Using ADS to Post Process Simulated and Measured Models

Presented by Leon Wu
March 19, 2012

Presentation Outline

- Connector Models From Simulation
- Connector Models From Measurement
- The Post-processing, The Correlation
  - Model Quality Factor
  - Feature Selective Validation
- Channel Simulation
- Conclusions

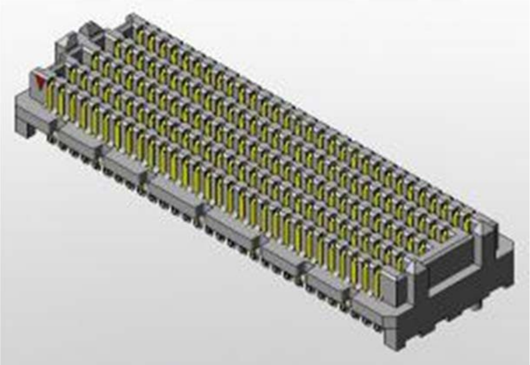
Connector Models - Brief History

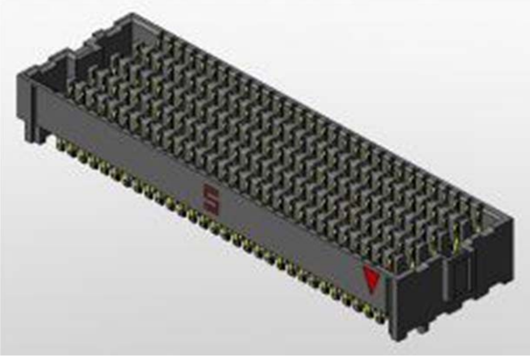
– Connector models started as simple lumped element models	’70’s - ‘80’s
– Evolved into distributed models including coupling	‘80’s to ‘90’s
– Multiport microwave network simulation [S]	‘90’s to present
– Increased adoption of de-embedded measurements for correlation	‘00’s to present

Connector Models From Simulation

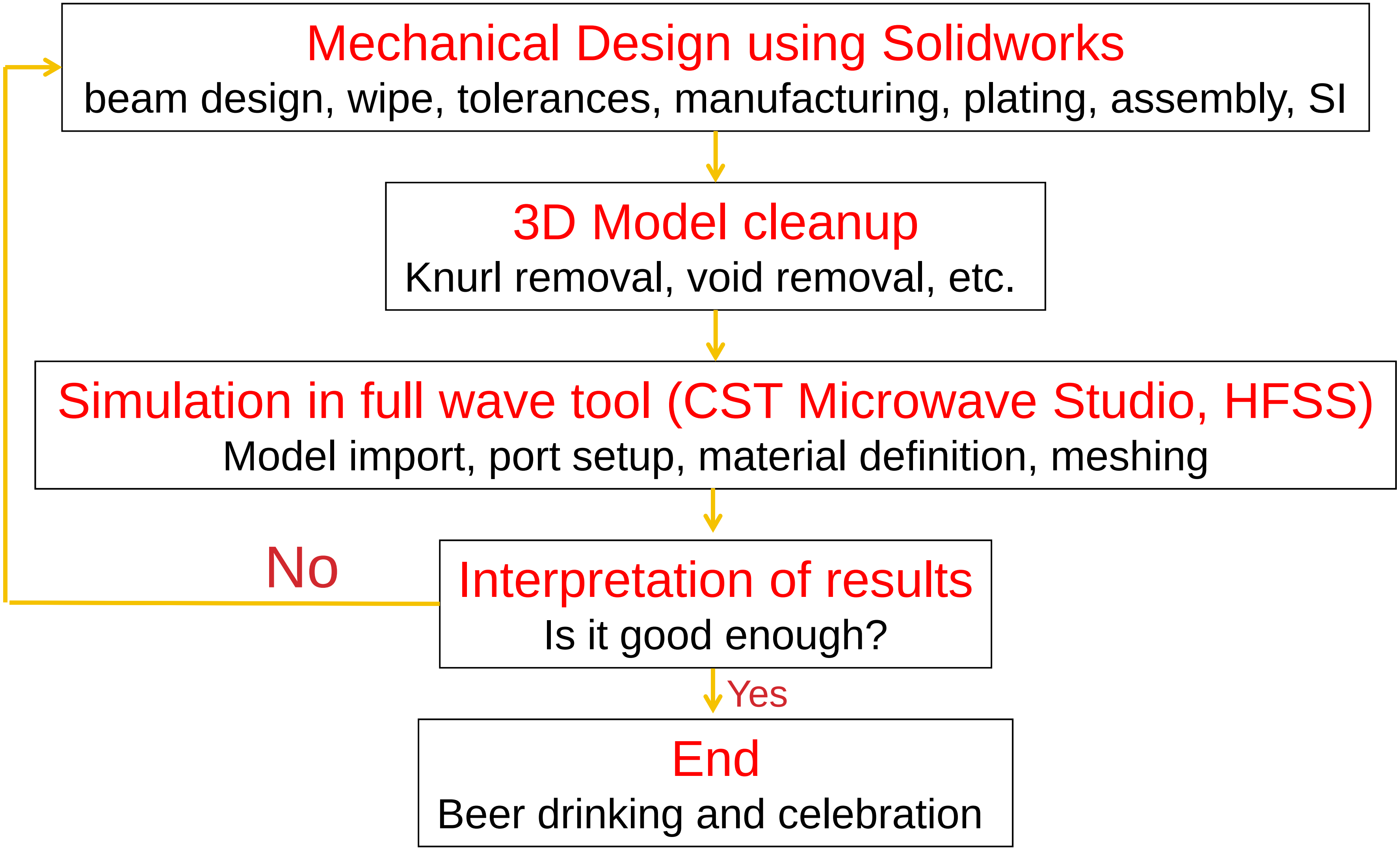
- For this study, we consider a high density, open pin field array connector - SEARAY™ SEAM/SEAF Series
- Up to 10 rows, 50 pins/row on .050” pitch
  (500 pins)
- Typically used in an offset GGSSGG pattern

G G S S G G S S G G
S S G G S S G G S S





Typical Development Process



Mechanical Design using Solidworks

beam design, wipe, tolerances, manufacturing, plating, assembly, SI

3D Model cleanup

Knurl removal, void removal, etc.

Simulation in full wave tool (CST Microwave Studio, HFSS)

Model import, port setup, material definition, meshing

Interpretation of results

Is it good enough?

End

Beer drinking and celebration

Connector Models From Simulation

What could possibly go wrong?

- Meshing
- Material parameters
- Port setup
- Geometry capture

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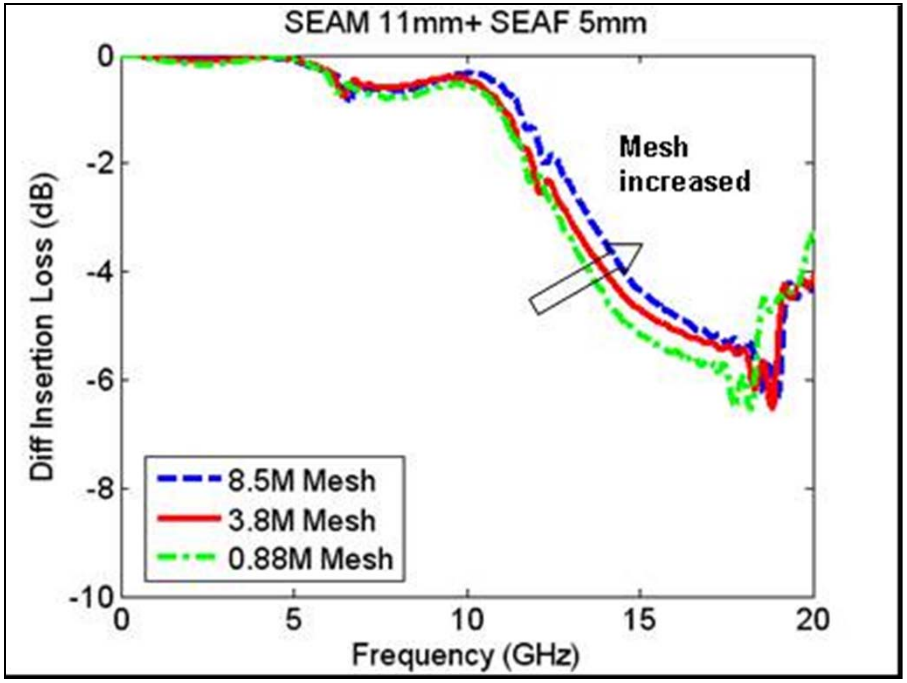

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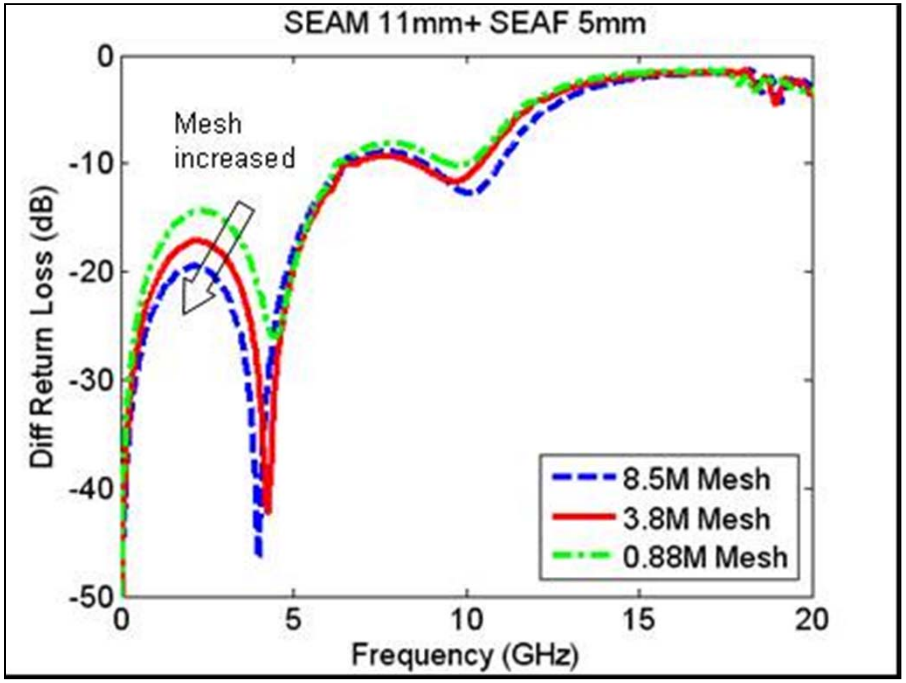

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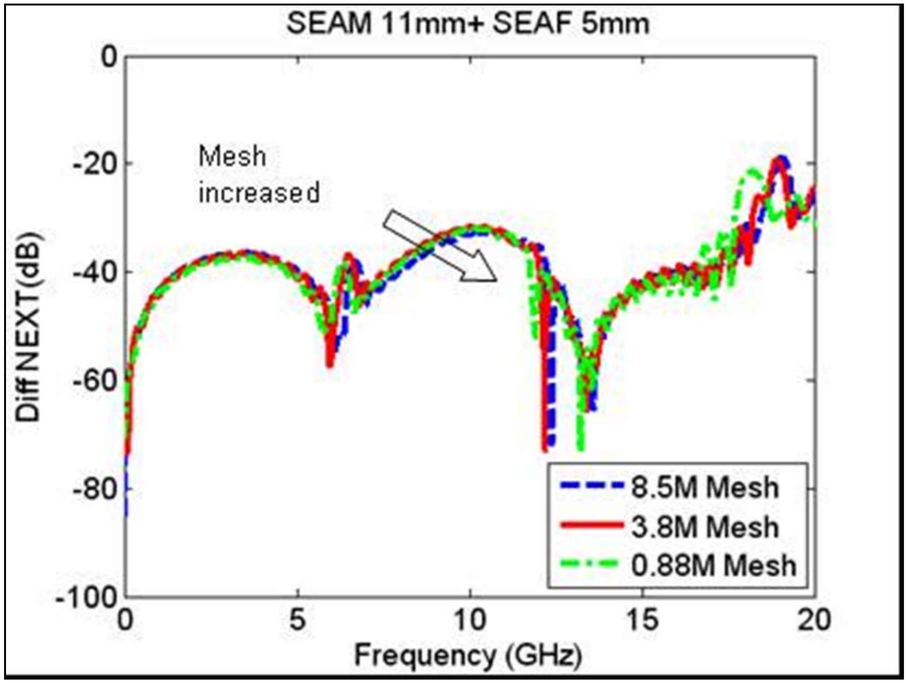

