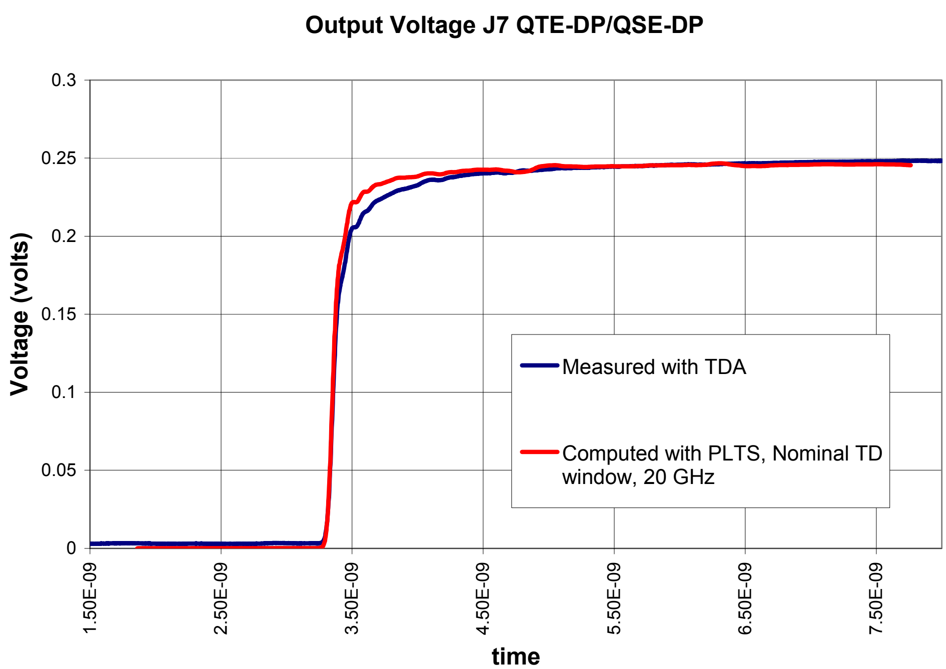

Figure 4: Comparison of Single-Ended TDT Voltages

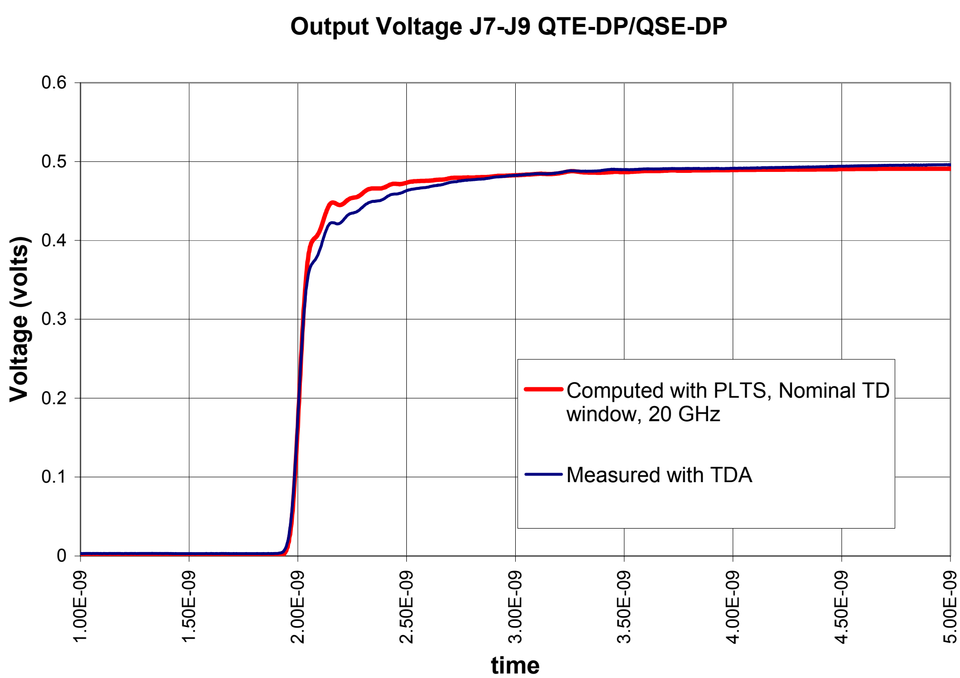

Figure 5 Comparison of Differential TDT Voltages

The correlation between the PLTS and TDA appears to be moderate based on the Figures 4 and 5. The differences were studied and are fundamental in nature. The PLTS TDT does not include the effect of instrumentation cable, whereas the TDA TDT includes the degradation associated with the lossy instrumentation cables. Improved correlation was achieved when the instrumentation cables were shortened from 1 meter to 6 inches.

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Frequency Domain Comparison

Since TDA has the ability to transform data from the time domain into the frequency domain, we can also make frequency domain comparisons.

