DesignCon 2012
WHERE CHIPHEADS CONNECT

Connector Models – Are They Any Good?

Jim Nadolny, Leon Wu
Samtec
Tuesday, January 31, 2012

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- **Some Brief Housekeeping Notes:**
  - Track 14, RF/Microwave Techniques for Signal Integrity
  - Ballroom G, Santa Clara Convention Center

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- **Presentation Outline**
  - Brief History
  - Connector Models From Simulation
  - Connector Models From Measurement
  - Correlation
    - Model Quality Factor
    - Feature Selective Validation
  - Conclusion

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- **Brief History**
  - Connector models started as simple lumped element models — ‘70s - ‘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

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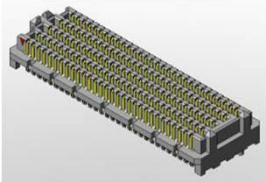
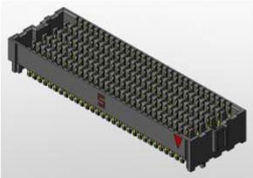
- **Connector Models From Simulation**
  - For this study, we consider a high density, open pin field array connector - SEARAY™ SEAM/SEAF Series
  - Up to 10 rows, 50 pins/row on .050" pitch (500 pins)
  - Typically used in an offset GSSG pattern → G S S G S S G / S S G S S G S





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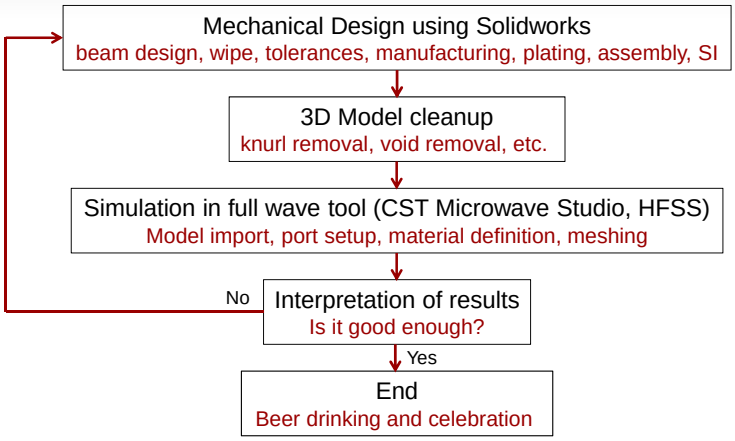
- **Typical Development Process**



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- **Connector Models From Simulation – what could possibly go wrong?**
  - Meshing
  - Material parameters
  - Port setup
  - Geometry capture

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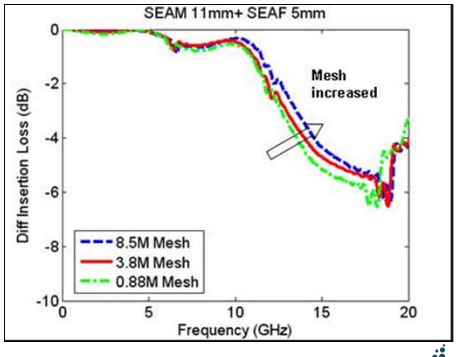

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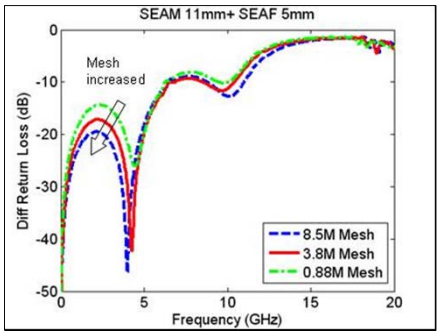

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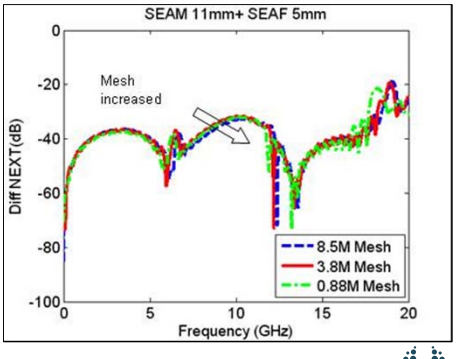

