EM Noise Mitigation in Electronic Circuit Boards and Enclosures

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

AFOSR MURI

June 2002 Review

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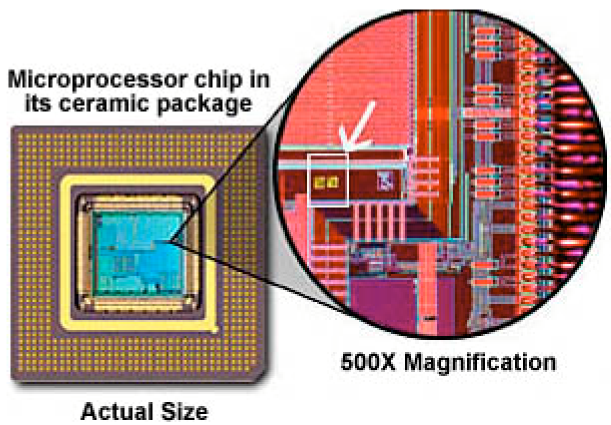
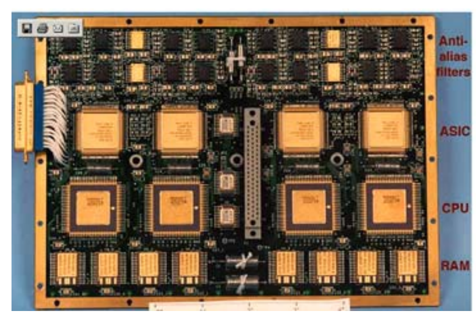
Primary Objectives

Make each of the following less susceptible
to EM noise, or alternatively, more quiet



Packages

Chasses



Printed circuit boards

Outline

- ***Quiet Chasses***

  a) Developing 3-Dimensional Full-Wave Predictive Tools for Cavity Resonance and S Parameter Computation and Extraction

  b) Using lossy material coating to reduce aperture radiation

  c) Using meta-material (high-impedance surface) to reduce emissions from apertures.

- ***Quiet Printed Circuit Boards***

  a) Developing fast predictive modeling tools

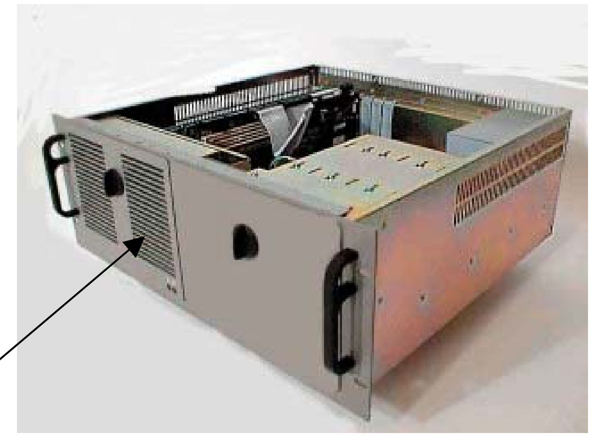
  b) Reducing noise in printed circuit boards using high-impedance surface.

Our Philosophy …

- Concept Development
- Numerical validation and prototyping
- Experimental verification

Apertures are Everywhere!! Highest Vulnerability

Shielding wall with opening for audio speaker



Opening for air ventilation

Opening for mounting display

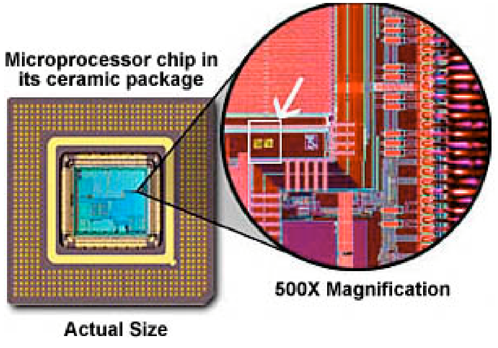
Shielding chassis with aesthetics design

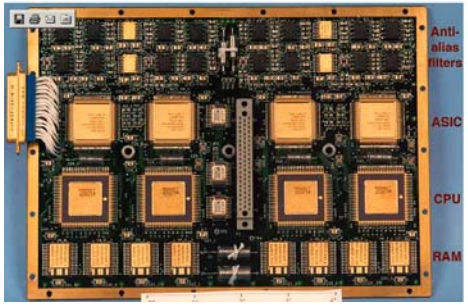
EM Interference – Entry Points and Noise Channels

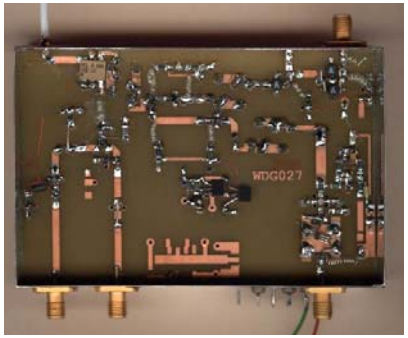
Chassis contains:

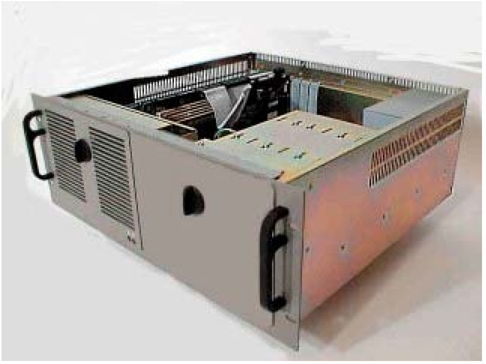
- Apertures– entry point of radiation
- Cables – entry point for conducted radiation
- Printed circuit boards (PCB) – constitute noise channels. If not “quiet” can be a source of interference and radiation

