Intelligent and Fast Electrical Design Space Exploration Techniques for Package-Boards

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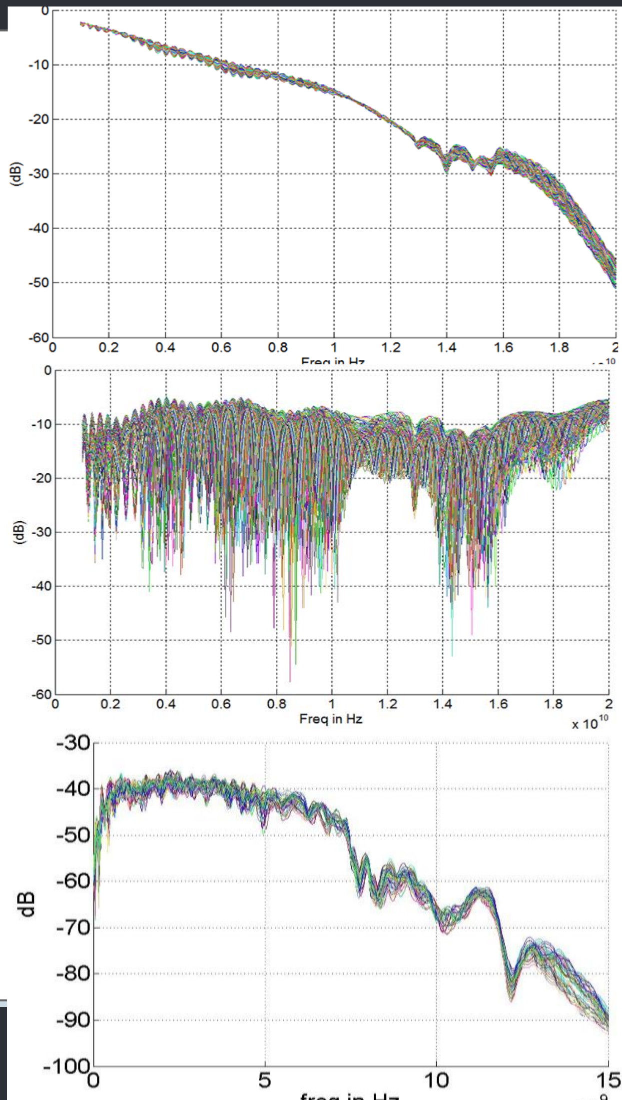
Agenda

- Signal Integrity (SI) Issues
- Problem Statement
- Solution
- Part I
- Part II
- Part III
- Conclusion