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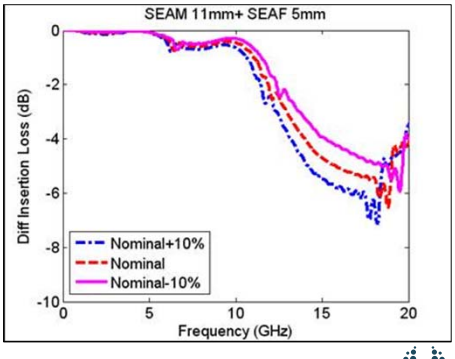

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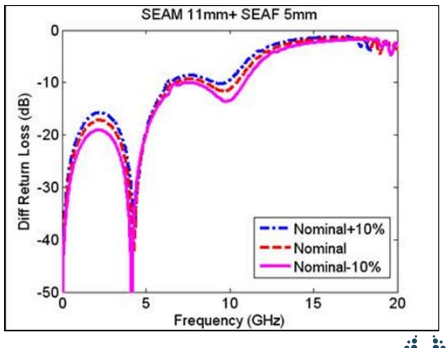

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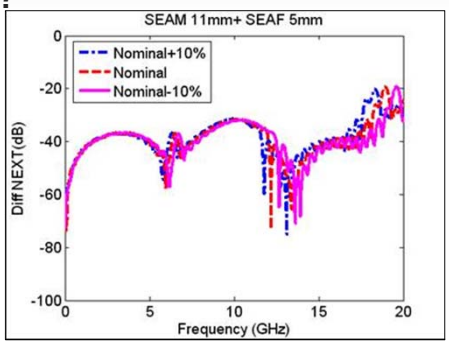

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- **Connector Models From Simulation – what could possibly go wrong?**
  - Meshing
  - Material parameters
  - Port setup
    - Coupled ports – waveguide or discrete?
    - Absorbing or perfect BC?
  - Geometry capture
    - Air voids?
    - Reference plane location?
    - Footprint effects?

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

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- **Connector Models From Measurement – what could possibly go wrong?**
  - Test board footprint
    - (aka geometry capture)
  - Insertion depth
  - Soldering/attachment
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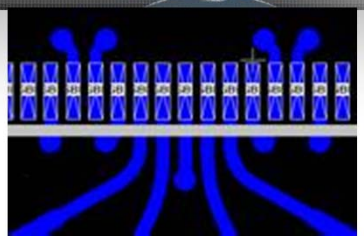
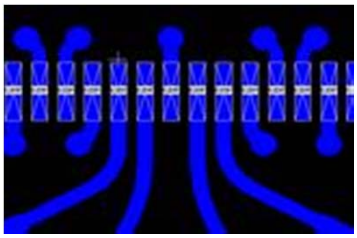


Case 1 – "inboard via"



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.

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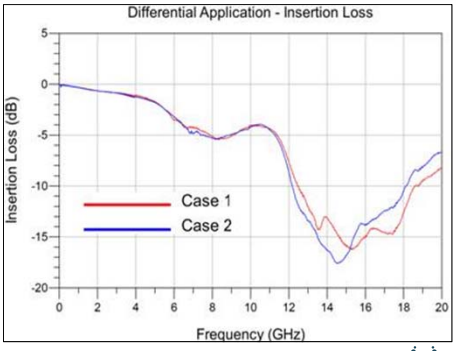

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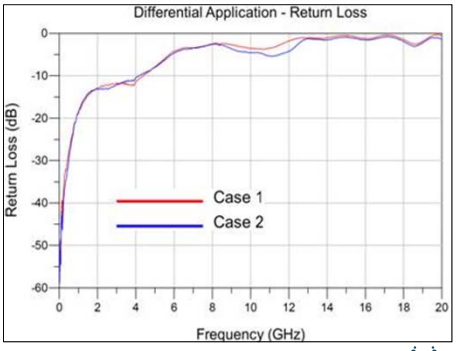

