EM Noise Mitigation in Circuit Boards and Cavities

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Microwave Effects and Chaos in 21st Century Analog & Digital Electronics

AFOSR MURI

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Previous Work and Recent Work

- ❑ Developing 3-dimensional full-wave predictive tools for cavity Resonance and S Parameters

[completed]

- ❑ Developing fast predictive modeling tools for PCB analysis

[completed]

- ❑ Using lossy material coating to reduce aperture radiation

[parametric study; experimental validation]

Previous Work and Recent Work

- Reducing noise in printed circuit boards using high impedance surface

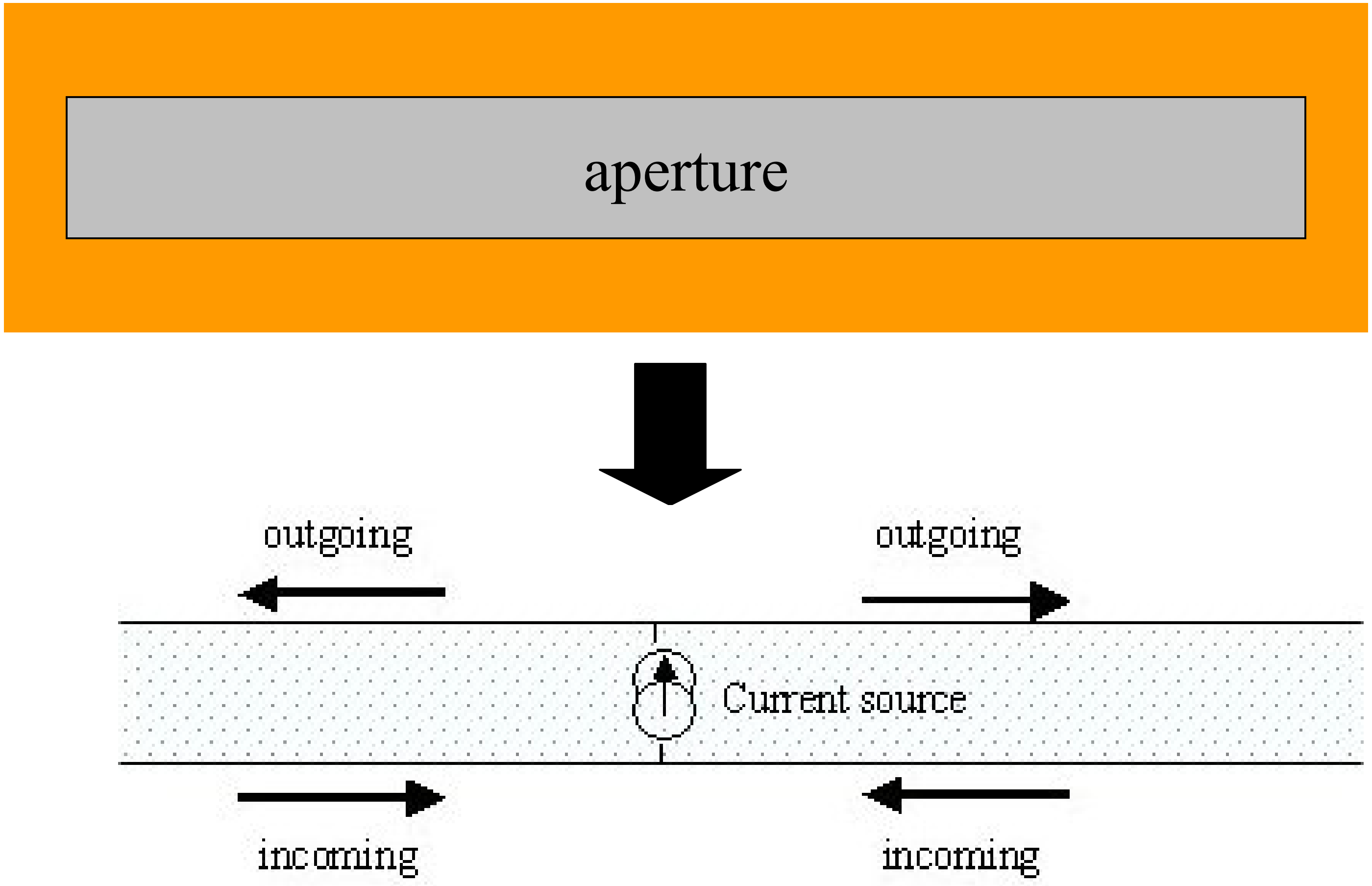
[experimental verification; concept improvement; wideband extension]

- Reduction of coupling between cavities using high-impedance surfaces

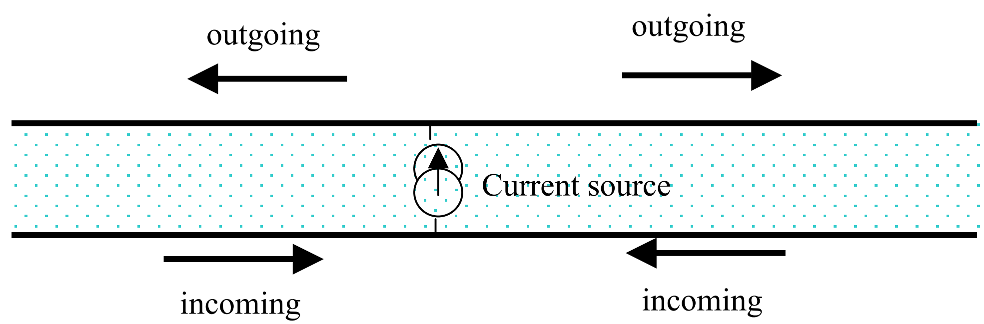
[concept validation through numerical experiments]

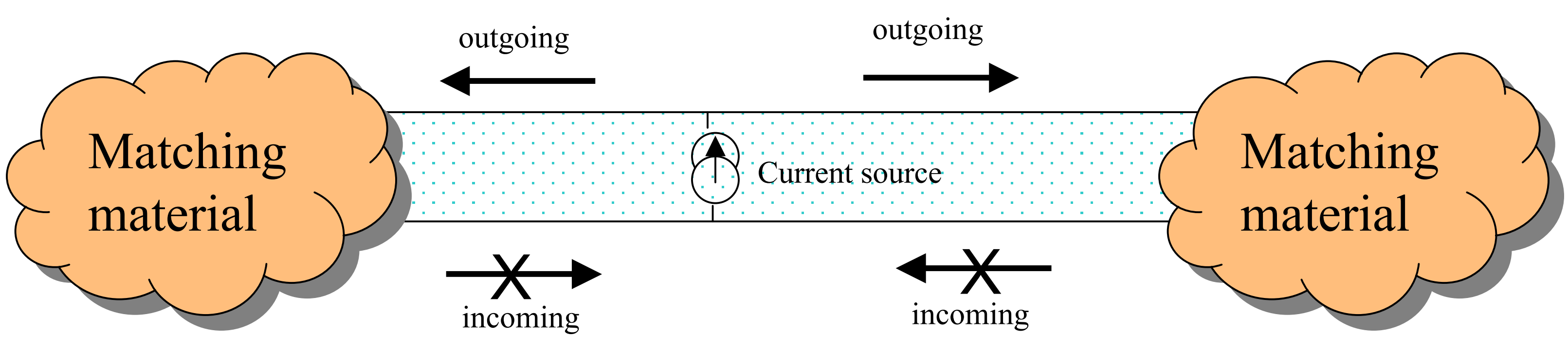
Part I:
Noise mitigation from apertures without reduction of aperture size

