Measurements of High-Speed Interconnects in Automotive-Grade PCBs

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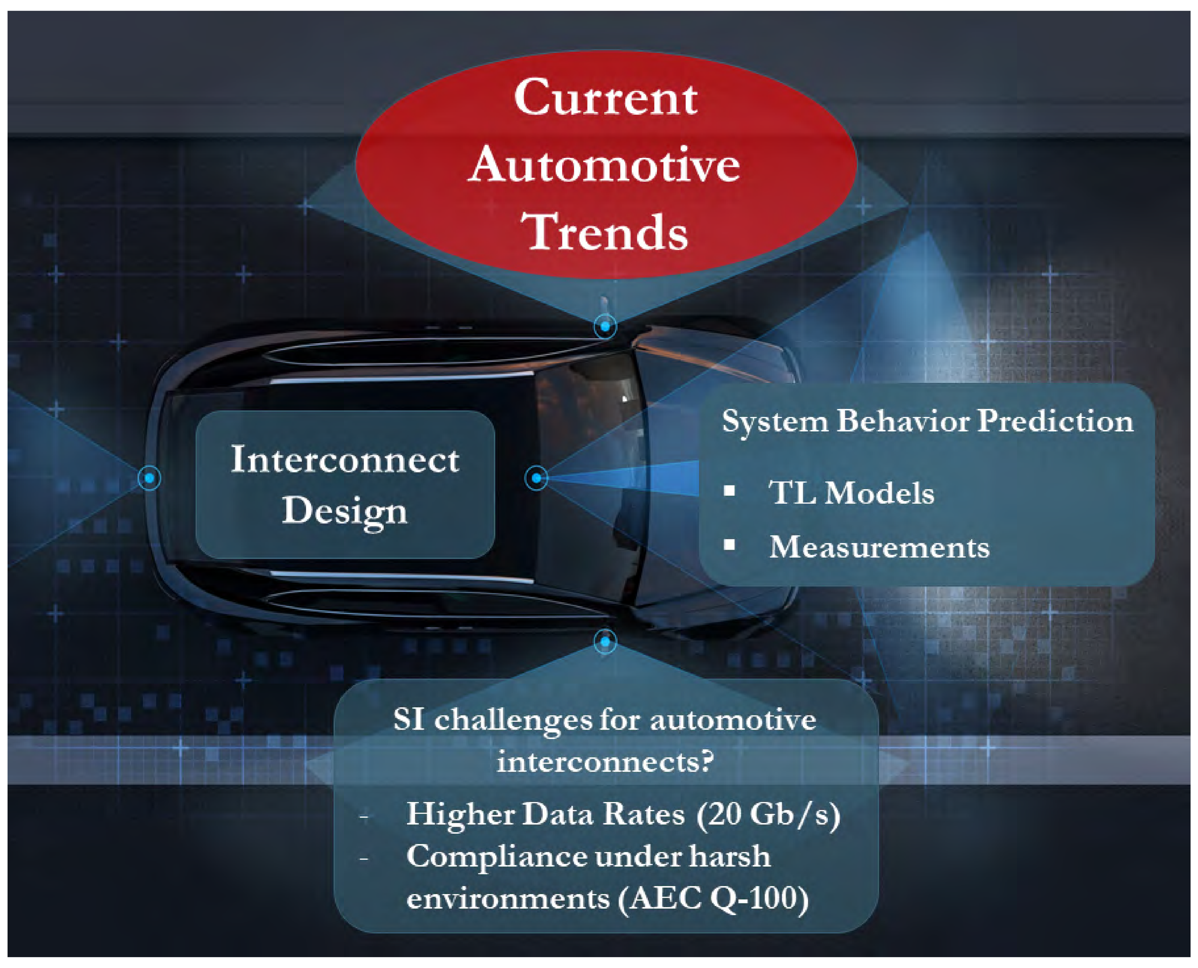
Abstract

Three multi-layer printed circuit boards (PCBs) with different base materials were measured up to 25 GHz to obtain their respective insertion loss profile. First-Order statistical analysis was performed to analyze the measurement's repeatability. The loss per inch profile of the measured interconnects is obtained via two de-embedding methodologies. The repeatability of the de-embedding process is also analyzed via calculation of the mean and standard deviation.