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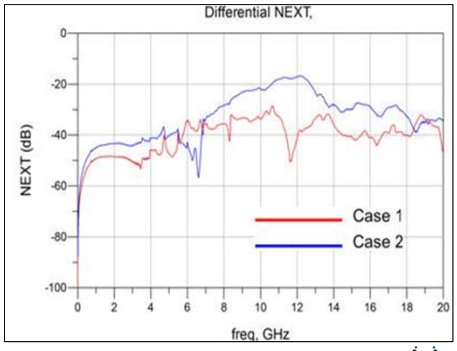

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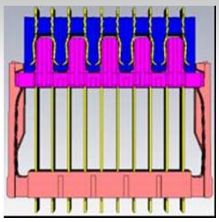
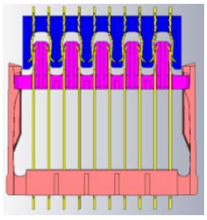


"Fully Mated"



"Shift 19.7 mils"

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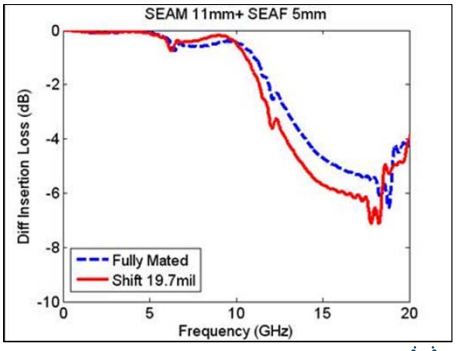

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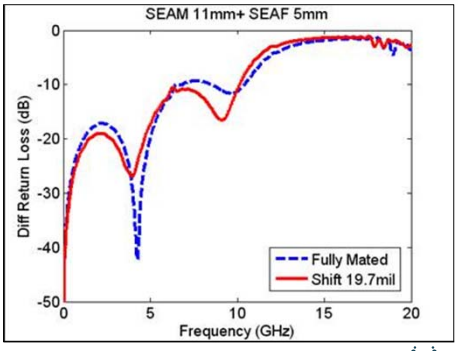

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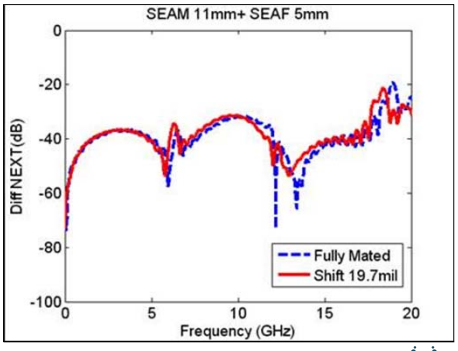

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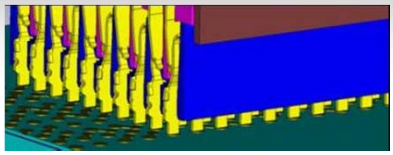
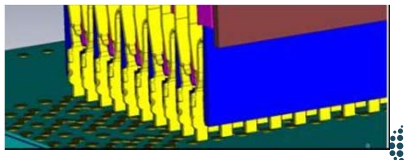


"Middle of Pad"



"Edge of Pad"

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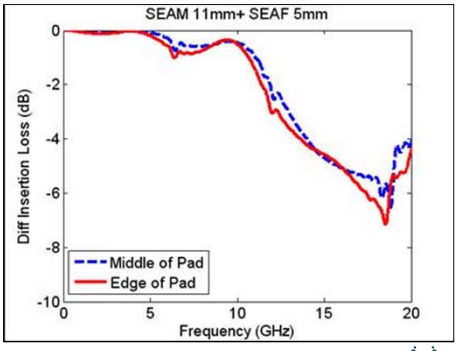

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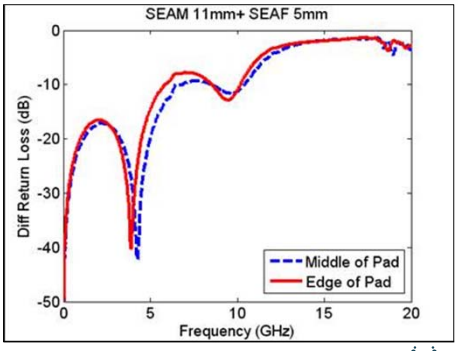

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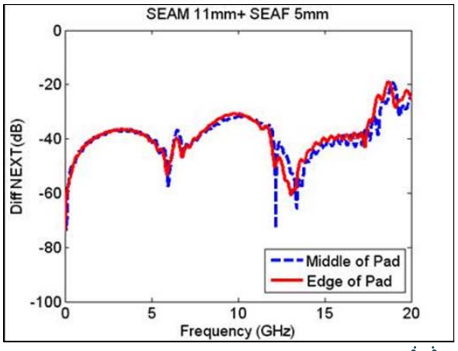
    - We will re-visit later!