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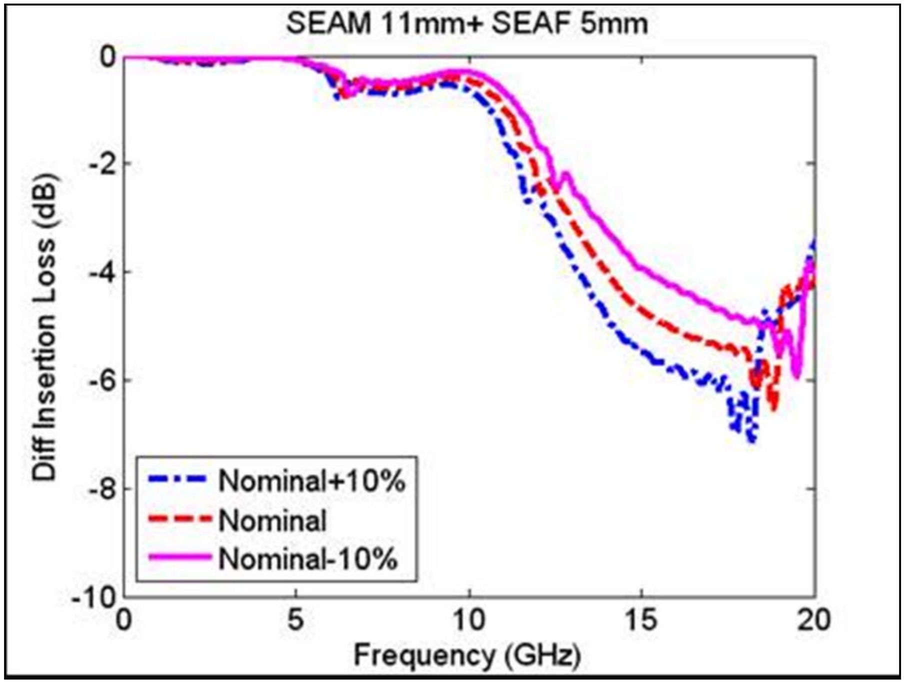

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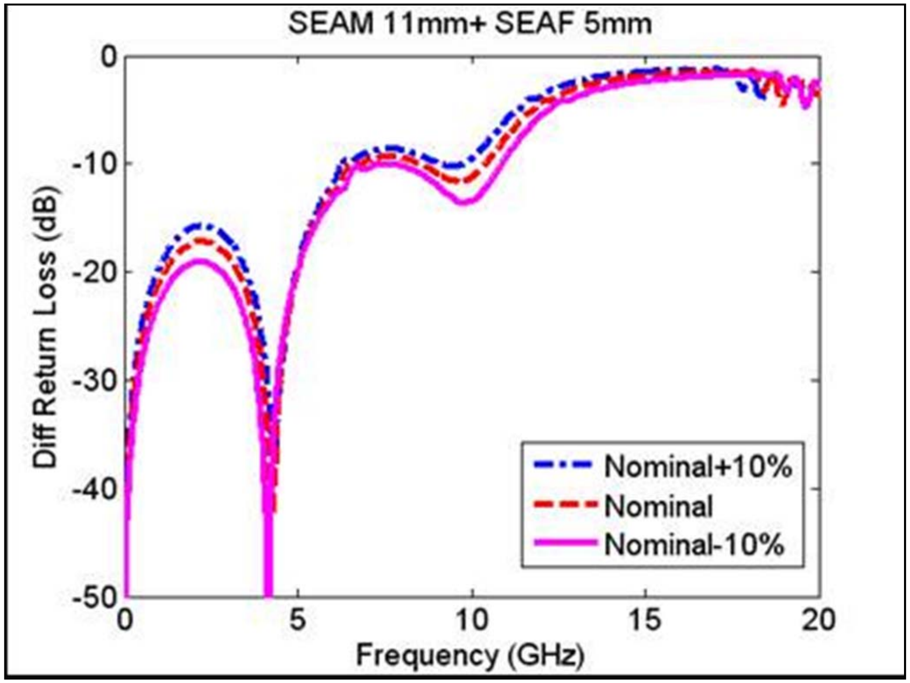

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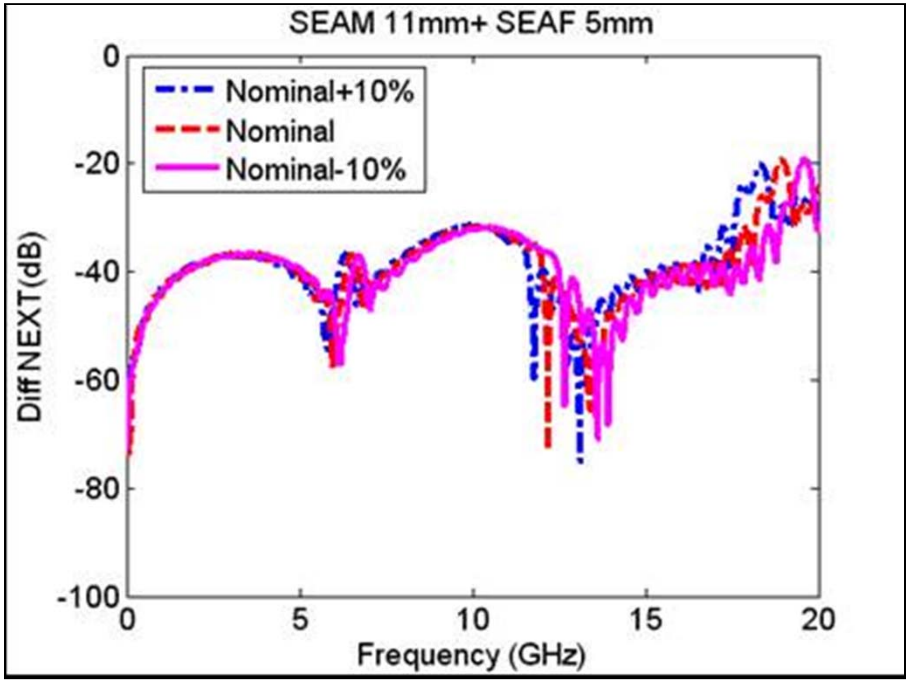

Connector Models From Simulation

What could possibly go wrong?

- Meshing
- Material parameters
- Port setup
  - Coupled ports – waveguide or discrete?
  - Absorbing or perfect BC?
- Geometry capture
  - Air voids?
  - Reference plane location?
  - Footprint effects?

No data here…just need "skill" with the full wave tools ☺

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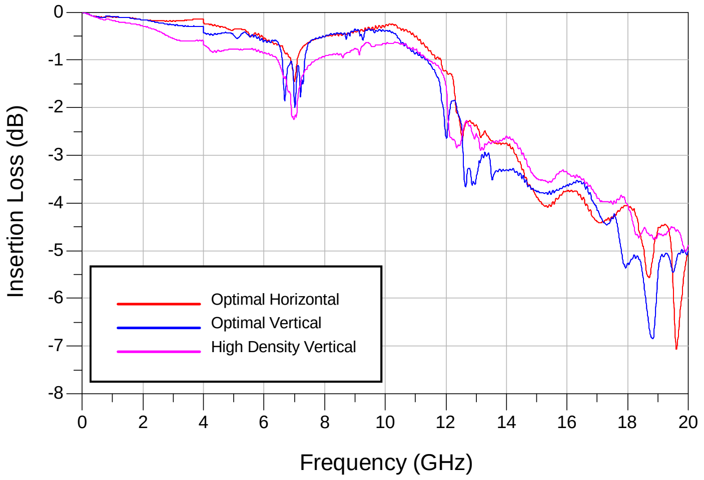
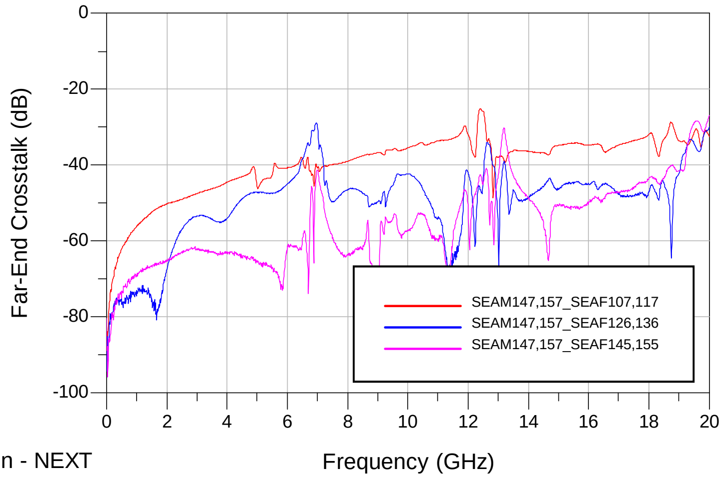
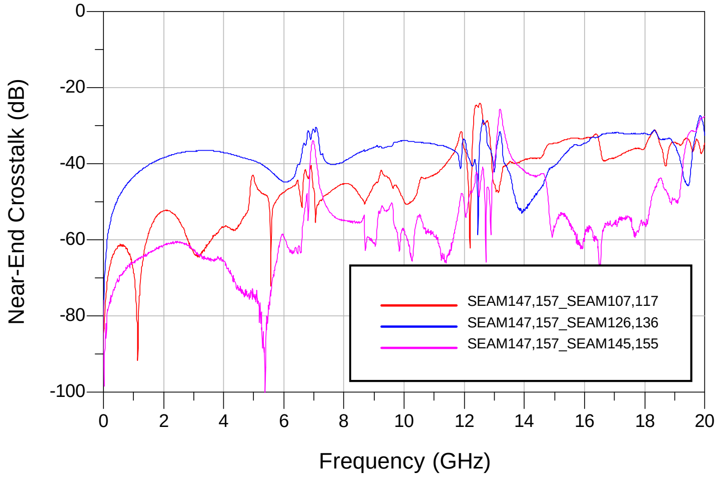
Connector Models From Measurement

Frequency Domain

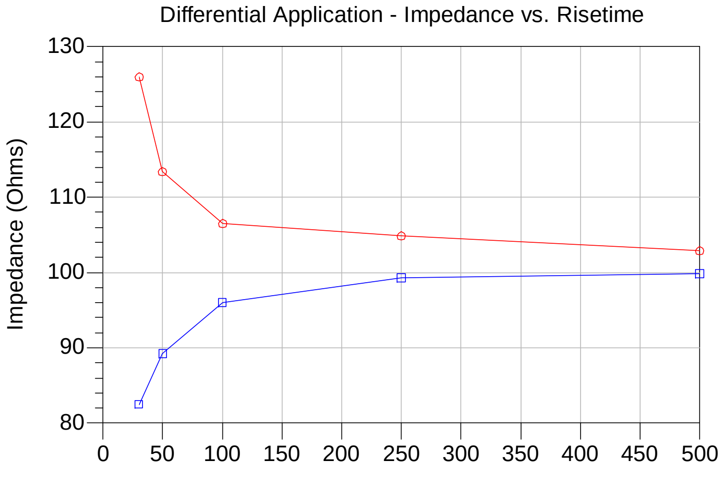

Differential Application - Insertion Loss


Differential Application - FEXT

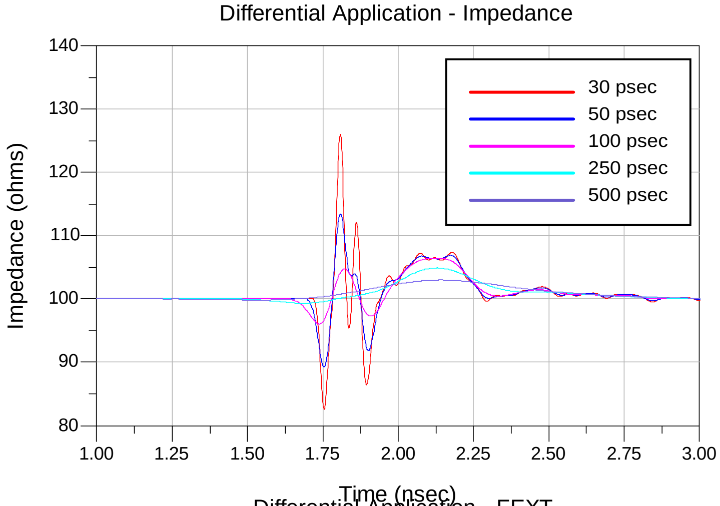

Differential Application - NEXT

Connector Models From Measurement

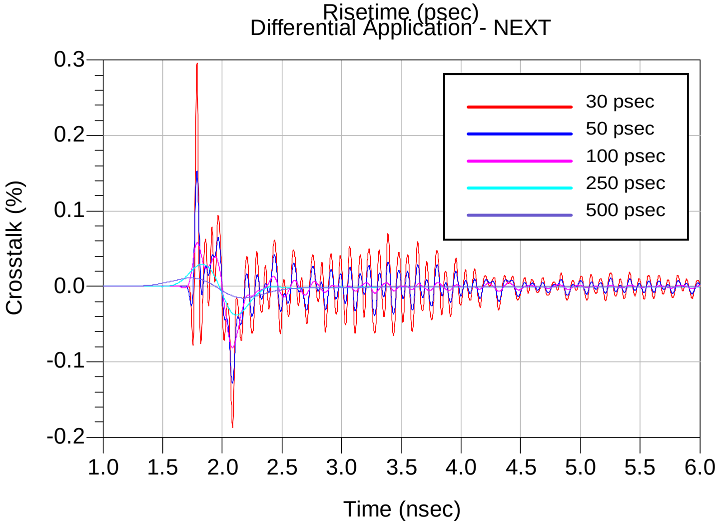
Time Domain (Post processing)



