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

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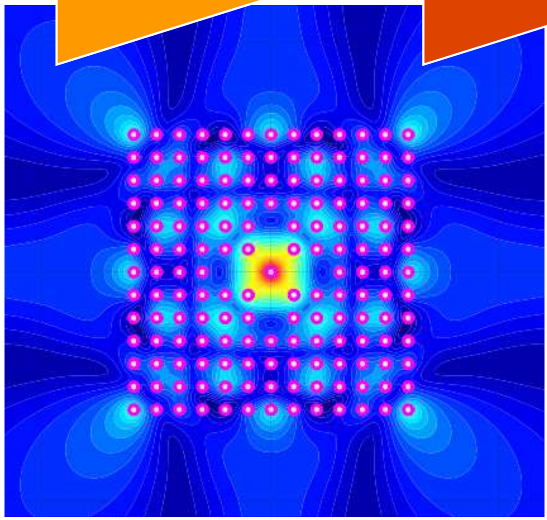
Hamburg, Germany

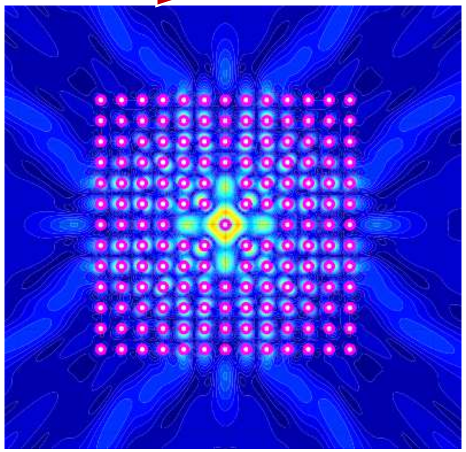
I. Introduction

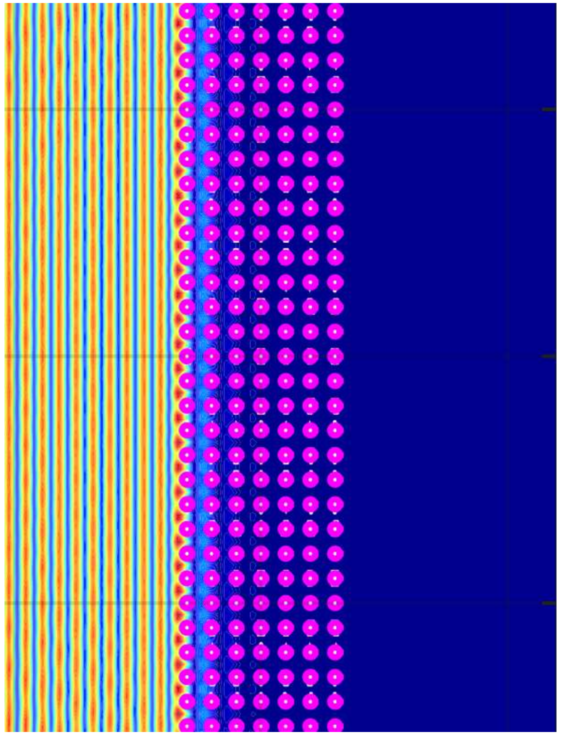
Signals on layer crossing vias excite parallel plate mode waves

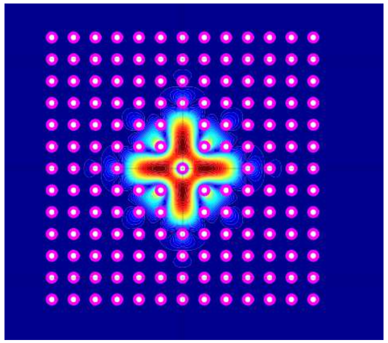
Via fences as EBG structures operating in first bandgap