Motivation



Project Description

- Vector Network Analyzer (VNA) measurements of various interconnects in three different multi-layered PCBs.
- Calculation of the insertion loss (IL) per inch for the various interconnects measurements.
- Proof the measurement repeatability via calculation of first-order statistical values.

Device Under Test (DUT)

- DUT: Three PCB stack-ups (1-8b-1) with thickness of 1.6 mm.
- Screwed-in SMAs into PCB launches.
- Three different base materials:
  - Low Loss (LL): 0.010≤ Df <0.015
  - Very Low Loss (VLL): 0.005≤ Df <0.010
  - Ultra Low Loss (ULL): 0.002< Df <0.005
- Three striplines with lengths 2, 5, and 10 inches.

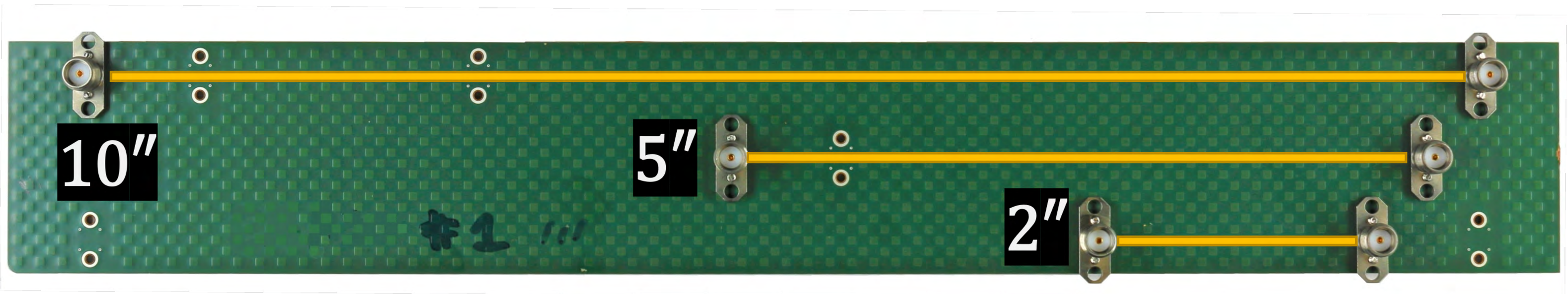


Figure 1: Top view of the DUT.

Measurement Setup

- 32 GHz VNA, calibrated with Short-Open-Load-Through (SOTL) kit up to 25 GHz.
- Three boards per material. Total boards: 9.
- Frequency Range: 10 MHz - 25 GHz.