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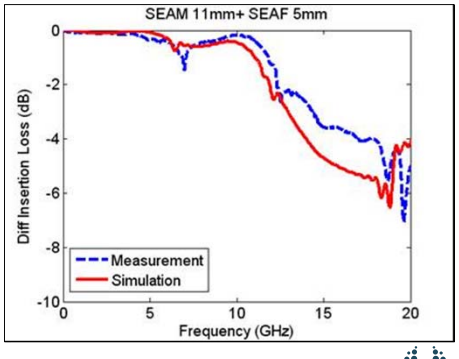
- **Correlation – How well do the measurements match the simulation?**
  - Good?



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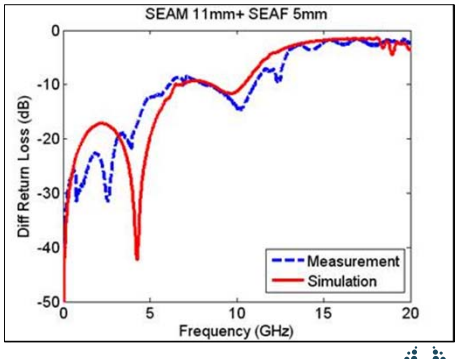
- **Correlation – How well do the measurements match the simulation?**
  - So-so?



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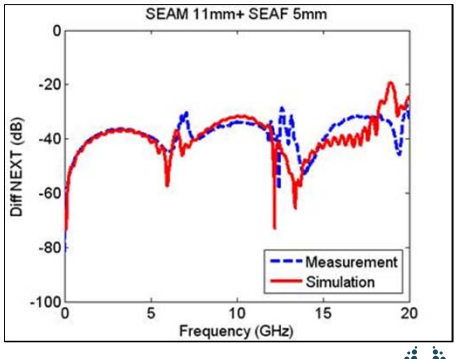
- **Correlation – How well do the measurements match the simulation?**
  - Not too shabby?



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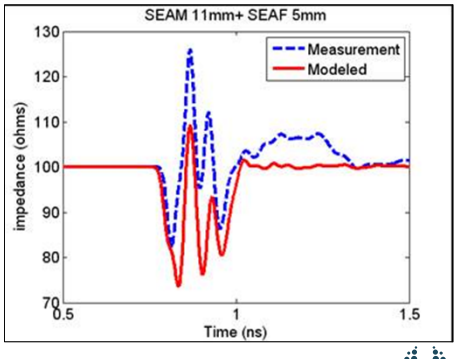
- **Correlation – How well do the measurements match the simulation?**
  - Solid "B" work?



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- **Model 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

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

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

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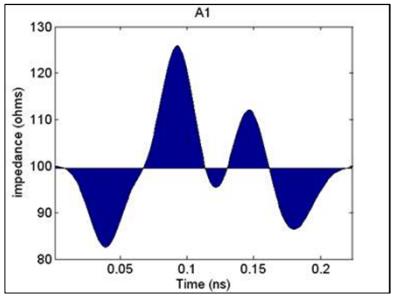
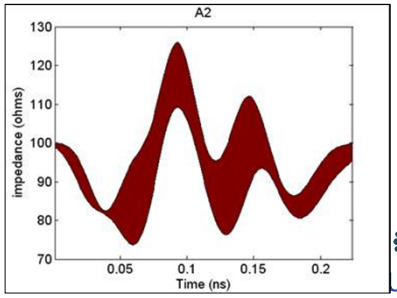
- **Impedance MQF = -0.15**