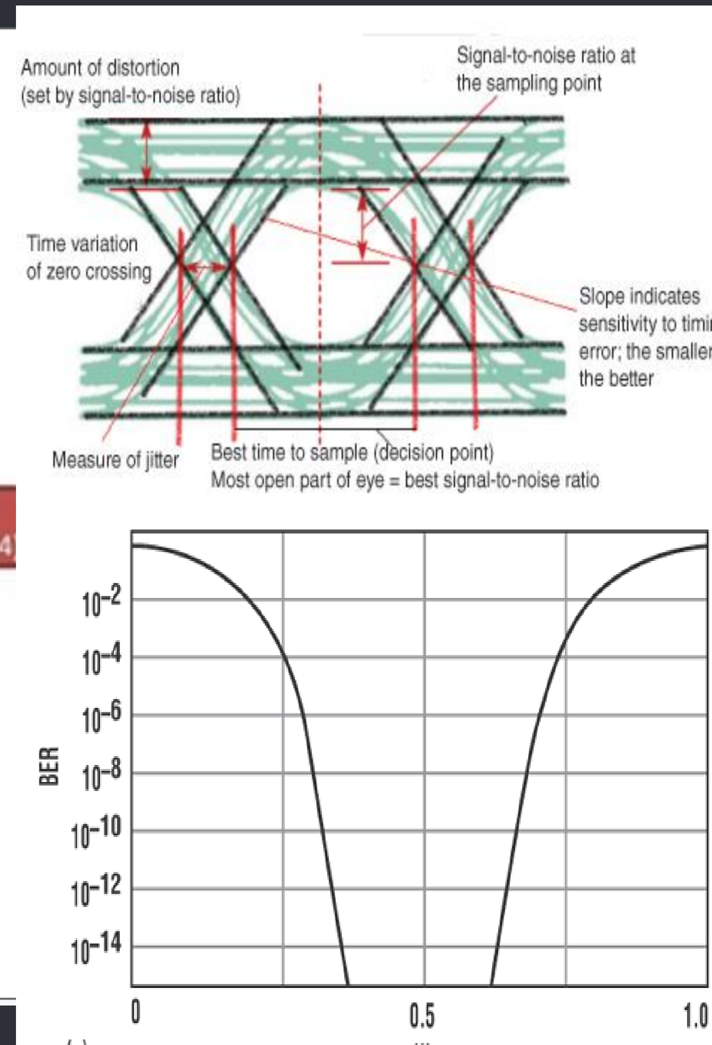
Signal Integrity Issues: What & Why

Frequency Domain



Channel
(10 inch FR4)