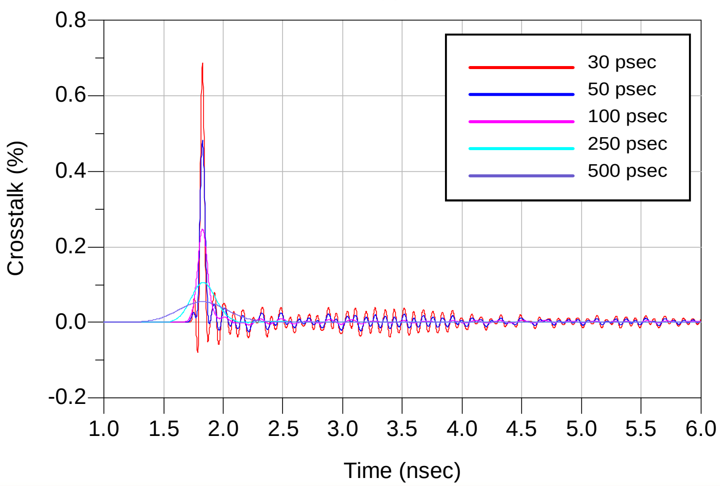
Differential Application - Impedance vs. Risetime



Differential Application - Impedance



Differential Application - NEXT



Differential Application - FEXT

Connector Models From Measurement

What could possibly go wrong?

- Test board footprint
  (aka geometry capture)
- Insertion depth
- Soldering/attachment
- Calibration

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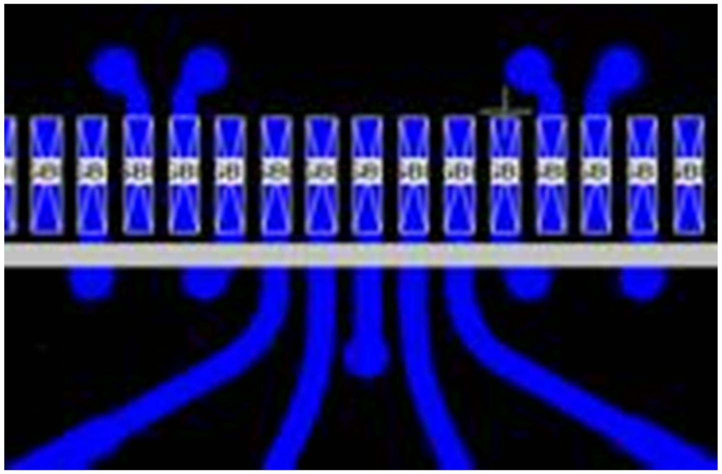

Case 1 – “inboard via”

Case 2 – “outboard via”

* Note – the data on the following three slides is for a 2 row FT5/FS5 Series connector. It is the only data that is not for the 16mm array SEAM/SEAF Series.

Connector Models From Measurement

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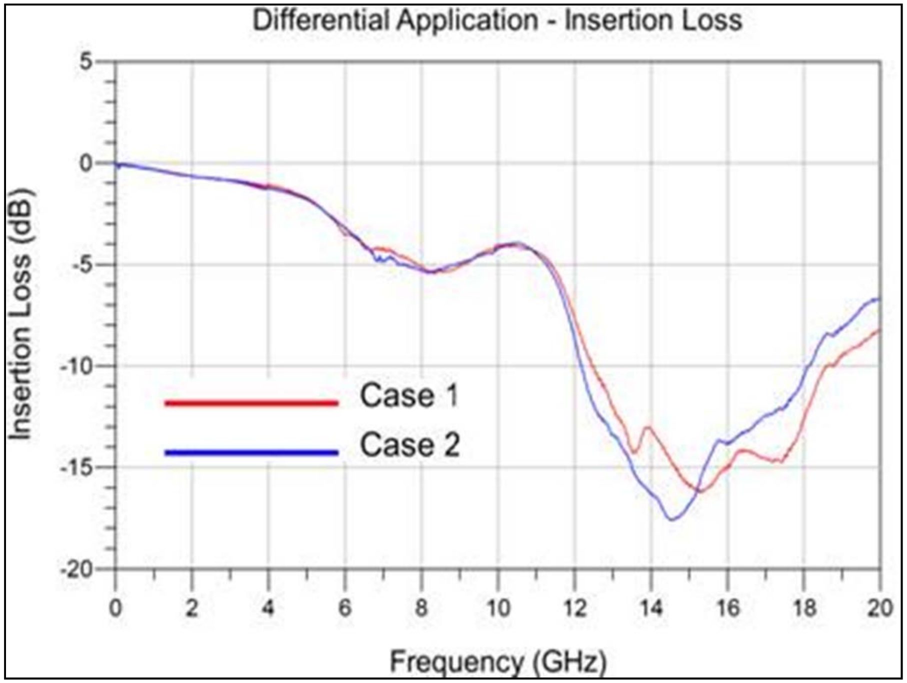

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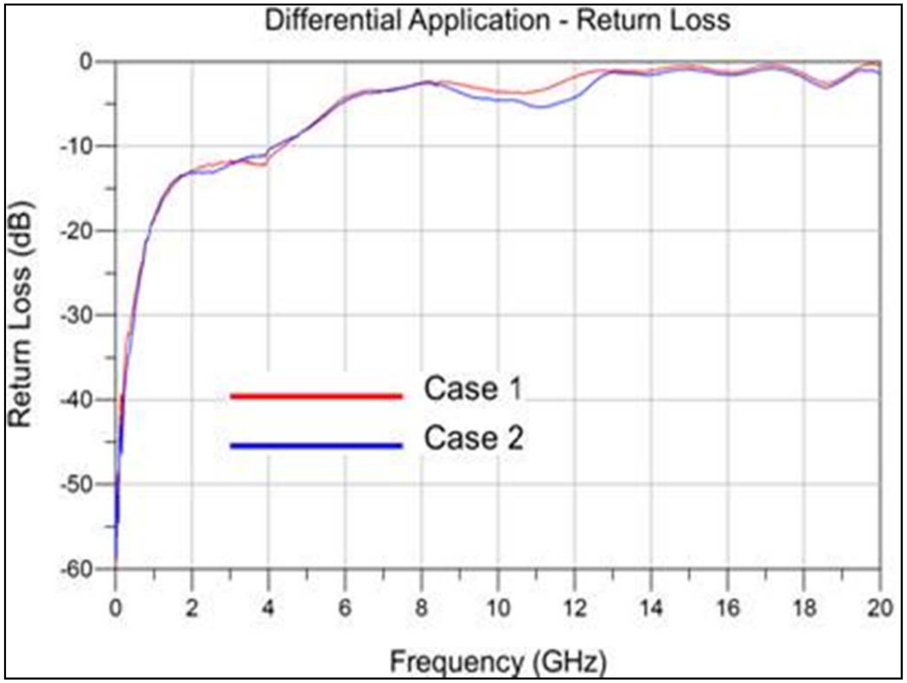

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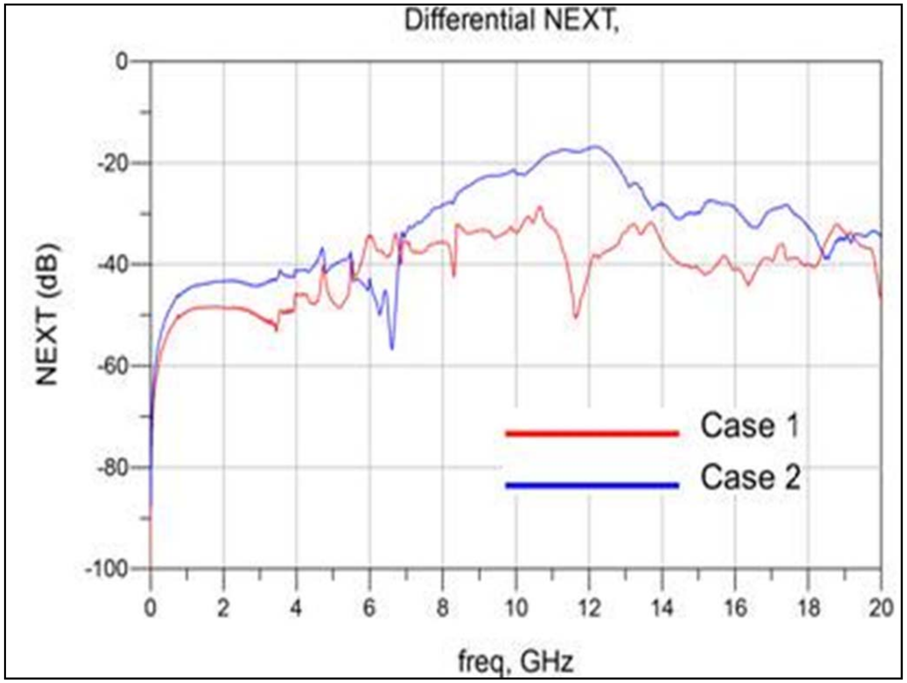

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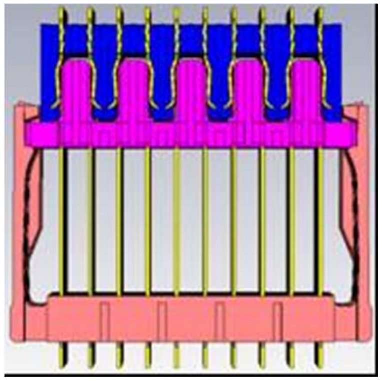
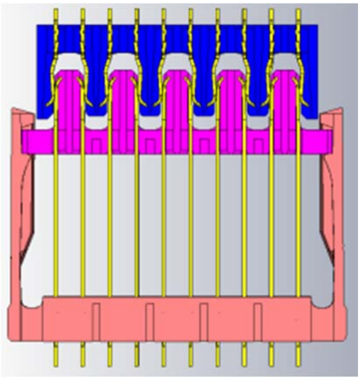


"Fully Mated"



"Shift 19.7 mils"

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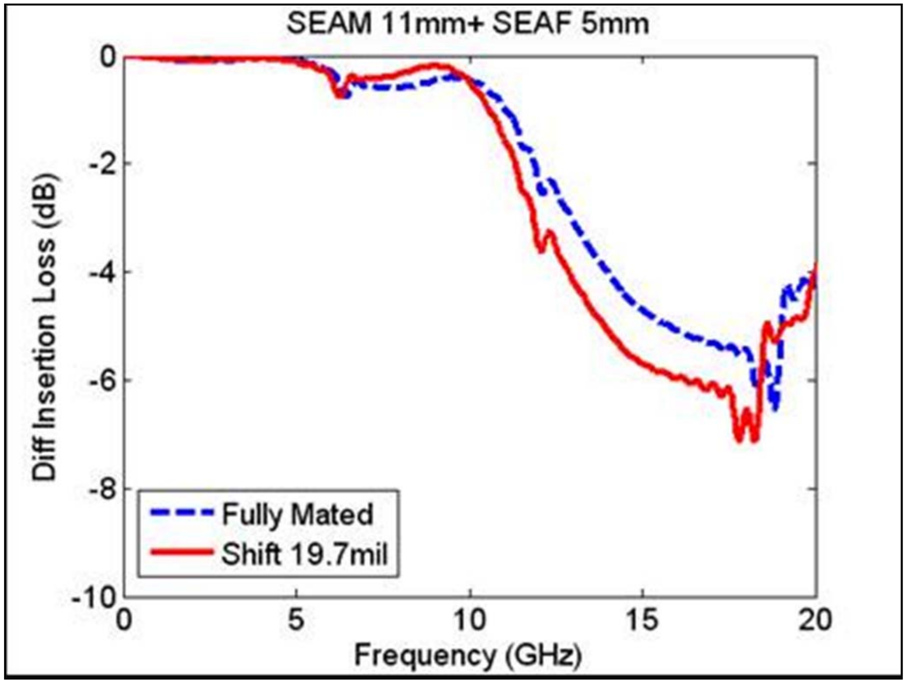