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

X1- reference area



X2- area between curves



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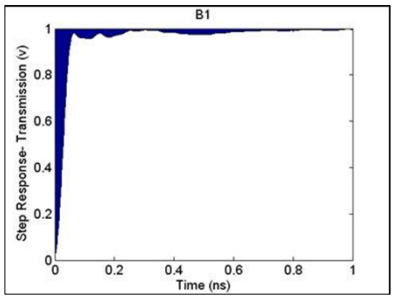
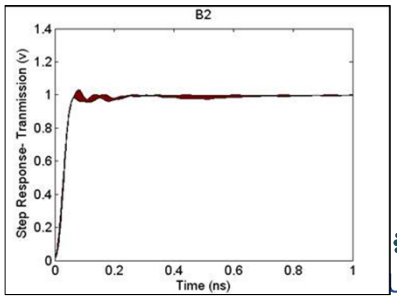
- **Insertion Loss MQF = 0.43**
  - Insertion Loss is computed as the Time Domain transmission

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

X1- reference area



X2- area between curves



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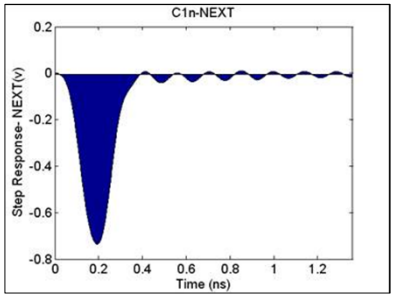
- **Near End Crosstalk (NEXT) MQF = 0.85**
  - NEXT is computed in the Time Domain

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

X1- reference area



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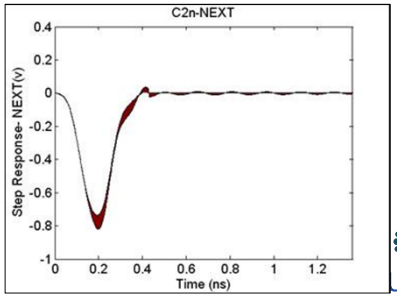

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- **MQF Observations**
  - MQF does change with rise time
    - The time domain waveforms were computed using [S] and Agilent ADS 2011.05, and the output depends on the input
  - MQF is computed over the region of interest
    - Time window span impacts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

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- **Feature Selective Validation (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)**

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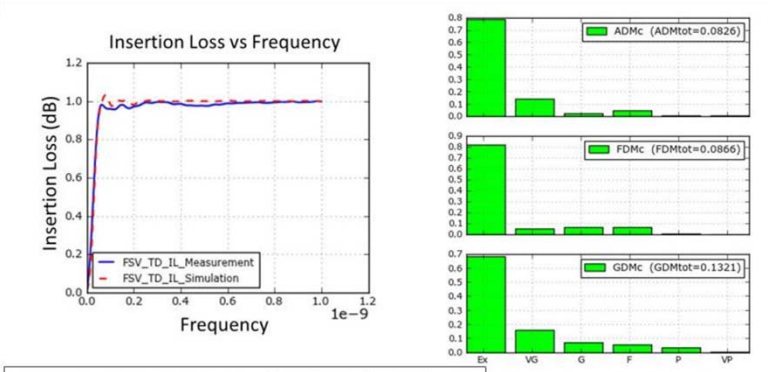
- **FSV – Insertion Loss**



Insertion Loss GDMtot=0.13 – "Very Good" Correlation

FSV Quantitative Metrics

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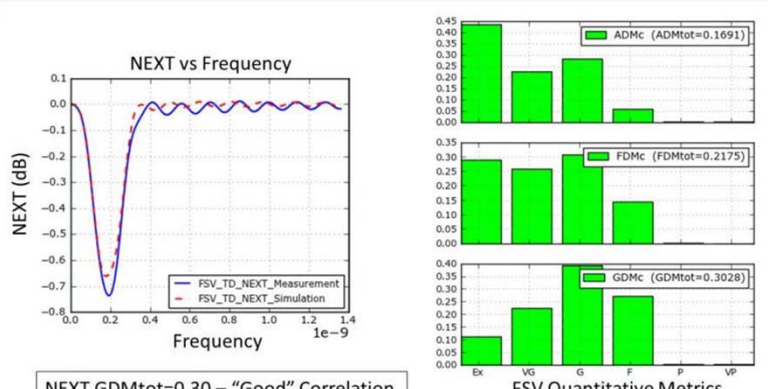
- **FSV – NEXT**