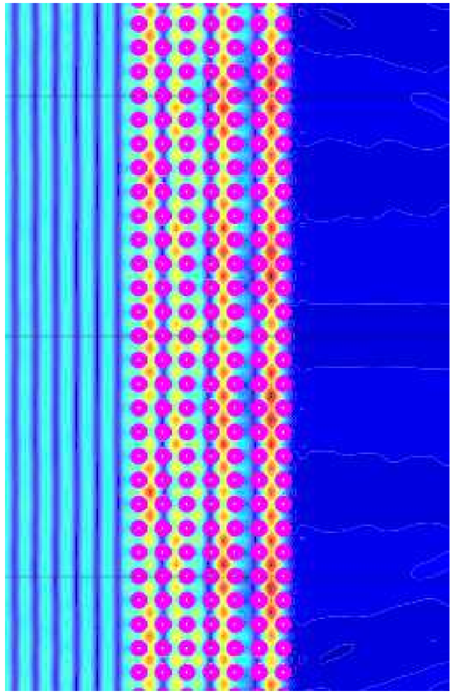
Effective shielding mechanism











Outline

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

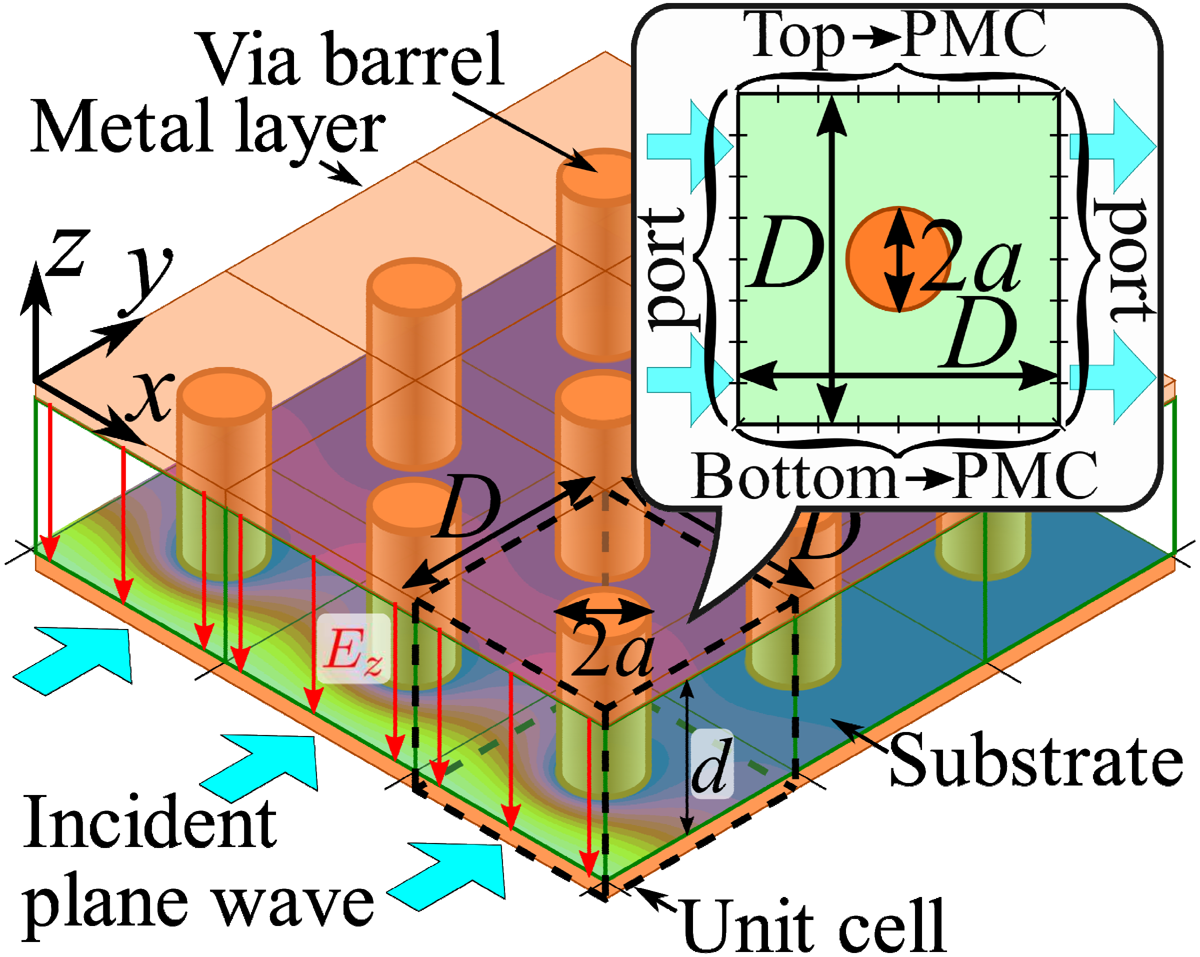
IV. Conclusions

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)



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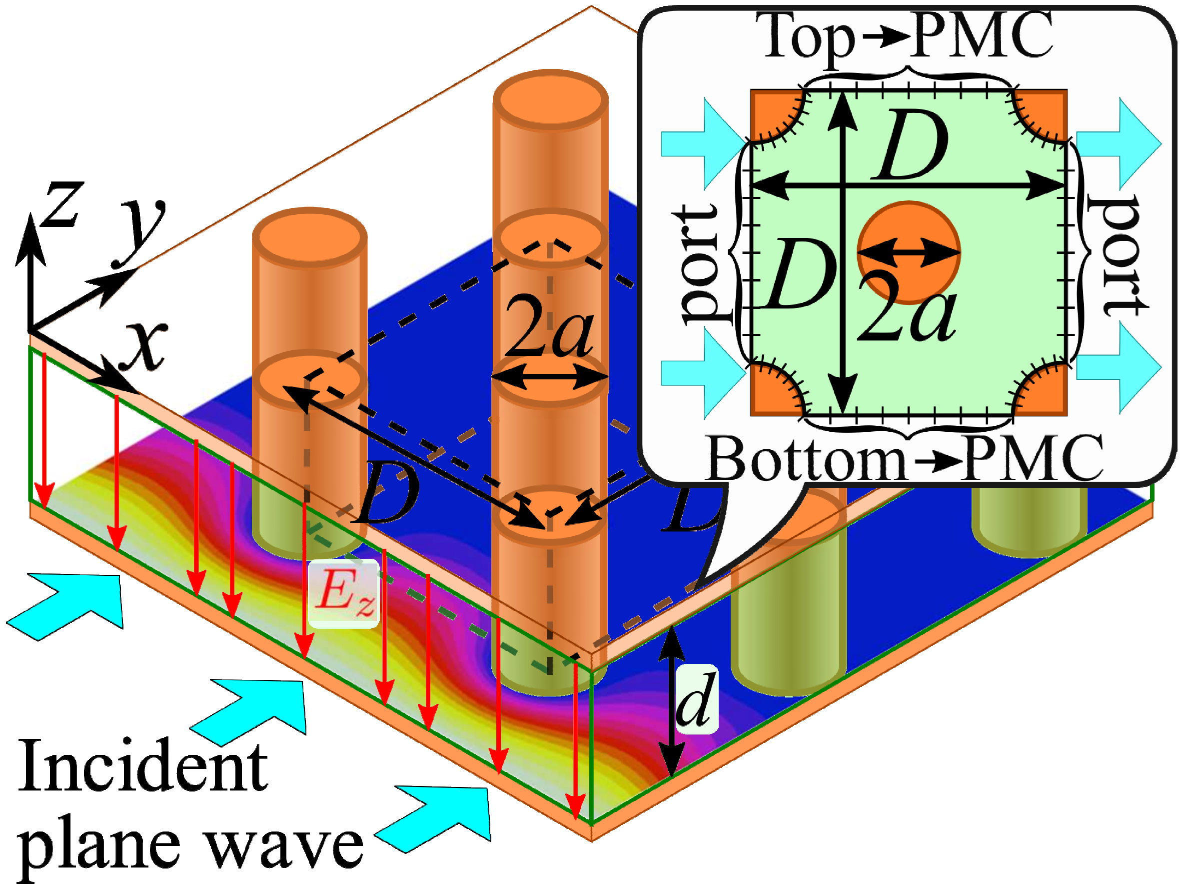

- **Idealized infinite large via array**
- **Parallel plate structure**
- **Definition of two different unit cells (two main directions)**
- **Different setups simulated**
- **Loss-less materials**

OVERVIEW OF THE BASIC SETUPS FOR THE SIMULATIONS.