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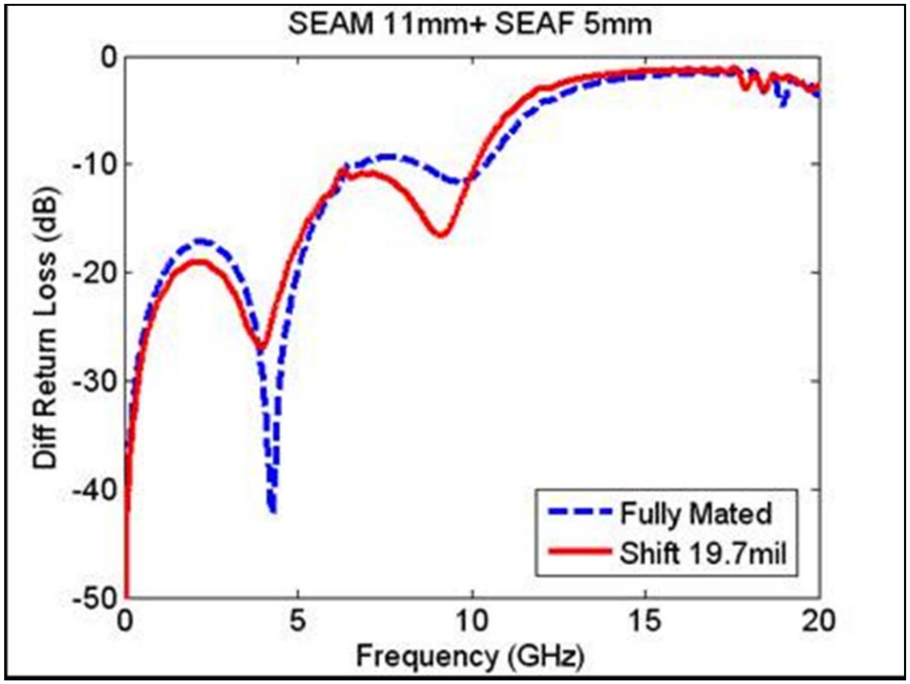

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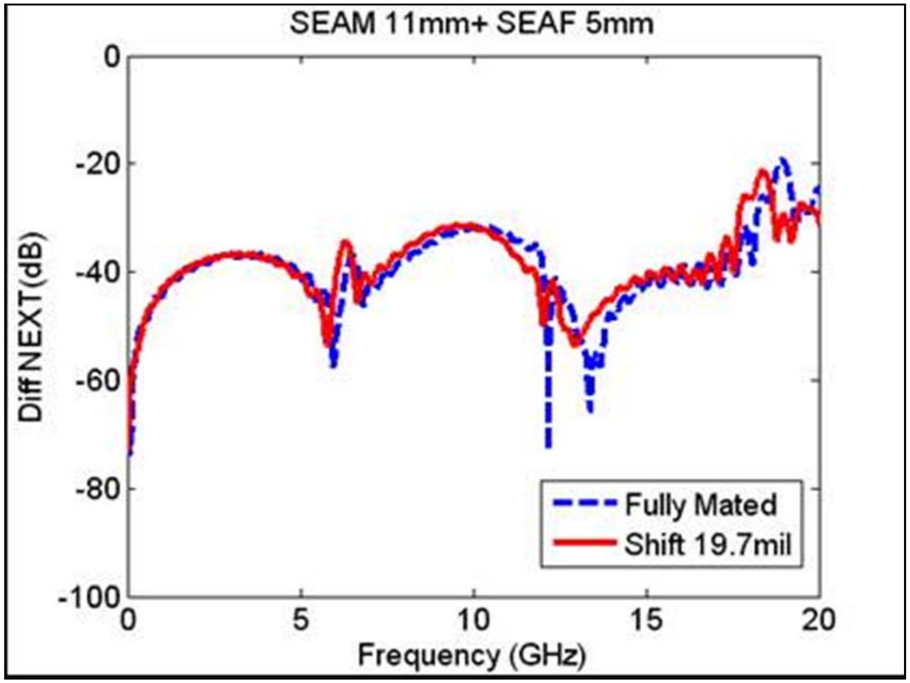

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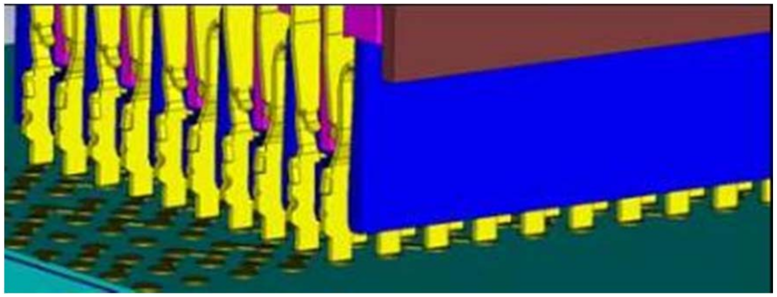
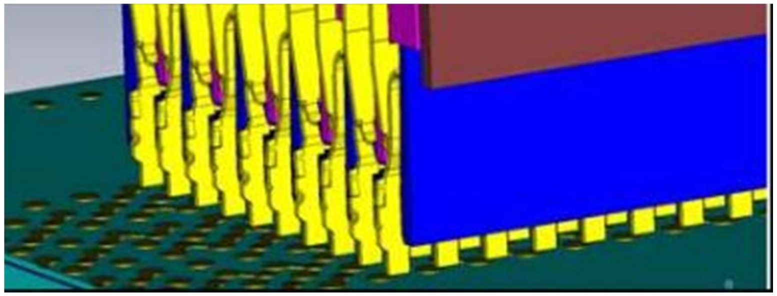


"Middle of Pad"



"Edge of Pad"

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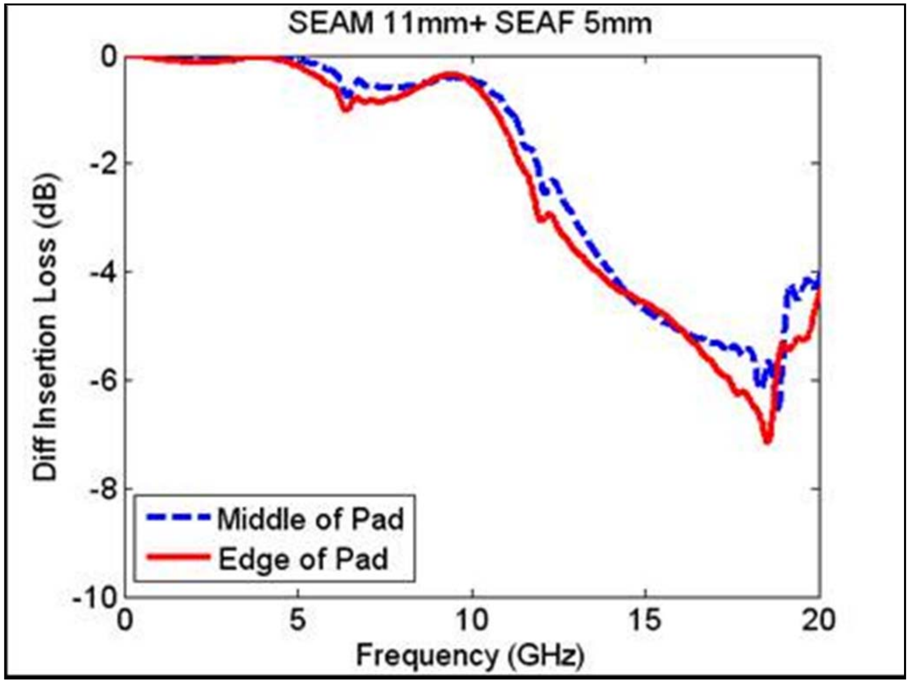
SEAM 11mm+ SEAF 5mm

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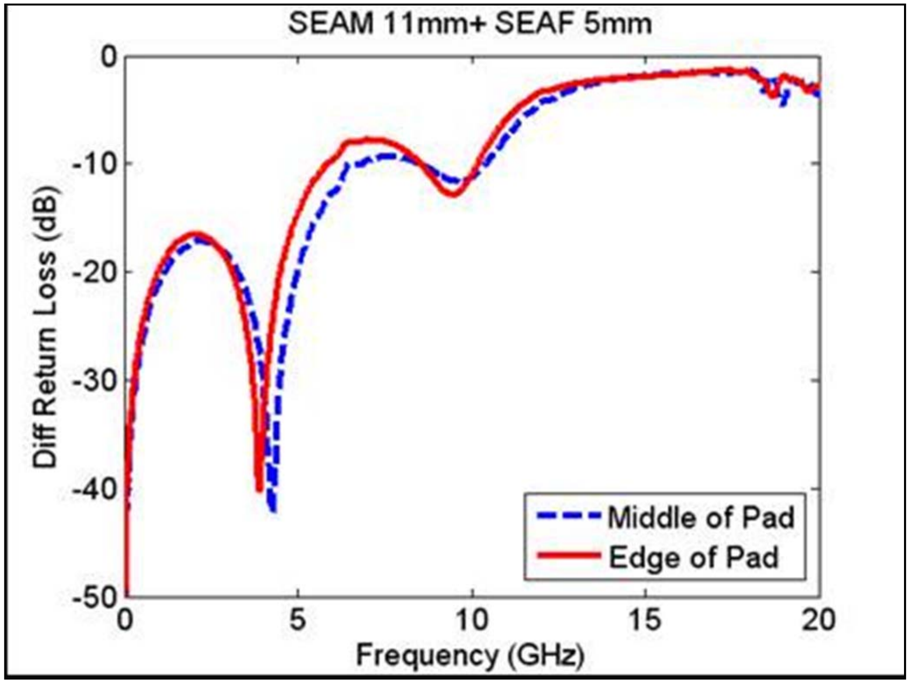

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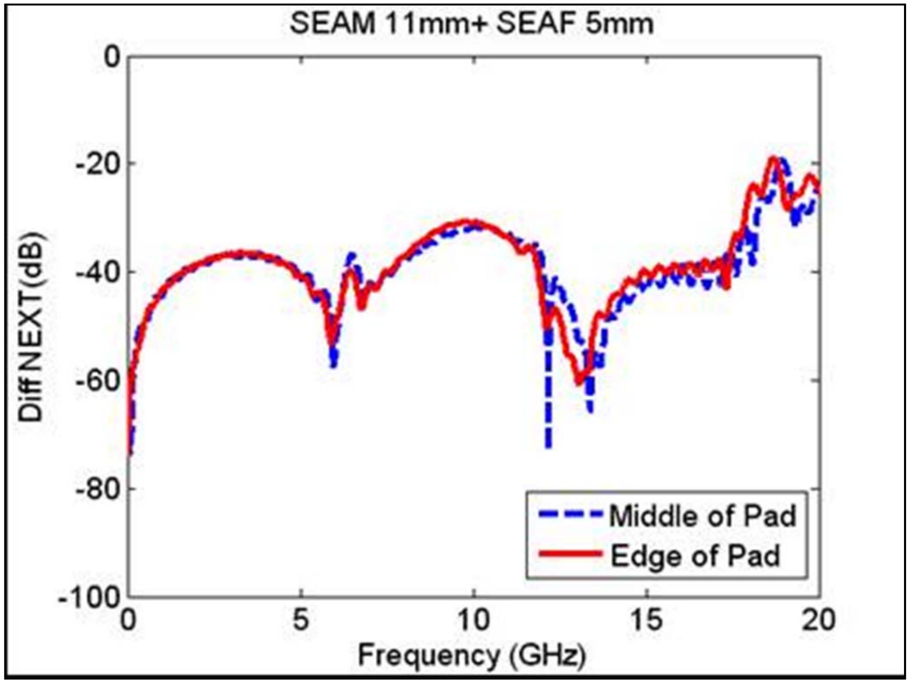

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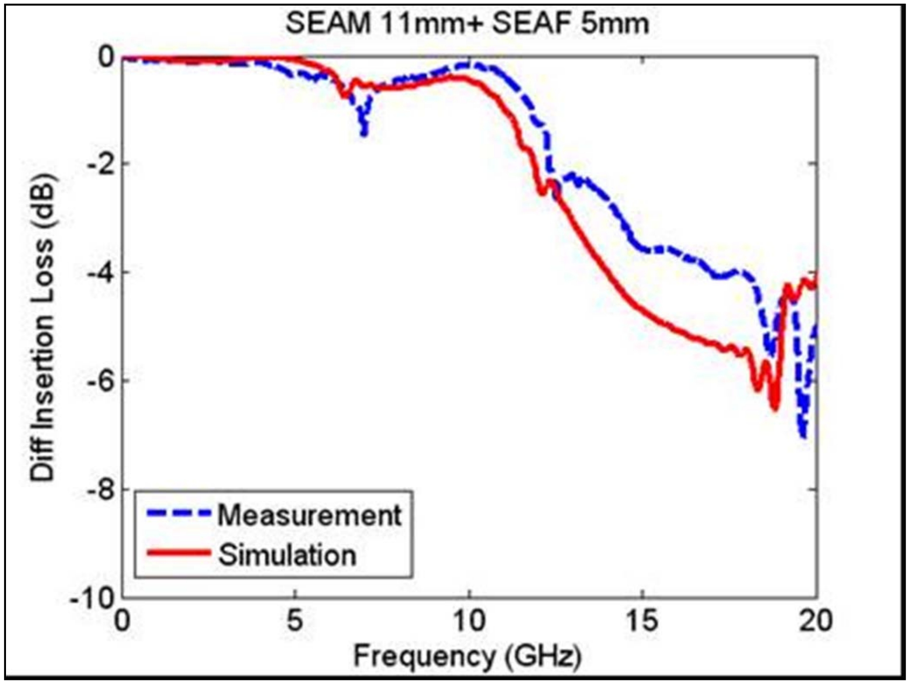
Correlation

How well do the measurements match the simulation?