Transmission Line Interpretation of Apertures

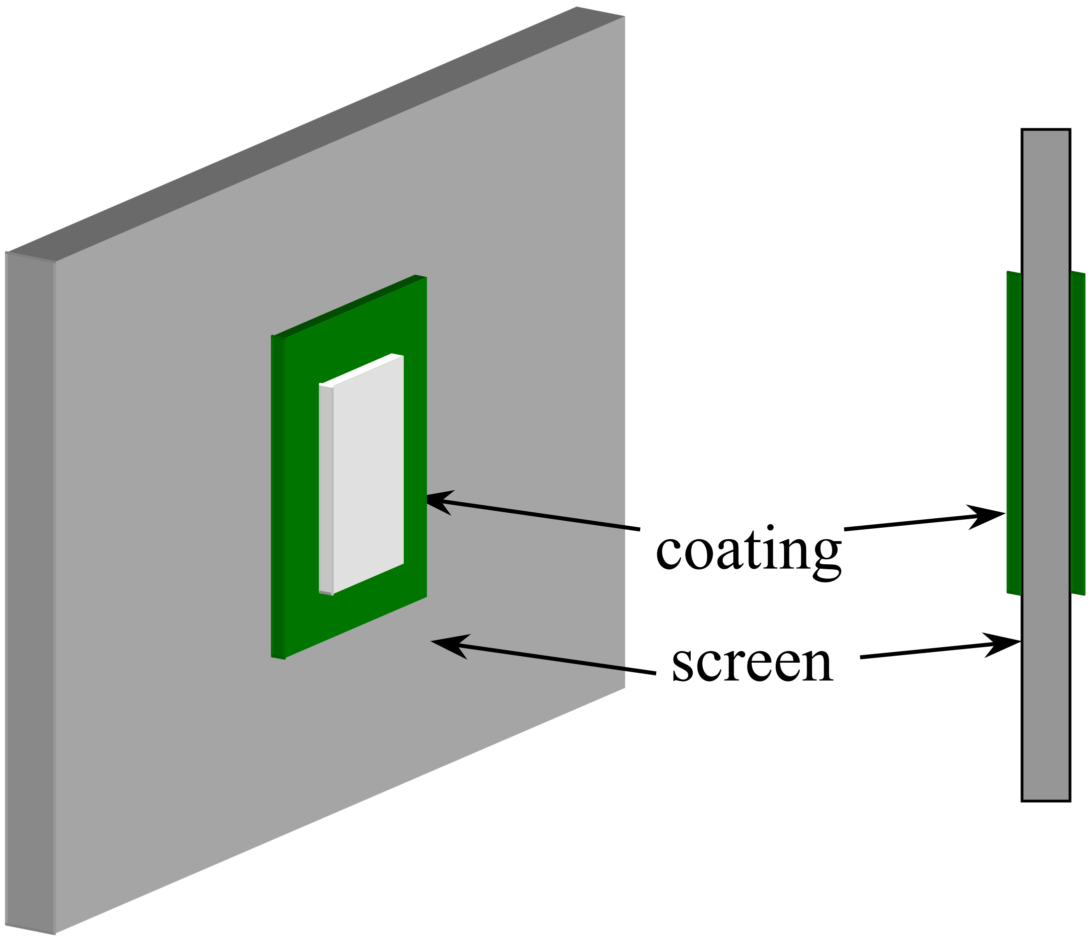


Transmission Line Interpretation of Apertures with Matched Termination

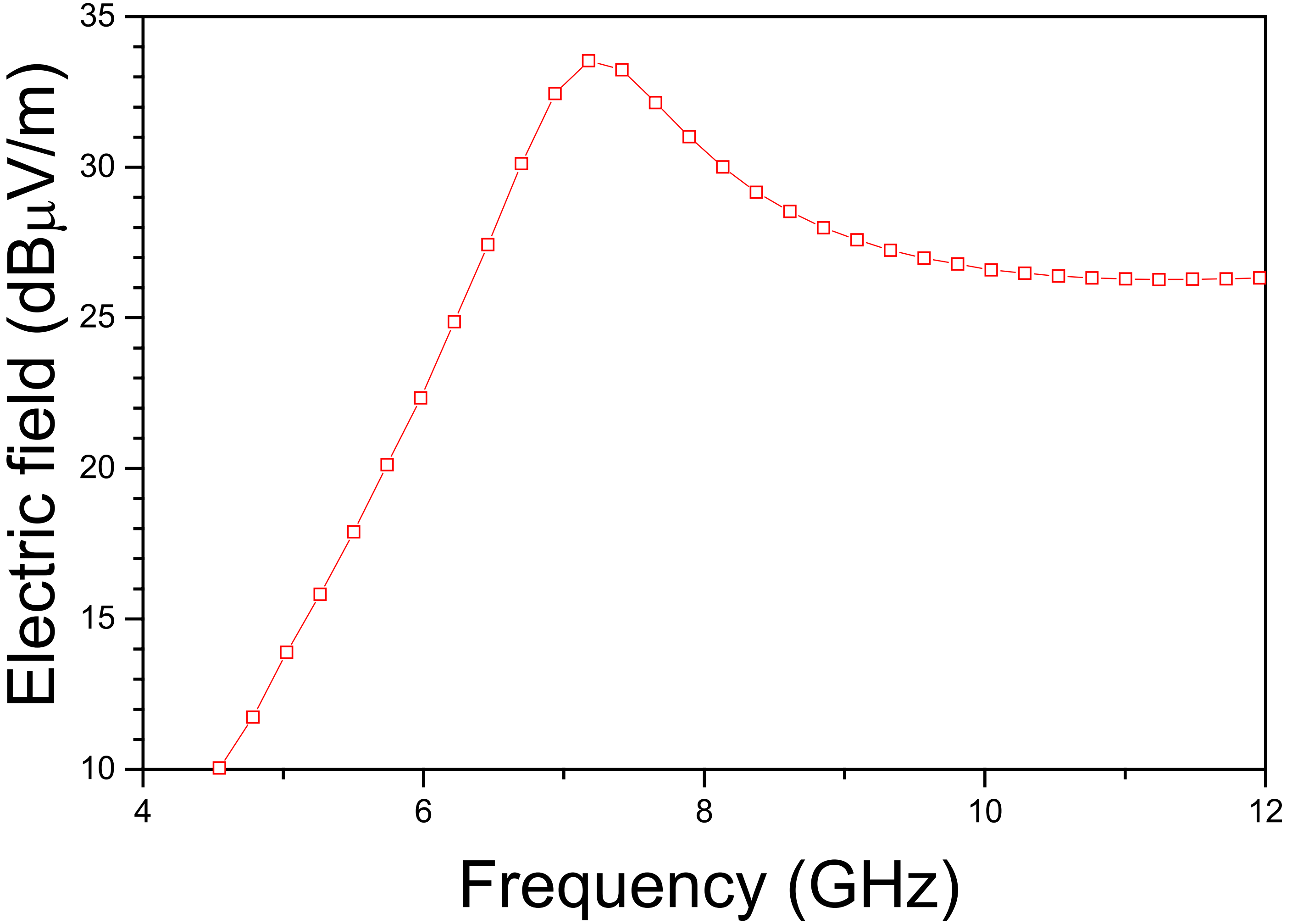




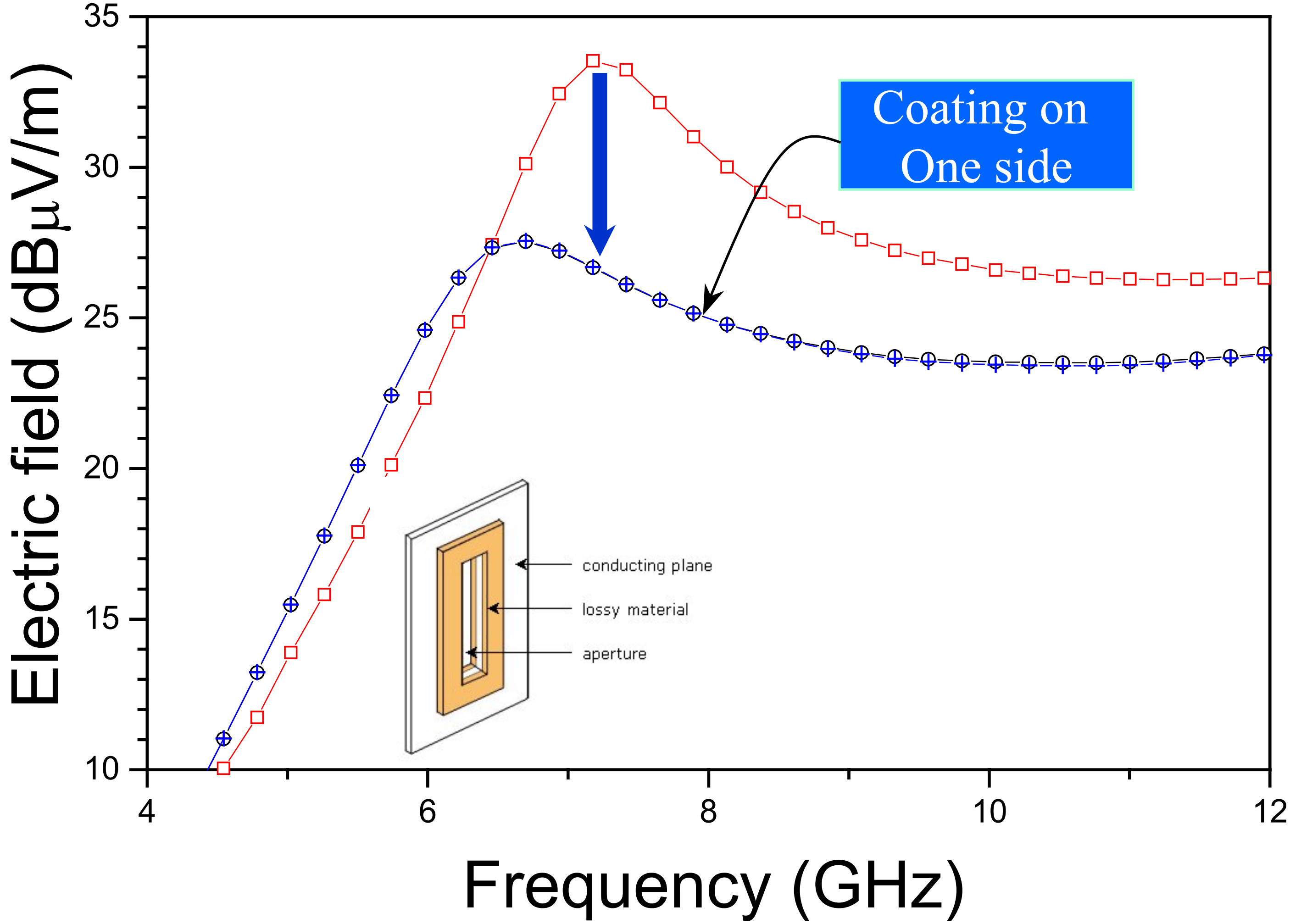
“Loaded” Aperture



Aperture without Coating



Reduction of Radiated Field at Resonance



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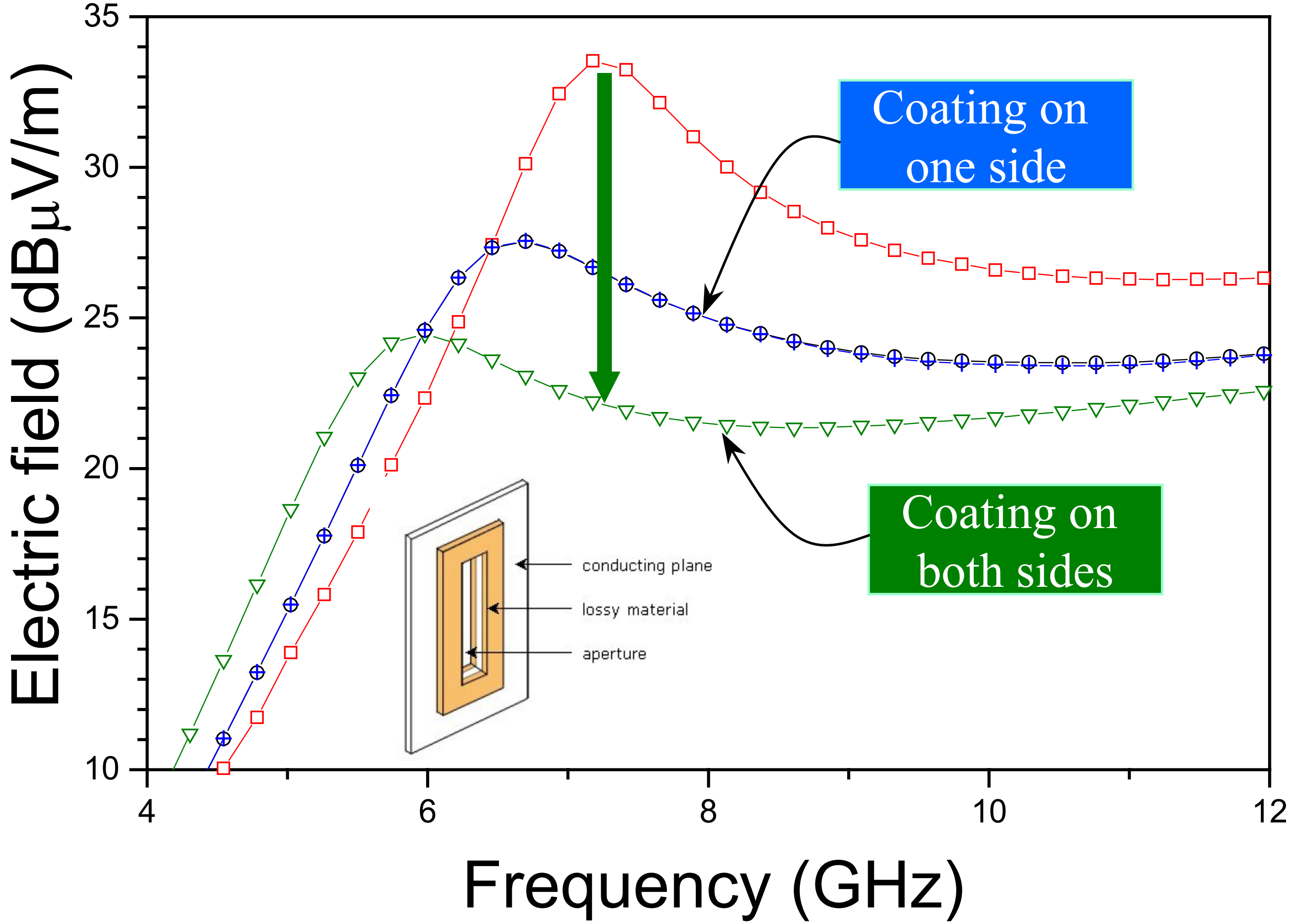
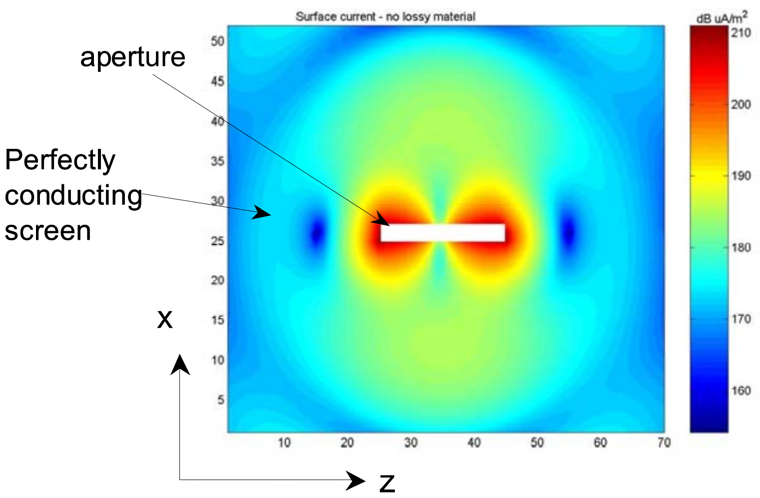
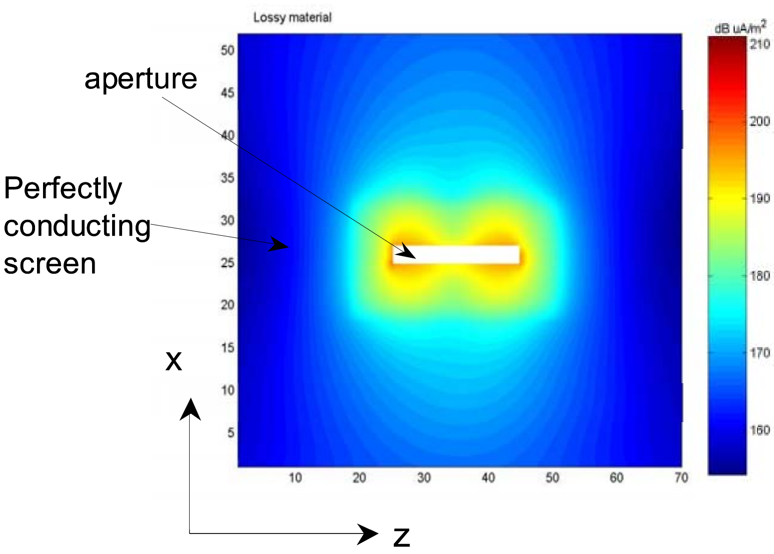