	Relative permittivity ε_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

$$d = 0.25\,\text{mm}.$$

Contour Integral Method for Planar Structures

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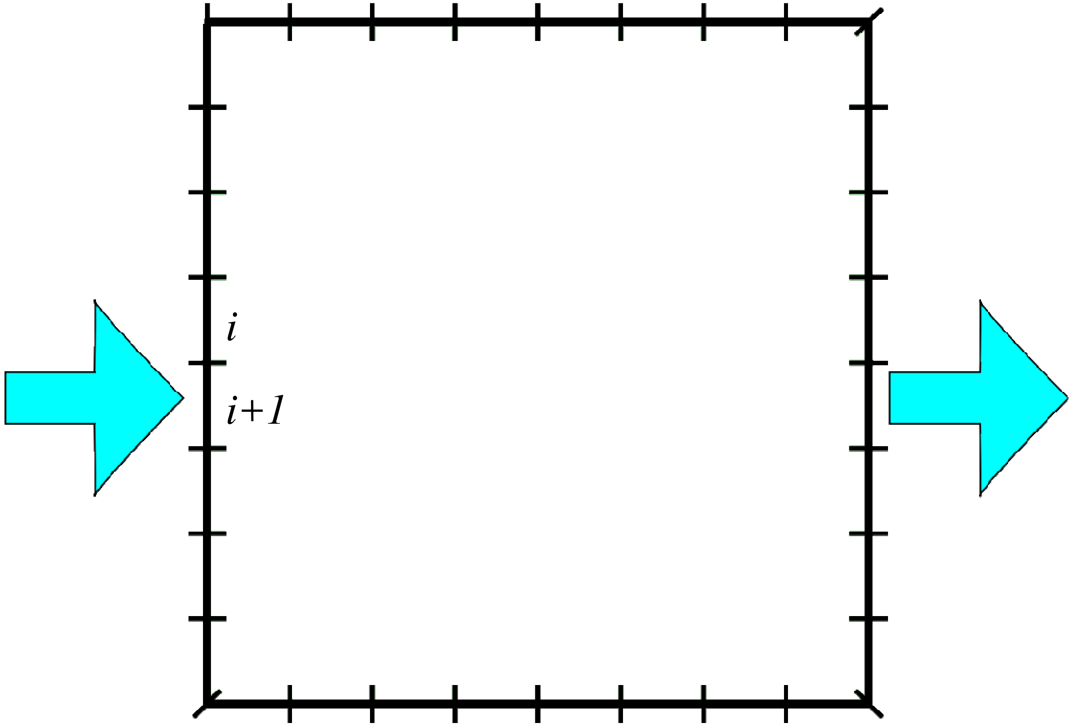
Contour Integral [1]

Planar and passive microwave circuits

Linear ports on the contour



[1] T. Okoshi, *Planar circuits for microwaves and lightwaves*, 1st ed. Berlin, Germany: Springer, 1985.

Contour Integral Method for Planar Structures

Contour Integral [1]

Planar and passive microwave circuits

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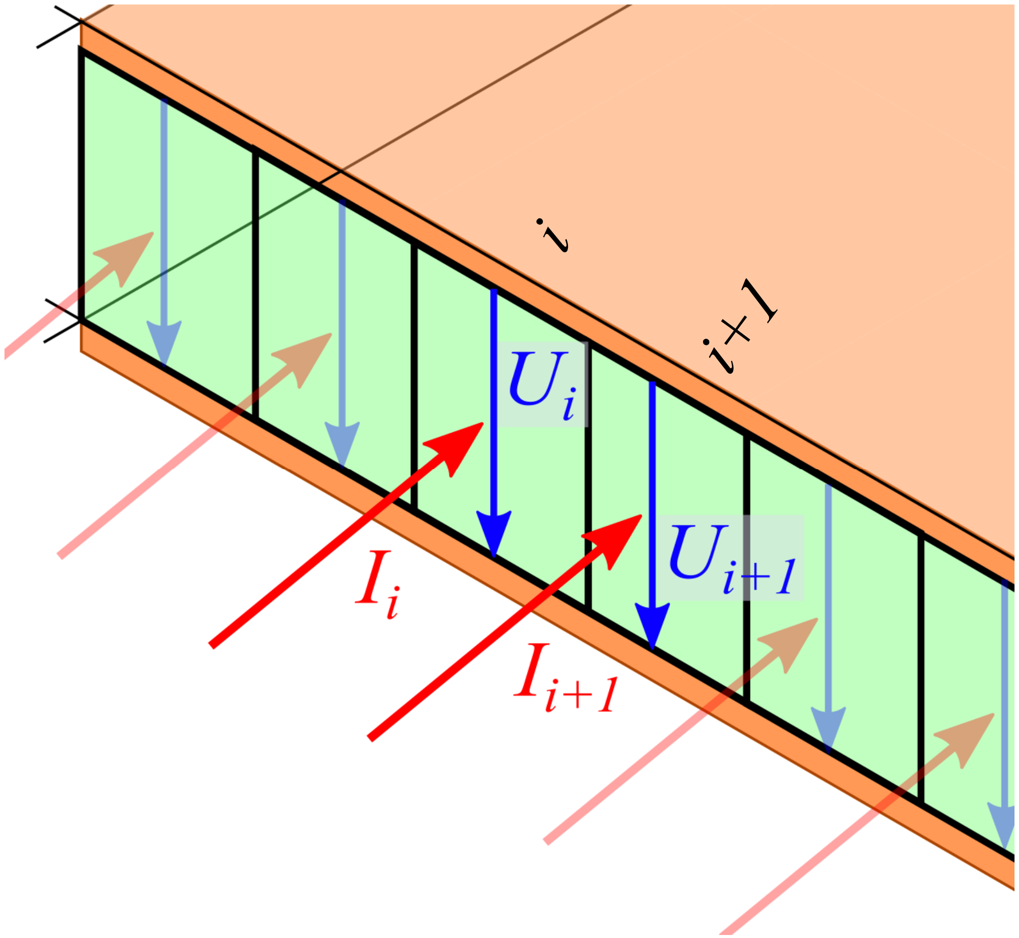


Contour Integral Method for Planar Structures

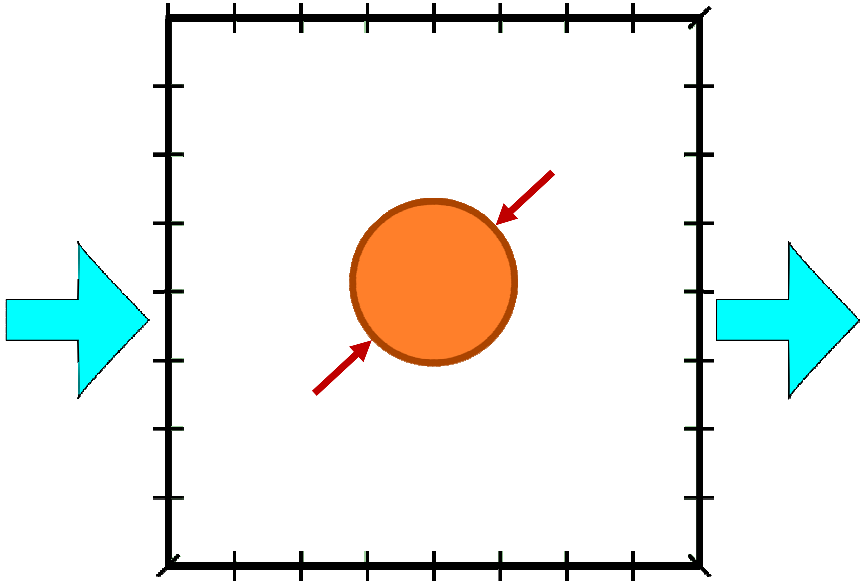
Contour Integral [1]