Insertion Loss

As described in Section 5, a phase offset is introduced to the TDA data due to the use of a SMA female-SMA female barrel in the reference measurement. The phase of this adapter was measured to be 48 pS. This electrical length was subtracted from the TDA data to get the phase correlation shown in Figures 6 and 7.

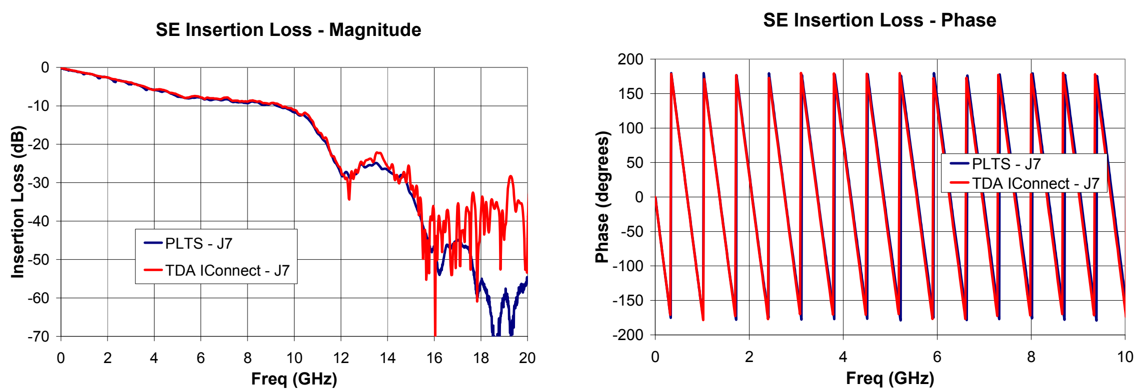

Figure6: Single-Ended Insertion Loss – Magnitude (left), Phase (right)

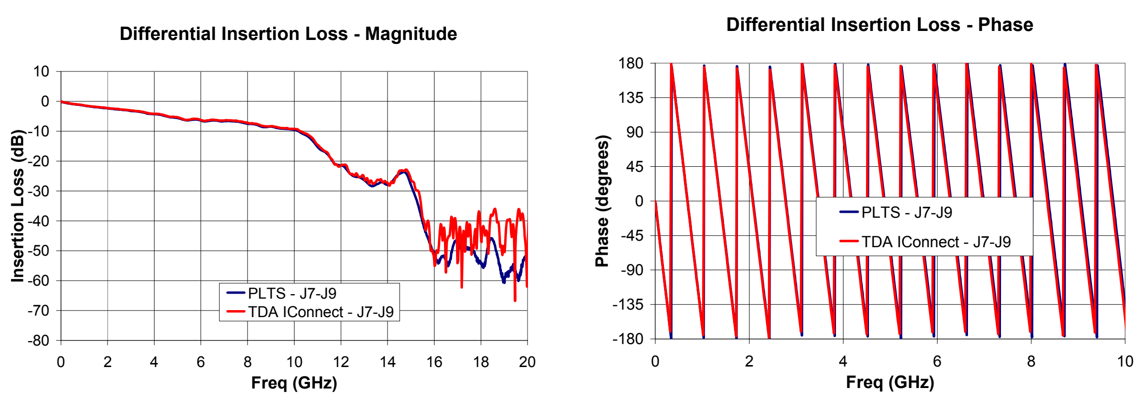

Figure 7: Differential Insertion Loss – Magnitude (left), Phase (right)

Overall, the correlation between PLTS and TDA is quite good for the single-ended and differential insertion loss. As expected, the PLTS dynamic range is greater than that achieved with TDA.

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Return Loss

The return loss measurements used an open circuit as a reference, so it does not have the phase offset associated with the insertion loss measurements. Generally, the correlation between the two sets of data is quite good with a maximum magnitude difference of approximately 2 dB as shown in Figures 8 (left) and 9 (left). The correlation between the phase data sets is also quite good as shown in Figures 8 (right) and Figure 9 (right). Where the phase response has a complex response, the correlation is not as good as shown in Figure 10.

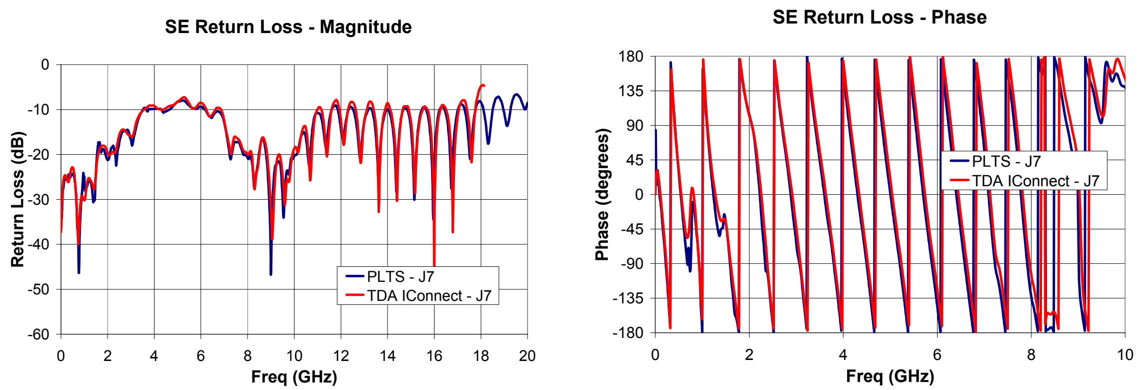

Figure 8: Single-Ended Return Loss – Magnitude (left), Phase (right)

