Connector Models – Are They Any Good?

Jim Nadolny, Leon Wu
Samtec
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Some Brief Housekeeping Notes:

• Track 14, RF/Microwave Techniques for Signal Integrity
• Ballroom G, Santa Clara Convention Center
• Presentation Outline
  • Brief History
  • Connector Models From Simulation
  • Connector Models From Measurement
  • Correlation
    • Model Quality Factor
    • Feature Selective Validation
  • Conclusion

• 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
• 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

No
- Interpretation of results
- Is it good enough?

Yes
- 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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![Graph showing frequency response with different mesh sizes](image1)

• Connector Models From Simulation – what could possibly go wrong?
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  • Geometry capture

![Graph showing frequency response with different material parameters](image2)
Connector Models From Simulation – what could possibly go wrong?

- Meshing
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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
  • Calibration

* 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 – what could possibly go wrong?
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Connector Models From Measurement – what could possibly go wrong?
- Test board footprint
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    • We will re-visit later!

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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?

Correlation – How well do the measurements match the simulation?
- Solid “B” work?
• Presentation Outline
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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

\[ xx = \log_{10}\left(\frac{x_1}{x_2}\right) \]

• \( xx \) = Model Quality Factor for impedance, insertion loss and crosstalk
  • \( x_1 \) = reference area
  • \( x_2 \) = area between measured and simulated curves
• Impedance MQF = -0.15

\[ MQF = \log_{10} \frac{x_1}{x_2} \]

X1 - reference area

X2 - area between curves

• Insertion Loss MQF = 0.43

\[ MQF = \log_{10} \frac{x_1}{x_2} \]

Insertion Loss is computed as the Time Domain transmission

X1 - reference area

X2 - area between curves
• Near End Crosstalk (NEXT)  
  MQF = 0.85  
  • NEXT is computed in the Time Domain

\[ MQF = \log_{10} \frac{x_1}{x_2} \]

\[ x_1 \]

\[ x_2 \]

\[ X1- \text{ reference area} \]

\[ X2- \text{ area between curves} \]

• 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
Presentation Outline

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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)
• FSV – Insertion Loss

![Insertion Loss vs Frequency Graph]

- Insertion Loss GDMtot=0.13 – “Very Good” Correlation

FSV Quantitative Metrics

• FSV – NEXT

![NEXT vs Frequency Graph]

- NEXT GDMtot=0.30 – “Good” Correlation

FSV Quantitative Metrics
• FSV – Impedance

- Impedance vs Time

- Return Loss GDMtot=0.75 – “Fair” Correlation

- FSV Quantitative Metrics

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    - Watch Jim Squirm 😊
  - Conclusion
• 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

• 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

\[
[S_{\text{simulation}}] = [S_s]
\]

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 \([S_s']\)
• Applying “Real World” imperfections of test boards result in much better impedance match

![Graph showing impedance vs time for SEAM 11mm+ SEAF 5mm](image)

• FSV – Impedance

![Graph showing impedance vs time for FSV TD impedance Measurement and Simulation](image)
• Conclusion
  • Connector models are good!

• Acknowledgements
  • Craig Rapp, Viky Jia, Henry Dai – measurements
  • Al Neves – TRL/M calibration support
  • Scott McMorrow – Full Wave simulation support
• References
  • MQF
    • Intel Corporation, “Intel Connector Model, Quality Assessment Methodology”, September 2011
  • FSV
    • Universitat Politecnica De Catalunya, FSV downloadable code
    • www.upd.edu/web/gcem