Planar and passive microwave circuits

Linear ports on the contour

Smooth field distribution at circular inclusions
→ Fourier expansion [2, 3]

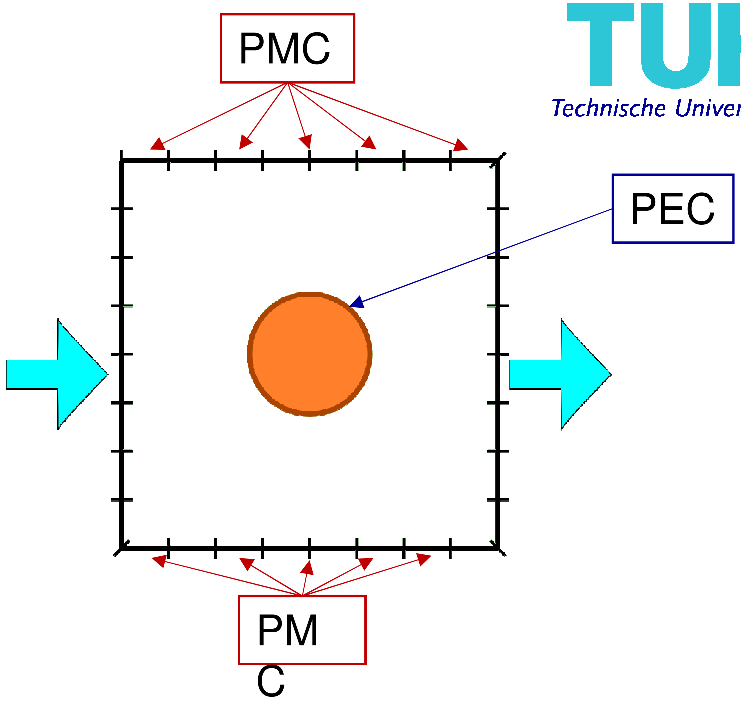
$$\mathbf{Z}^{\mathrm{CIM}} \in \mathbb{R}^{n \times n}$$



[2] X. Duan, R. Rimolo-Donadio, H.-D. Brüns, and C. Schuster, *"Circular ports in parallel-plate waveguide analysis with isotropic excitations,"* IEEE Trans. Electromagn. Compat., vol. 54, no. 3, pp. 603–612, Jun. 2012.
[3] ——, *"Extension of the contour integral method to anisotropic modes on circular ports,"* IEEE Trans. Compon. Packag. Manuf. Technol., vol. 2, no. 2, pp. 321–331, Feb. 2012.

II. Proposed Simulation Method
Unit Cell Analysis

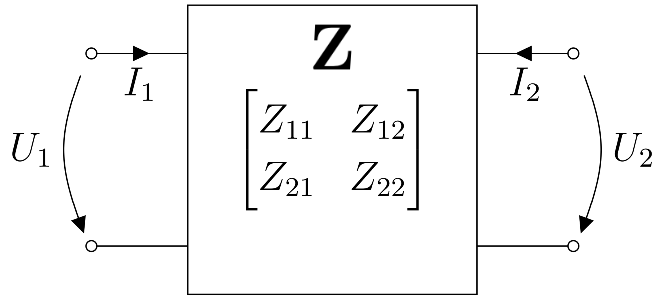
$$\mathbf{Z}^{\mathrm{CIM}} \in \mathbb{R}^{n\times n} \Rightarrow \mathbf{Z} \in \mathbb{R}^{2\times 2}$$



Applying of boundary conditions

Port combination by averaging over voltages

$$U^{\mathsf{Port}} = \frac{1}{N}\sum_i U_i$$



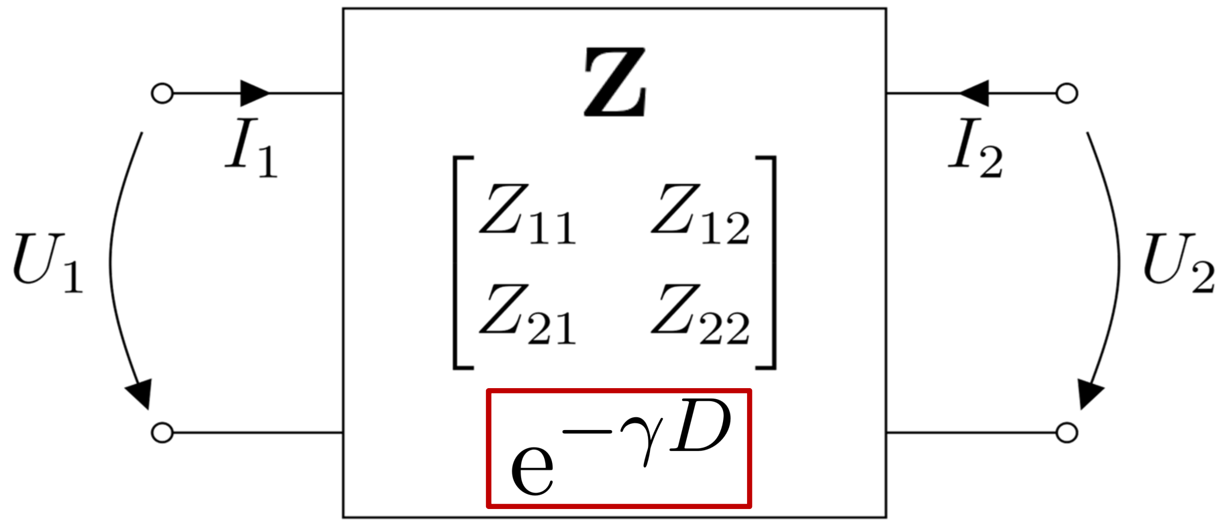
Unit Cell Analysis

Periodical structure
→ Periodical field [4]

Phase delay between unit cells [4]

Solution for 2x2 matrices [5]

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



[4] R. E. Collin, *Field Theory of Guided Waves*, 2nd ed. New York, NY, USA: Wiley Interscience, 1991.
[5] Y. Toyota, A. E. Engin, T. H. Kim, M. Swaminathan, and K. Uriu, *"Stopband prediction with dispersion diagram for electromagnetic bandgap structures in printed circuit boards,"* in IEEE Int. Symp. Electromagn. Compat., Aug. 2006, pp. 807–811.