Surface Current Density Distribution

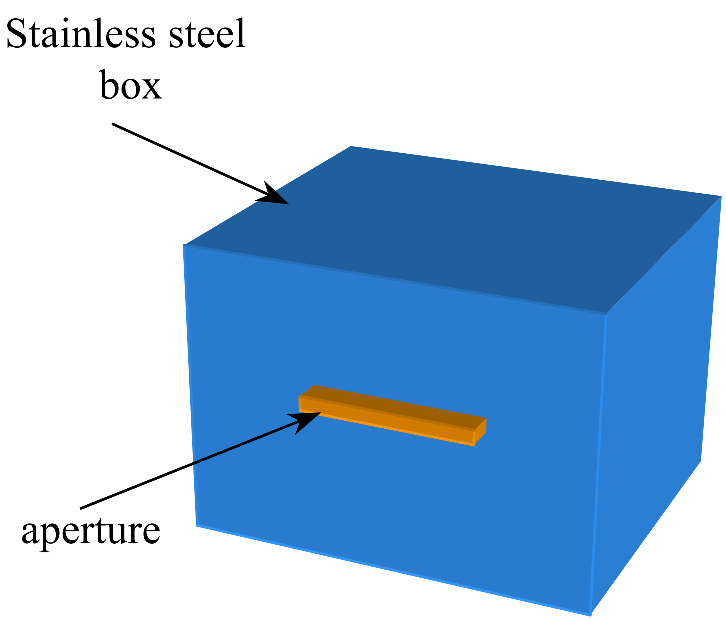


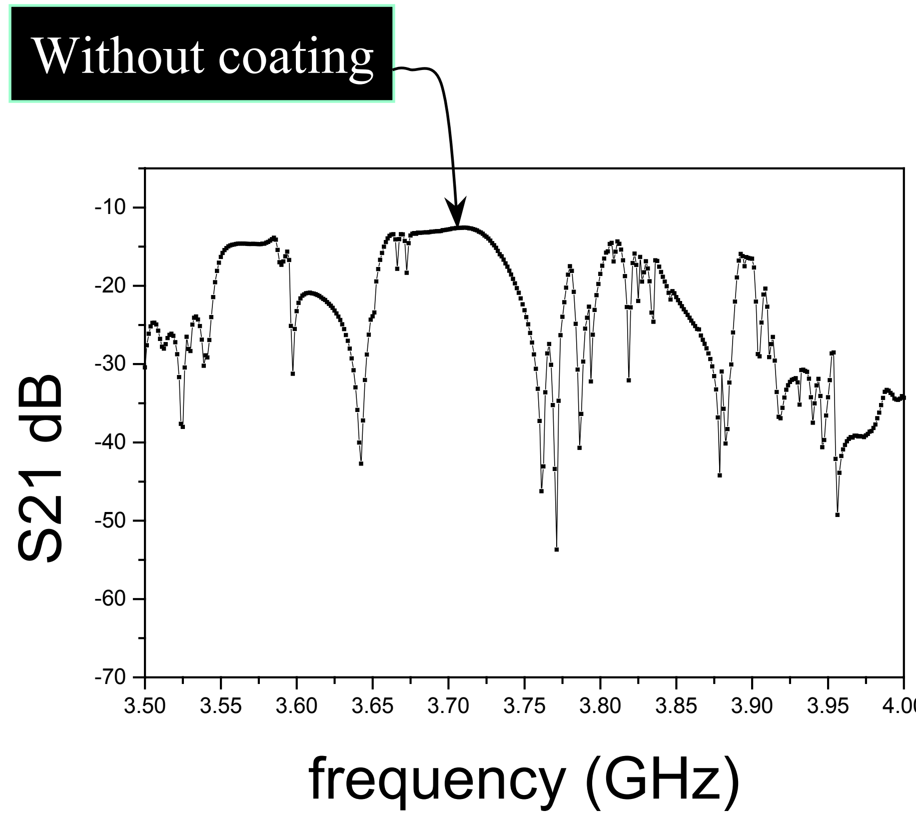
Before



After

Effect of Coating on Aperture Field: Experimental Validation





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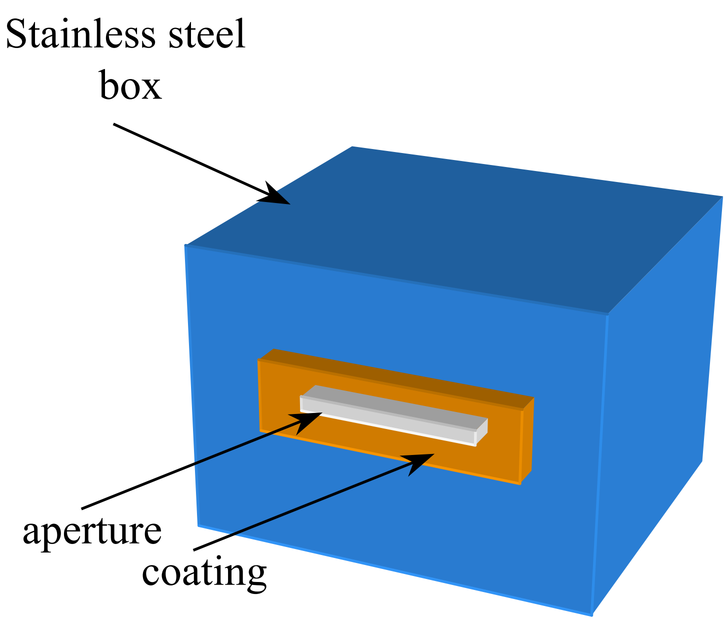
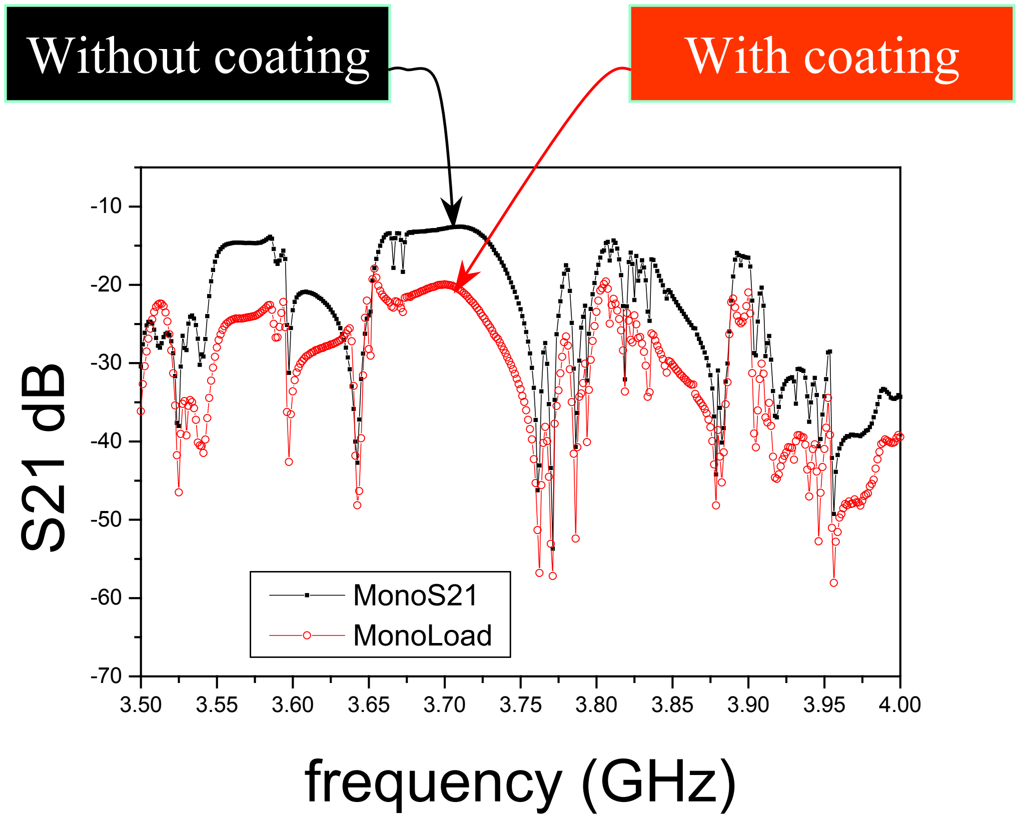
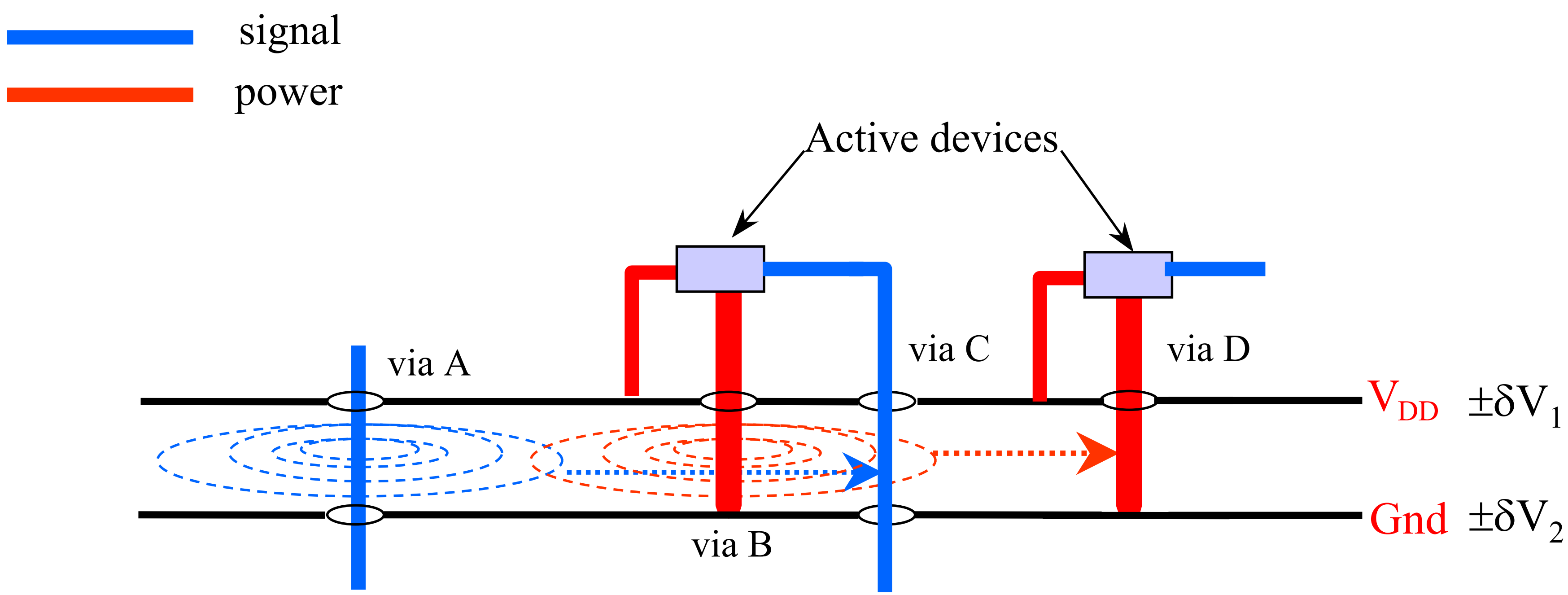