NEXT GDMtot=0.30 – "Good" Correlation

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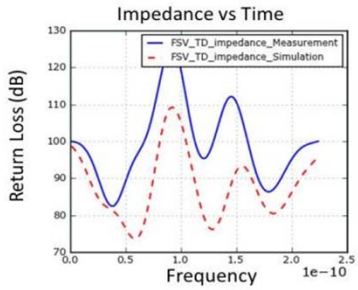
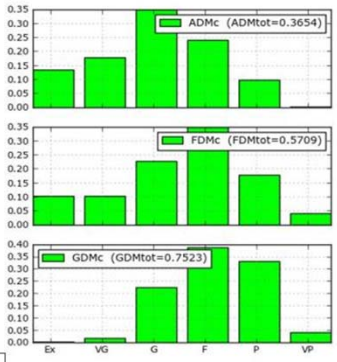
- **FSV – Impedance**



Return Loss GDMtot=0.75 – "Fair" Correlation



FSV Quantitative Metrics

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- **Presentation Outline**
  - Brief History
  - Connector Models From Simulation
  - Connector Models From Measurement
  - Correlation
    - Model Quality Factor
    - Feature Selective Validation
    - Watch Jim Squirm ☺
  - Conclusion

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- **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

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- **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 – $[S_{b1}]$, $[S_{b2}]$

↓

$[S_{b1}]\,[S_s]\,[S_{b2}]$

↓

Obtain [S] for the TRL/M calibration standards

↓

Use Matlab implementation of TRL/M algorithm to deembed $[S_{b1}]$, $[S_{b2}]$

↓

Compute Z from $[S_S']$

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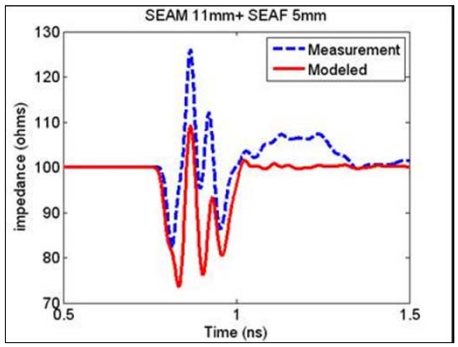
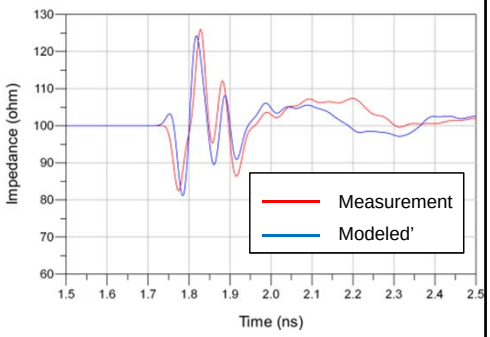
- **Applying "Real World" imperfections of test boards result in much better impedance match**





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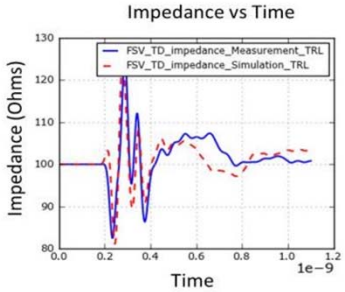
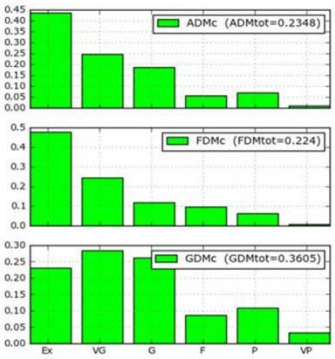
- **FSV – Impedance**



NEXT GDMtot=0.36 – "Good" Correlation



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- **Conclusion**
  - Connector models are good!

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  - Craig Rapp, Viky Jia, Henry Dai – measurements
  - Al Neves – TRL/M calibration support
  - Scott McMorrow – Full Wave simulation support

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- **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.

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