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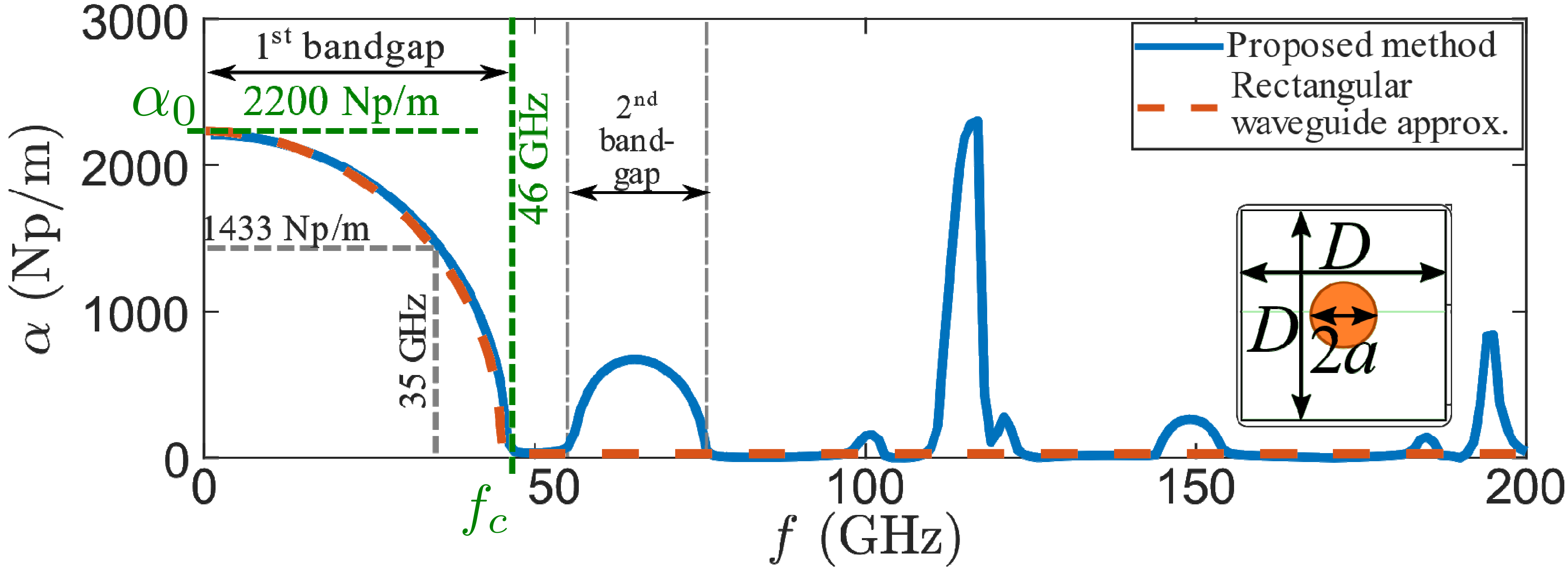

$$\alpha = \underbrace{(\pi/\tilde{a})}_{\alpha_0} \cdot \sqrt{1-(f/f_c)^2}$$

[6] D. K. Cheng, *Field and wave electromagnetics, 2nd ed. Reading*, MA, USA: Addison-Wesley Publishing Company, Inc., 1989.

Structure A

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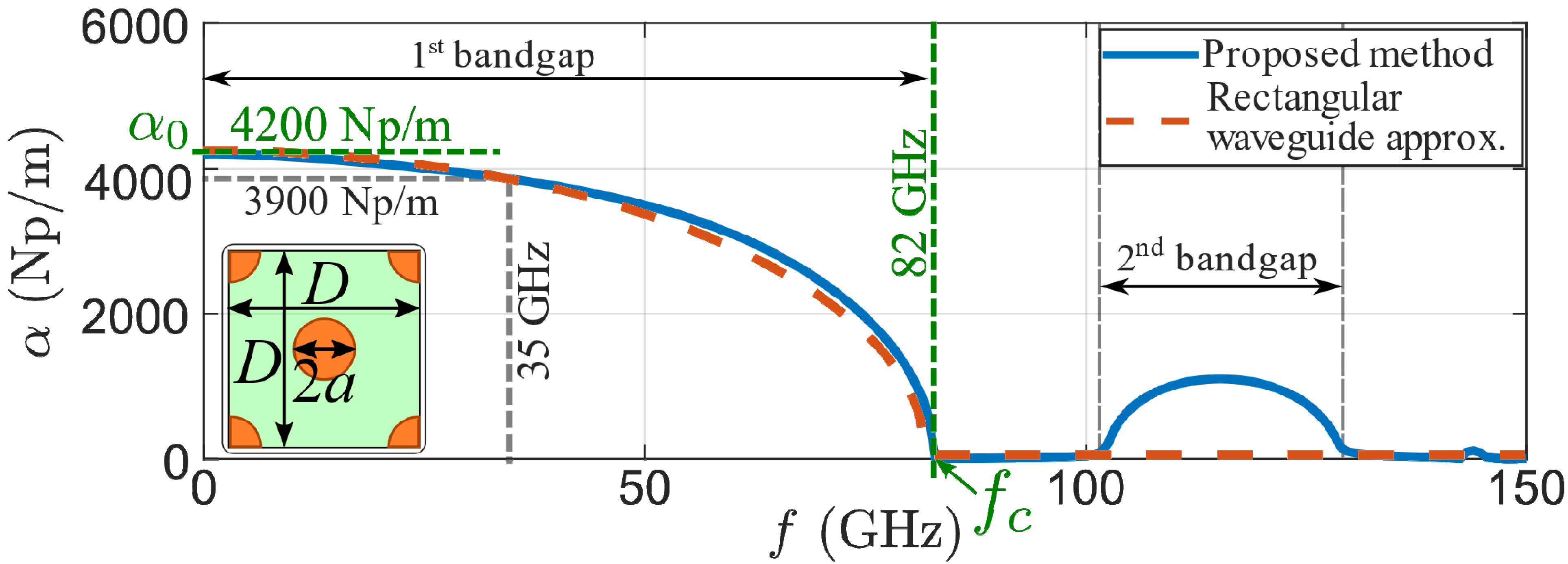
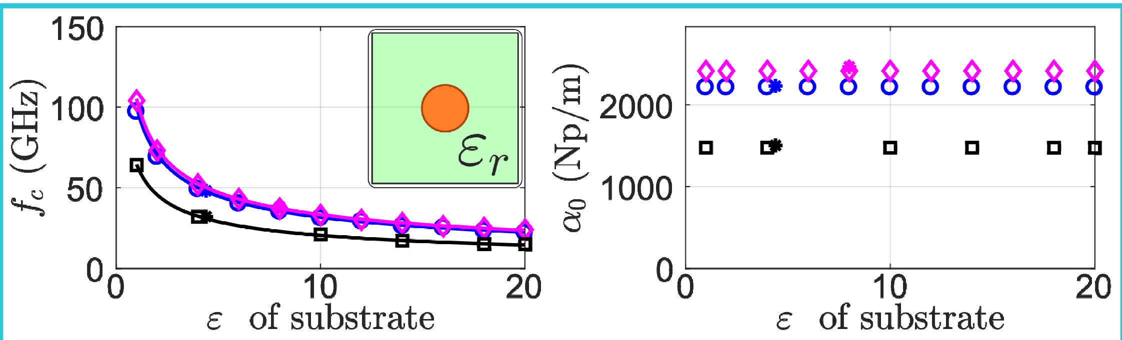