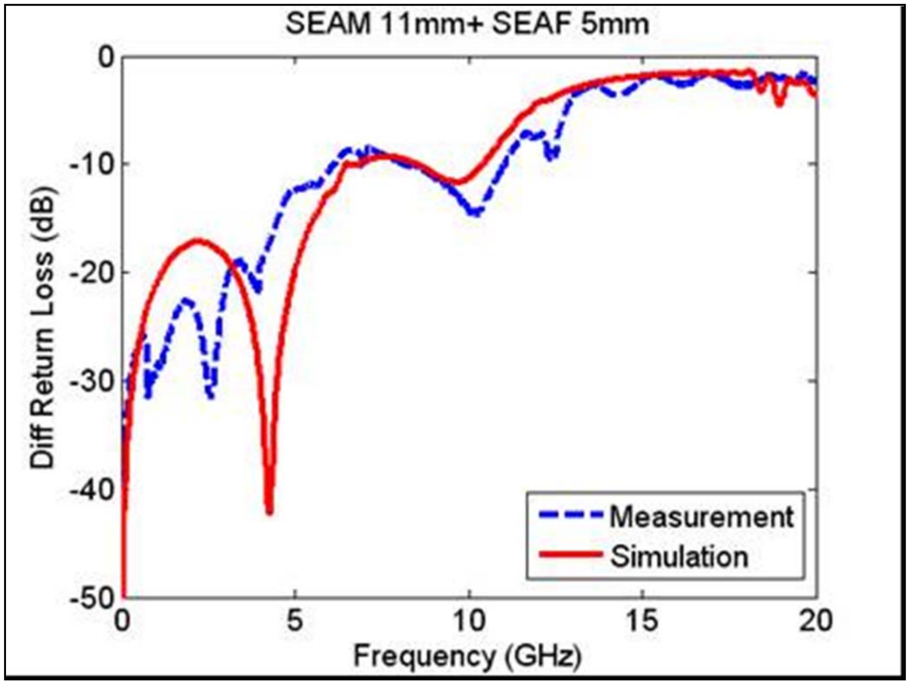
- Good?



Correlation

How well do the measurements match the simulation?

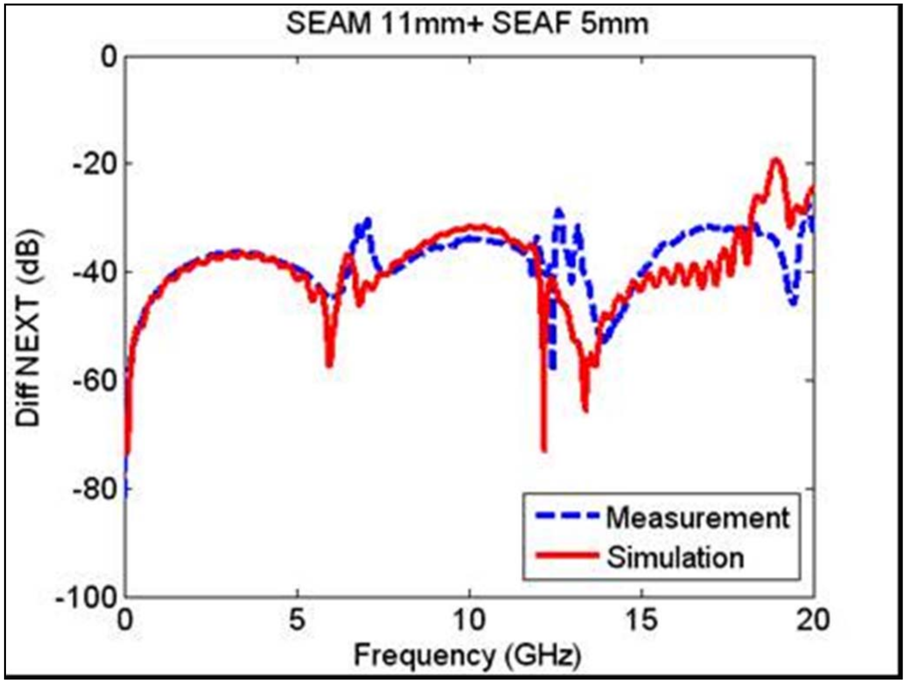
- So-so?



Correlation

How well do the measurements match the simulation?

- Not too shabby?



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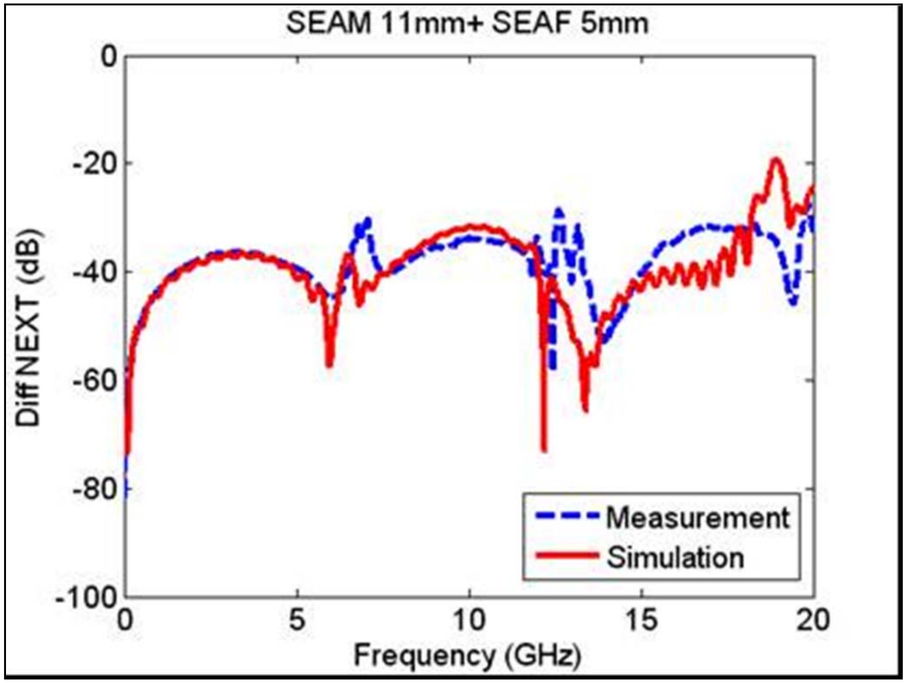
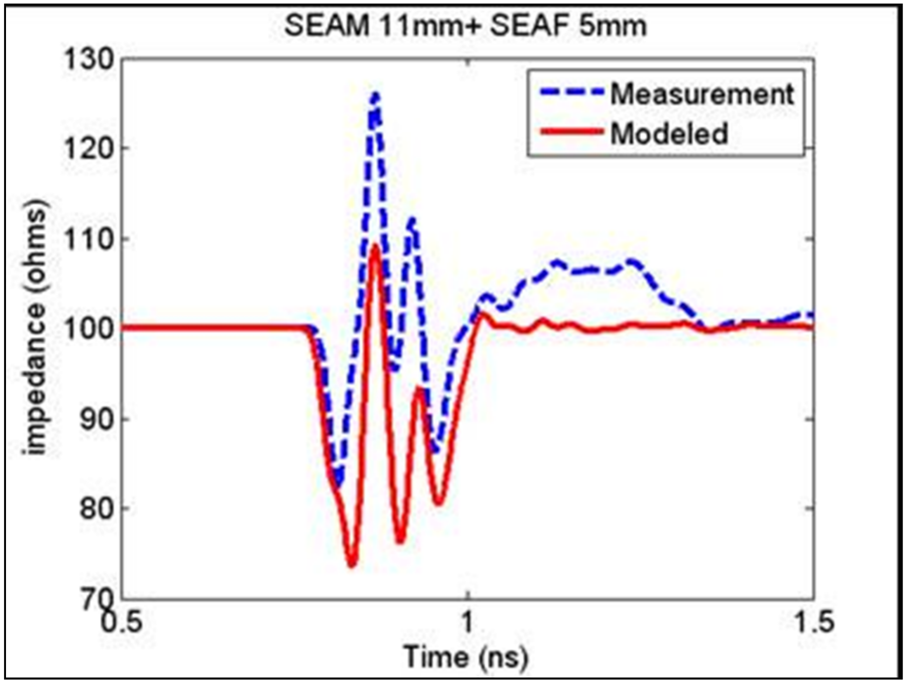


Correlation

How well do the measurements match the simulation?

- Solid "B" work?



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Model Quality Factor

Model correlation can be quantified to avoid qualitative judgment (“not too shabby of a match”)

Method 1 – Model Quality Factor (MQF) championed by Intel

- Requires the computation of areas under a curve
- Big xx – good correlation
- Small xx – poor correlation

$$MQF = \log_{10} \frac{x_1}{x_2}$$

- **xx= Model Quality Factor for impedance, insertion loss and crosstalk**
- **x_1= reference area**
- **x_2= area between measured and simulated curves**