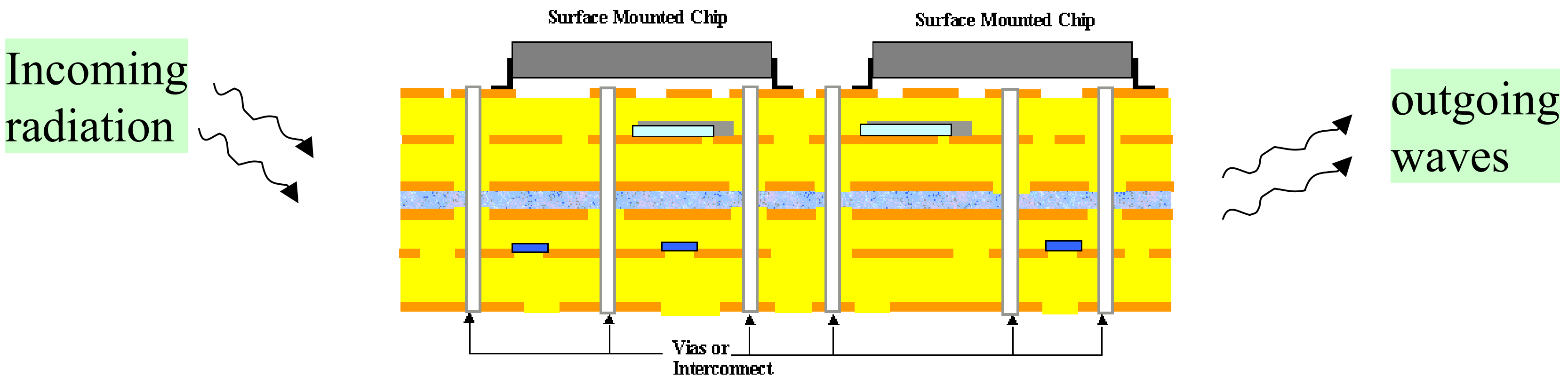


Part II:
Reduce switching and other noise in Printed Circuit Boards

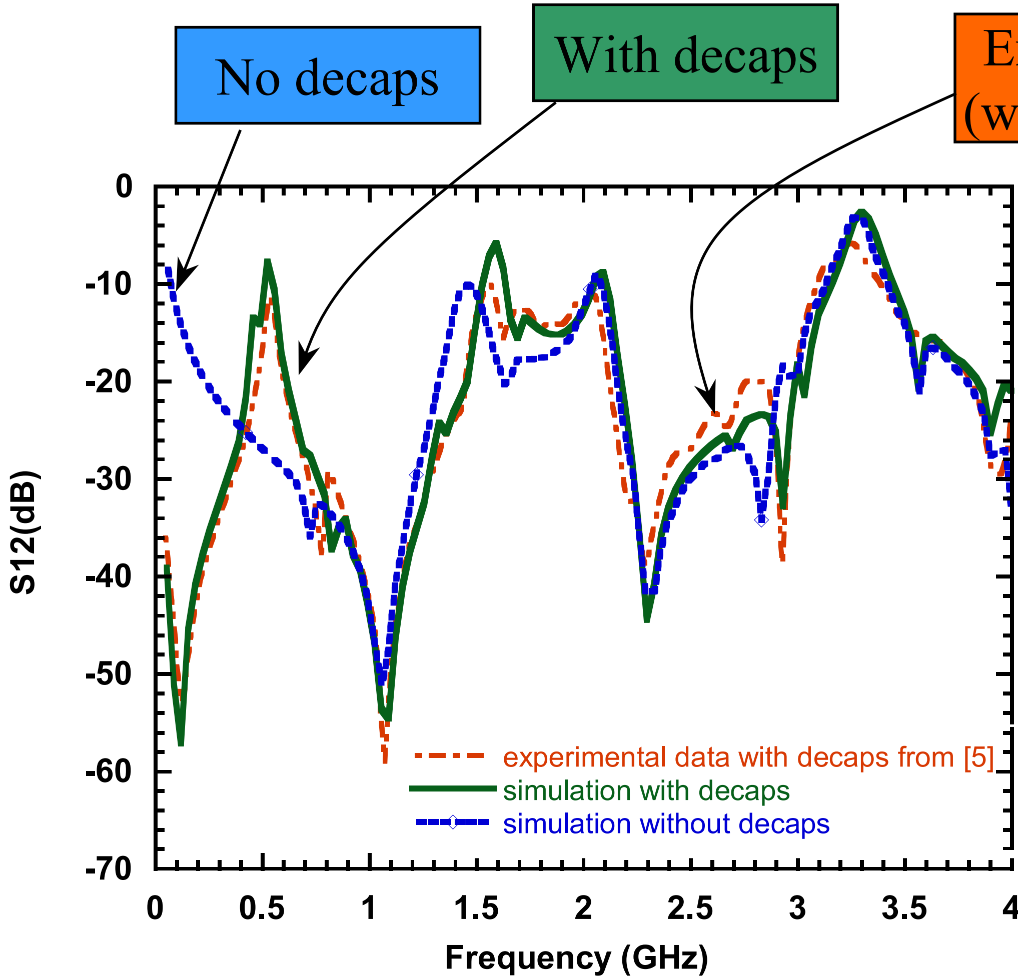
EM Noise in PCB

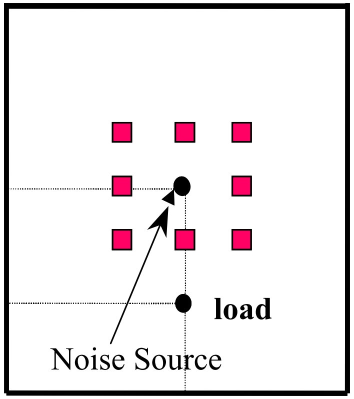


Coupling to Sensitive Devices in a Multi-Layer Stack up



Decoupling Capacitors around Noise Source



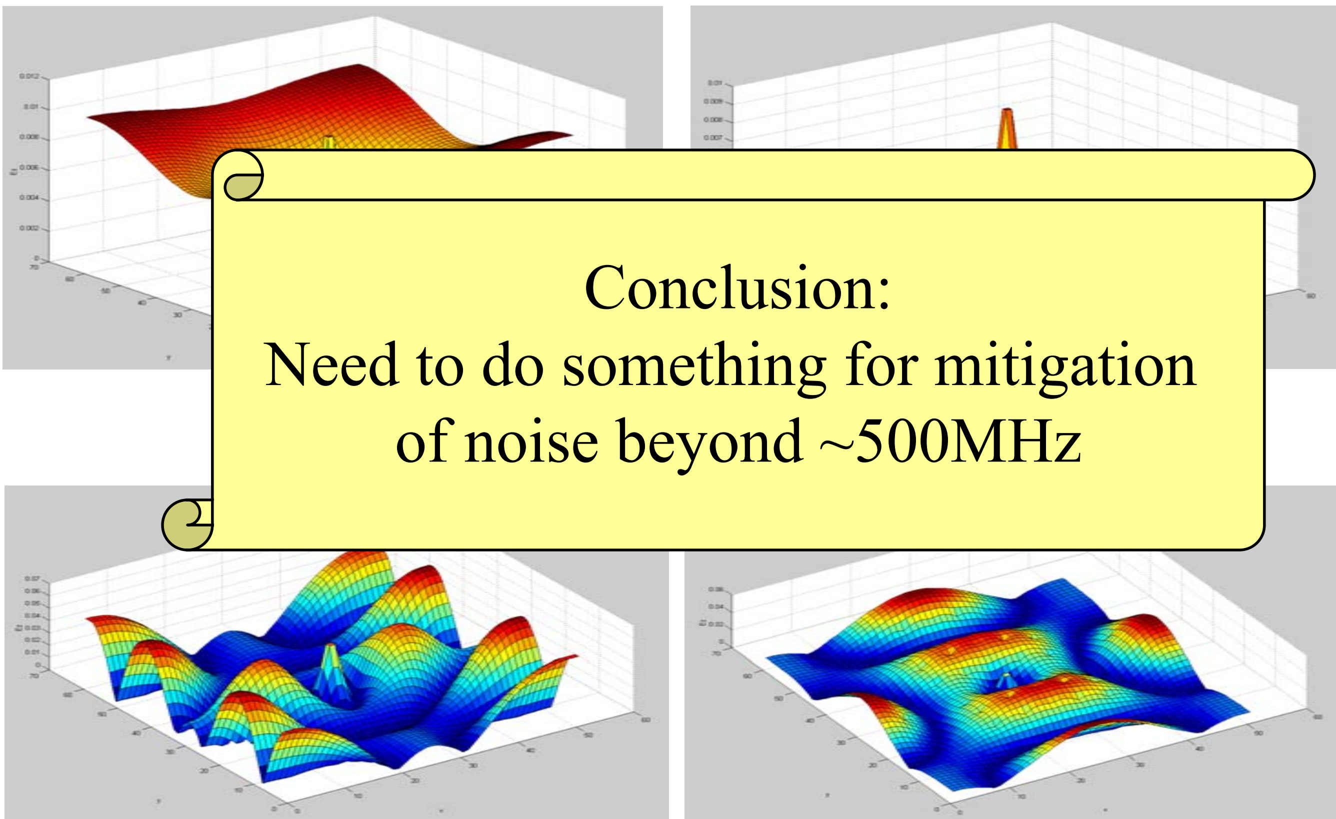


8 decoupling capacitors around noise source:

C=10nF, L=2nH, R=50mΩ

Classical Methods: Ineffective at Microwave Frequencies

•Effect of Capacitors Placement at **200**MHz and 1GHz



Conclusion:
Need to do something for mitigation of noise beyond ~500MHz

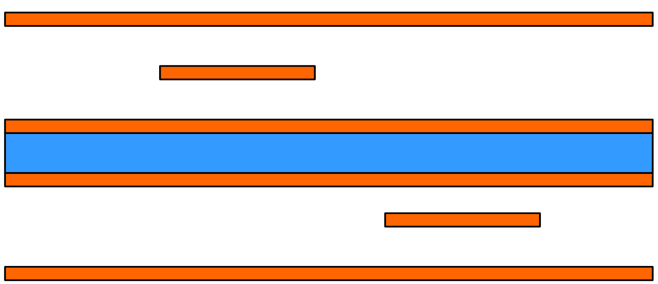
Effective

NOT Effective

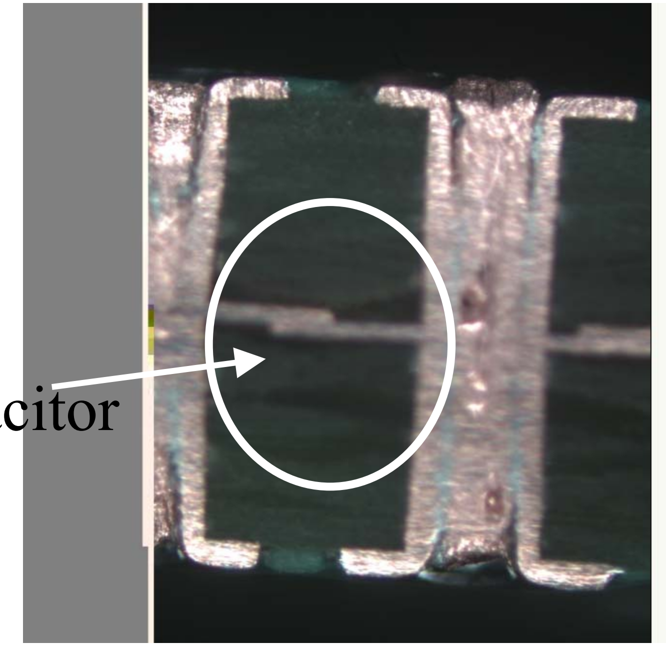
no caps 1 GHz **99 caps 1 GHz**

Possible Solutions

Embedded *Capacitance*



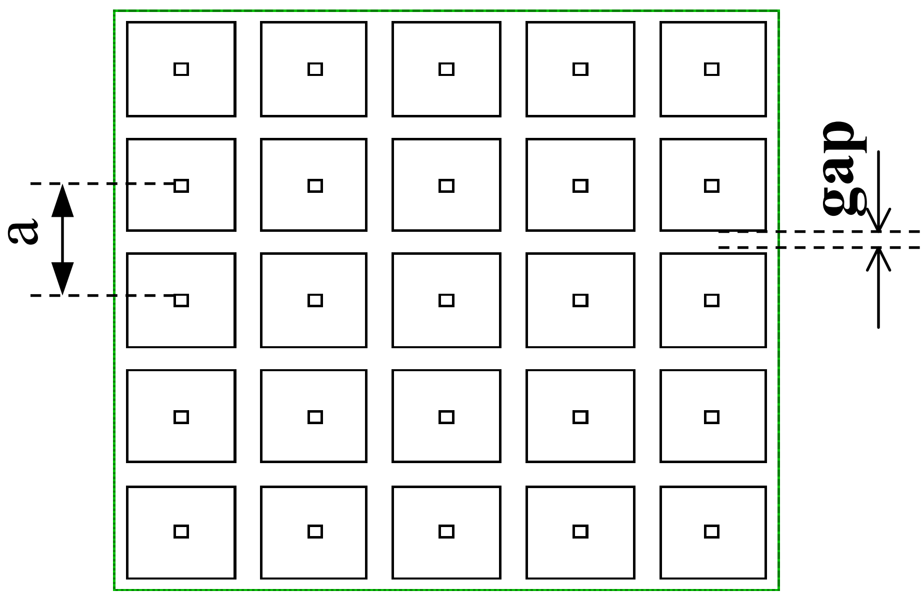
Embedded *Capacitors*



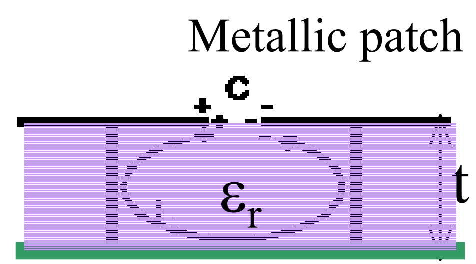
High-Impedance Surface

as a novel concept for switching noise mitigation

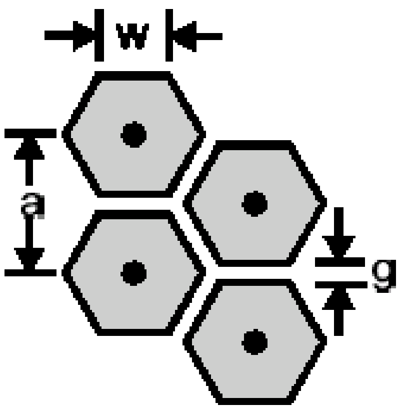
High-Impedance Surface for Surface Wave Suppression

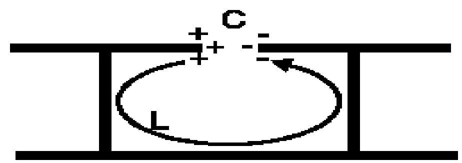


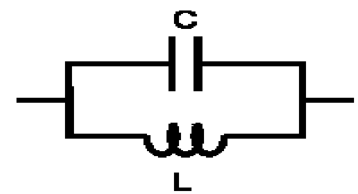
Top view of HIS with square patches

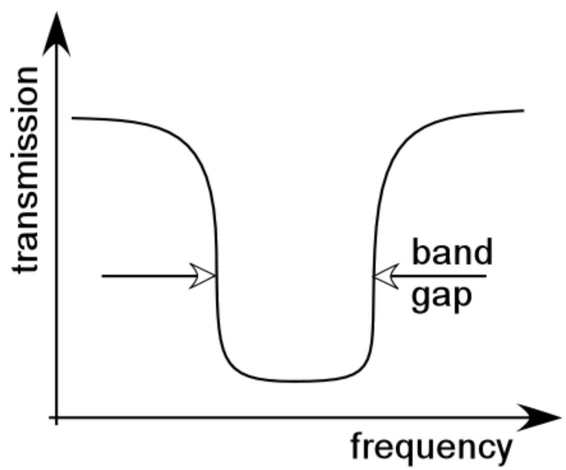


Interpretation: HIS as a Series of Parallel LC Resonators



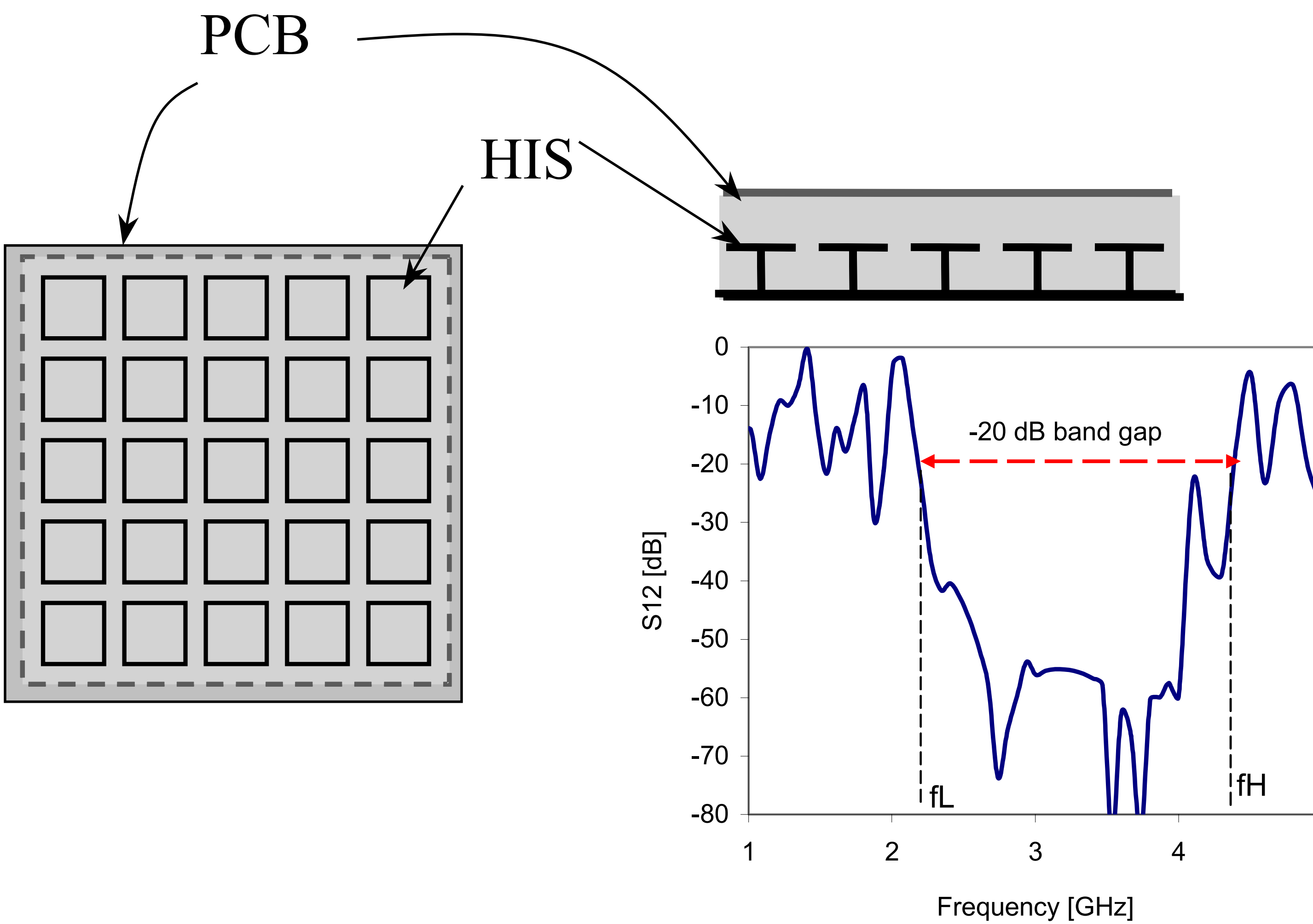




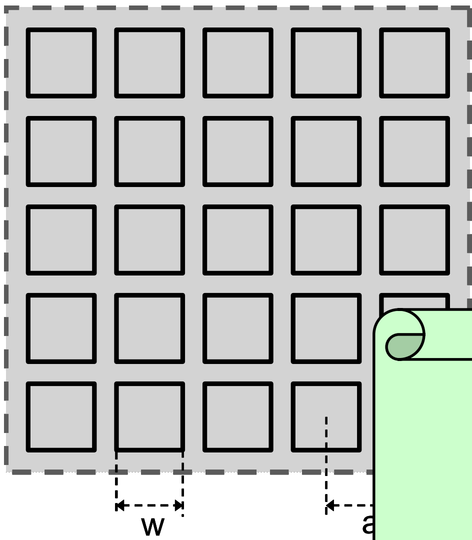


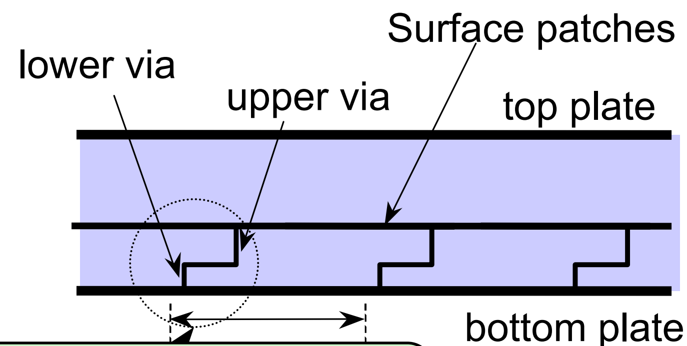
$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Power Plane with Embedded HIS

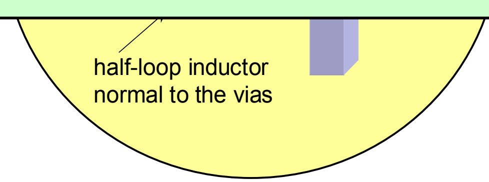


Widening the Gap!