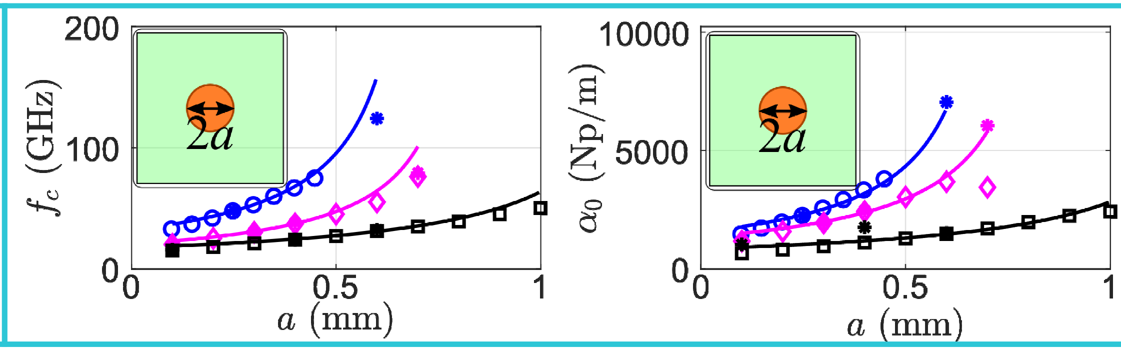
$$\alpha = \underbrace{(\pi/\tilde{a})}_{\alpha_0} \cdot \sqrt{1 - (f/f_c)^2}$$ [6]

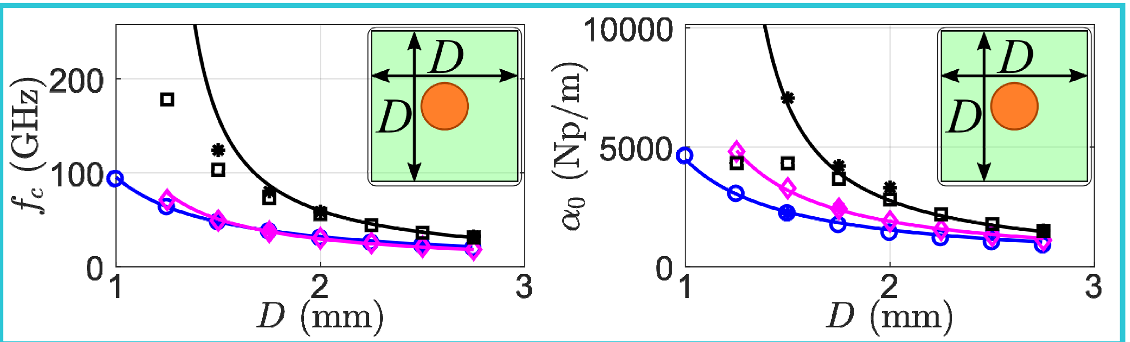
Structure B

III. Application and Derivation of Approximations

Approximations Using Fitting





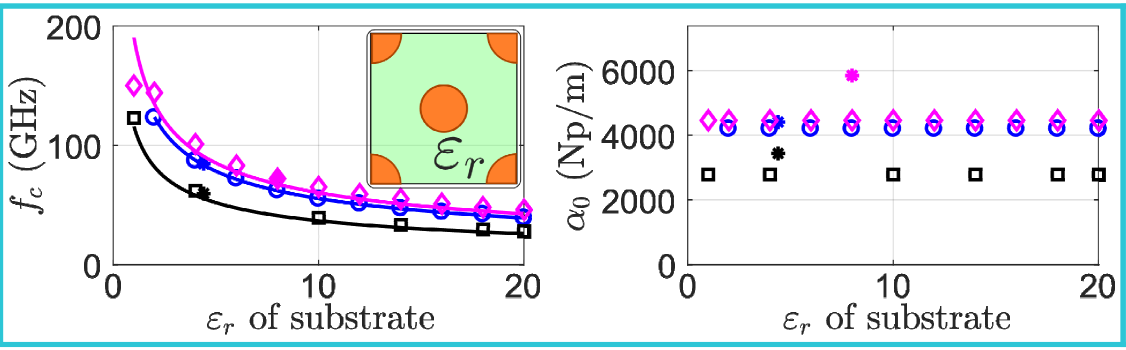


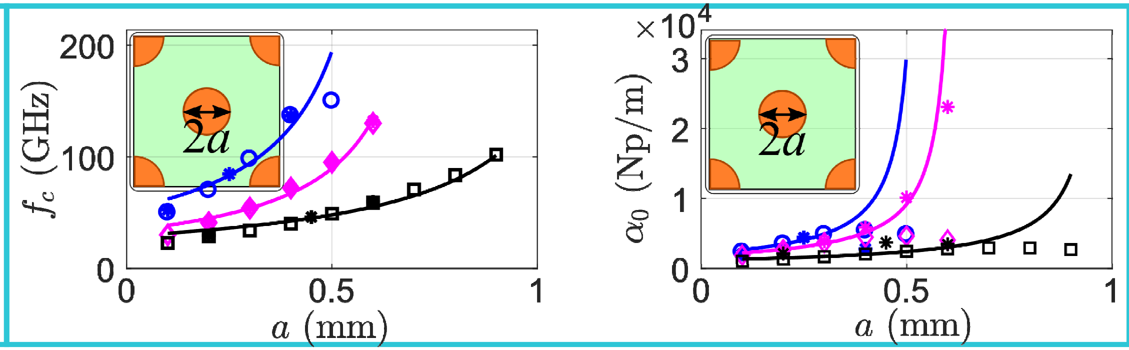
	CIM simulation	FEM simulation	Fit function
Setup 1	○ (blue)	✱ (blue)	— (blue)
Setup 2	◇ (magenta)	✱ (magenta)	— (magenta)
Setup 3	□ (black)	✱ (black)	— (black)