Time Domain



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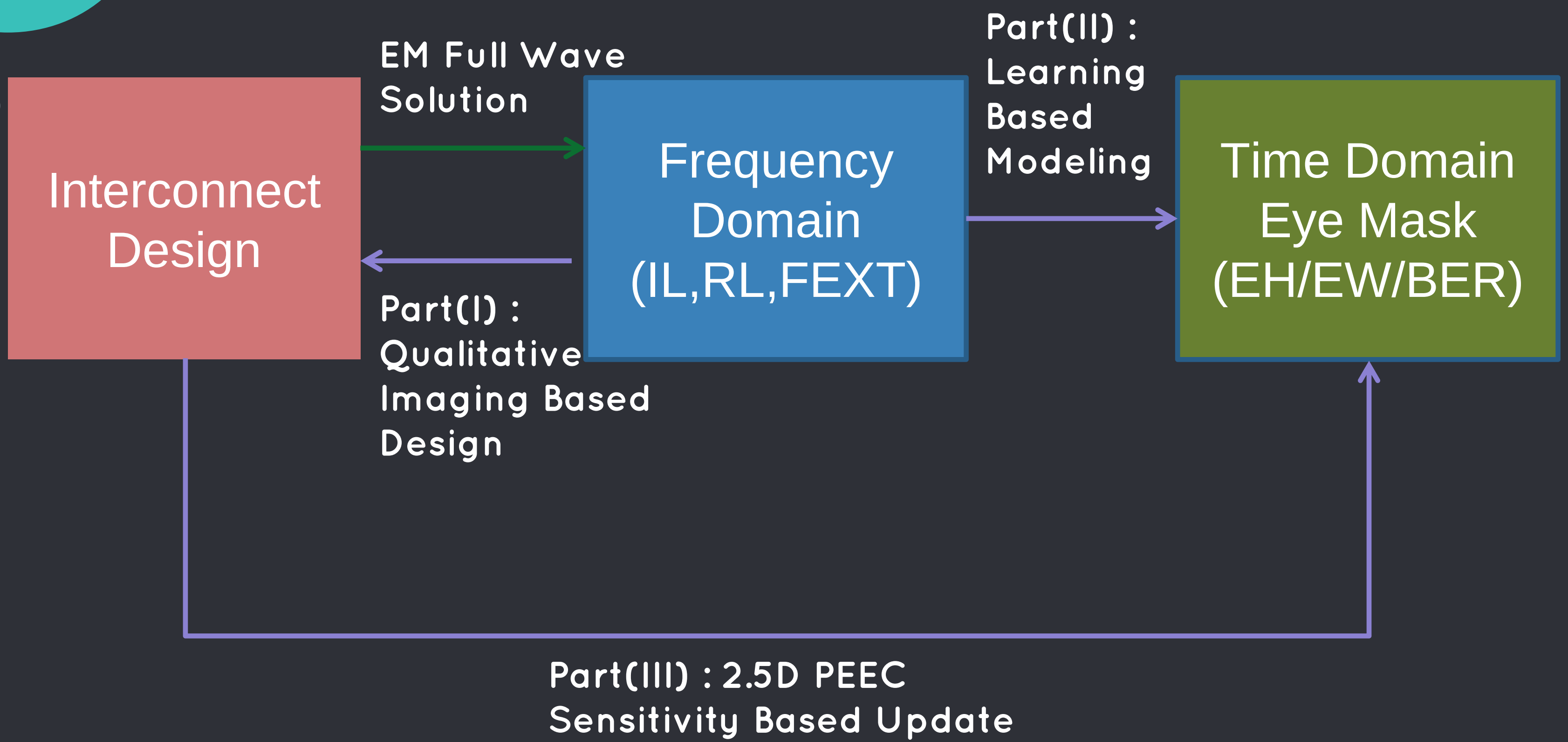
Problem