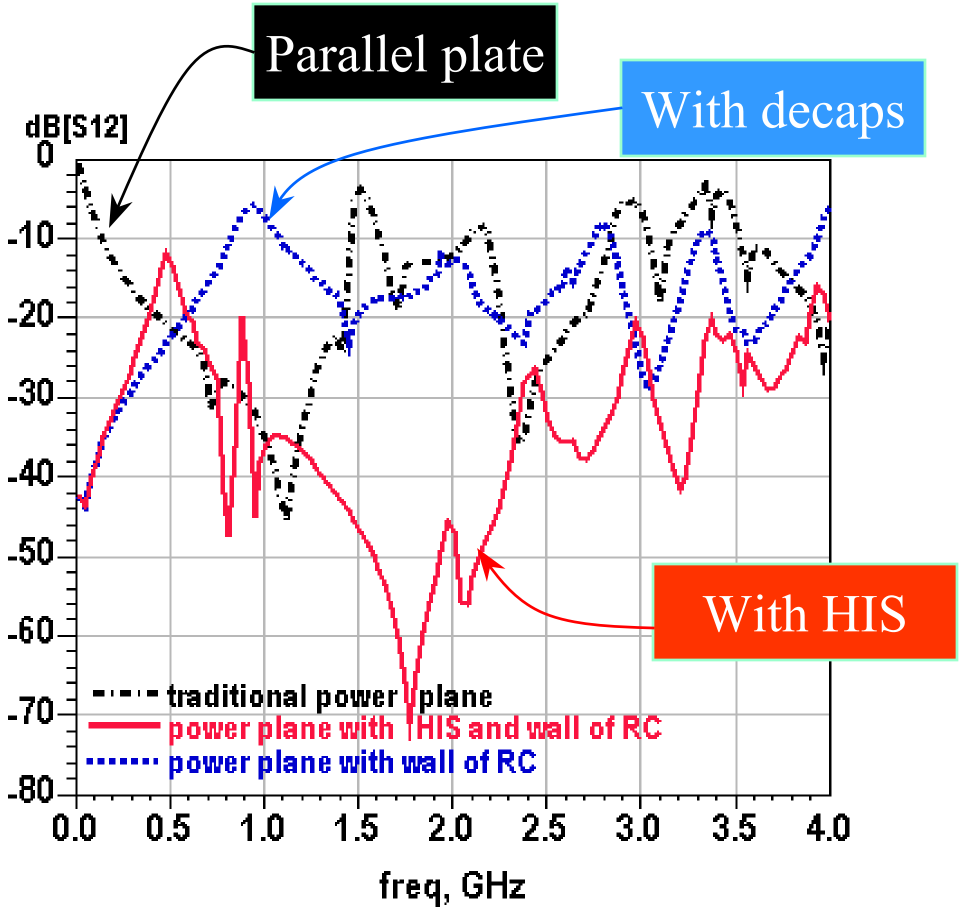


Increasing inductance while maintaining constant periodicity

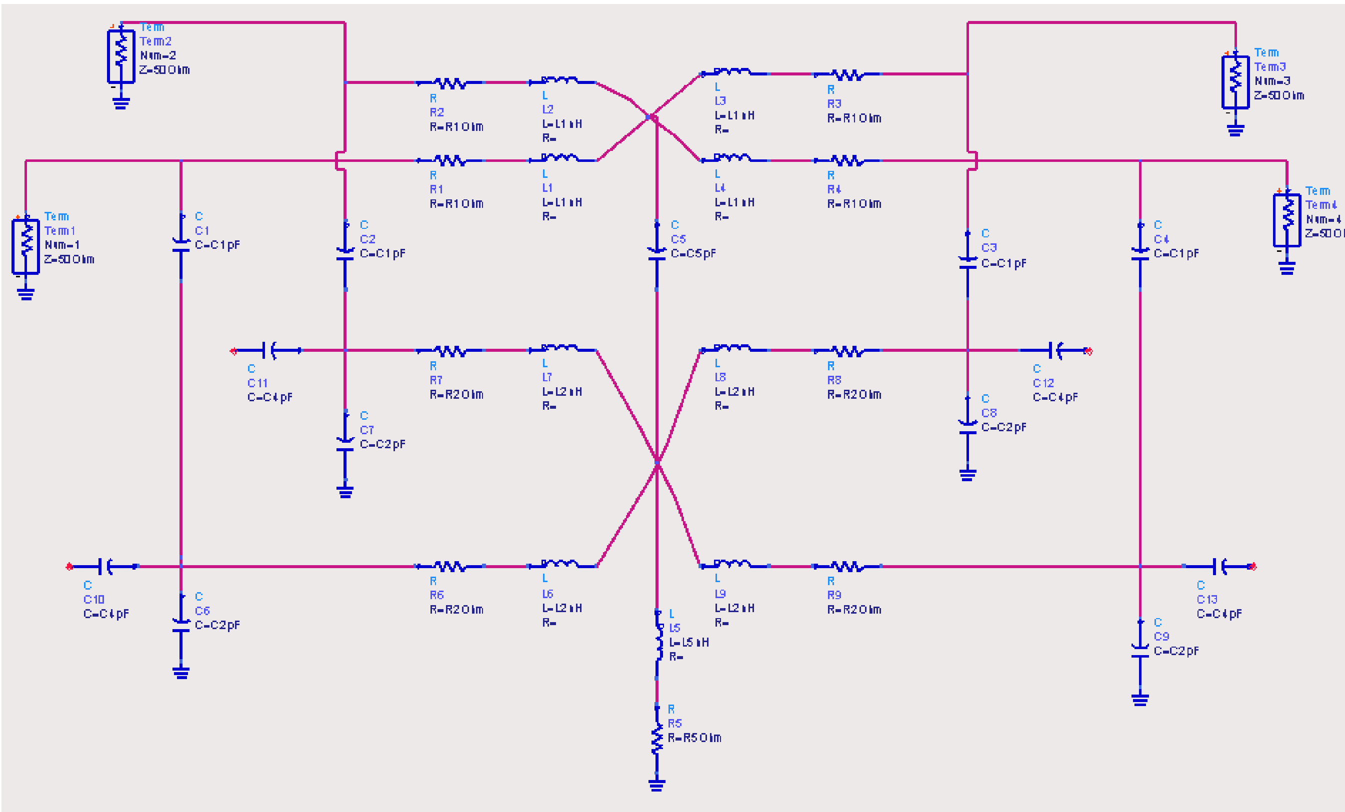


HIS Inductance-Enhanced Power Planes

Achieved a 3.2 GHz –20 dB bandwidth!



Physics-Based Model of a Unit Cell



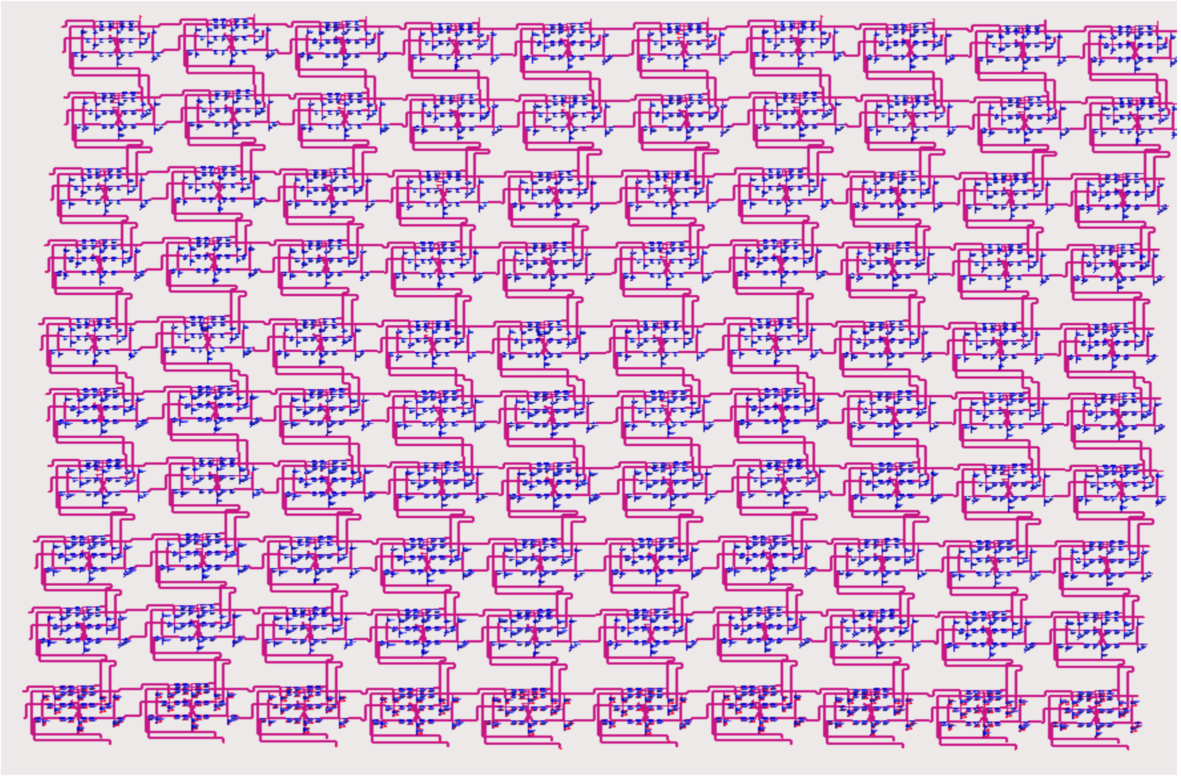
} Top plate

} Substrate

} Patch

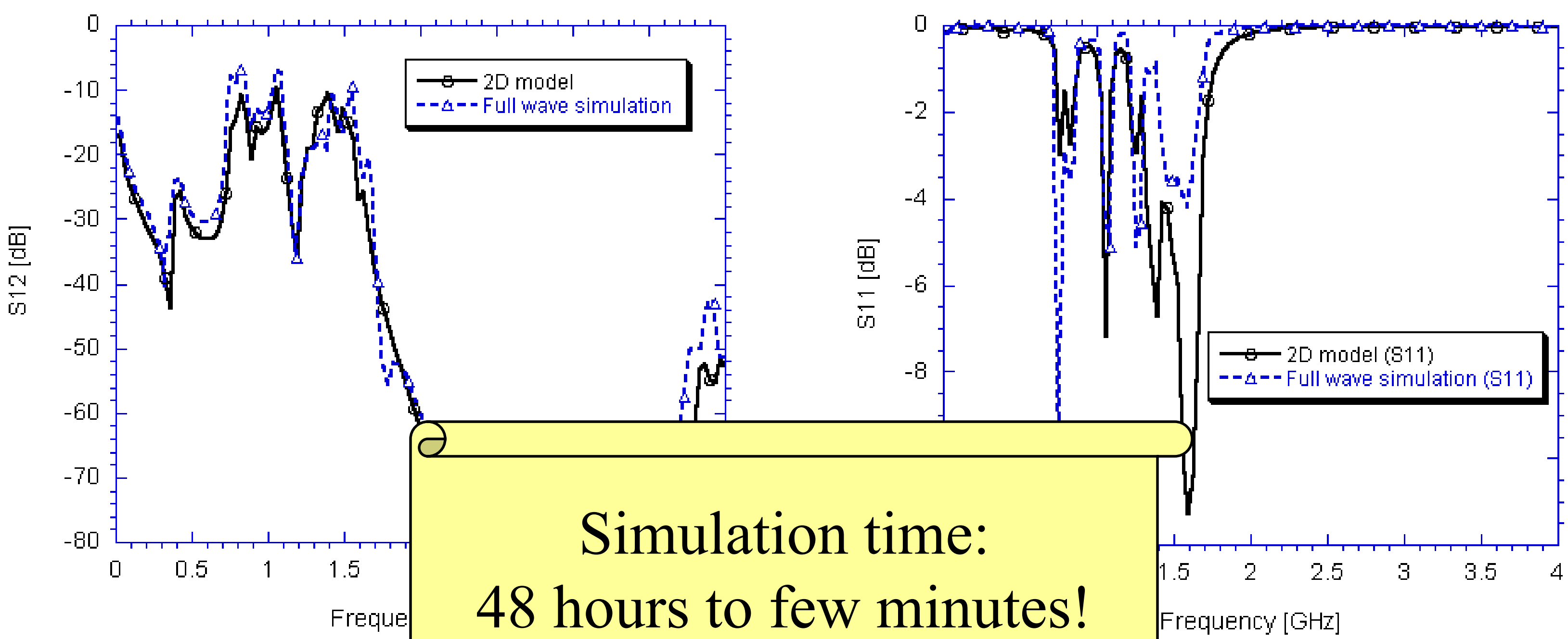
} Substrate

Compact Model of Complete Power Plane



2D cascaded model of a 10cmx10cm power plane with a total of 100 cells

Full-Wave Model vs. Circuit Model

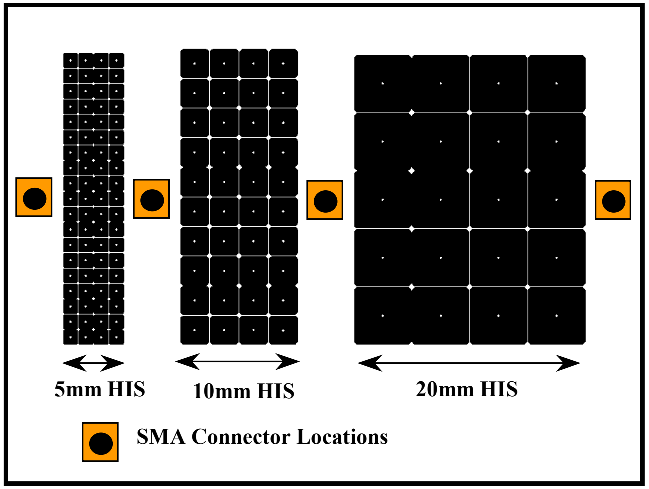


Simulation time:
48 hours to few minutes!