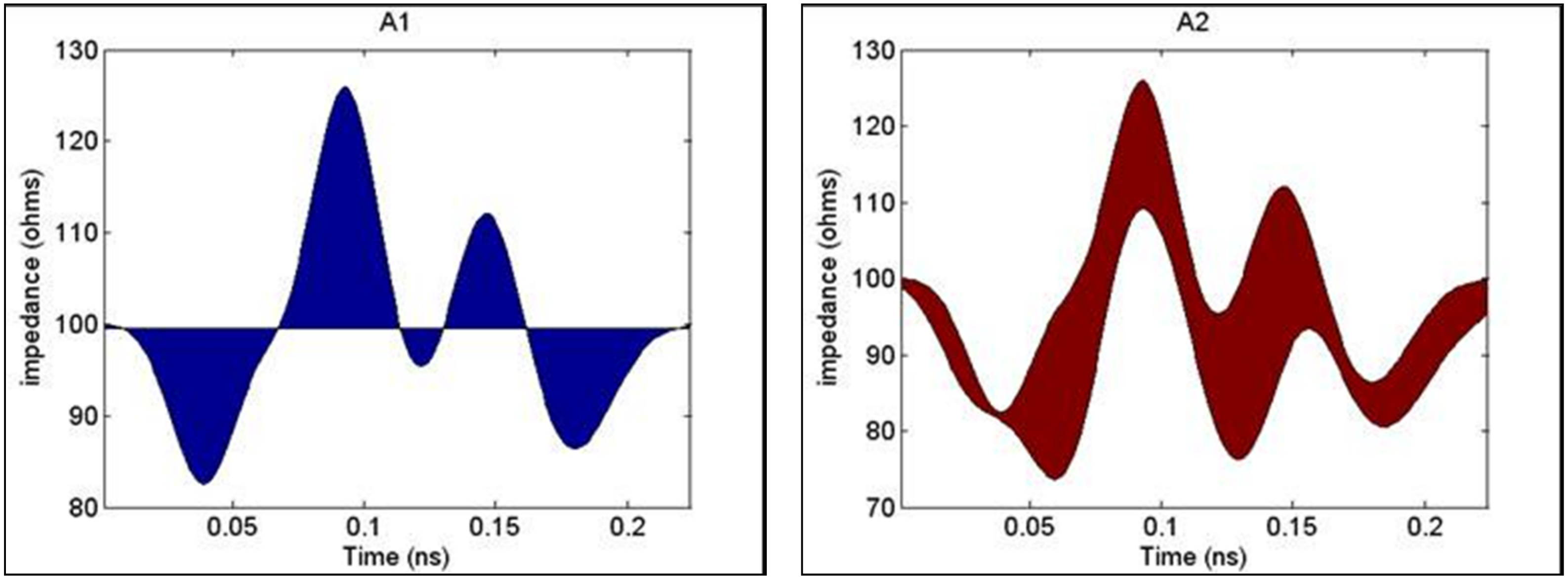
Model Quality Factor

Impedance MQF = -0.15

$$MQF = \log_{10} \frac{x_1}{x_2}$$

X1- reference area

X2- area between curves



Model Quality Factor

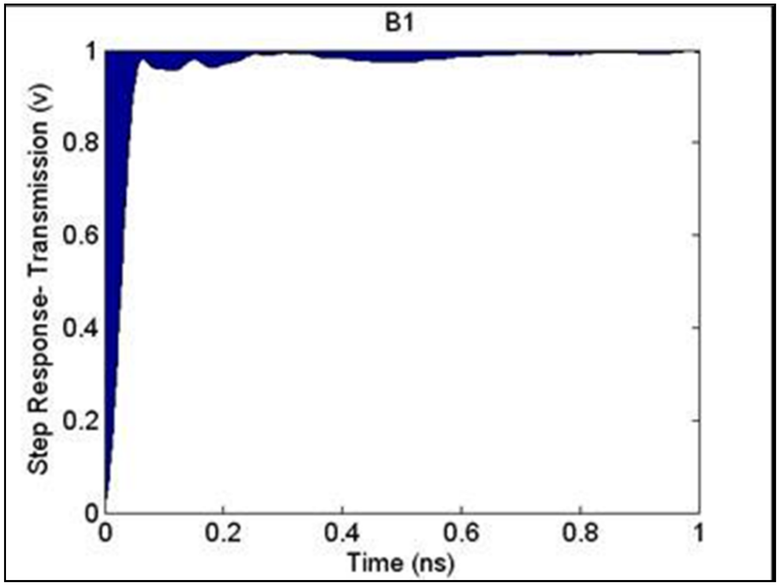
Insertion Loss MQF = 0.43

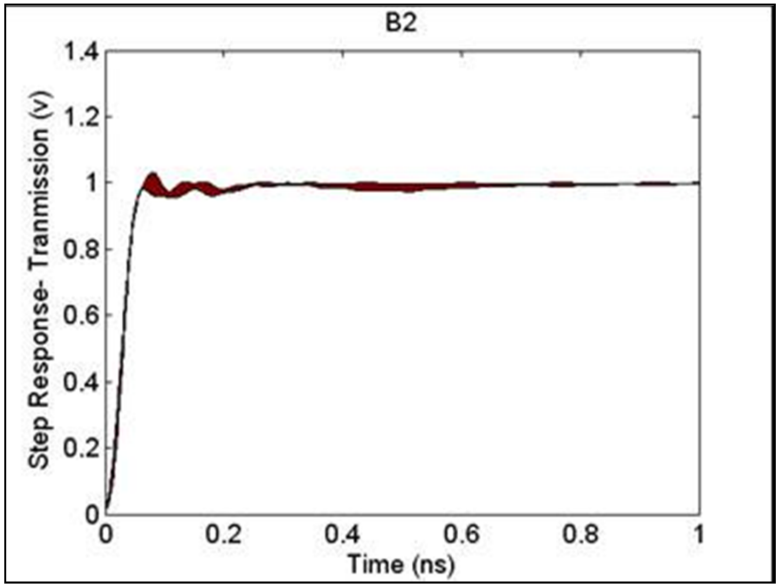
- Insertion Loss is computed as the Time Domain transmission

$$MQF = \log_{10} \frac{x_1}{x_2}$$

X1- reference area

X2- area between curves





Model Quality Factor

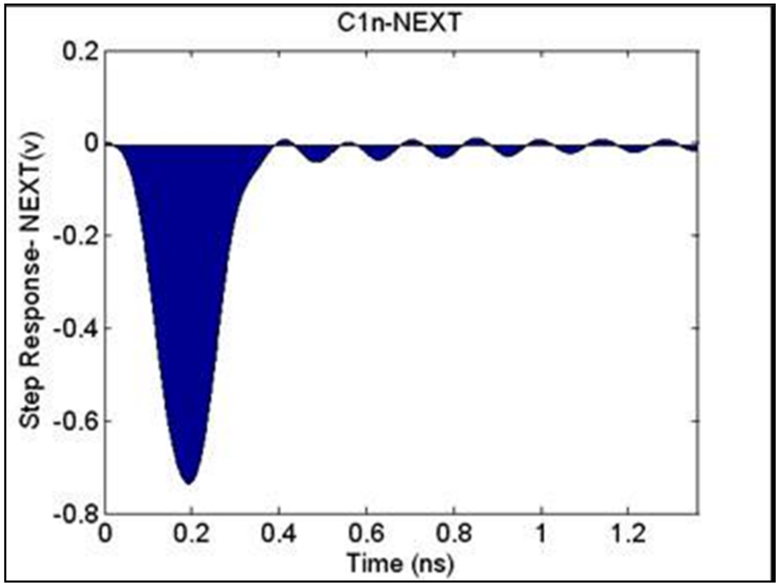
Near End Crosstalk (NEXT) MQF = 0.85

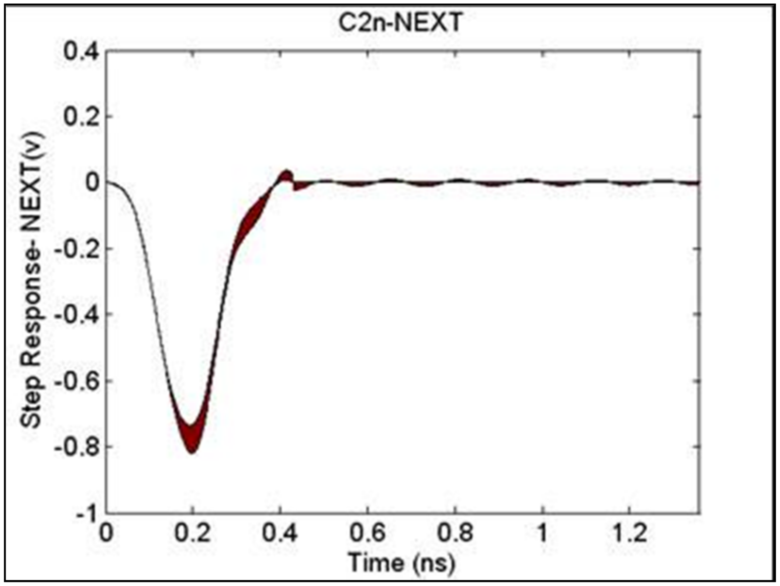
- NEXT is computed in the Time Domain

$$MQF = \log_{10} \frac{x_1}{x_2}$$

X1- reference area

X2- area between curves





MQF Observations

- MQF does change with Rise Time
  - The Time Domain waveforms were computed using [S] and Agilent ADS 2011.05, and the output depends on the input
- MQF is computed over the region of interest
  - Time window span impacts MQF and is defined in the document

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Feature Selective Validation

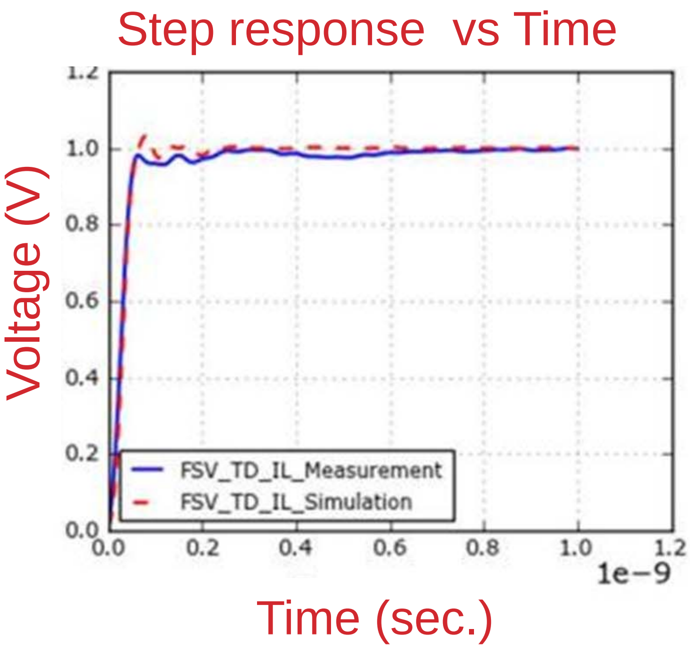
Feature Selective Validation (FSV) is a method with three components:

- Amplitude Difference Measure (ADM)
  - Absolute difference between two data sets
- Feature Difference Measure (FDM)
  - Calculate the first derivative of the data sets to accentuate the change or “features” in the data
- Global Difference Measure (GDM) is the geometric mean of ADM and FDM. GDM is the overall quality metric.

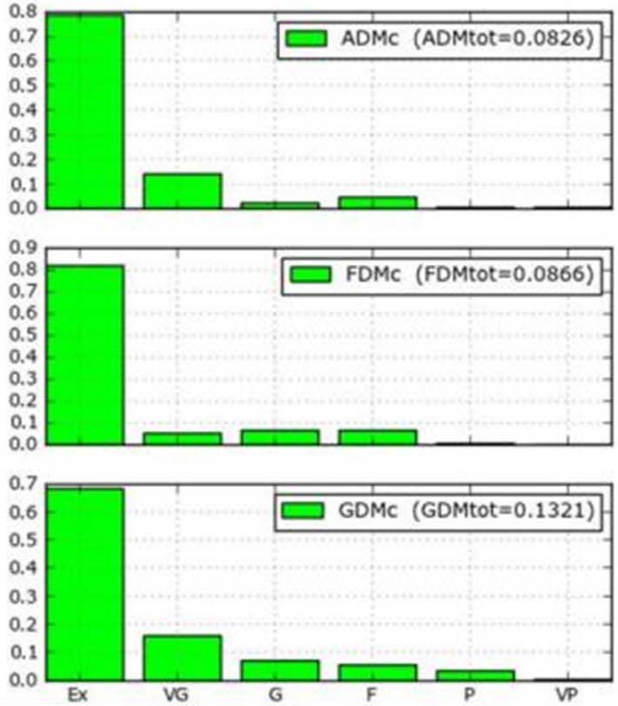
Small values of ADM, FDM and GDM means good correlation while high values mean poor correlation (opposite of MQF)

Numeric values of XDM are mapped to qualitative terms (Excellent, Very Good, Good, Fair, Poor, Very Poor)

