PREDICTION OF FREQUENCY DEPENDENT SHIELDING BEHAVIOR FOR GROUND VIA FENCES IN PRINTED CIRCUIT BOARDS

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I. Introduction

Signals on layer crossing vias excite parallel plate mode waves.

Via fences as EBG structures operating in first bandgap.

Effective shielding mechanism.
I. Introduction

II. Proposed Simulation Method
   • Considered via array structures
   • Contour Integral Method for Planar Structures
   • Unit Cell Analysis

III. Application and Derivation of Approximations
   • Standard Setup and Rectangular Waveguide
   • Approximations Using Fitting
   • Application to Finite Size Arrays

IV. Conclusions
II. Proposed Simulation Method
Considered via array structures

- Idealized infinite large via array
- Parallel plate structure
- Definition of two different unit cells (two main directions)
II. Proposed Simulation Method

Considered via array structures

Idealized infinite large via array

Parallel plate structure

Definition of two different unit cells (two main directions)
II. Proposed Simulation Method

Considered via array structures

- Idealized infinite large via array
- Parallel plate structure
- Definition of two different unit cells (two main directions)
- Different setups simulated
- Loss-less materials

### Overview of the basic setups for the simulations.

<table>
<thead>
<tr>
<th></th>
<th>Relative permittivity $\varepsilon_r$</th>
<th>Via radius $a$</th>
<th>Unit cell length $D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setup 1</td>
<td>4.4</td>
<td>0.25 mm</td>
<td>1.5 mm</td>
</tr>
<tr>
<td>Setup 2</td>
<td>8</td>
<td>0.4 mm</td>
<td>1.75 mm</td>
</tr>
<tr>
<td>Setup 3</td>
<td>4.4</td>
<td>0.6 mm</td>
<td>2.75 mm</td>
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\[ d = 0.25 \text{ mm}. \]
II. Proposed Simulation Method

Contour Integral Method for Planar Structures

Contour Integral [1]

Planar and passive microwave circuits

Linear ports on the contour

II. Proposed Simulation Method

Contour Integral Method for Planar Structures

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II. Proposed Simulation Method

**Contour Integral Method for Planar Structures**

- **Contour Integral** [1]
- **Planar and passive microwave circuits**
- **Linear ports on the contour**
- **Smooth field distribution at circular inclusions** → **Fourier expansion** [2, 3]

\[ Z_{CIM} \in \mathbb{R}^{n \times n} \]


II. Proposed Simulation Method

Unit Cell Analysis

**Z**^CIM \in \mathbb{R}^{n \times n} \Rightarrow **Z** \in \mathbb{R}^{2 \times 2}

Applying of boundary conditions

Port combination by averaging over voltages

\[ U_{\text{Port}} = \frac{1}{N} \sum_i U_i \]
II. Proposed Simulation Method

Unit Cell Analysis

Periodical structure → Periodical field \([4]\)

Phase delay between unit cells \([4]\)

Solution for 2x2 matrices \([5]\)

\[
\gamma = \frac{1}{D} \arccosh \left( \frac{Z_{11} + Z_{22}}{2Z_{12}} \right)
\]

\[
Z = \begin{bmatrix}
Z_{11} & Z_{12} \\
Z_{21} & Z_{22}
\end{bmatrix}
\]

\[
e^{-\gamma D}
\]


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Standard Setup and Rectangular Waveguide

\[ \alpha = \left( \frac{\pi}{\tilde{a}} \right) \cdot \sqrt{1 - \left( \frac{f}{f_c} \right)^2} \]

\[ \alpha_0 \]

1st bandgap: 2200 Np/m

2nd bandgap: 1433 Np/m

35 GHz

\[ f_c \]

\[ f \ (\text{GHz}) \]

III. Application and Derivation of Approximations

Standard Setup and Rectangular Waveguide

\[ \alpha = \left( \frac{\pi}{\tilde{a}} \right) \cdot \sqrt{1 - \left( \frac{f}{f_c} \right)^2} \]  

[6]

Structure B
III. Application and Derivation of Approximations

Approximations Using Fitting

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<th>Fit function</th>
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Relative permittivity $\varepsilon_r$ | Via radius $a$ | Unit cell length $D$
---|---|---
Setup 1 | 4.4 | 0.25 mm | 1.5 mm
Setup 2 | 8  | 0.4 mm  | 1.75 mm
Setup 3 | 4.4 | 0.6 mm  | 2.75 mm

Til Hillebrecht

Prediction of Frequency Dependent Shielding Behaviour for Ground Via Fences in Printed Circuit Boards
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Approximations Using Fitting

Fitting based on rectangular waveguide behavior

Adjusting effective distance

Rectangular Waveguide [6]

\[ f_c^R = \frac{c_0}{\sqrt{\varepsilon_r} 2\tilde{a}} \]

\[ \alpha_0^R = \frac{\pi}{\tilde{a}} \]

Structure A

\[ f_c^A = \frac{c_0}{\sqrt{\varepsilon_r} (1.5 \cdot 2D - 1.5 \cdot 4a)} \]

\[ \alpha_0^A = \frac{\pi}{1.353 \cdot D - 1.305 \cdot 2a} \]

Structure B

\[ f_c^B = \frac{c_0}{\sqrt{\varepsilon_r} (1.27 \cdot \sqrt{2}D - 0.98 \cdot 4a)} \]

\[ \alpha_0^B = \frac{\pi}{1.36 \cdot D / \sqrt{2} - 1.34 \cdot 2a} \]
III. Application and Derivation of Approximations

Application to Finite Size Arrays (HFSS)
III. Application and Derivation of Approximations

Application to Finite Size Arrays (HFSS)
Outline

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- Fast and accurate numerical Method
- Up to 4200 Np/m attenuation below cutoff-frequency
- 2 parameters for fitting equations $\alpha_0, f_c$

Further research
- Other arrangements of vias within unit cell
- Adaptation to power ground structures
THANK YOU FOR YOUR ATTENTION