Repeatability of S-Parameter Measurements

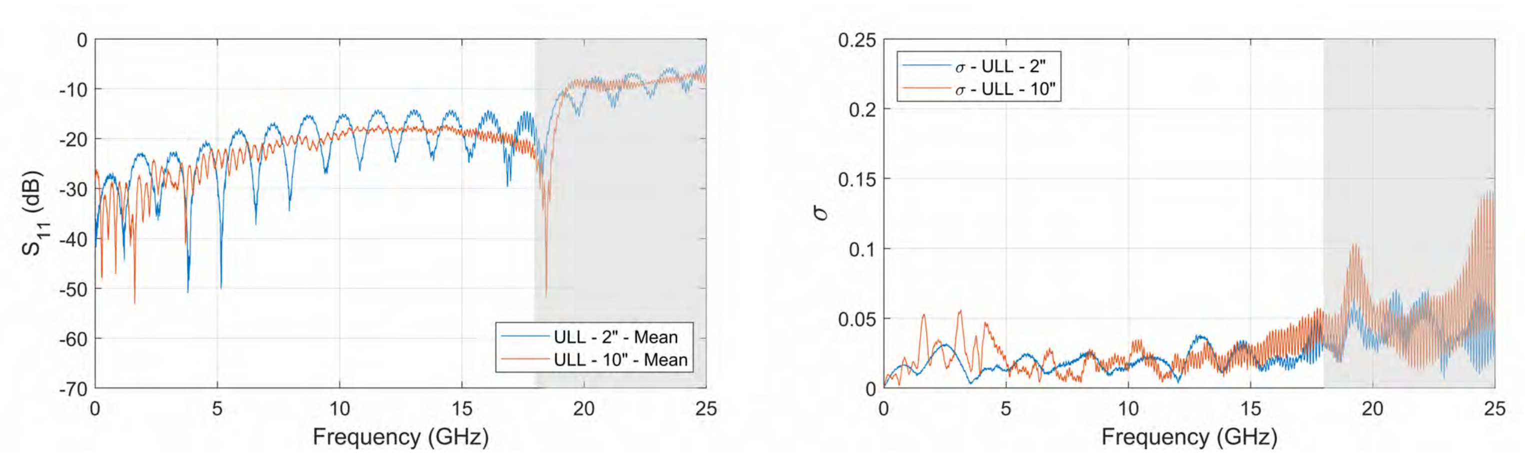


Figure 2: Return loss mean and standard deviation for the LL material. The gray zone (17-25 GHz) highlights the effect of non-idealities on the fixtures.

- Measurement repeatability was checked by calculating the mean and standard deviation of the return loss (RL).
- Repeatability also analyzed for VLL and ULL materials.

Calculation of the Insertion Loss per Inch

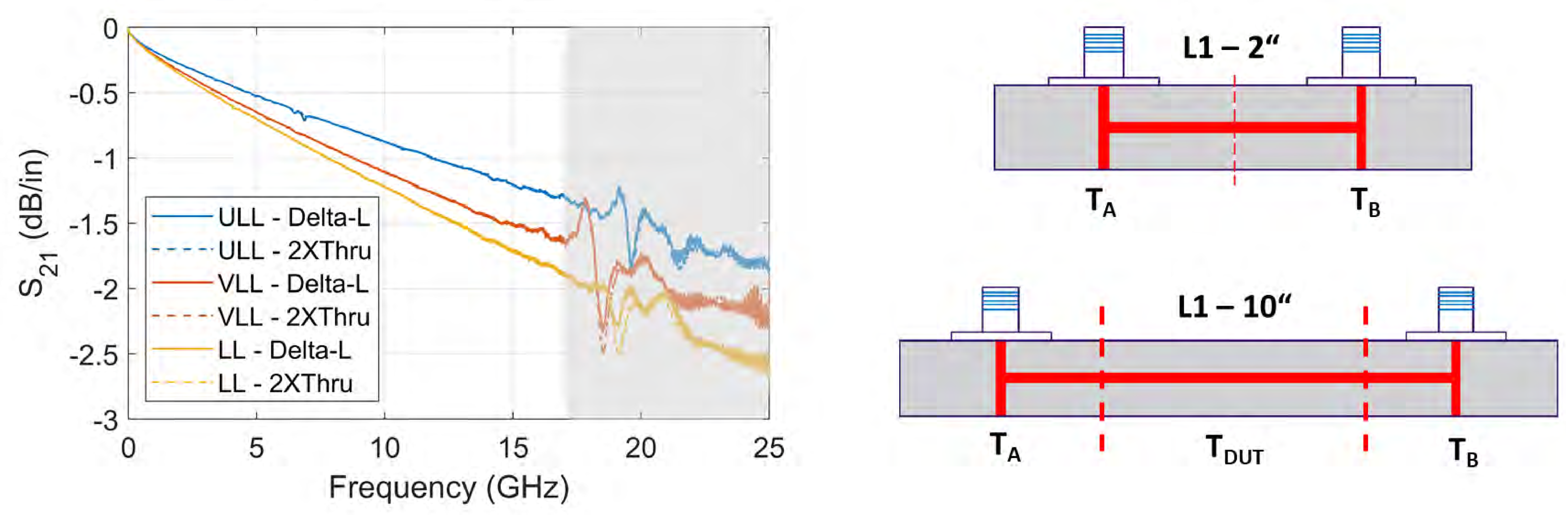


Figure 3: (Left) Insertion loss per inch for three different materials after deembedding via two different methods. The gray zone (17-25 GHz) highlights the effect of non-idealities on the fixtures, (Right) Illustration of the required lines to be measured to apply the de-embedding methods.