4. Packages – constitute noise channels





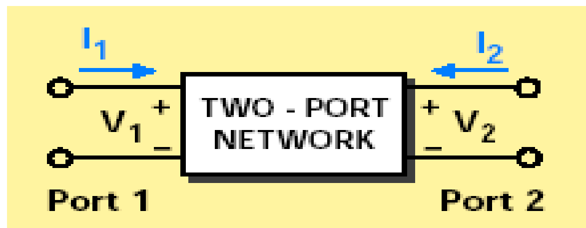


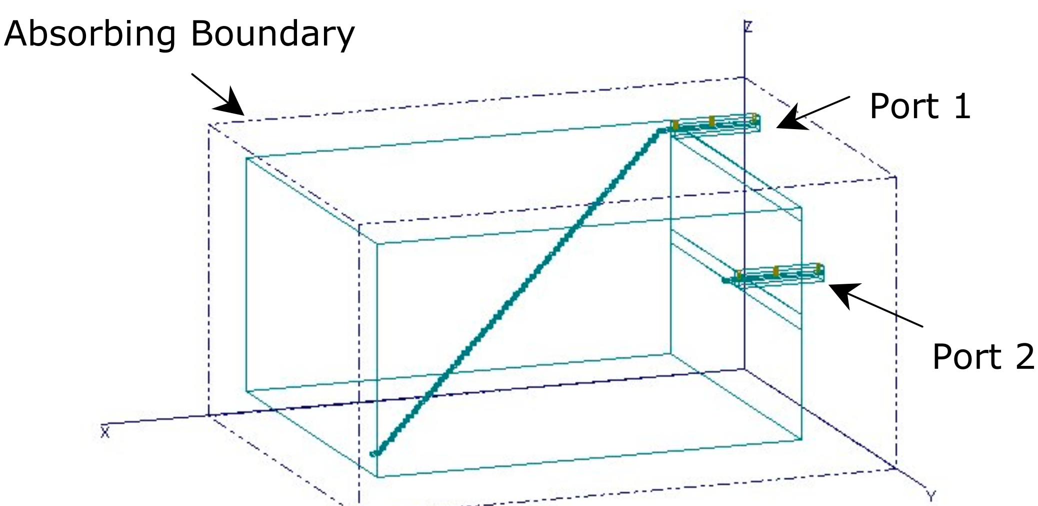


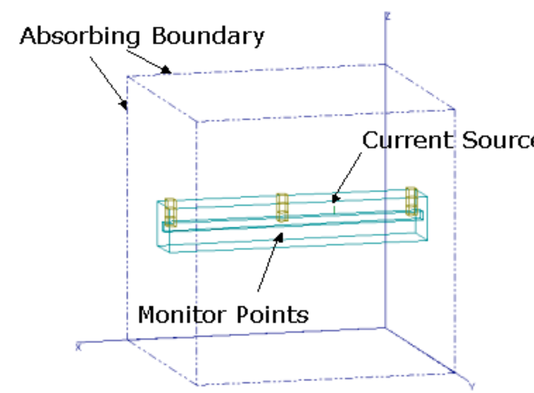
S Parameter Calculation and Extraction – Resonance Prediction

