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Accurate PCB simulation model for 112Gbps Serdes Testing

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Teradyne



Virtual ▪ October 26-29, 2021

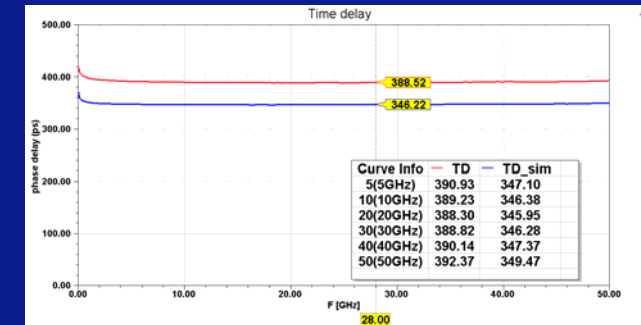
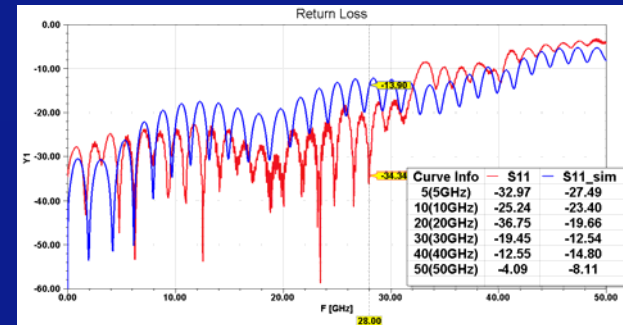
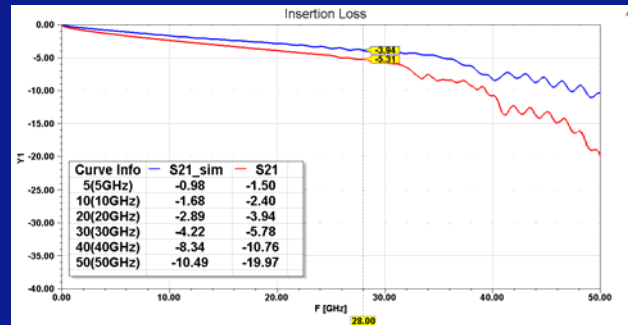


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112Gbps Serdes Testing Challenge on PCB simulation

- 112Gbps Serdes is a big challenge in ATE load board design.
 - Nyquist frequency for 112Gbps PAM4 Serdes is 28GHz. A good SI (signal integrity) performance for DC-56GHz is required to guarantee the signal transmission on PCB.
 - In traditional simulation model, many assumptions are used, so simulation results can hardly match the real-world measurement over 15GHz.

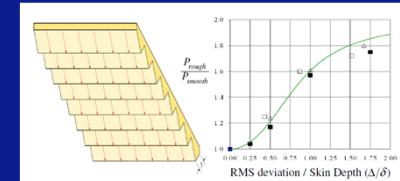


112Gbps Serdes Testing Challenge on PCB simulation

- 112Gbps Serdes is a big challenge in ATE load board design.
 - Nyquist frequency for 112Gbps PAM4 Serdes is 28GHz. A good SI (signal integrity) performance for DC-56GHz is required to guarantee the signal transmission on PCB.
 - In traditional simulation model, many assumptions are used, so simulation results can hardly match the real-world measurement over 15GHz.
 - Material properties and manufacturing variations of PCB will dominate the result accuracy of simulation.
 - Accurate simulation model is needed to get good correlation between simulation and measurement.

Traditional PCB simulation model

- In traditional simulation model, many assumptions are used:
 - Pure copper conductivity (5.9×10^7 S/m);
 - Design value for geometries (trace width, dielectric thickness);
 - Simple copper roughness model (Hammerstad-Jenson / RMS);
 - RMS value come from material vendor.
- Dk is adjusted to get impedance match up with target



Accurate PCB simulation model

- Manufacturing variations
 - Copper conductivity
 - The conductivity of copper on PCB can be lower than pure copper.
 - Geometries (trace width, dielectric thickness)
 - Finished trace width can be smaller than designed value.
 - Copper surface roughness change
 - Copper surface is roughened by oxide process to get better adhesiveness in lamination.
 - Dielectric material properties (Dk/Df)
 - Datasheet values are the baseline. They might be slightly changed in PCB fabrication.



Accurate PCB simulation model

- Material characterization

Adjust the Dk / Df / Roughness inputs in 3D solver to get the simulated Time delay & AC resistance & insertion loss match up to S-parameter measurement

S parameter measurement

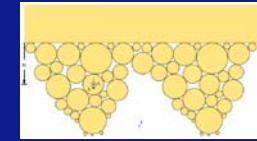
$$TD = \frac{\text{rad}(S_{21})}{2\pi f}$$

$$R_{AC} = \text{Re}\left(\frac{1}{Y_{11}}\right)$$

?
Dk

?
Copper roughness

Huray model



$$\frac{P_{rough}}{P_{smooth}} \approx 1 + \frac{3}{2} \sum_{i=1}^j \left(\frac{N_i 4\pi a_i^2}{A_{hex}} \right) \left/ \left[1 + \frac{\delta}{a_i} + \frac{\delta^2}{2a_i^2} \right] \right.$$