Facilitate intelligent and fast design space exploration for Signal-Integrity(SI) aware package boards

Solution



Interconnect Design
EM Full Wave Solution
Frequency Domain (IL,RL,FEXT)
Part(I) : Qualitative Imaging Based Design
Part(II) : Learning Based Modeling
Time Domain Eye Mask (EH/EW/BER)
Part(III) : 2.5D PEEC Sensitivity Based Update

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Part I

Qualitative Imaging Based Design

Part I: Design

$$Ci = fi(x_{00} + \Delta x_0, x_{10} + \Delta x_1, \ldots x_{N0} + \Delta x_N), \quad C_{i0} = fi(x_{00}, x_{10}, \ldots x_{N0})$$

$$Ci = fi_0 + \frac{\partial fi_0}{\partial x_0}\Delta x_0 + \frac{\partial fi_0}{\partial x_1}\Delta x_1 + \ldots + \frac{\partial fi_0}{\partial x_N}\Delta x_N$$

$$Ci - Ci_0 = \sum_k \frac{\partial fi_0}{\partial x_k}\Delta x_k, i \in [1, N], k \in [1, M]$$

$$\Delta C_{M\times 1} = J_{M\times N}\Delta x_{N\times 1}$$

$$\lambda = Sg$$

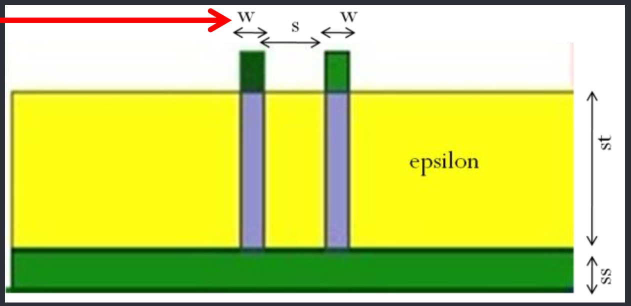
$$g = S^T \lambda$$

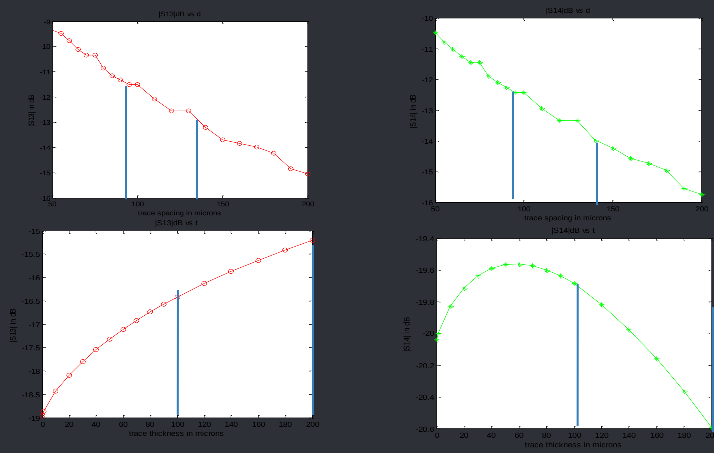
$$S = \frac{Z - Z_0}{Z + Z_0}$$

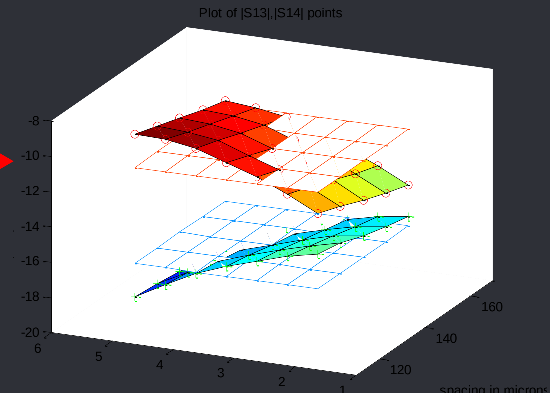
$$Z = \frac{V}{I}$$

$$I = \int J dS$$

$$\begin{bmatrix} |S13| \\ |S14| \end{bmatrix} = \begin{bmatrix} \frac{\partial |S13|}{\partial d} & \frac{\partial |S13|}{\partial t} \\ \frac{\partial |S14|}{\partial d} & \frac{\partial |S14|}{\partial t} \end{bmatrix} \begin{bmatrix} d \\ t \end{bmatrix}$$







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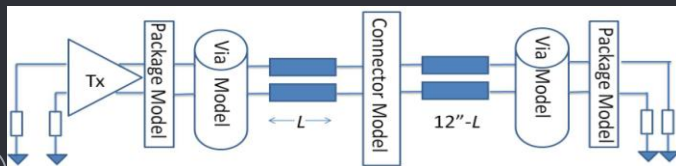
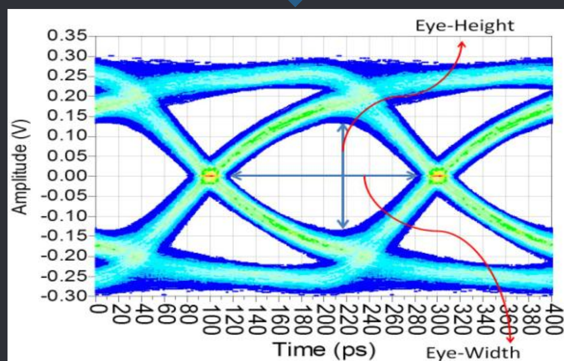
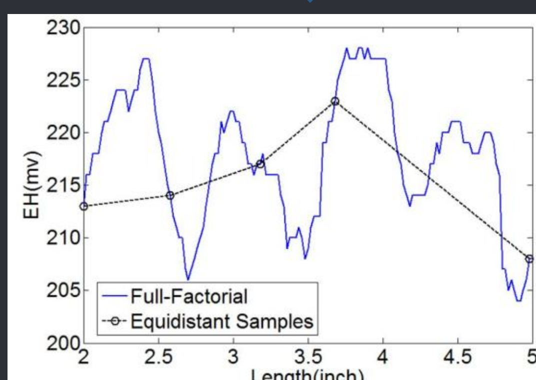
Part II