Finite-Difference Time-Domain Model

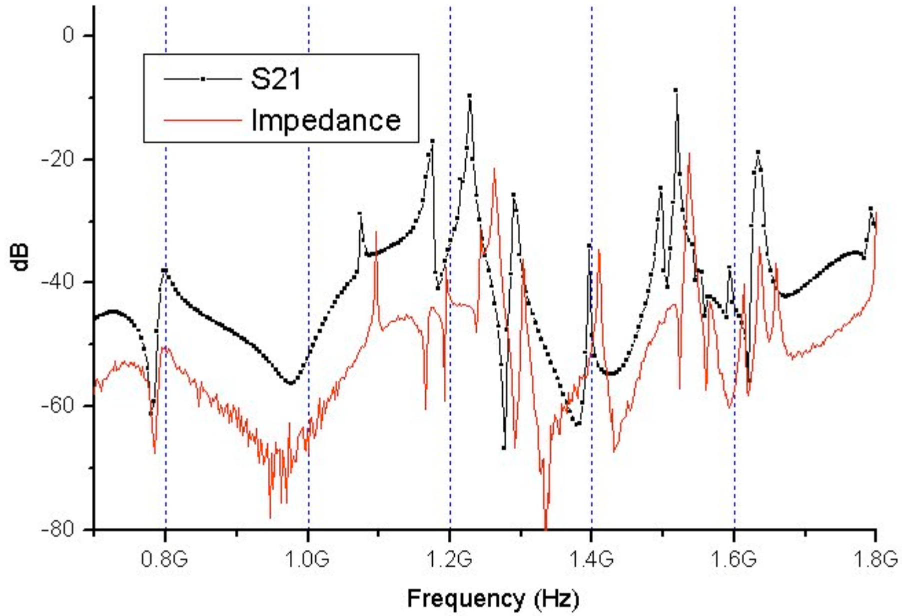
Treat enclosure as a two-port network







FDTD Simulation Results



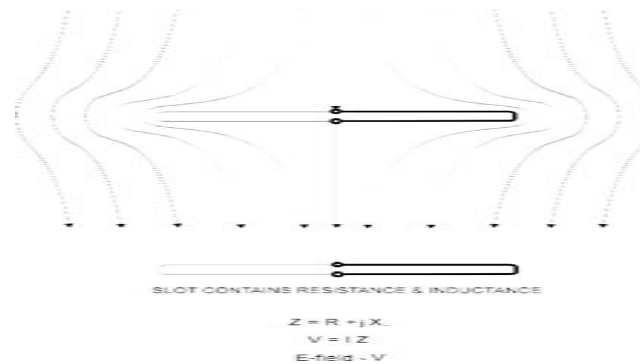
Minimizing Radiation from Apertures

Classical EM Aperture Research

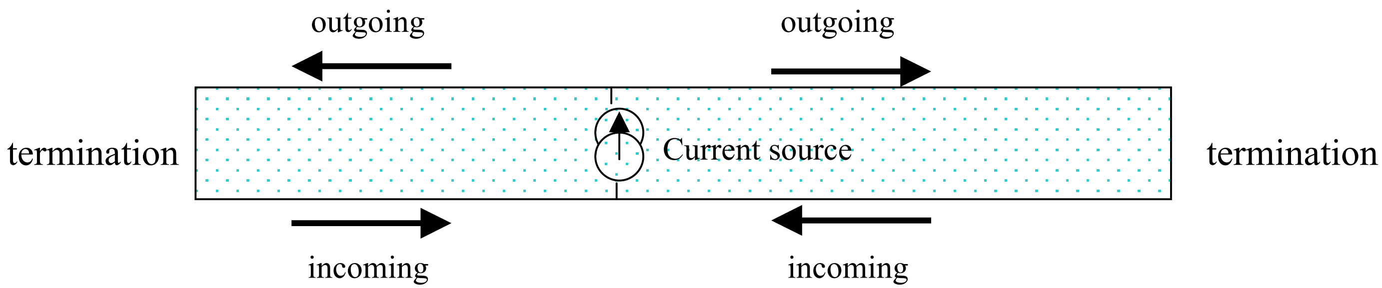
- Developing techniques to predict aperture radiation
- Multi-aperture coupling

Our emphasis:

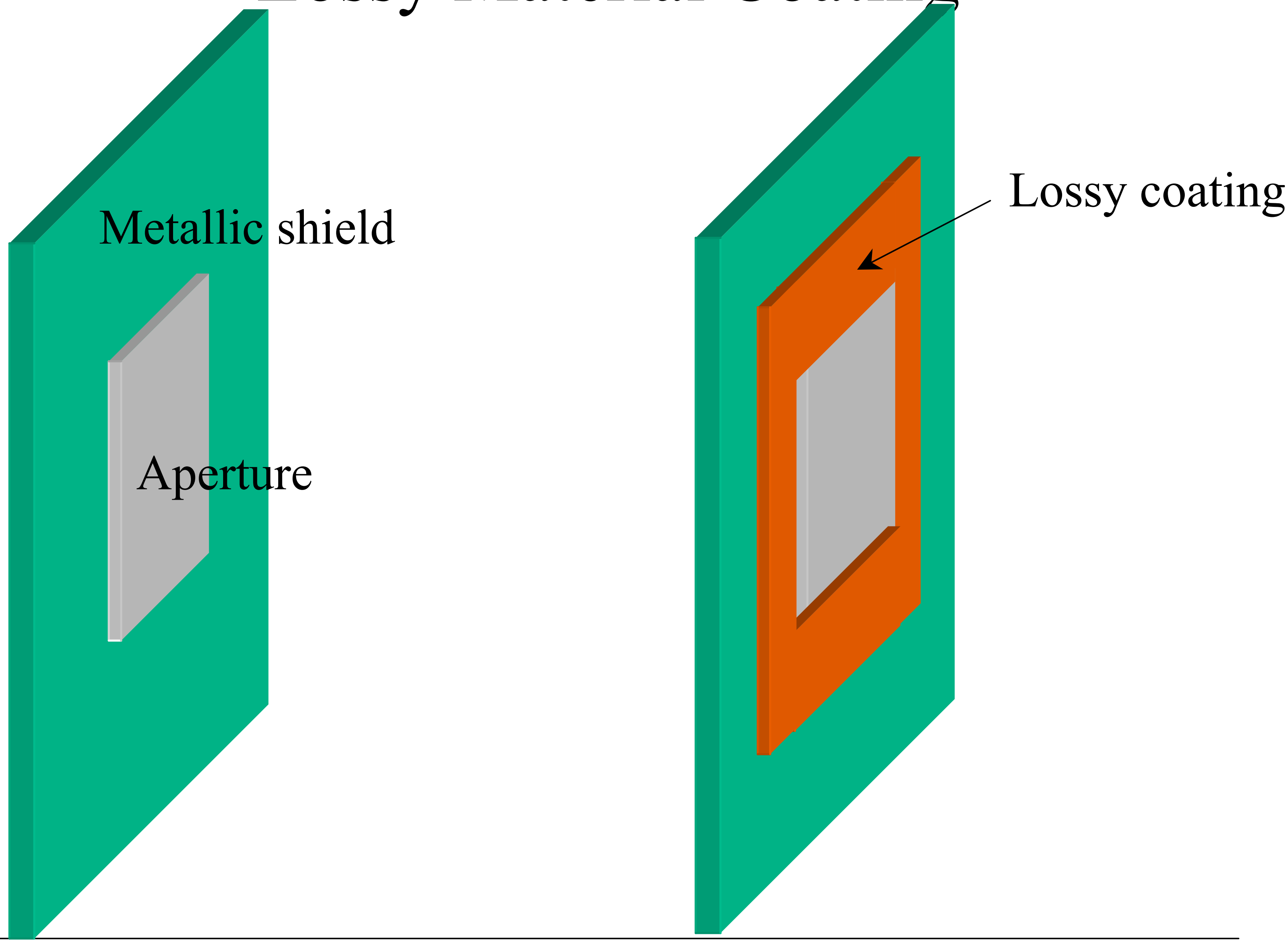
Understand physical distribution of current in the <u>close proximity</u> of Apertures and its effect on near- and far-field radiation