FSV – Insertion Loss

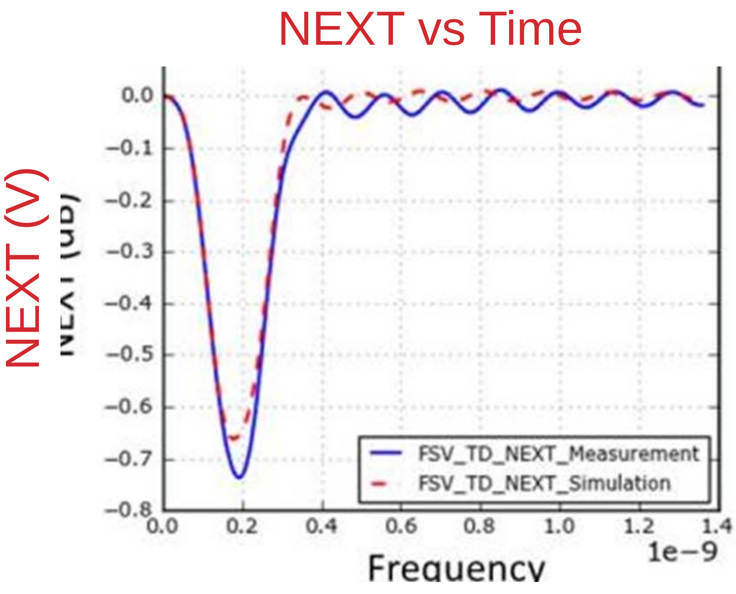


Insertion Loss GDMtot=0.13 – “Very Good” Correlation

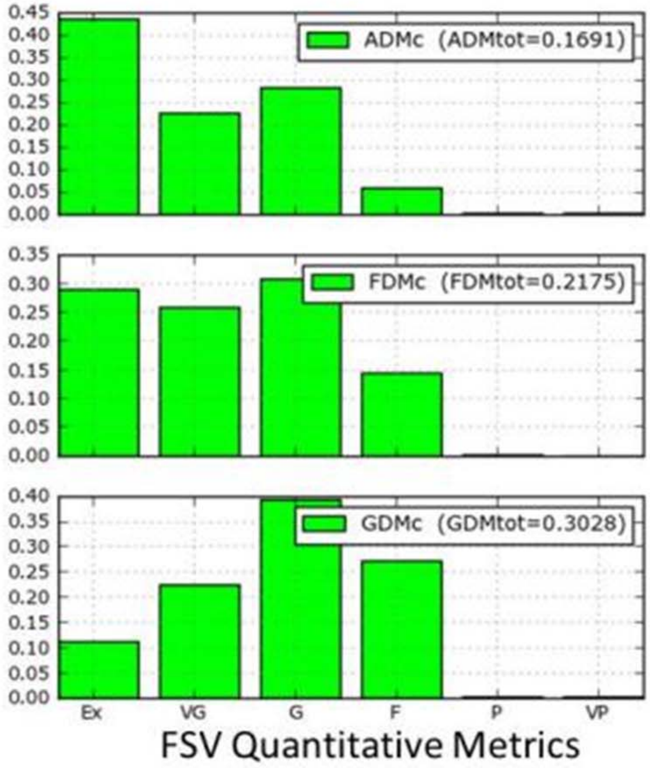


FSV Quantitative Metrics

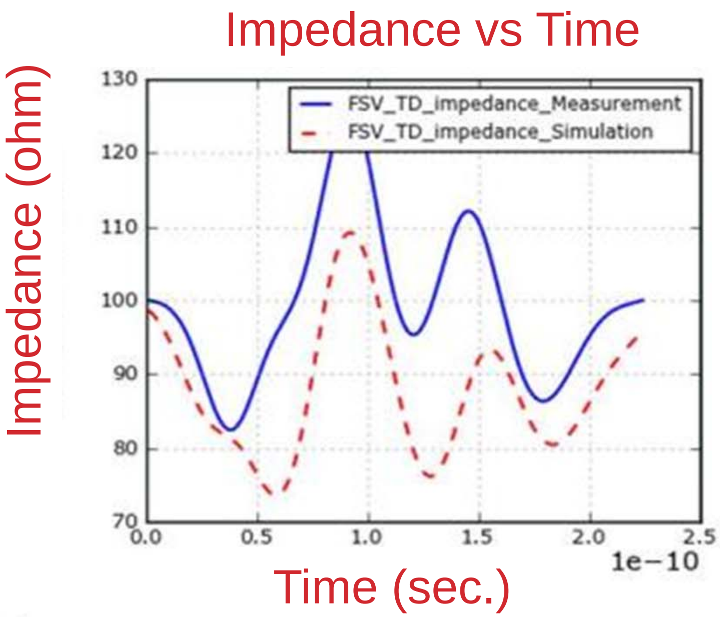
FSV – NEXT



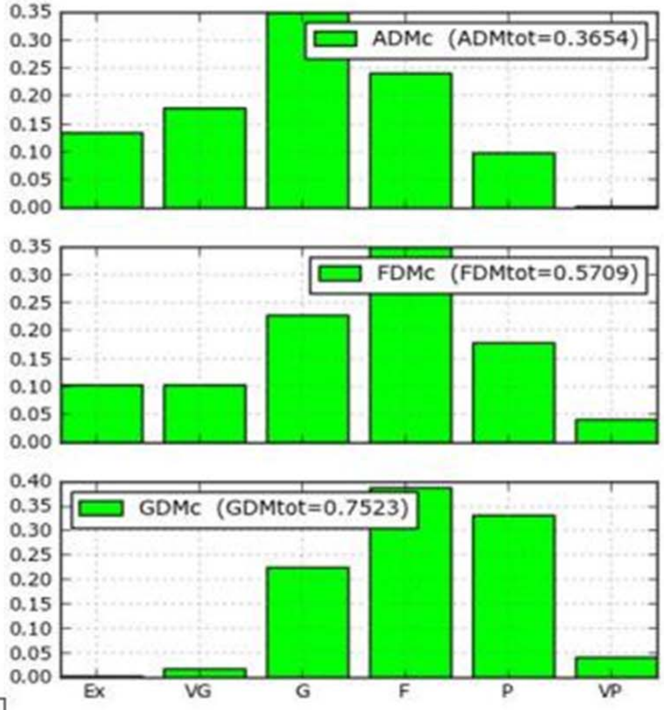
NEXT GDMtot=0.30 – Good Correlation



FSV – Impedance



Return Loss GDMtot=0.75 – “Fair” Correlation



FSV Quantitative Metrics

Additional Work on Impedance and Calibration

- The reference impedance of a TRL/M measurement is the line standard impedance
- This means the “measured” connector impedance can shift depending on the calibration standards
- Consider an experiment where we adjust the simulated impedance based on the measured calibration standards

“Real World” Board Effects

The approach – add “Real World” board effects to simulated response:

Simulate the connector as usual and obtain [S]

- Using ADS, add 46 ohm transmission line elements to [S]; these represent the actual measured trace values from the test boards
- Measure the line standards using an SOLT calibration - note that these are not 50 ohms
- Perform an external TRL/M calibration using Matlab to remove the 46 ohm transmission line elements on [S]
- Use this re-compiled simulation data and compare to the measured data

$[S_{simulation}] = [S_s]$

Add imperfect PCB effects – [Sb1], [Sb2]

[Sb1] [Ss] [Sb2]

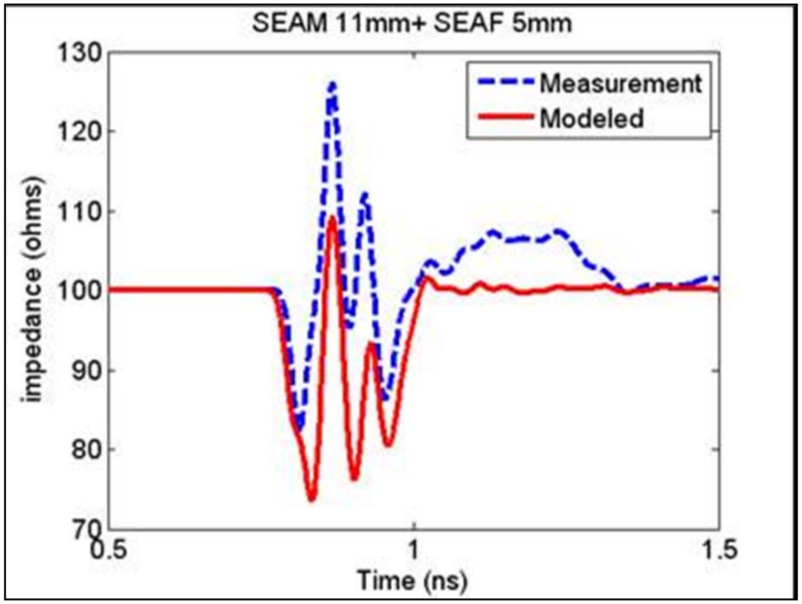
Obtain [S] for the TRL/M calibration standards

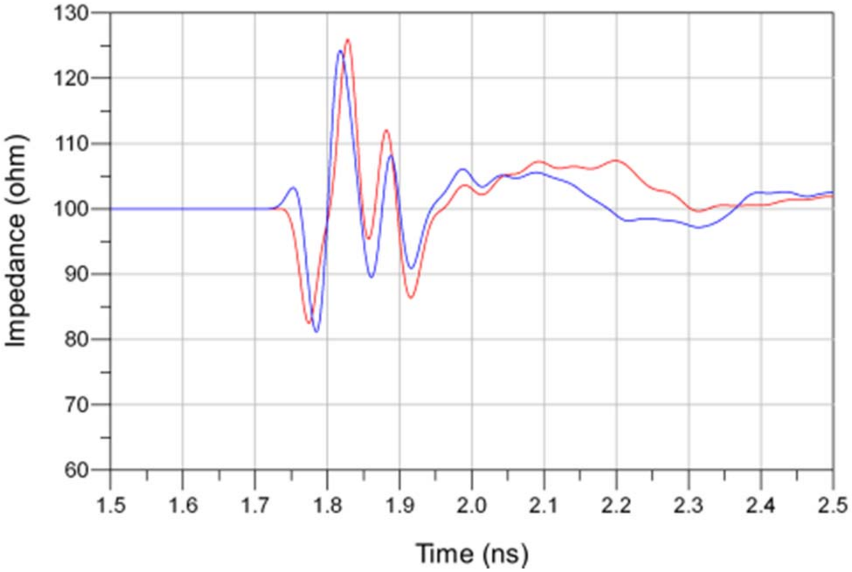
Use Matlab implementation of TRL/M algorithm to deembed [Sb1], [Sb2]

Compute Z from [SS’]

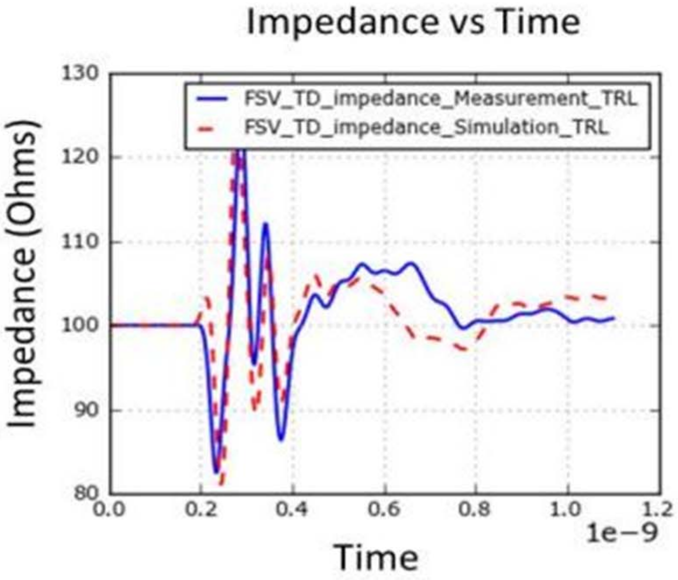
"Real World" Board Effects

Applying "Real World" imperfections of test boards result in much better impedance match

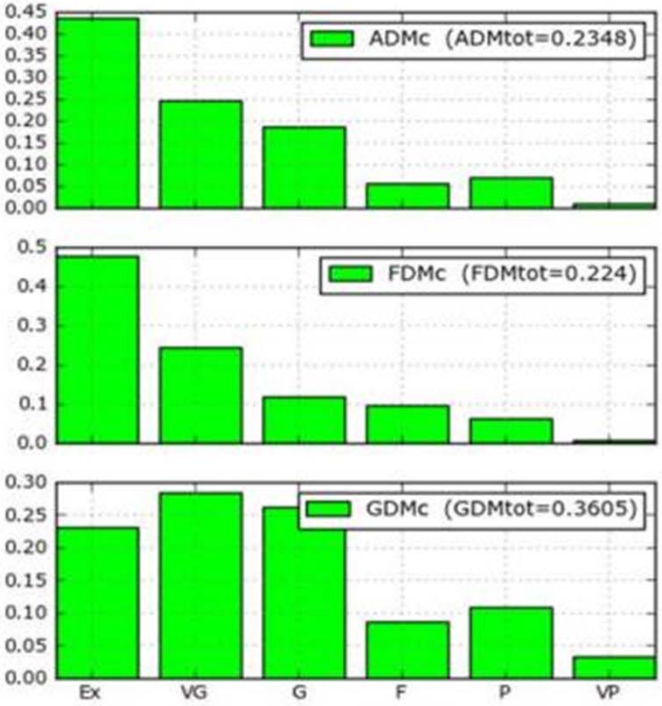




FSV – Impedance



NEXT GDMtot=0.36 – “Good” Correlation



FSV Quantitative Metrics

Presentation Outline

- Connector Models From Simulation
- Connector Models From Measurement
- The Post-processing, The Correlation
    - Model Quality Factor
    - Feature Selective Validation
- Channel Simulation
- Conclusions