Time delay

?
Copper roughness

Copper conductivity ✓

DC measurement

?
Dk/Df

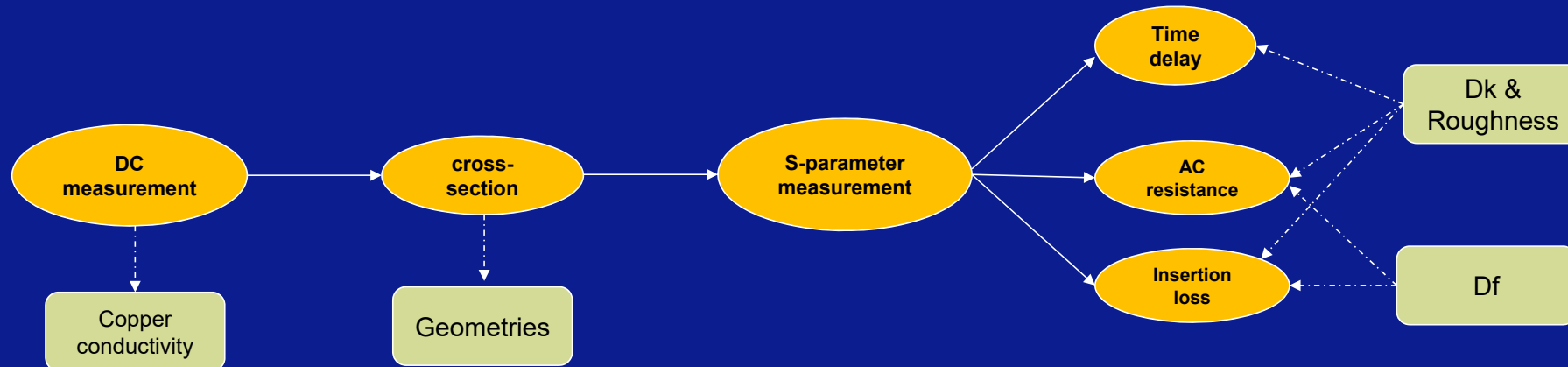
Trace geometry ✓

cross-section

AC resistance/
Insertion loss

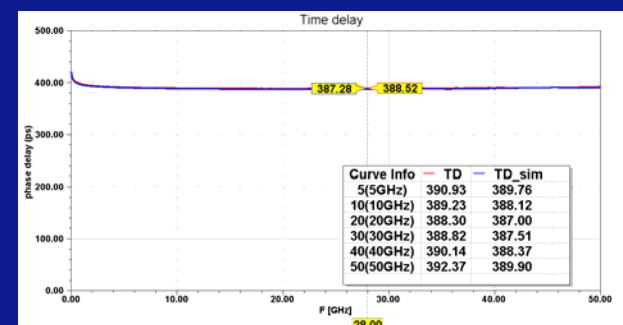
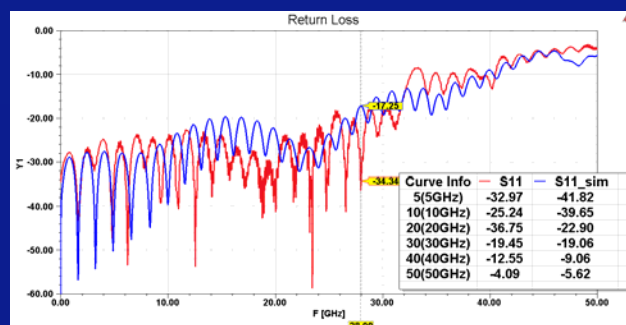
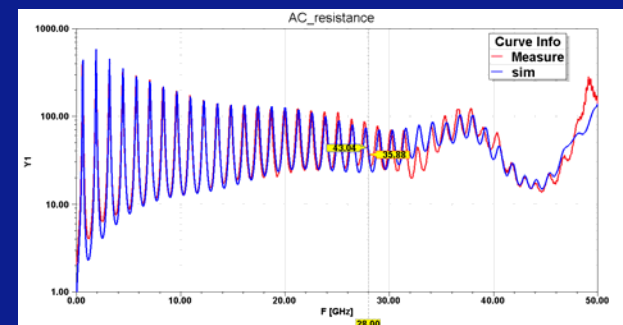
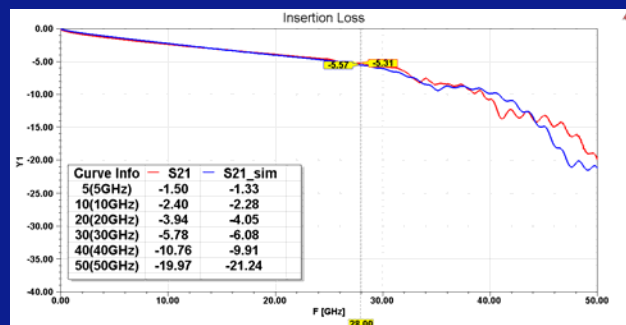
Accurate PCB simulation model

- Material characterization



Accurate PCB simulation model

- Correlation between simulation (HFSS 2019R1) and measurement



Conclusion

- Accurate simulation model is badly needed for 112Gbps Serdes test in ATE load board design;
- Traditional simulation model used many assumptions which result in big mismatch between simulation and measurement;
- With the help of DC measurement, cross-section and S-parameter measurement, we introduce the accurate simulation model by considering manufacturing variations and characterizing material properties.
- The accurate simulation model correlates well to measurement up to 50GHz.

Reference

- *P. G. Huray, O. Oluwafemi, J. Loyer, E. Bogatin, X. Ye Impact of Copper Surface Texture on Loss: A Model that Works, DesignCon 2010*

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