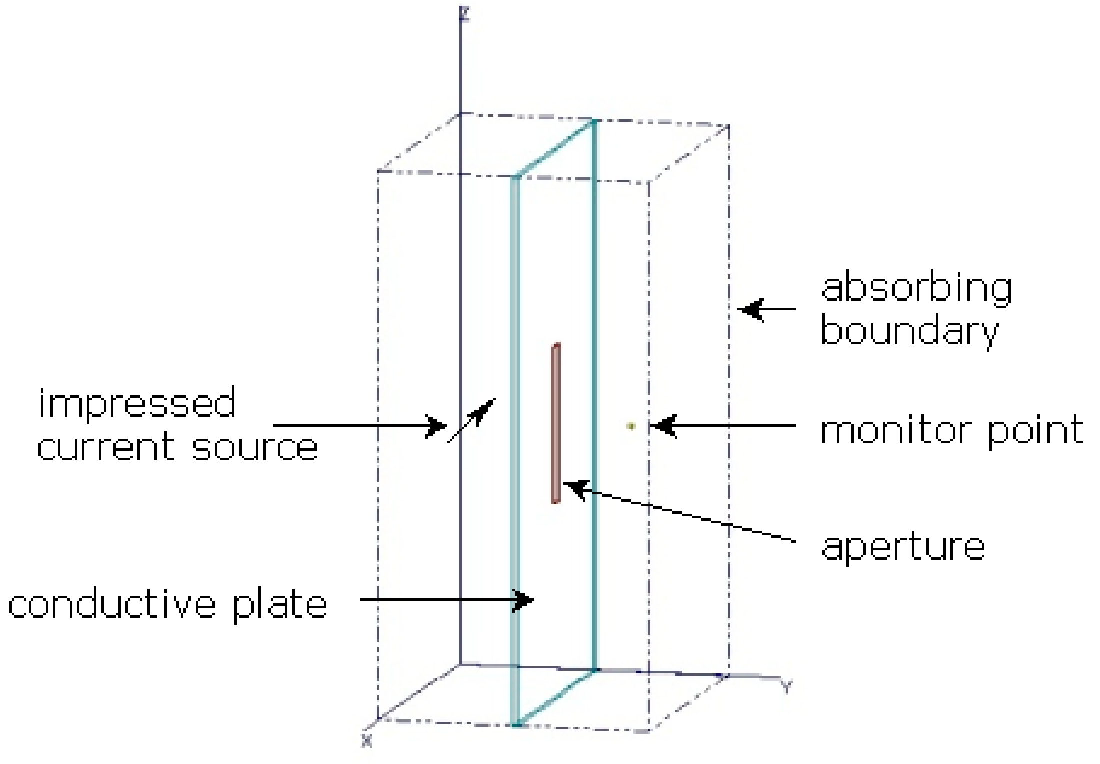
Transmission Line Interpretation of Aperture