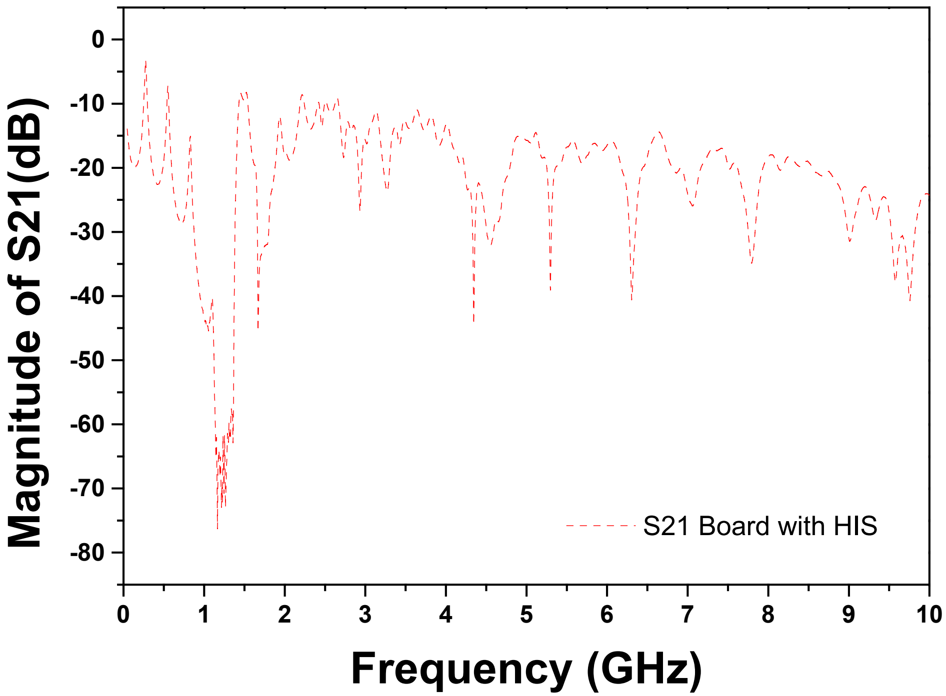
Wideband Noise Mitigation in PCBs

Can we increase the stop band?