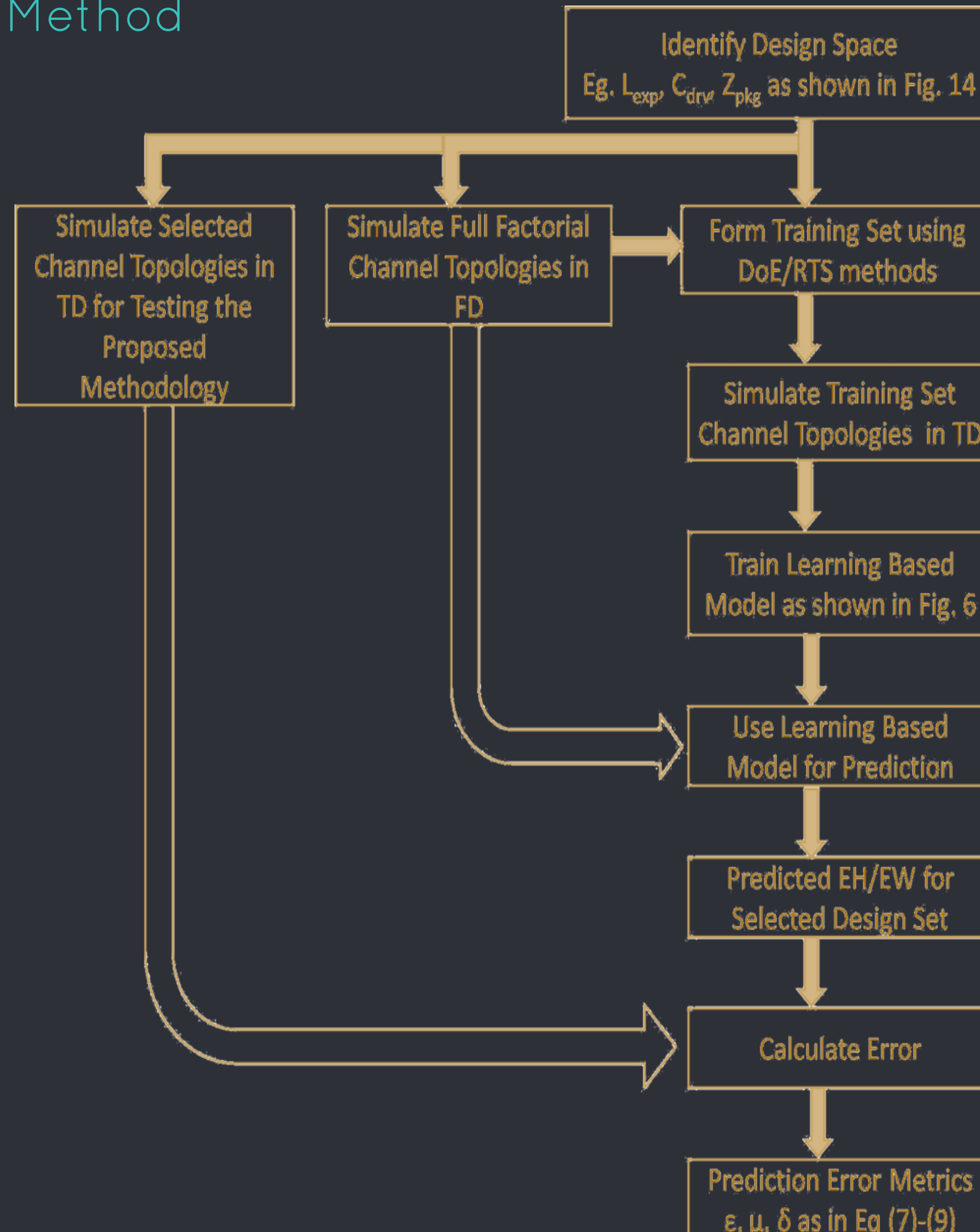
Learning based model generation for faster design space exploration

