Microwave measurements and electromagnetic simulations of printed circuit boards (PCBs) for high speed digital and radio frequency (RF) applications

Organisers
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Abstract
With ever increasing data rates, modern high speed digital signals contain significant frequency content in the microwave region of the spectrum. As a result, microwave techniques are required in the design of high speed digital systems to minimize cross-talk and to maintain signal integrity. Linked to the high-speed data transmission, the requirements on radio frequency (RF) front ends are also steadily increasing. Microwave measurements (using Vector Network Analyzers (VNAs) as well as oscilloscopes) and three dimensional (3D) electromagnetic simulation both have a role to play in the development of such high speed digital and RF systems. This workshop will present state of the art measurement techniques for high speed digital and RF Printed Circuit Boards (PCBs) as well as the application of contemporary electromagnetic simulation tools to obtain a better understanding of such systems.

Programme
9:00 - 09:25 Microstrip and stripline configurations for printed circuit board (PCB) applications and selected measurement issues
 Siddharta Sinha,1 Franz-Josef Schmucke,1, Ralf Doerner, and Andrej Rumiantsev,1,2
1 FBH, Berlin, Germany and 2 MPI Corporation, Hsin Chu, Taiwan
→ Abstract
9:25 - 9:50 A reference printed circuit board (PCB) for validating microwave measurements on PCBs and a differential calibration kit for traceable measurements
Martin Salter,1 Nick Ridler,1 Djamel Allal,2 Francois Ziade,2 and Martin Hudlicka and Tomas Pavlick,2
1 NPL, Teddington, UK, 2 LNE, Paris, France and 3 CMI, Prague, Czech Republic
→ Abstract
9:50 - 10:15 Radiation of Microstrip Edge Mounted Transitions – Measurement Problems
Karel Hoffmann, CTU, Prague, Czech Republic
→ Abstract
10:15 - 10:40 De-embedding techniques in measurements of printed circuit board (PCB) backplanes and dense fixture environments
Jon Martens, Anritsu, Morgan Hill, CA, USA
→ Abstract
10:40 - 11:20 Coffee Break
11:20 - 11:45 Using Microprobing, Modeling and Error Correction Techniques to Optimize Channel Design
Mike Resso, Keysight Technologies, Santa Rosa, CA, USA
→ Abstract
11:45 - 12:10 Multiport Vector Network Analyzers: A powerful tool for the verification of high-data-rate digital circuit designs
Thilo Bednorz, Rohde & Schwarz GmbH & Co. KG, Munich, Germany
→ Abstract
12:10 - 12:35 Closing the loop between measuring and modelling insertion loss on printed circuit boards (PCBs)
Paul Carre, Neil Chamberlain, and Martyn Gaudion, Polar Instruments Ltd, Guernsey, UK
→ Abstract
12:35 - 13:00 Panel Discussion
9:00 - 09:25 Microstrip and stripline configurations for printed circuit board (PCB) applications and selected measurement issues
Siddharta Sinha\(^1\), Franz-Josef Schmueckle\(^2\), Ralf Doerner\(^1\), and Andrej Rumiantsev\(^3\), FBH, Berlin, Germany and \(^3\)MPI Corporation, Hsin Chu, Taiwan

**Abstract**
Printed circuit boards (PCBs) with their stacked layer system offer the possibility of manifold embedded line types. The properties in terms of propagation, radiation and coupling of such simple line types are usually known. But special parts such as transitions, measurement probes and connectors can give rise to various problematic electromagnetic behaviours. The desired and parasitic electromagnetic effects appearing in the PCB and the environment of the measurement devices will be described. Improved and optimized parts with low parasitic values and good transmission performance will be presented.

Based on these findings, we will discuss selected aspects of the measurement scenario and will give recommendations for calibration and correction algorithms, as well as suitable calibration structures. Special attention is paid to such important issues as the calibration reference impedance and the location of the reference plane.