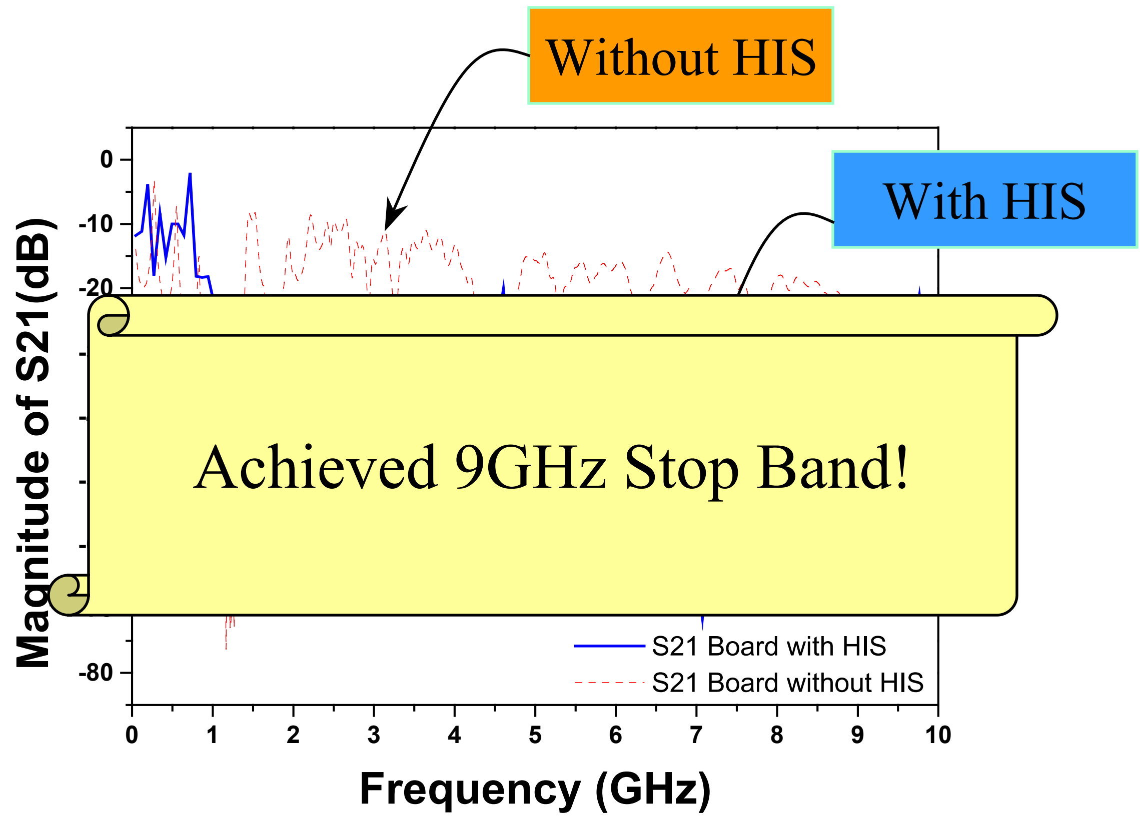
Concept: cascaded filter design



Experimental Validation

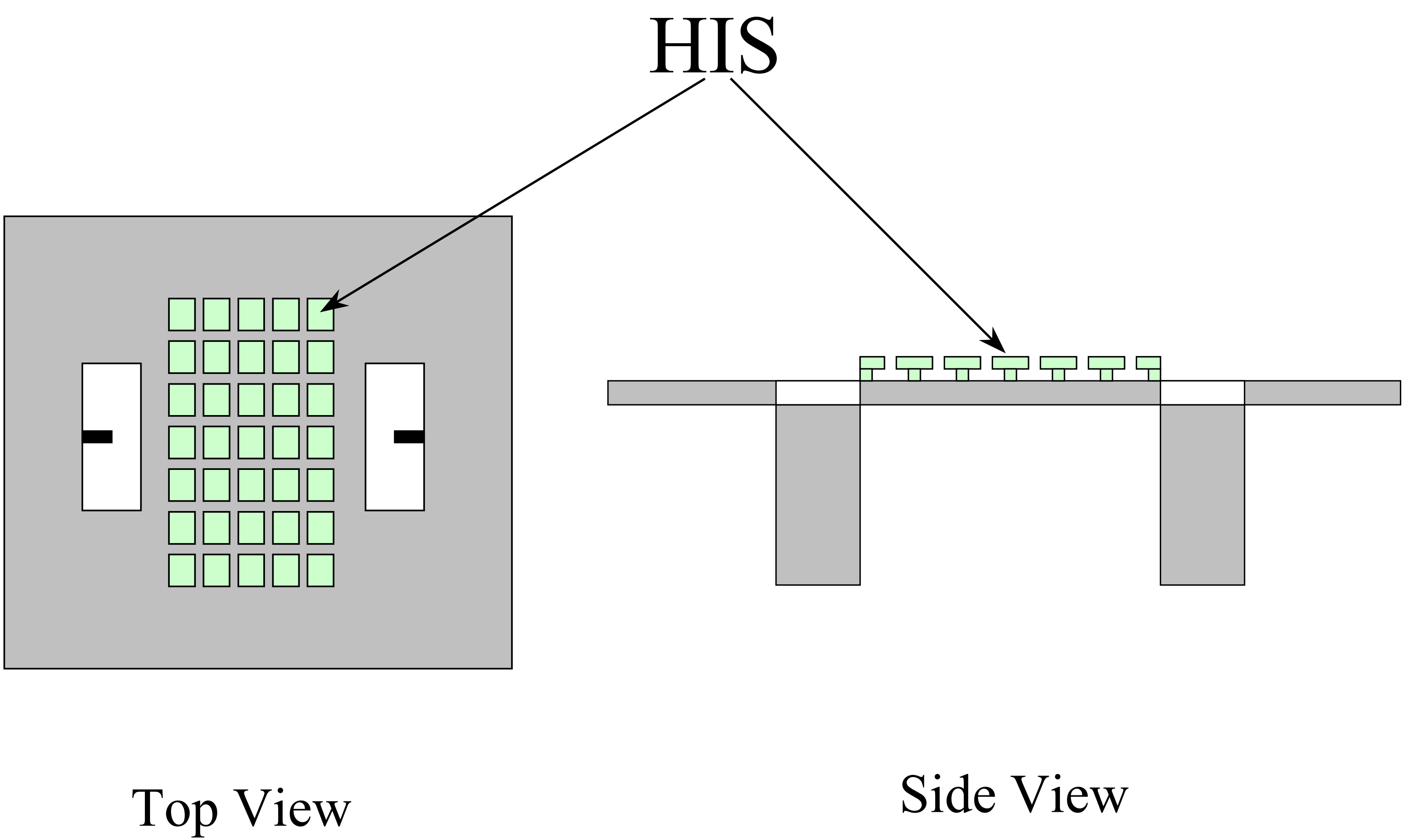


Experimental Validation

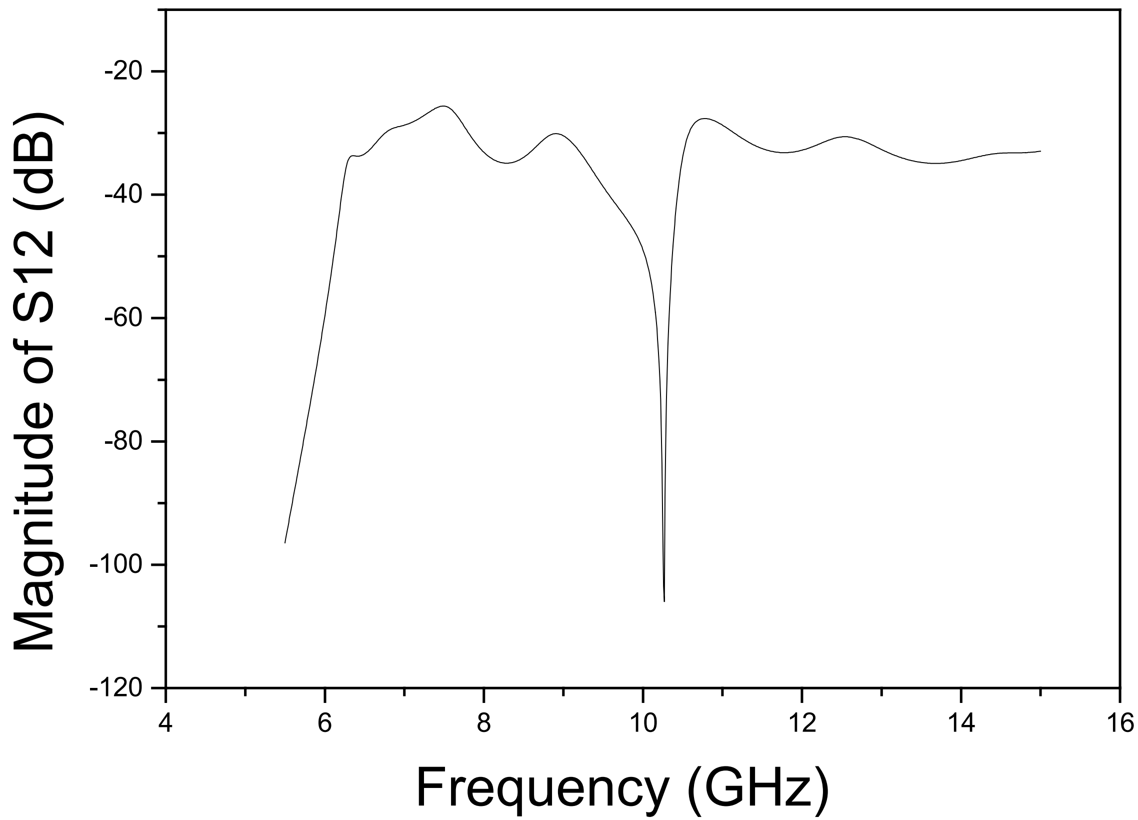


Part III:
Reduction of coupling between cavities

Close Proximity Cavities



Effect of HIS on Coupling



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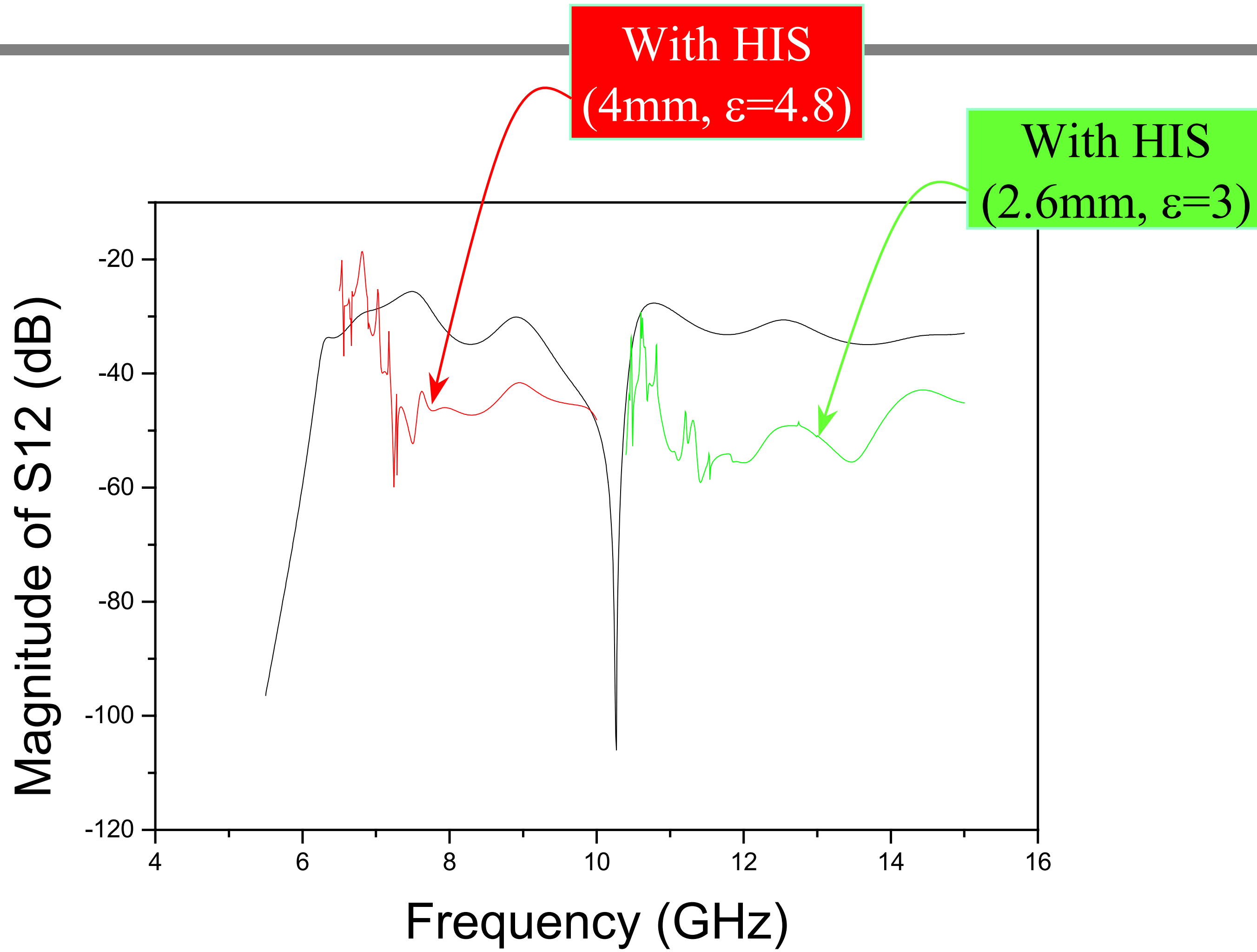
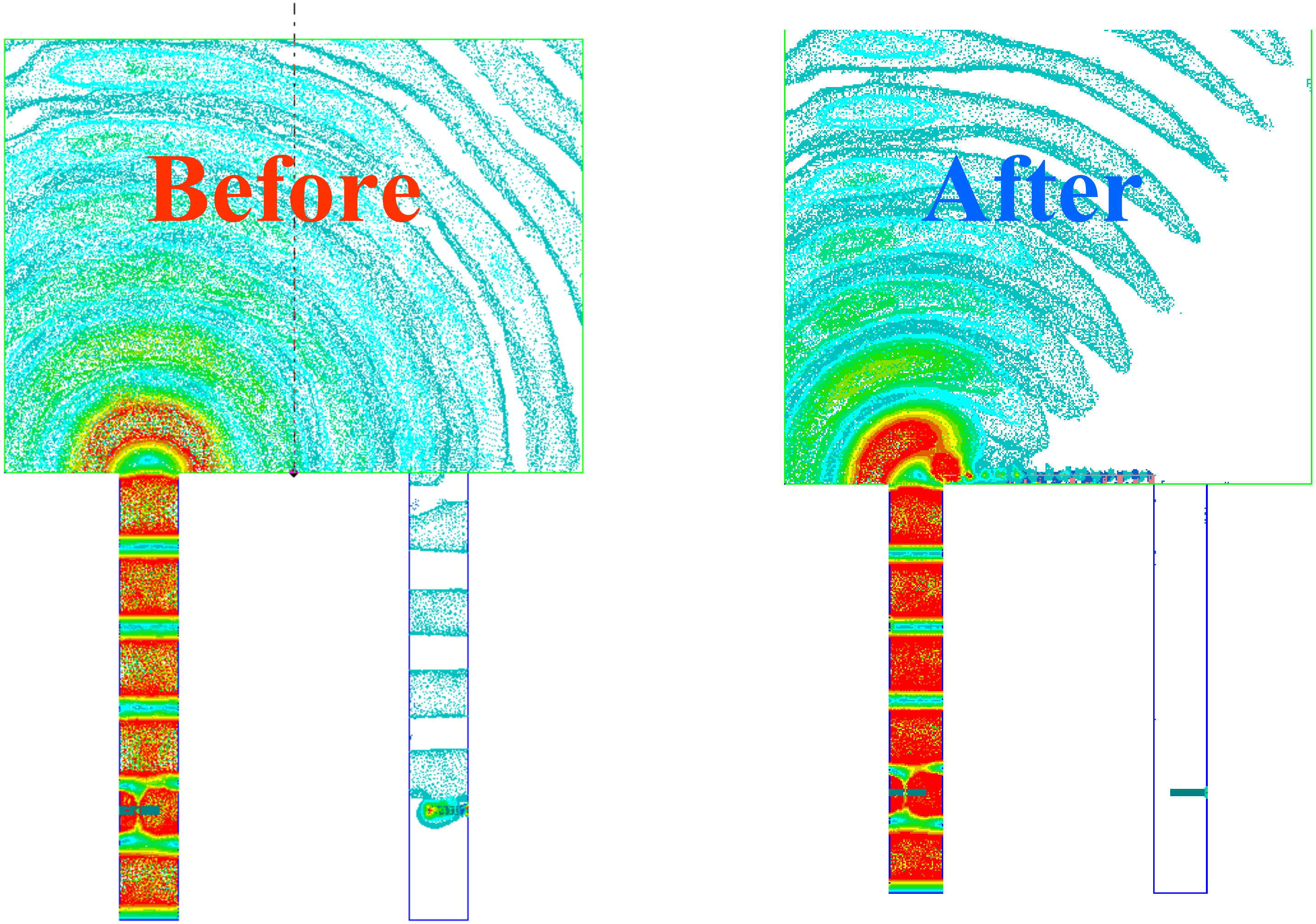
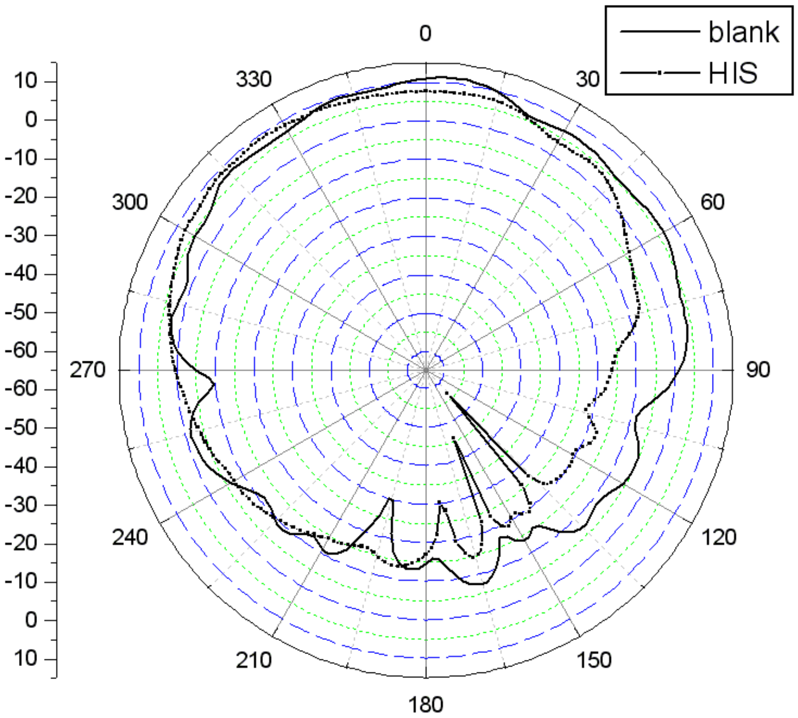


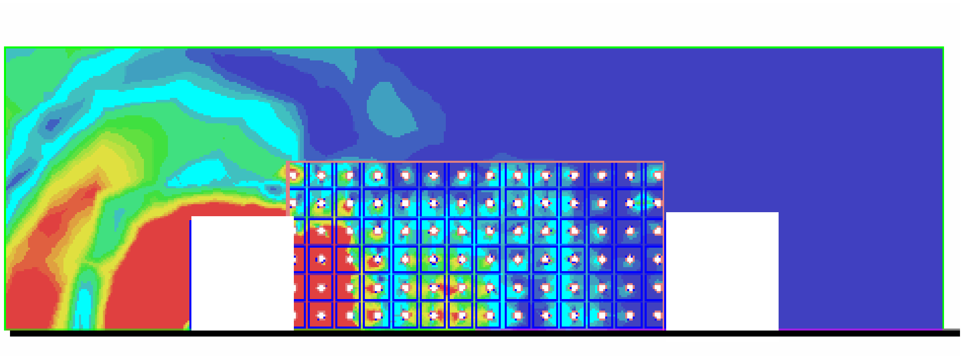
Field Pattern at 12.6GHz



Field Patterns at 12.6GHz (H-plane)