Learning Based Modeling : Method

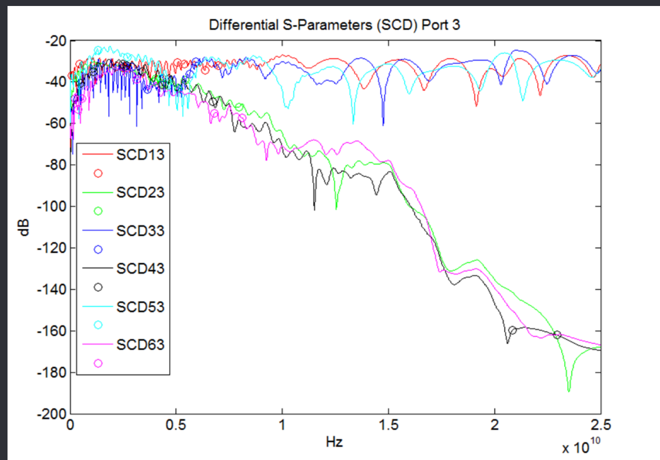


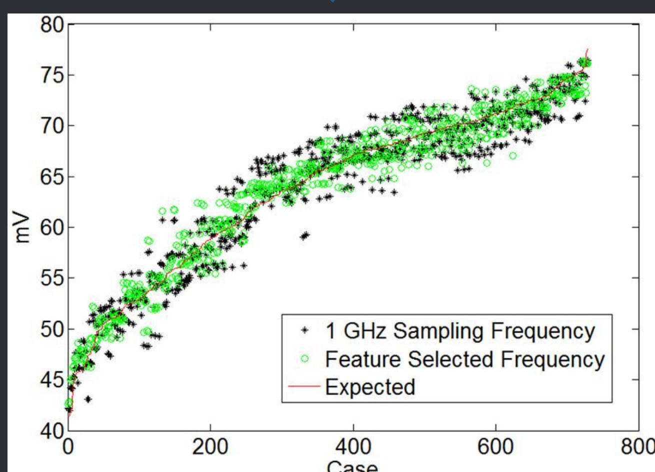






Learning Based Modeling : Results



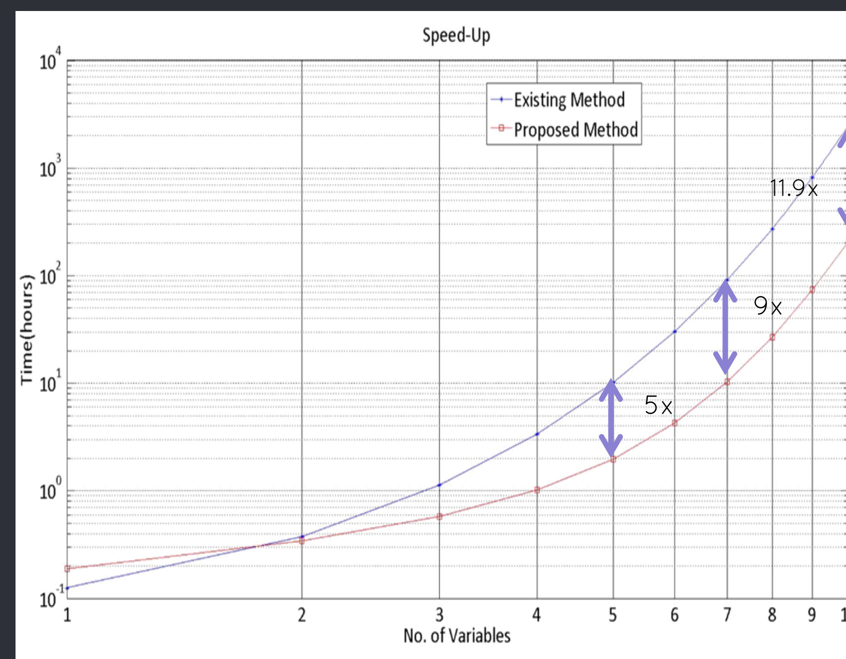


	ε (%)	μ [mV/ps]	δ [mV/ps]
EH	2.2	1.1	5.1
EW	1.5	0.8	3.4

$$\varepsilon(\vec{a},\vec{b}) = \sqrt{\frac{\sum_{i=1}^{N}\left|a_i - b_i\right|^2}{\sum_{i=1}^{N}\left|a_i\right|^2}}$$

$$\mu(\vec{a},\vec{b}) = \frac{\sum_{i=1}^{N}\left|a_i - b_i\right|}{N}$$

$$\delta(\vec{a},\vec{b}) = \underset{i \in [1,N]}{MAX} \left|a_i - b_i\right|$$



Images [5]

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Part III

2.5D PEEC sensitivity based real time Z-Pararmeter update for geometry variation

2.5D Partial Element Equivalent Circuit (PEEC) & Mesh Based Sensitivity

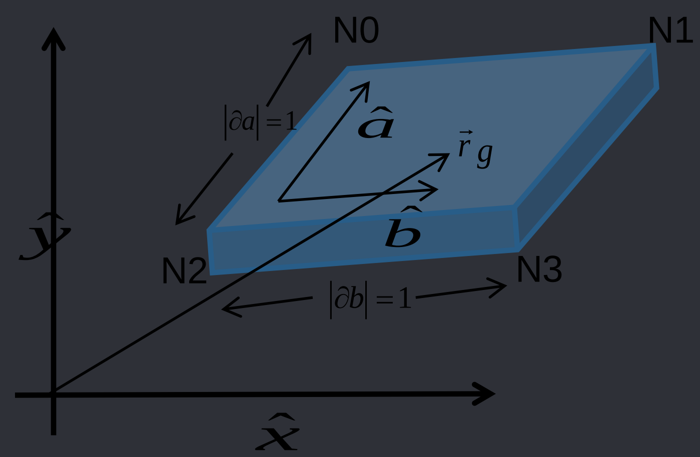
$$dl = \left|\frac{\partial r_g}{\partial a}\right|$$