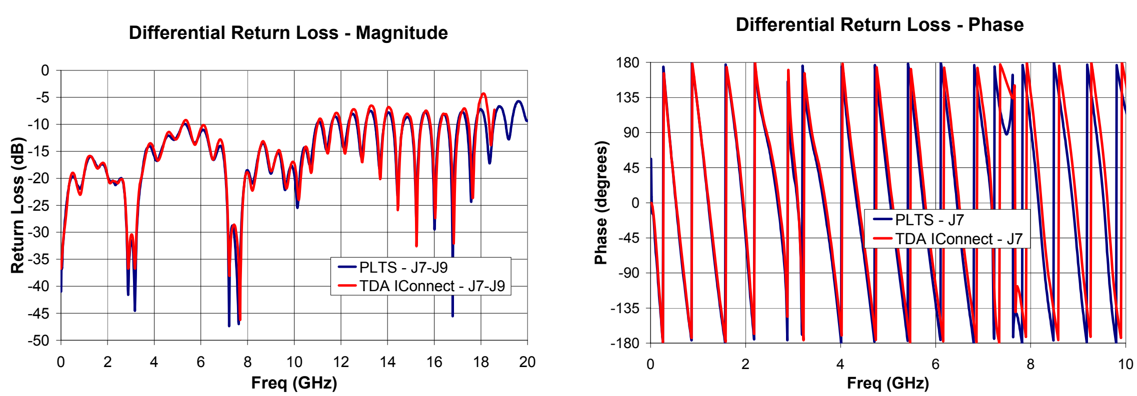

Figure 9: Differential Return Loss – Magnitude (left), Phase (right)

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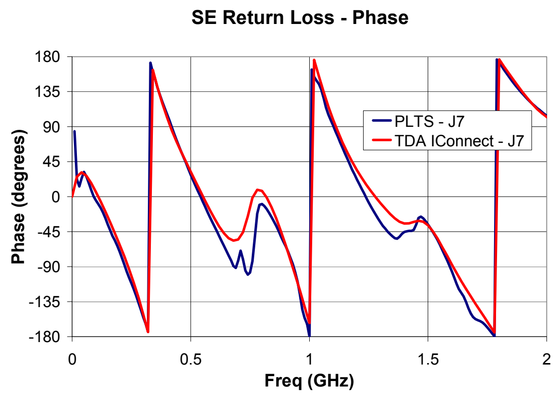

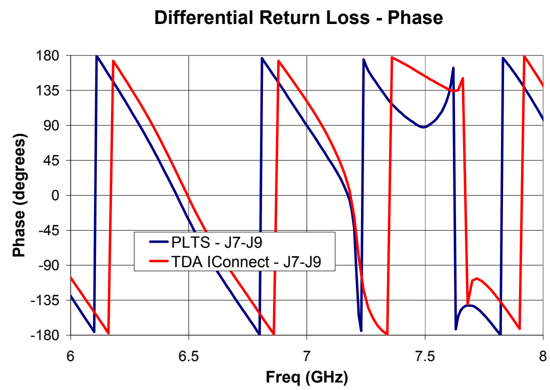

Figure 10: Expanded Phase Plots, Single-Ended Return Loss (left), Differential Return Loss (right)

Equipment List

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Agilent Physical Layer Test System (PLTS)

- Agilent Technologies E8364B 10 MHz - 50 GHz PNA Series Network Analyzer
- Agilent Technologies N4421B 10 MHz - 50 GHz S-Parameter Test Set
- Agilent Physical Layer Test System Version 2.500 (Control Software)

IConnect and MeasureXtractor (TDA)

- Tektronix CSA 8000 Communication Signal Analyzer
- Tektronix 80E04 Sampling Head
- Time Domain Analysis Systems Inc., IConnect and MeasureXtractor (TDA) Version 3.5.0

Summary

In this report, we demonstrated that data taken in the frequency domain and post-processed using PLTS has very reasonable correlation with data taken in the time domain. We also showed that data taken in the time domain and post processed into the frequency domain using TDA has very reasonable correlation with data taken in the frequency domain. Correlation of the phase response extracted from TDA has not been widely published which makes this report unique. Also, it was noted that TDT voltage waveforms between PLTS and TDA are fundamentally different in that PLTS de-embeds the influence of the test cables whereas TDA does not have an obvious method for doing so.