Calibration of Probes for EMC Near-Field Scanning

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Outline

1. Introduction
2. Calibration structures
3. Probe compensation
4. Measurements
5. Summary
Purpose of this work

- Measurement of all 6 field components on scanning plane above PCB
- Post-processing techniques can reconstruct entire field from ≥2 probe outputs
- Application of probes with multiple outputs to determine entire electromagnetic field on scanning plane
- Calibration of probes
Introduction

Probe calibration process

- Measurement of probe output above calibration structure
- Full-wave simulation of near-field pattern above calibration structure
- Spatial 2D-Fourier-transformation of the measured and simulated results
- Calculation of probe transfer function in spatial frequency domain
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Calibration of Probes for EMC Near-Field Scanning

Calibration structures

Used PCBs: microstrip structures with ground plane, 16cm x 10cm
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Calibration structures

Transient simulation of near-fields

- 50Ω SMA Port modelled as waveguide port
- Frequency range 1MHz – 3GHz
- Low frequencies → long simulated period
- xy-resolution: 1mm
- \( \approx 2.4 \) million meshcells
- Simulation time 1h 35m
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Calibration structures

Transient simulation of near-fields

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Calibration structures

Transient simulation of near-fields

- 2 E- and H-field monitors per decade, 1MHz-3GHz
- 3D-fields on 2D-plane
- ASCII-export of field data
- 1mm spatial resolution
- Further calculations in Matlab

Settings for 2D/3D Plot Data Export

- Number of steps fixed
- Step width fixed
- Same step width for all directions

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Purpose of probe compensation

- Reconstruction of field components from output signals

Approaches

- Pointwise compensation („antenna factor“)
  No compensation of parasitic field coupling and spatial convolution

- Deconvolution compensation (plane wave theory)
  Compensation of parasitic coupling and spatial convolution possible
Plane Wave Theory

• Representation of the electromagnetic field as a superposition of plane waves:

\[
\tilde{A}(x, y, h_s) = \frac{1}{4\pi^2} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \tilde{T}^A(k_x, k_y, h_s) e^{i(k_x x + k_y y)} dk_x dk_y
\]

• Relations between field components (Maxwell's equations)

Only 2 of 6 field components are independent!

\[
\begin{align*}
\vec{k} \cdot \vec{T}^E &= 0 \\
\vec{k} \times \vec{T}^E &= \omega \mu \vec{T}^H \\
\vec{k} \cdot \vec{T}^H &= 0 \\
\vec{k} \times \vec{T}^H &= -\omega \varepsilon \vec{T}^E
\end{align*}
\]
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**Probe Compensation**

Calibration

- Determination of probe reaction on each component of the plane wave spectrum

- Procedure:
  - Scan of $\geq 2$ DUTs with known fields
  - Spatial Fourier-Transformation of fields and probe output
  - Determination of calibration coefficients

- Result: calibration data for each probe output mode and for 2 field components

- $>2$ calibration DUTs: overdetermined LSE, noise reduction
Compensation Process

- Scan of DUT with $\geq 2$ probes / modes / polarizations
- Spatial Fourier-Transformation of probe output
- Calculation of 2 field components using calibration coefficients
- Inverse spatial Fourier-Transformation of fields
- Calculation of remaining field components
- $>2$ modes: overdetermined LSE, noise reduction
- Use of probe with multiple outputs decreases positioning errors
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Positioning System

- PCBs 160x200mm²
- Step size 10µm (x,y)
- z position fixed
- Amplitude and phase measurement by VNA
Calibration of Probes for EMC Near-Field Scanning Measurements

Probes

- Probe A: Electric dipole, 2 outputs
- Probe B: Combined dipole / loop probe, 4 outputs
- Both made of semi-rigid coaxial cables with 2.2mm outer diameter
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Measurements

Probe A

Used PCBs: microstrip structures with ground plane
Results
Output Signals of probe A at 3.16 GHz

P1, dm

P2, dm

P1, cm
Calibration of Probes for EMC Near-Field Scanning Measurements

<table>
<thead>
<tr>
<th>Electric field</th>
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<tbody>
<tr>
<td>From probe compensation (2 modes, 2 polarizations)</td>
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<td>From Microwave Studio</td>
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Magnetic field

From probe compensation (2 modes, 2 polarizations)

From Microwave Studio

From Microwave Studio

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Probe B

Additional PCBs

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Results

Output Signals of probe B at 3.16 GHz

- $E_x$ mode
- $E_z$ mode
- $H_x$ mode
- $H_z$ mode
Calibration of Probes for EMC Near-Field Scanning Measurements

Electric field

From probe compensation (4 modes, 1 polarization)

From Microwave Studio

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Measurements

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Observations

- Better results with calibration using >2 DUTs
- Calibration quality depends on PCB selection
- Compensation using >2 probe outputs improves results
- Magnetic field calculation from separate calibration better than from electric field
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Summary

- Presentation of a planar near-field scanning system
- Calculation of calibration field patterns using Microwave Studio
- Application of probe compensation techniques using plane wave theory
- Extraction of electric and magnetic field components from the scan data, comparison with CST simulation results
- Probes with multiple outputs well suited for probe-compensated near-field measurements
Thank you for your attention!