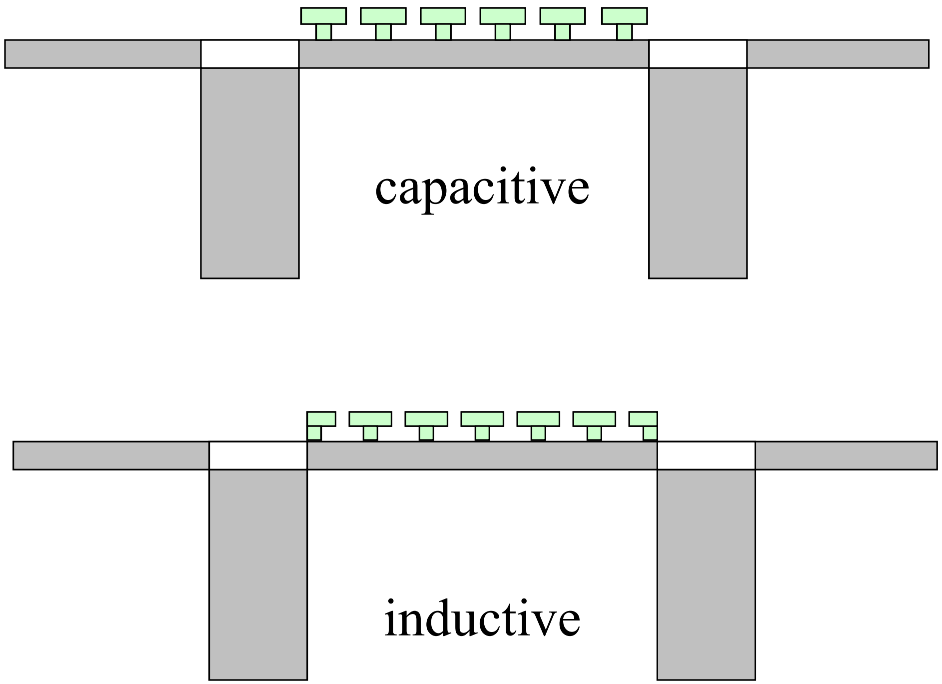


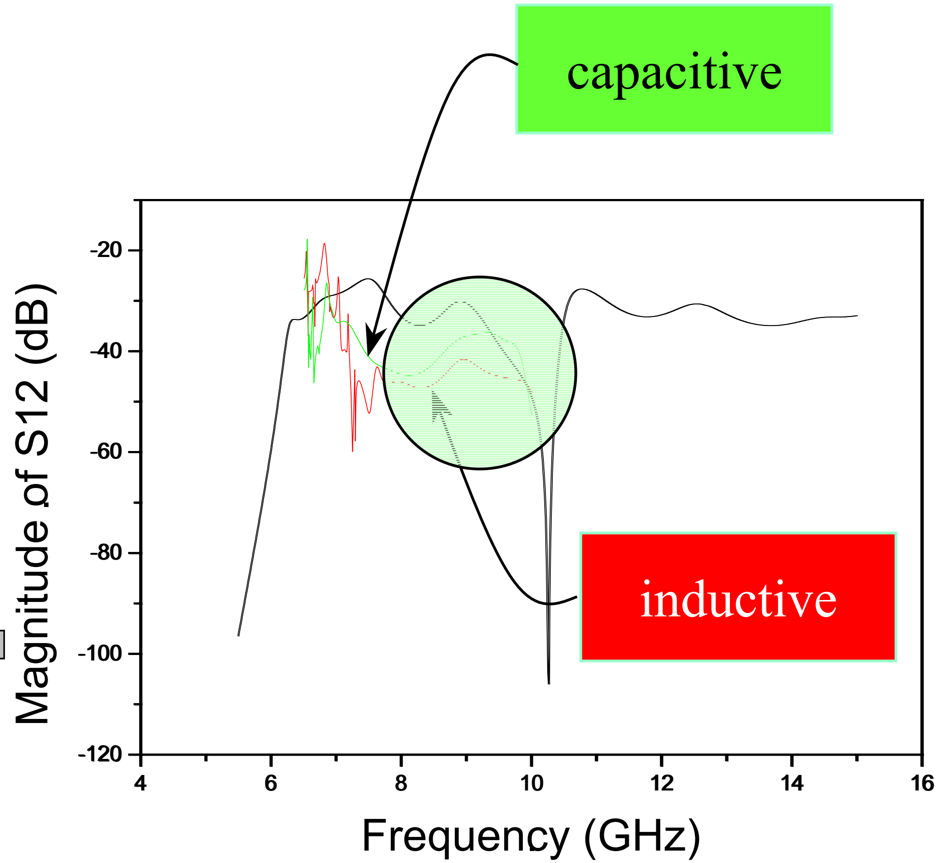
Radiation pattern



Top view

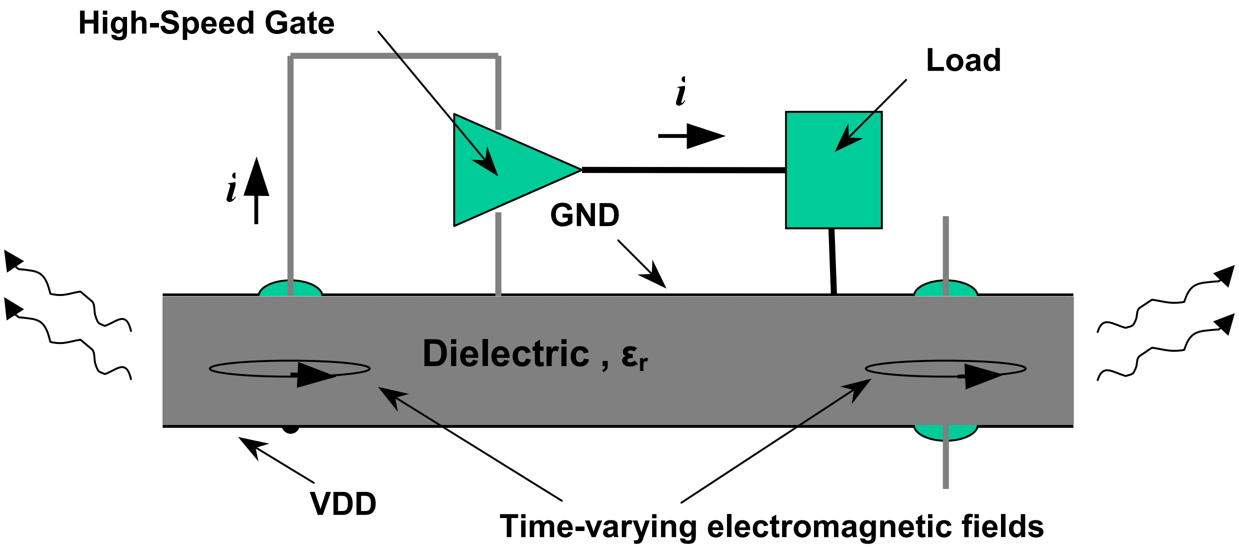
"Inductive" vs. "Capacitive" HIS





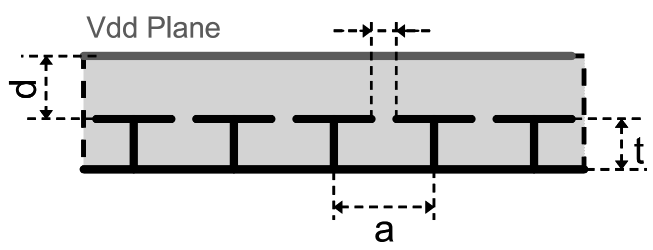
Part IV:
EMI Reduction from PCBs (Interference and Immunity)

External Radiation from PCBs



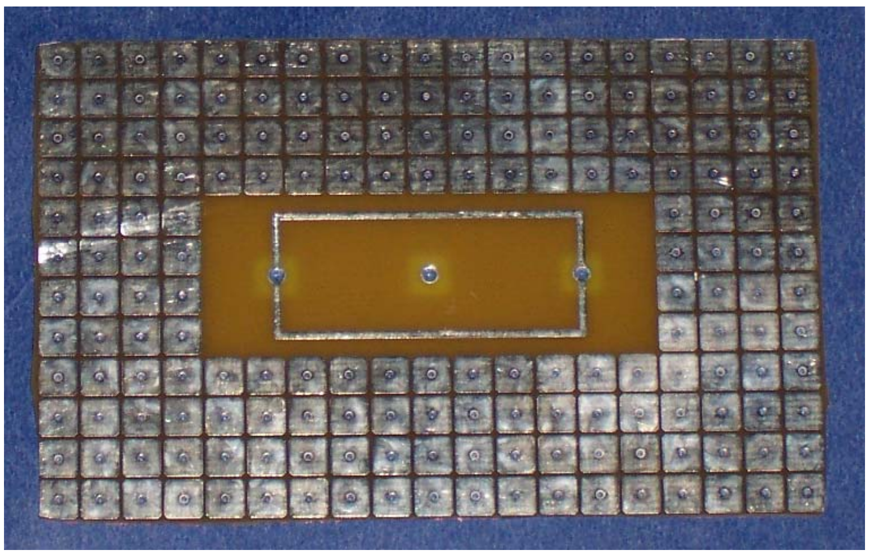
EMI Reduction through HIS

Concept:
Same as switching noise mitigation…
If waves don't travel within the PCB, they will not radiate!

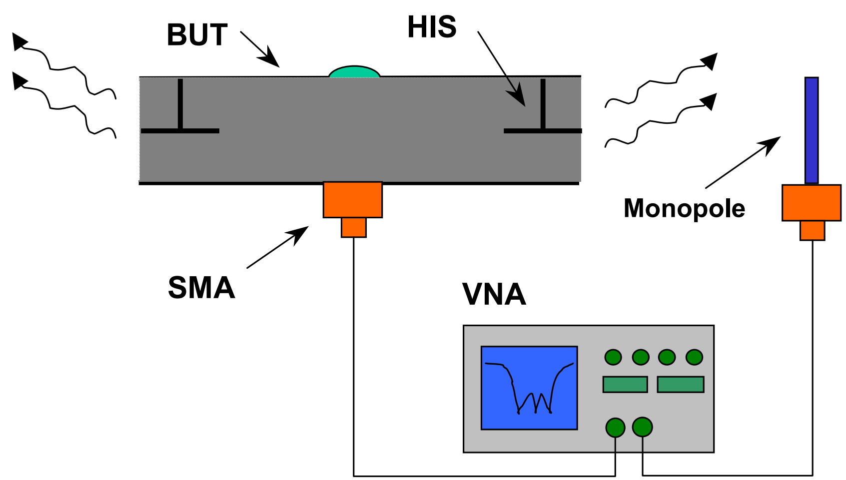


EMI Measurement Setup

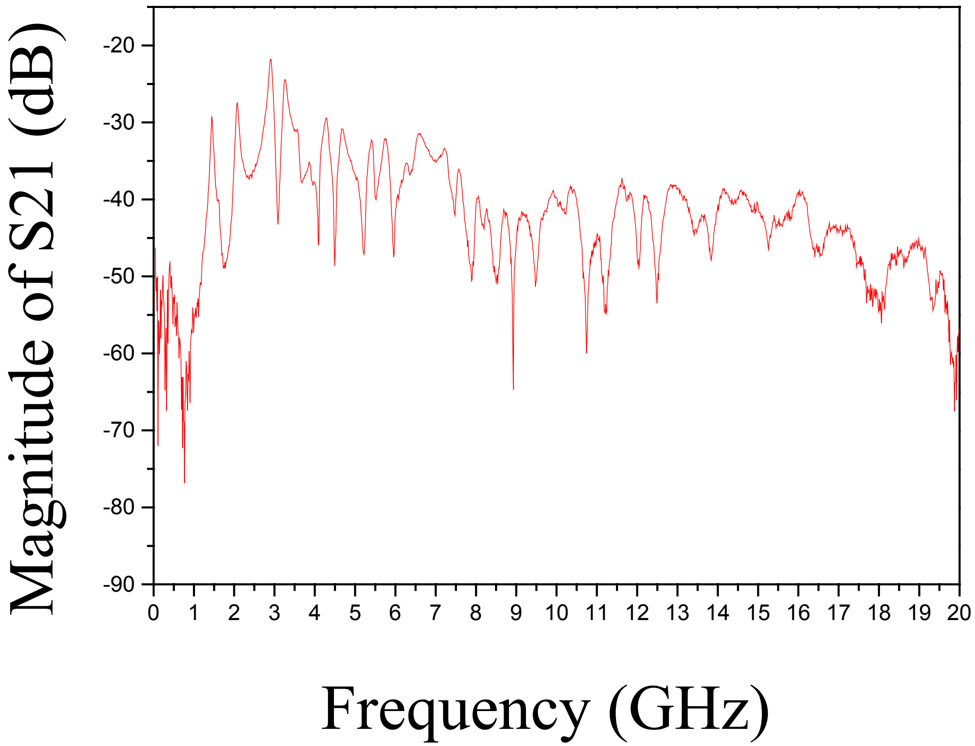
5mm x 5mm patches



10cm x 6.5cm board



Effect of HIS on EMI



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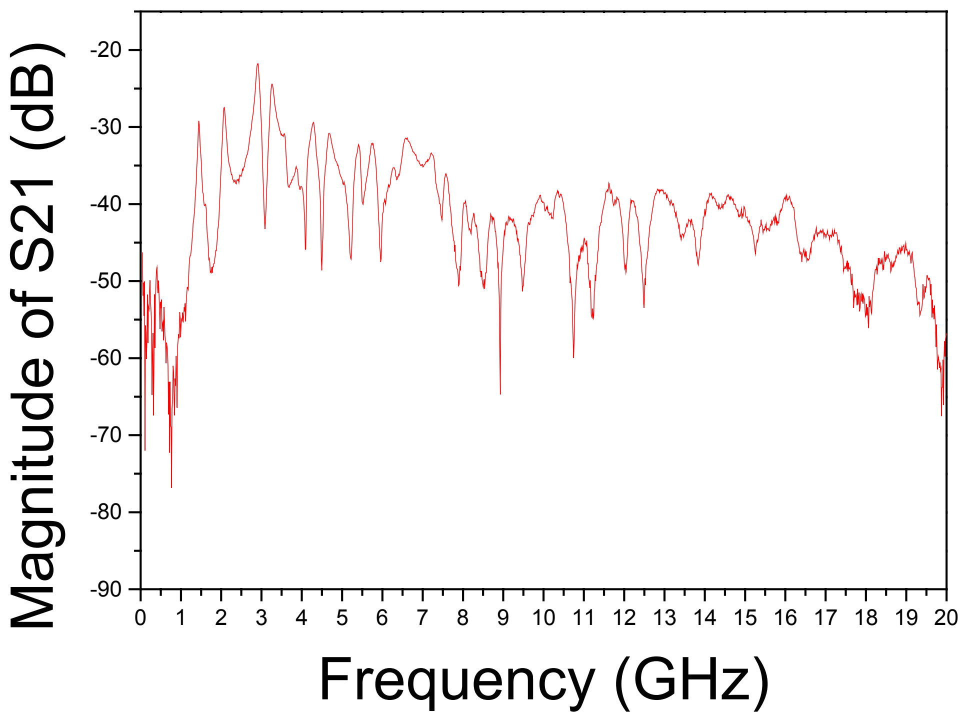

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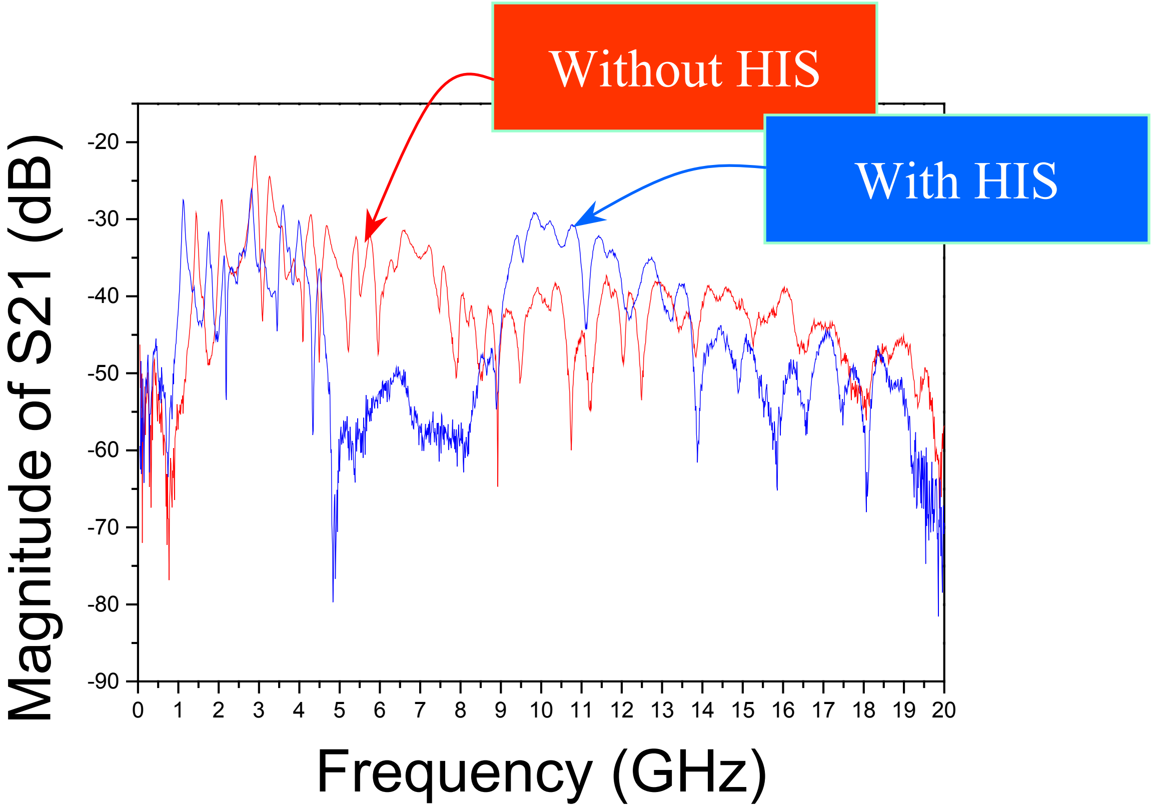

Present and Future Work

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- Derivation of analytical expressions for some chaos cavities
- Reduced-size bandgap material for miniaturized systems
- Extension of the cascaded HIS concepts to general surface suppression applications

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