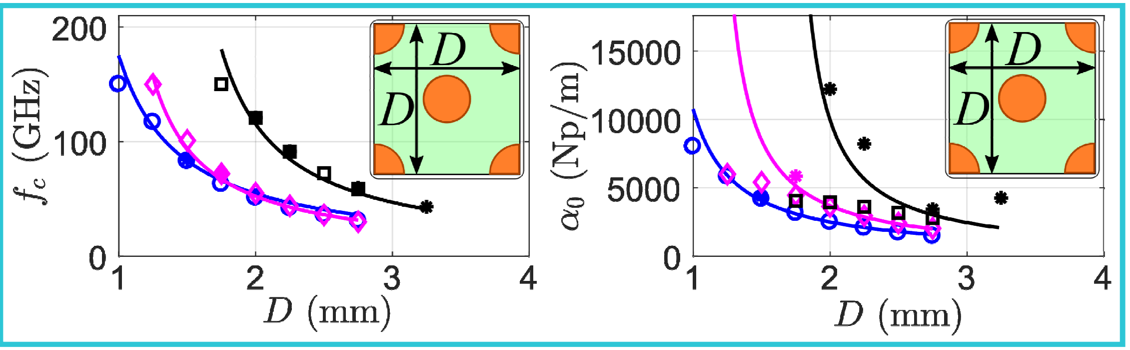
	Relative permittivity ε_r	Via radius a	Unit cell length D
Setup 1	4.4	0.25 mm	1.5 mm
Setup 2	8	0.4 mm	1.75 mm
Setup 3	4.4	0.6 mm	2.75 mm

III. Application and Derivation of Approximations

Approximations Using Fitting







	CIM simulation	FEM simulation	Fit function
Setup 1	○	*	—
Setup 2	◇	*	—
Setup 3	□	*	—

	Relative permittivity ε_r	Via radius a	Unit cell length D
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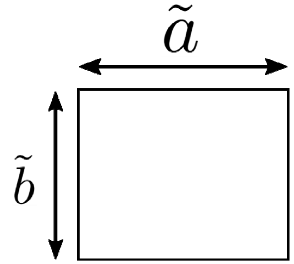
Approximations Using Fitting

Fitting based on rectangular waveguide behavior

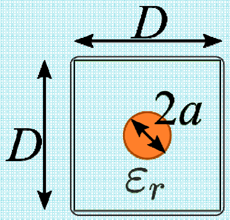
Adjusting effective distance

Rectangular Waveguide [6]

$$f_c^R = \frac{c_0}{\sqrt{\varepsilon_r} 2\tilde{a}} \qquad \alpha_0^R = \frac{\pi}{\tilde{a}}$$



Structure A

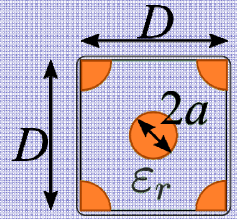


$$\tilde{a}^A \rightarrow D - 2a$$

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

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

Structure B

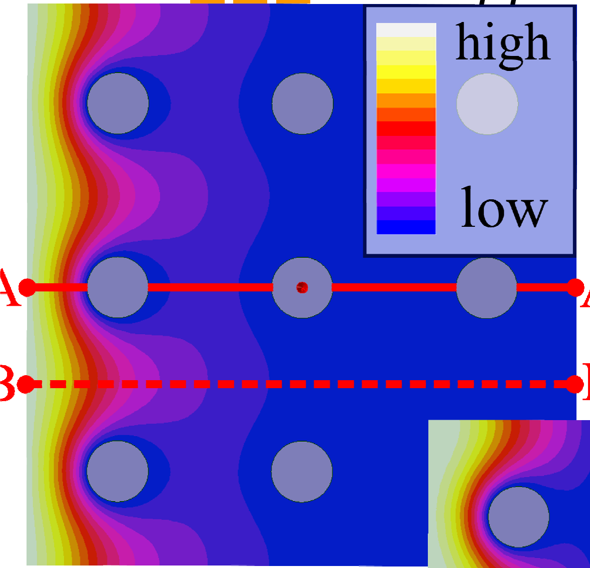


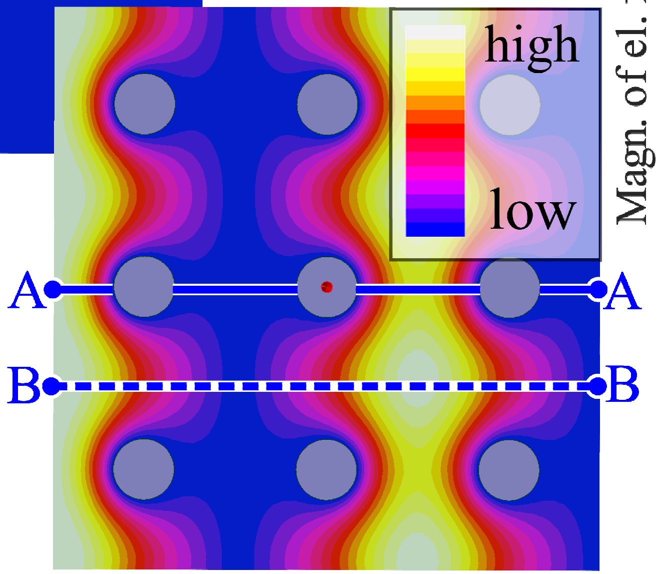
$$\tilde{a}^B \rightarrow \frac{\sqrt{2}}{2} D - 2a$$

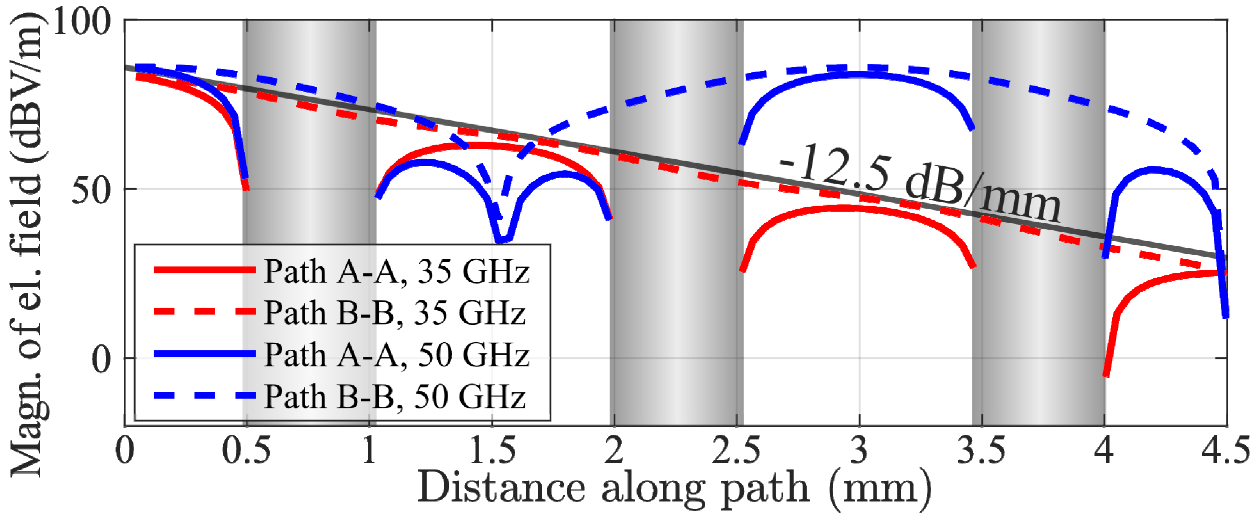
$$f_c^B = \frac{c_0}{\sqrt{\varepsilon_r}\left(1.27 \cdot \sqrt{2} D - 0.98 \cdot 4a\right)}$$

$$\alpha_0^B = \frac{\pi}{1.36 \cdot D/\sqrt{2} - 1.34 \cdot 2a}$$

Application to Finite Size Arrays (HFSS)