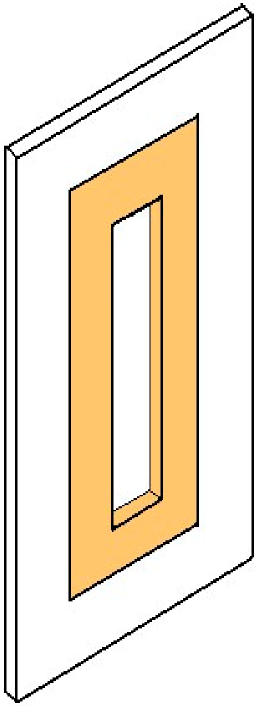
Lossy Material Coating



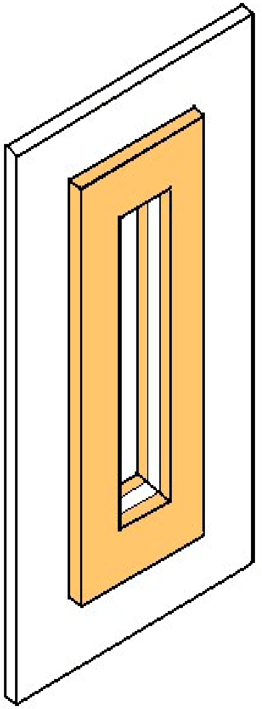
FDTD Modeling



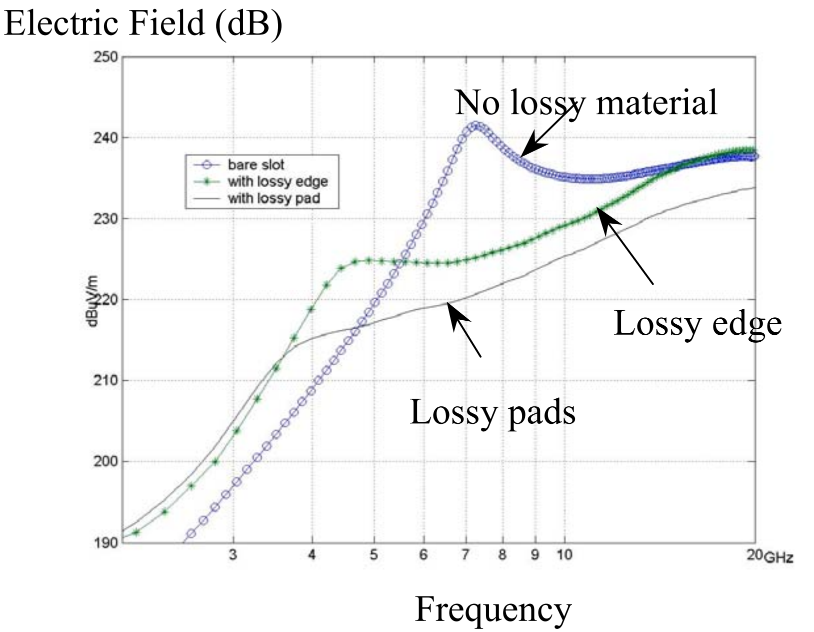
Alternative techniques



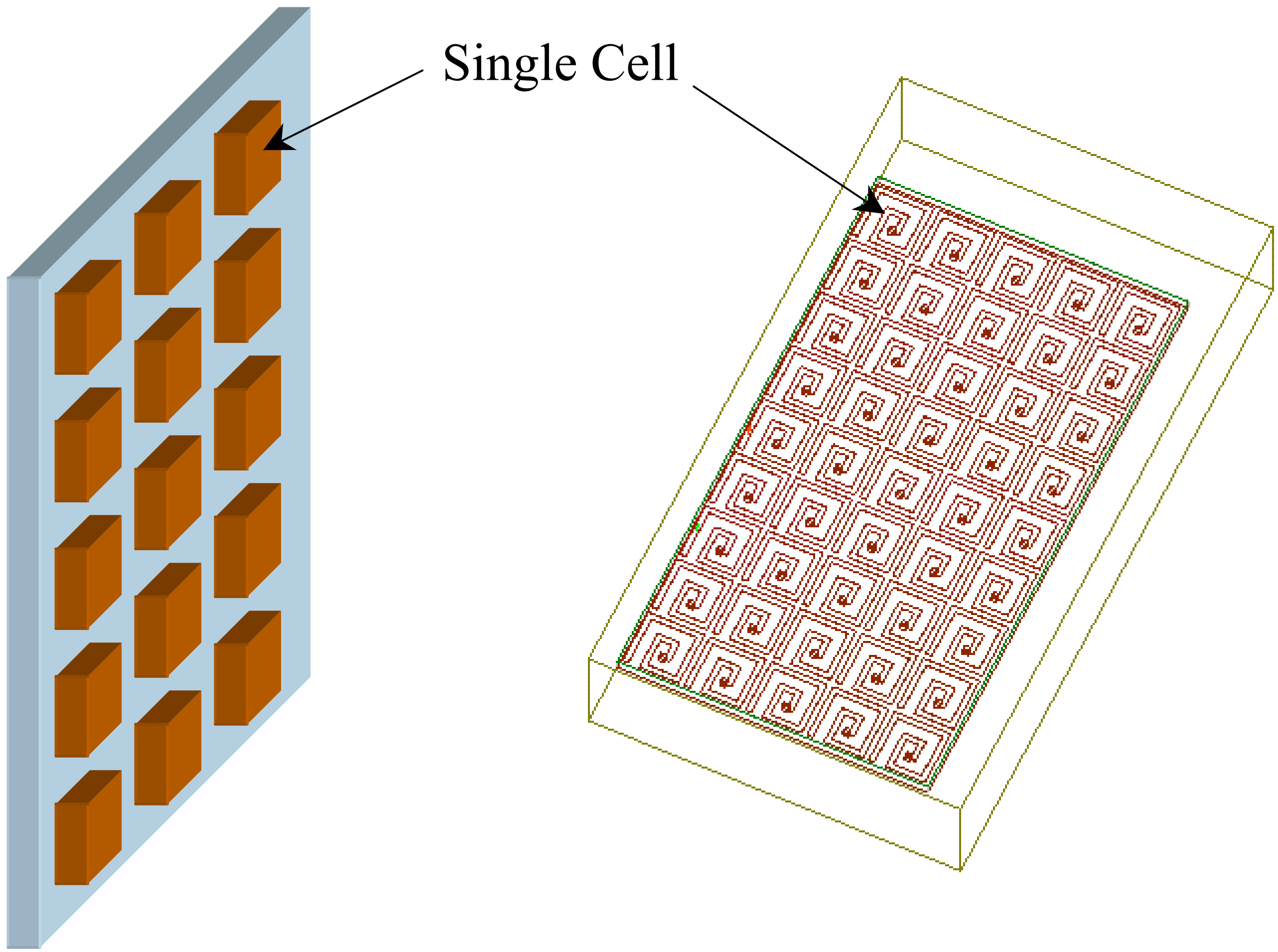
Lossy edge



Lossy pads

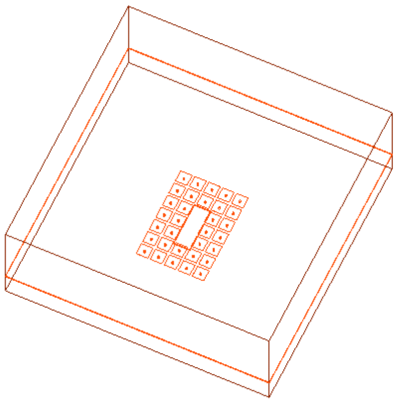


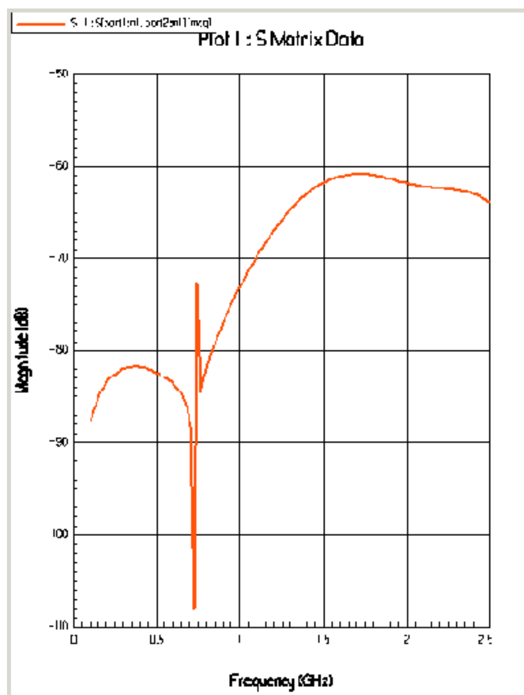
Electromagnetic Band Gap Structures