9:25 - 9:50 A reference printed circuit board (PCB) for validating microwave measurements on PCBs and a differential calibration kit for traceable measurements
Martin Salter\(^1\), Nick Rider\(^2\), Djamel Alafia\(^2\), Francois Ziade\(^2\), Martin Hudlicka\(^2\) and Tomas Pavlicek\(^2\), \(^1\)NPL, Teddington, UK, \(^2\)LNE, Paris, France and \(^3\)CMI, Prague, Czech Republic

**Abstract**
This talk will describe a reference printed circuit board (PCB) that has been developed for validating and comparing microwave measurement methods on PCBs. The four layer reference board contains various structures including vector network analyser (VNA) calibration standards, VNA verification standards and transmission line interconnects. The structures occur in different varieties: connectorised and probed, differential and single-ended, and, microstrip and stripline. The talk will also describe the development of a multimode TRL calibration kit, based on accurate 3D simulations using CST Microwave Studio. A comprehensive uncertainty budget will be presented for establishing traceability via differential standards for mixed-mode S parameter measurements.

9:50 - 10:15 Radiation of Microstrip Edge Mounted Transitions – Measurement Problems
Karel Hoffmann, CTU, Prague, Czech Republic

**Abstract**
Measurement uncertainty problems on microstrip associated with interaction of electromagnetic fields around coaxial to microstrip transitions, microstrip lines and microstrip calibration standards are studied in the frequency band up to 26 GHz using CST Microwave Studio. Multimode propagation in the whole structure which makes it impossible to apply standard calibration methods is illustrated. A hardware solution enforcing single mode propagation is suggested and tested using a simulation testing method similar to a standard calibration/verification procedure. Significant reduction in the measurement uncertainties can be achieved.

10:15 - 10:40 De-embedding techniques in measurements of printed circuit board (PCB) backplanes and dense fixture environments
Jon Martens, Anritsu, Morgan Hill, CA, USA

**Abstract**
Many de-embedding techniques have been developed over the years that are targeted at measurement problems in PCB assemblies, multilane fixtures, backplanes and related environments where the electromagnetic complexities and marginal repeatability of the interface may make traditional methods suboptimal. These alternate techniques are sometimes based on partial solutions of the interface taking into account match distribution or symmetry assumptions or pre-calculations. These steps have a number of accuracy implications depending on the parameters of the fixture/board assembly being de-embedded and those of the DUT itself. This talk will explore some of these accuracy dependencies and what steps can sometimes be taken to minimize issues for several common methods based on minimal standards connections.

11:20 - 11:50 Using Microprobing, Modeling and Error Correction Techniques to Optimize Channel Design
Mike Resso, Keysight Technologies, Santa Rosa, CA, USA

**Abstract**
Complex channel topologies transmitting Gigabit data streams challenge the best digital design engineers today. Advanced error correction techniques alone are not a cure all for what ails the signal integrity of our telecommunication systems. Multiple technical disciplines and various domain analysis tools are now required to provide proper insight into performance. This paper will discuss step-by-step channel analysis methodologies using microprobing, modeling and measurement tools to show accurate results to 20 GHz. A typical design case study using new international proprietary memory architecture will be discussed.

11:50 - 12:20 Multiport Vector Network Analyzers: A powerful tool for the verification of high-data-rate digital circuit designs
Thilo Bednorz, Rohde & Schwarz GmbH & Co. KG, Munich, Germany

**Abstract**
Time domain analysis is a powerful tool to characterize the quality of data transfer e.g. via single ended and differential transmission lines, printed circuit boards (PCBs) and connectors. Most of these measurements such as impedance versus time, skew and eye diagrams were done in the past using Time Domain Reflectometry (TDR) oscilloscopes. This talk will show the capabilities and advantages of a multiport vector network analyzer to perform these measurements.

12:20 - 12:40 Closing the loop between measuring and modelling insertion loss on printed circuit boards (PCBs)
Paul Carre, Neil Chamberlain, and Martyn Gaudion, Polar Instruments Ltd, Guernsey, UK

**Abstract**
Using modeling tools to predict and analyse the relative effects of dielectric loss, copper roughness, and structure geometry on insertion loss and characteristic impedance of printed circuit board (PCB) tracks, we show how correlation of measured and modelled S-parameters leads to an improvement in measurement confidence.