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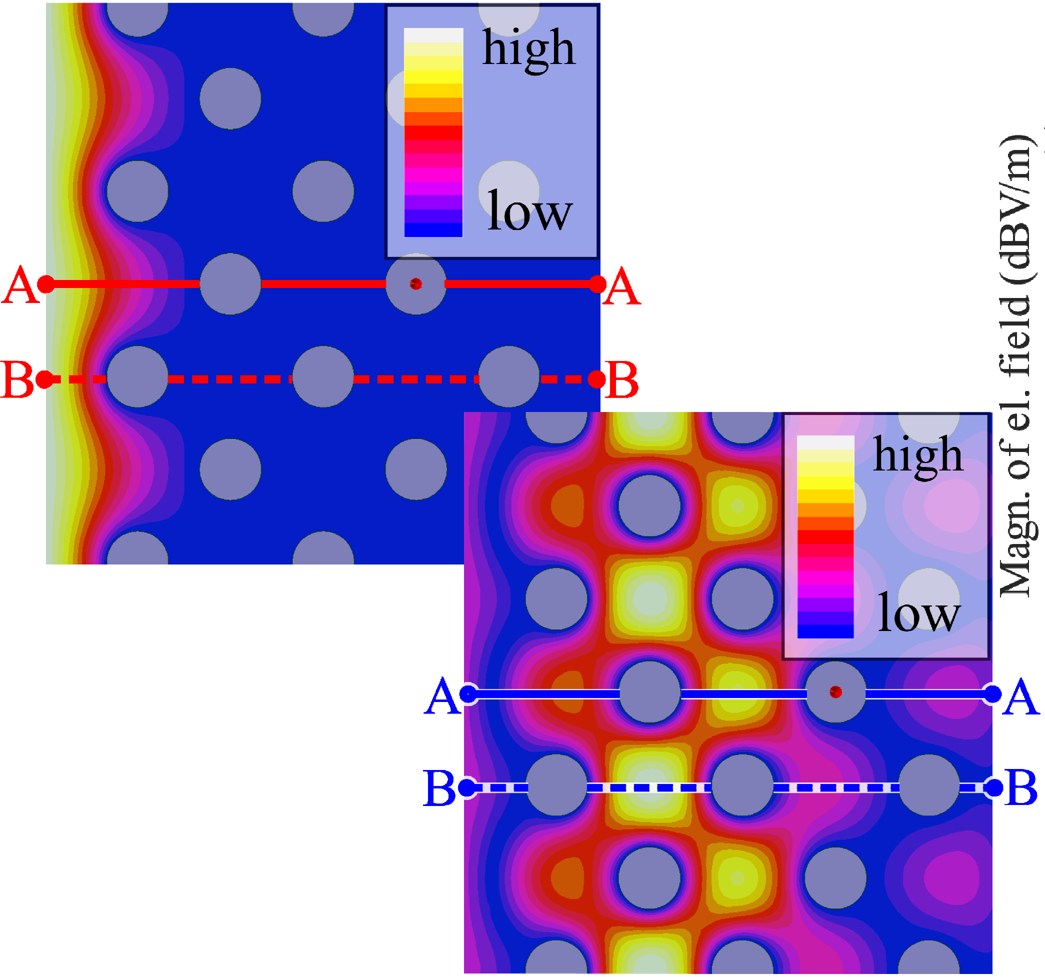

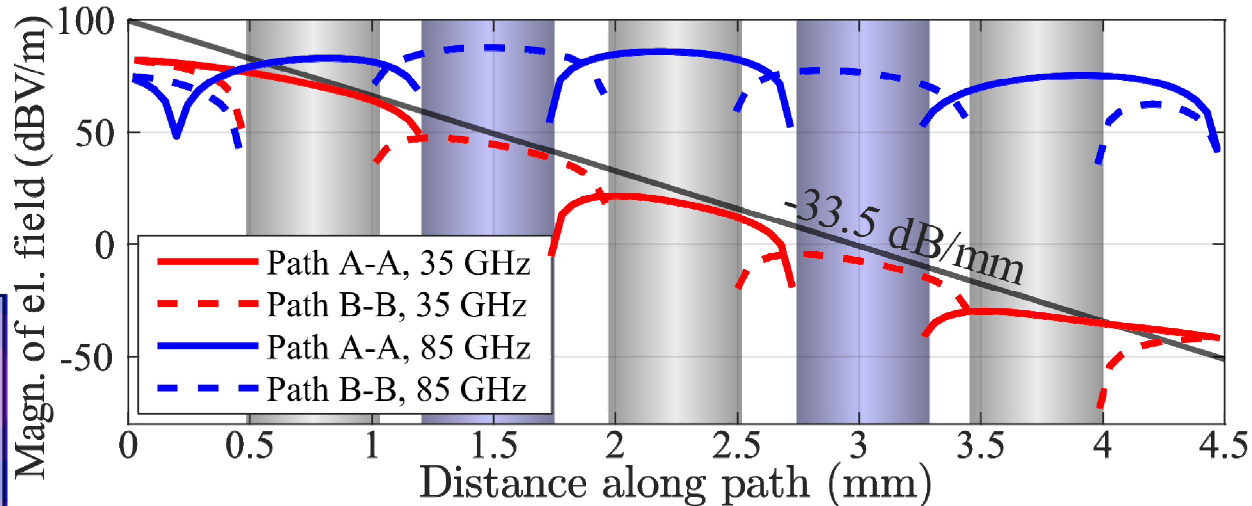

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Fast and accurate numerical Method

Up to 4200 Np/m attenuation below cutoff-frequency

2 parameters for fitting equations α_0, f_c

Further research

- Other arrangements of vias within unit cell
- Adaptation to power ground structures

THANK YOU FOR YOUR ATTENTION