- IL per inch is calculated using two de-embedding methods. Delta-L [1] and 2X-Through [2].
- Variations from 17 GHz can be attributed to asymmetries in the fixtures and non-idealities of the SMA connectors.

2D-Simulation vs Measurement

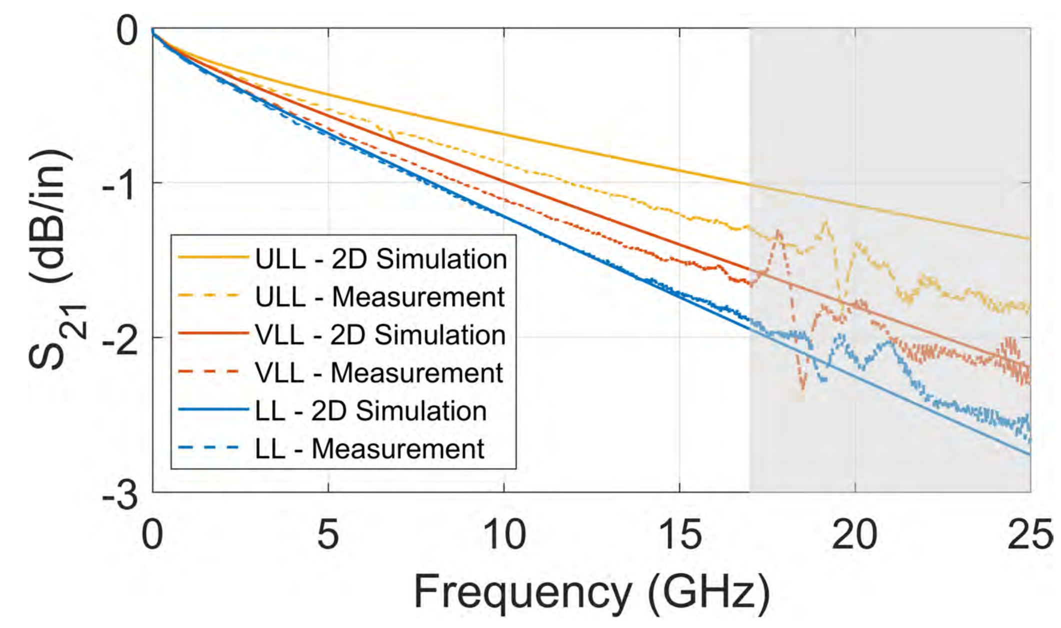


Figure 4: IL per inch for three different material. Comparison of 2D-Model versus de-embedded measurements. The gray zone (17-25 GHz) highlights the effect of non-idealities on the fixtures.

- The PCB stack-ups were simulated in a 2D solver with frequency dependent models for the dielectric and surface correction factors.
- Dielectric is modeled with the Djordjevic-Sarkar model [3].
- Conductor roughness is modeled with the cannonball Huray model [4].

Conclusions

- IL per inch can be obtained with only two lines of different length up to around 17 GHz.
- Mismatch between simulation and measurements are due to underestimation of the roughness effect resulting in higher IL per inch profiles for the ULL and VLL materials.

Future Work

- Extraction of material properties (Dk/Df) of the DUT is ongoing with the goal of using the values in simulation models for higher accurate interconnect design.
- Study the effect of copper roughness in PCB stack-ups in the IL profile of automotive high-speed interconnects.

References

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[3] A. Djordjevic, R. Biljie, V. Likar-Smiljanic, and T. Sarkar, "Wideband frequency-domain characterization of fr-4 and time-domain causality," *IEEE Transactions on Electromagnetic Compatibility*, vol. 43, no. 4, pp. 662–667, 2001.

[4] L. Simonovich, "Practical method for modeling conductor roughness using cubic close-packing of equal spheres," in *2016 IEEE International Symposium on Electromagnetic Compatibility (EMC)*, 2016, pp. 917–920.

Acknowledgements

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