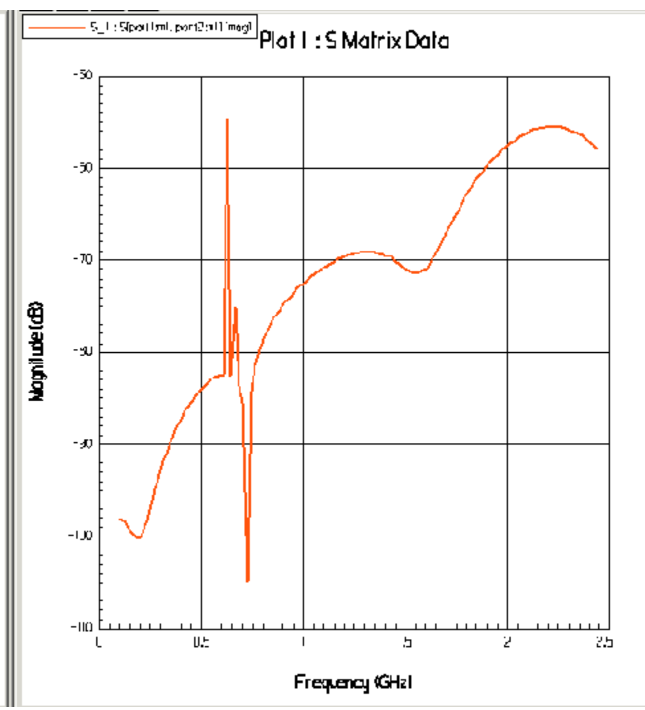
HFSS Simulation

Preliminary Results





Without HIS



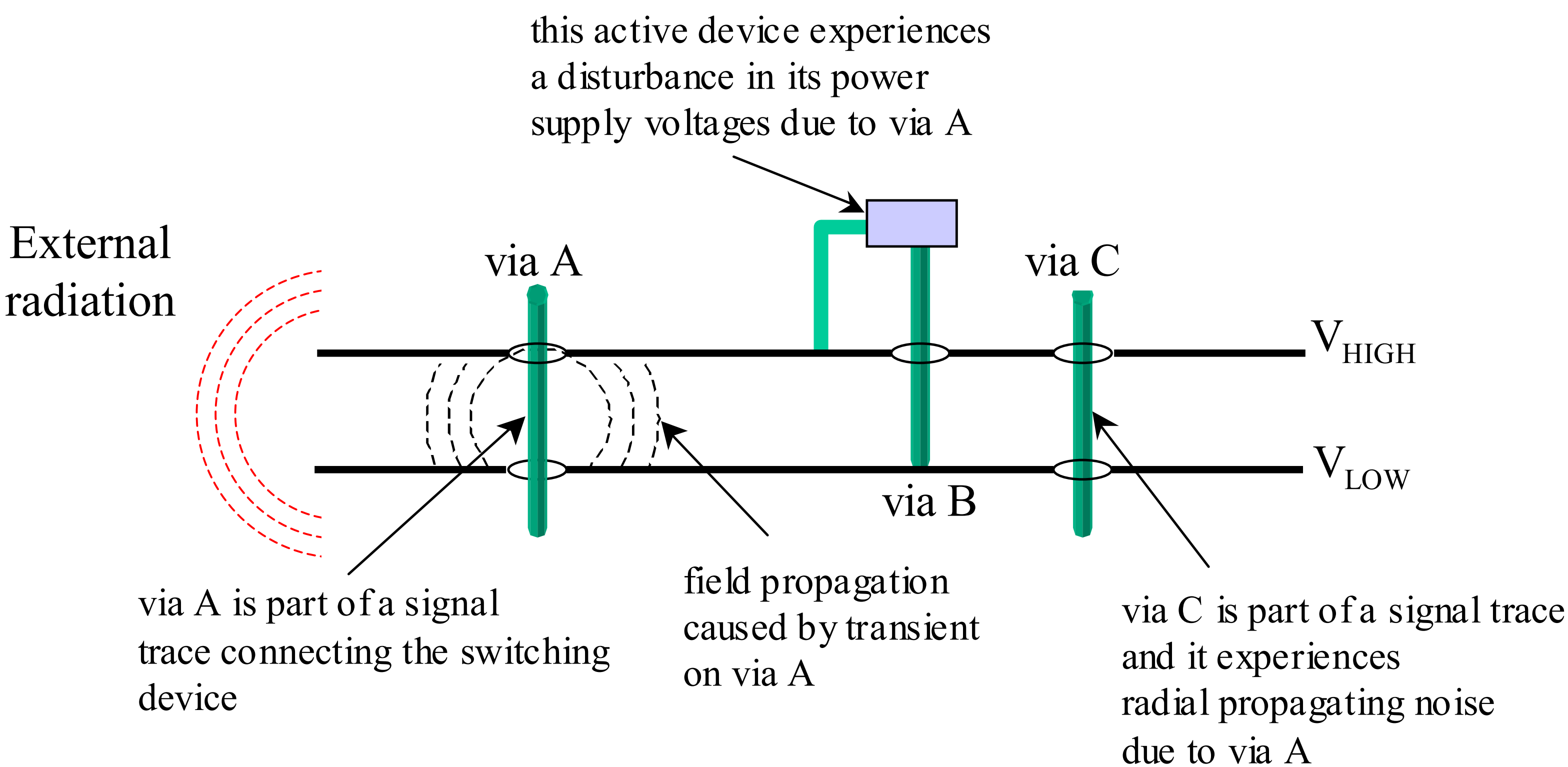
With HIS

On-going Research in Aperture Radiation

- Effect of conductivity on near and far field
- Effect of resistive film are on fields
- Effect of resistive film on coupling between adjacent apertures