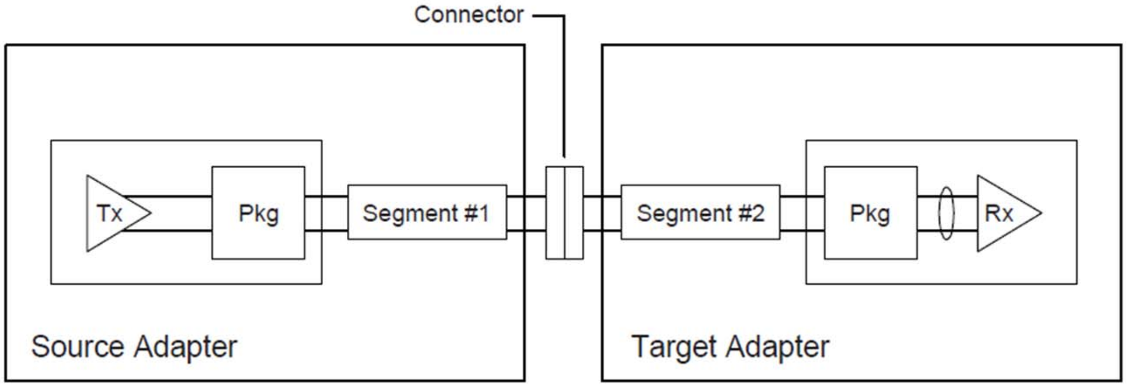
Channel Simulation Setup

In the channel simulation, ADS includes the Tx and Rx package models which are released by PCI-SIG.org, as defined by the PCI Express Base Specification, Rev 3.0 for 8.0 GT/s channel compliance testing

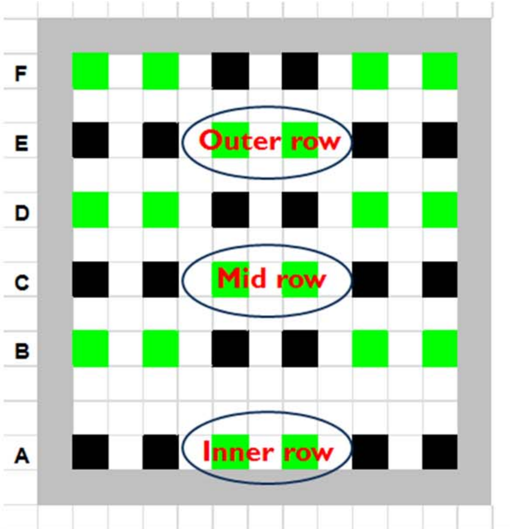
A variable length interconnect trace segment on the source adapter, with and without a 200 nF capacitor

A variable length interconnect trace segment on the target adapter

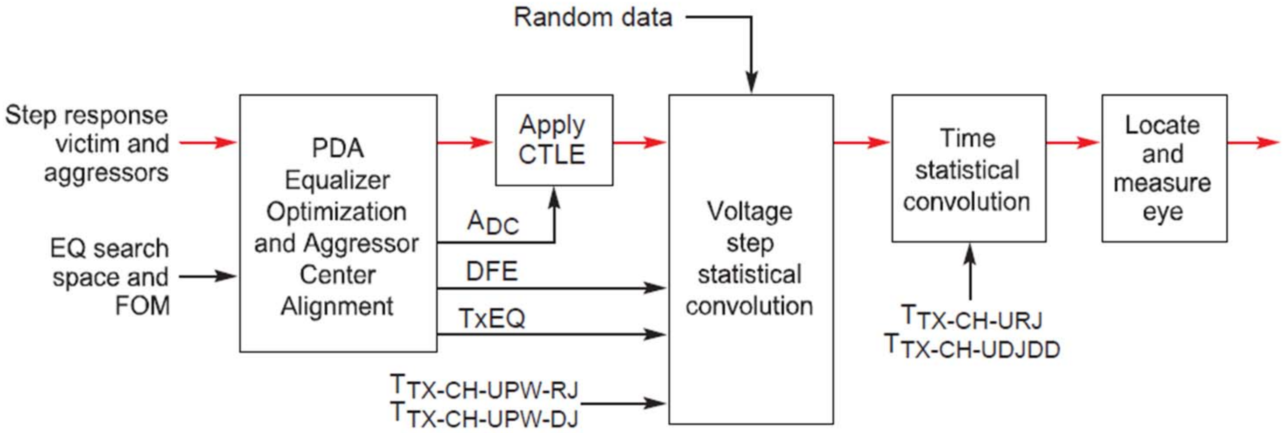
A Samtec SEAM-RA/SEAF-RA SEARAY™ Series connector touchstone S-parameter model



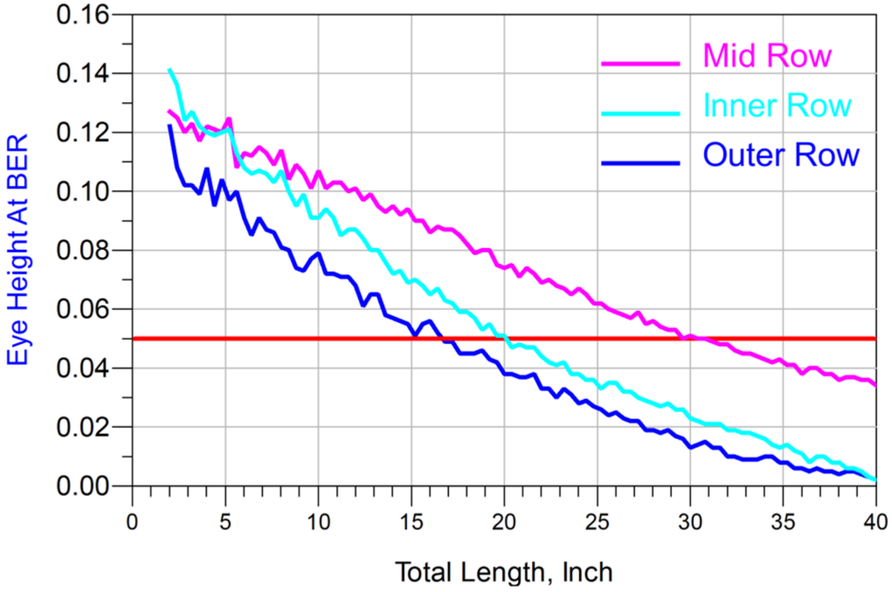
Setup



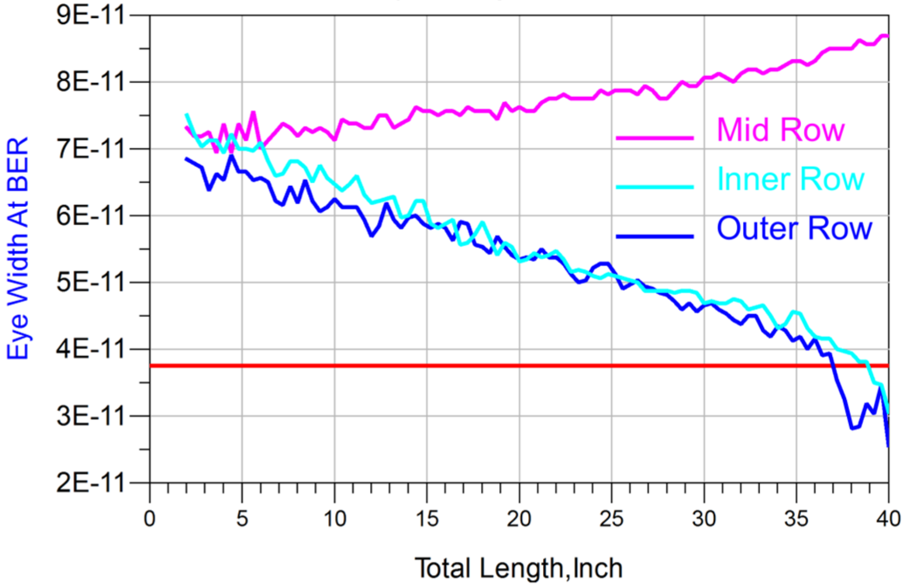
Optimal Horizontal Diff



The Performance

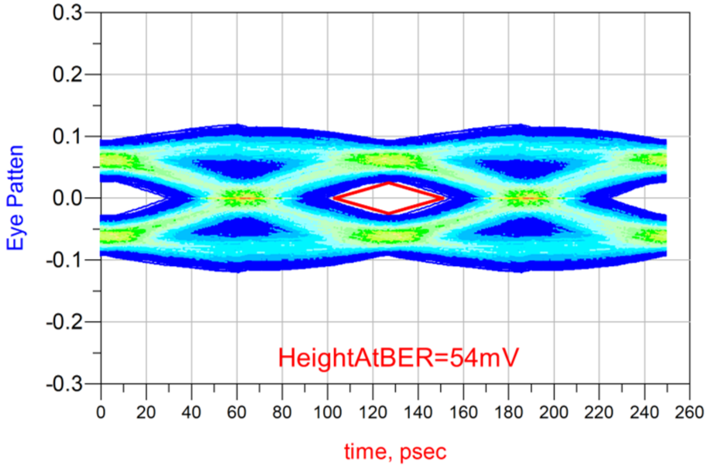


PCI Express 8.0 GT/s
Equalized Eye Height vs. Total Channel Height
with Equal Length Tx and Rx traces

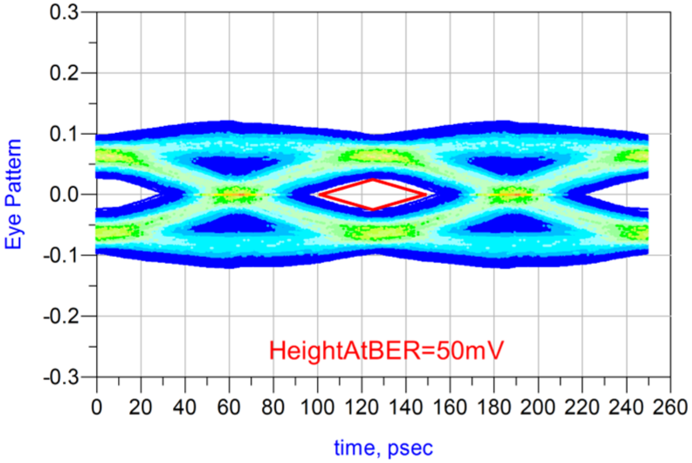


PCI Express 8.0 GT/s
Equalized Eye Width vs. Total Channel Height
with Equal Length Tx and Rx traces

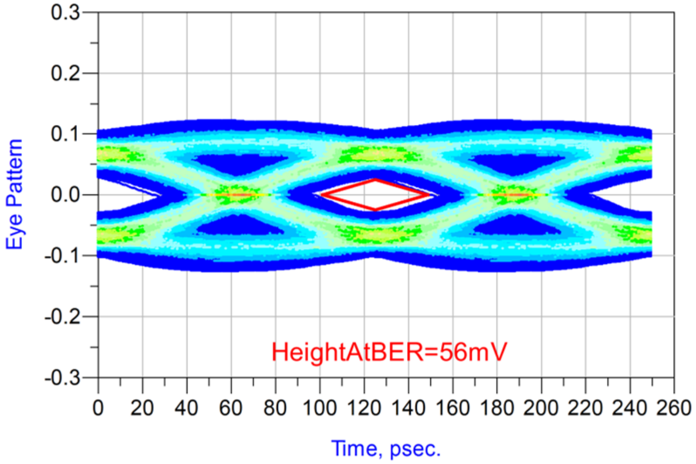
The Performance



Tx=Rx=10 inch
Txc=[-1.25,7,-1.25], CTLE=-10dB
Inner Row



Tx=Rx=9.6 inch
Txc=[-1.25,7,-1.25], CTLE=-10dB
Mid Row



Tx=Rx=8.2 inch
Txc=[-1.25,7,-1.25], CTLE=-10dB
Outer Row

References

- MQF
  - Intel Corporation, “Intel Connector Model, Quality Assessment Methodology”, September 2011
  - http://www.intel.com/content/www/us/en/architecture-and-technology/intel-connector-model-paper.html
- FSV
  - Universitat Politecnica De Catalunya, FSV downloadable code
  - www.upd.edu/web/gcem
  - A.P. Duffy, A.J.M. Martin, A Orlandi, G Antonini, T.M. Benson, M.S. Woolfson, "Feature Selective Validation (FSV) for validation of computational electromagnetics (CEM). Part I - The FSV method", IEEE Trans. on Electromagn. Compatibility, Vol 48, No 3, Aug 2006, pp 449 - 459.

Conclusion

- **Measured and modeled connector models can have a high degree of correlation provided test fixture artifacts are properly accounted for**
- **We introduced two different metrics for model correlation:**
  - MQF – Model Quality Factor
  - FSV – Feature Selective Validation
- **Samtec has developed a PCIe Gen 3 analysis suite with ADS**
  - Includes FIR, CTLE and DFE equalization as per PCIe Gen 3
  - Batch simulation and parameter sweeps are used to select the optimum equalization settings
  - Tx and Rx effects (jitter, package parasitics) are included in the suite


samtec