$$dA = \left|\left(\frac{\partial r_g}{\partial b} \times \hat{c}\right) \times \hat{a}\right|$$

$$dR = \frac{\rho dl}{dA}$$

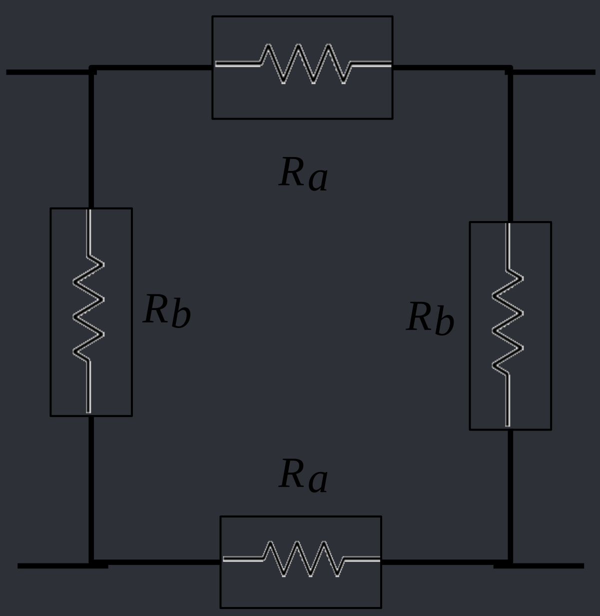
$$Ra = 2 \times \int_{-1}^{1}\int_{-1}^{1} \frac{\rho\left|\frac{\partial r_g}{\partial a}\right|^2}{\left|(\frac{\partial r_g}{\partial a}).(\frac{\partial r_g}{\partial b} \times \hat{c})\right|} dadb$$

$$Rb = 2 \times \int_{-1}^{1}\int_{-1}^{1} \frac{\rho t\left|\frac{\partial r_g}{\partial b}\right|^2}{\left|(\frac{\partial r_g}{\partial b}).(\frac{\partial r_g}{\partial a} \times \hat{c})\right|} dadb$$