Silencing Printed Circuit Boards

Noisy Circuit Boards – A source of internal interference and external radiation

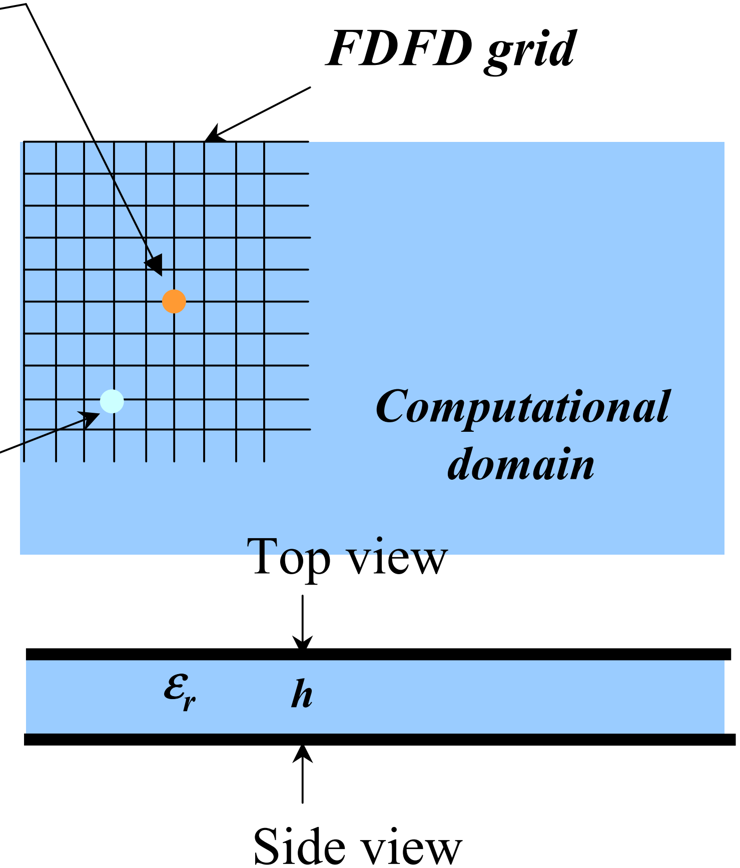


FDFD 2-D Model

Source located at r_o

$$[\nabla^2 + k^2]E_z(r) = \delta(r - r_0)$$

$$[\nabla^2 + k^2]E_z(r_z) = \frac{hE_z}{Z_c A}$$



Voltage-controlled Current source Representing lumped element

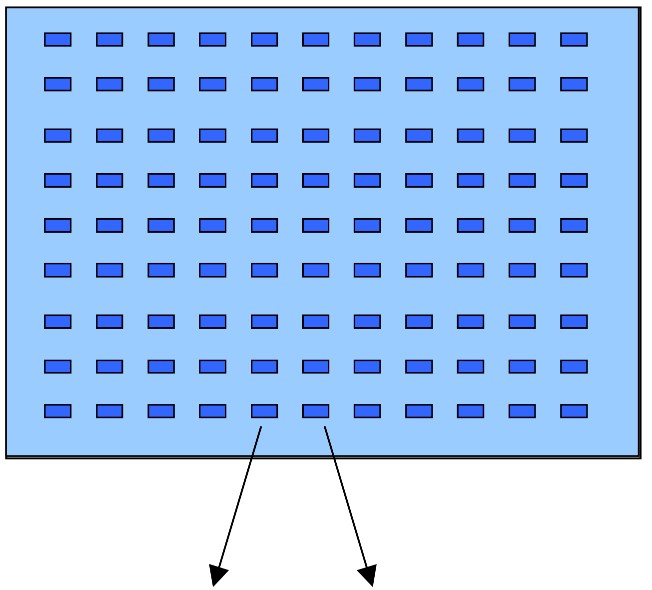
h = planes separation,

K = wave number,

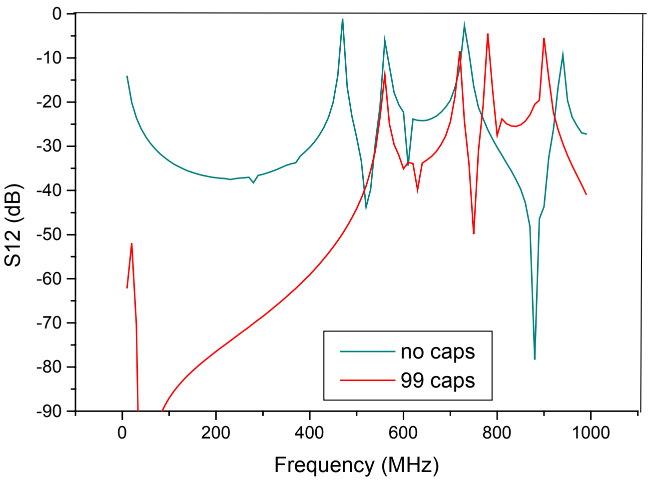
Z_c = impedance of load

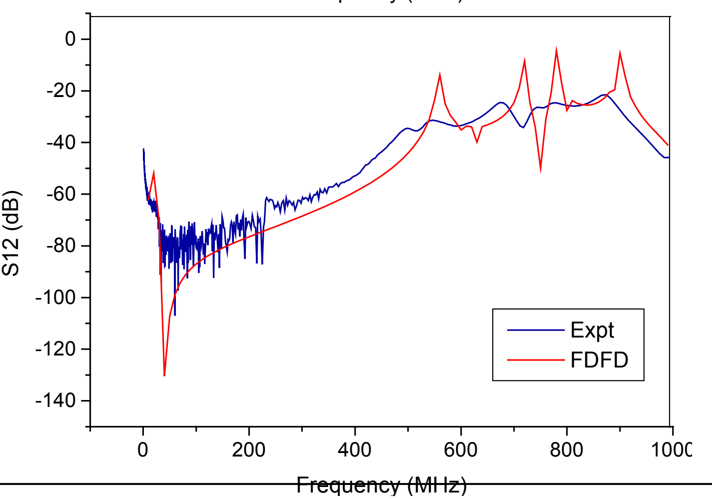
Numerical Validation and Results