$$Y_{N\times N} V_{N\times 1} = I_{N\times 1}$$

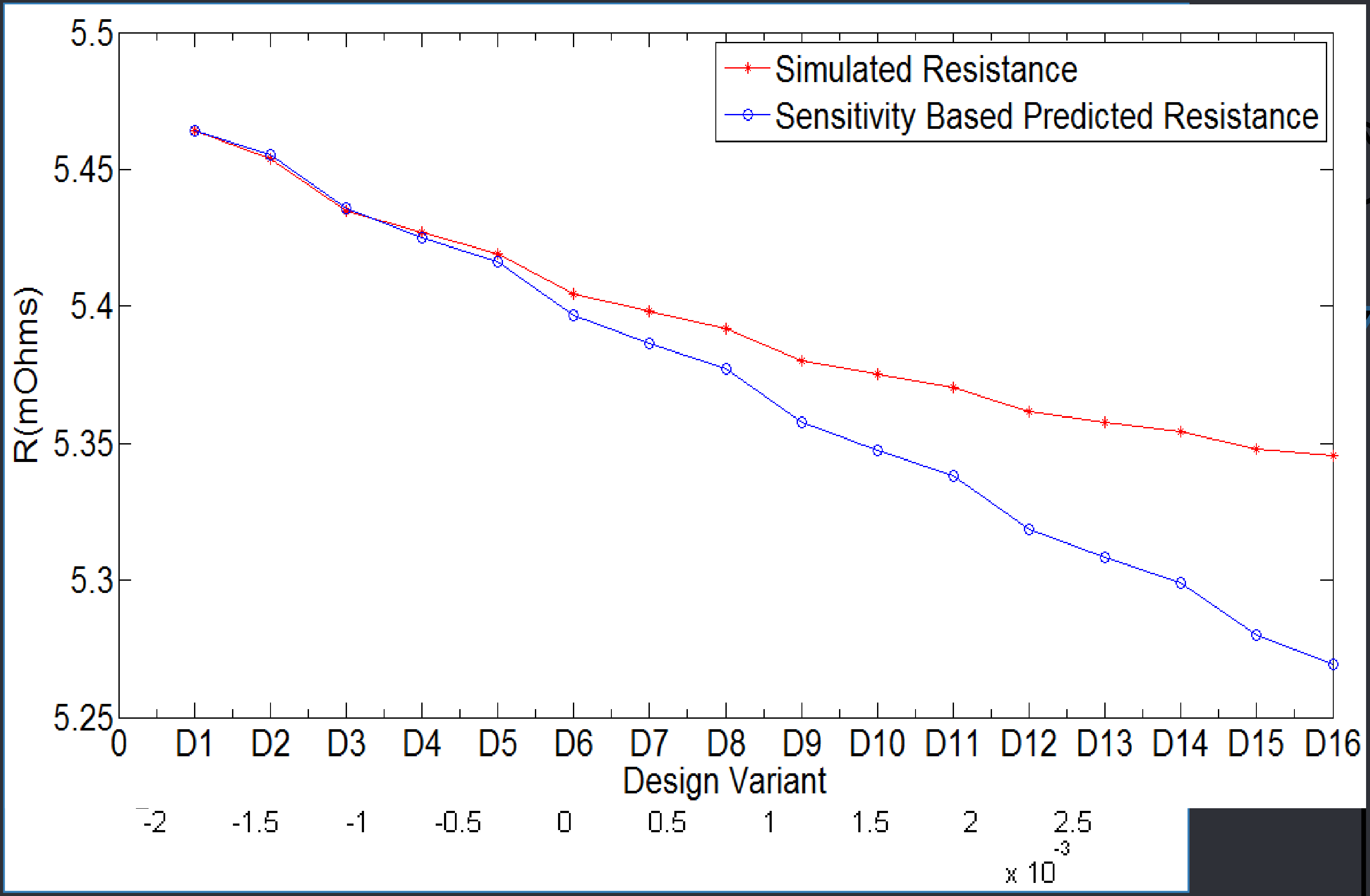
$$Y = \begin{bmatrix} \frac{1}{Ra1} + \frac{1}{Rb1} & -\frac{1}{Rb1} & 0 & -\frac{1}{Ra2} & 0 \\ -\frac{1}{Rb1} & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{Ra2} + \frac{1}{Rb1} & 0 & 0 \\ -\frac{1}{Ra2} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{Ram} + \frac{1}{Rb2} \end{bmatrix}$$



$$Ra = \frac{2\rho}{thickness} \times \int_{-1}^{1}\int_{-1}^{1} \frac{|\vec{k}|^2}{|\vec{k} \times \vec{l}|} dadb \quad , Rb = \frac{2\rho}{thickness} \times \int_{-1}^{1}\int_{-1}^{1} \frac{|\vec{l}|^2}{|\vec{l} \times \vec{k}|} dadb$$

$$\frac{\partial Ra}{\partial \vec{k}} = \left[\frac{\partial Ra}{\partial k_x}, \frac{\partial Ra}{\partial k_y}\right] \quad , \frac{\partial Rb}{\partial \vec{l}} = \left[\frac{\partial Rb}{\partial l_x}, \frac{\partial Rb}{\partial l_y}\right]$$

2.5D PEEC Sensitivity Based Real Time Update Results



Conclusion

A System that facilitates a real time update of SI metrics for changing geometry is presented with the power to give accurate design space sensitivity analysis for an initial design computed for a given set of user specifications

References

[1]http://anysilicon.com/wp-content/uploads/2016/02/Semicondcutor-packaging-history.jpg

[2]http://www.embedded.com/design/system-integration/4009930/Statistical-eye-simulation-and-modeling-high-speed-serial-links

[3]http://electronicdesign.com/test-amp-measurement/eye-diagrams-bathtub-curves-and-bit-error-rates

[4]N. Ambasana, A. Chandrasekhar and D. Gope, "Application of Qualitative Imaging Techniques to Electrical Performance-Aware Package Board Design," in *Electrical Performance of Electronic Packages and Systems*, California, 2013.

[5]N. Ambasana, G. Anand, B. Mutnury and D. Gope, "Eye-Height/Width Prediction from S-Parameters using Learning Based Models", to appear *IEEE Transactions on Components, Packaging and Manufacturing Technology*.

Thanks!

ANY QUESTIONS?

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