•Case 1: 30.5cm x 25cm Board with 99 Capacitors



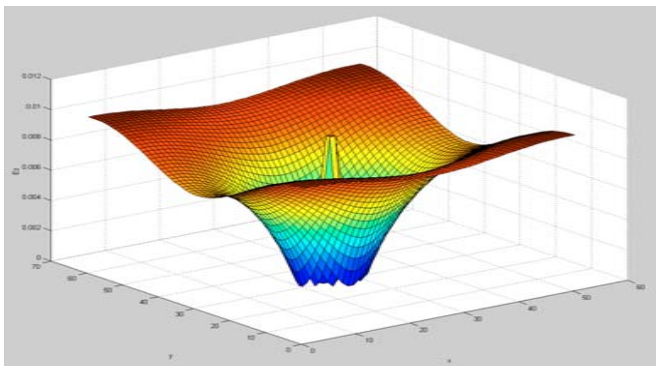
Decoupling Capacitors
C=10nF, L=2nH



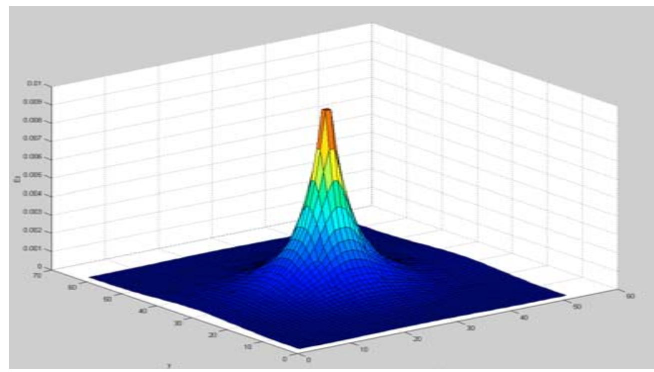


E field distribution across the board

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

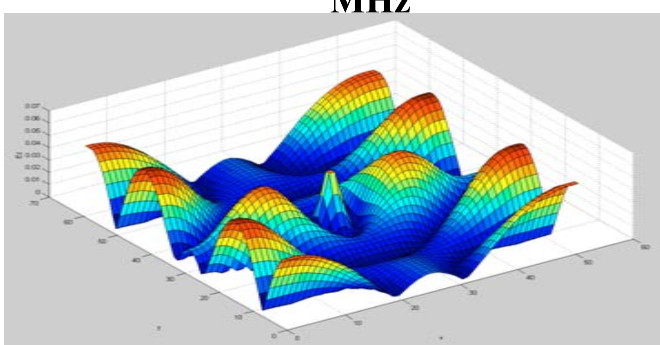


No caps 200 MHz

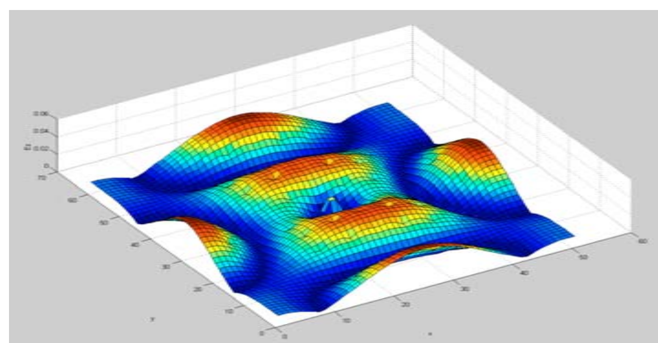


99 caps 200 MHz

Effective



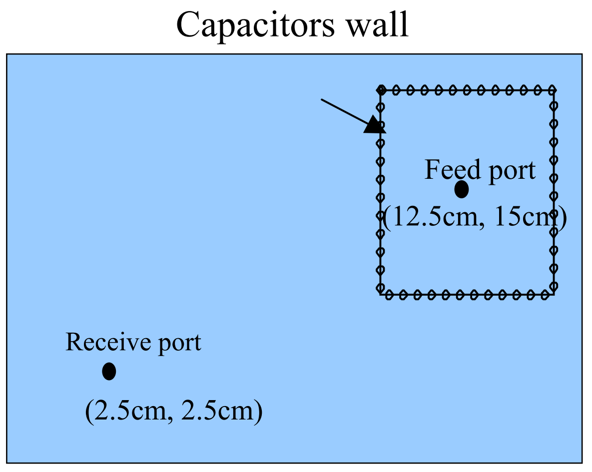
no caps 1 GHz

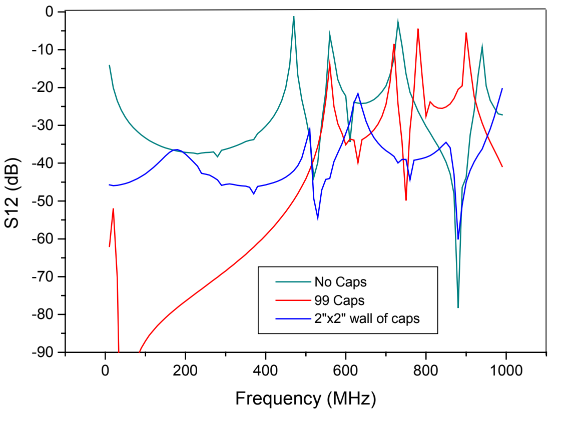


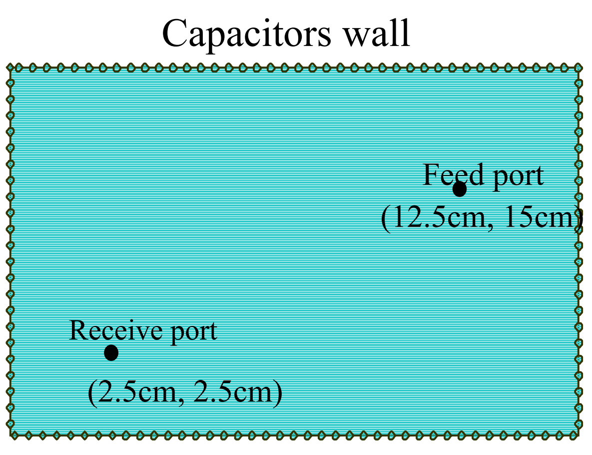
99 caps 1 GHz

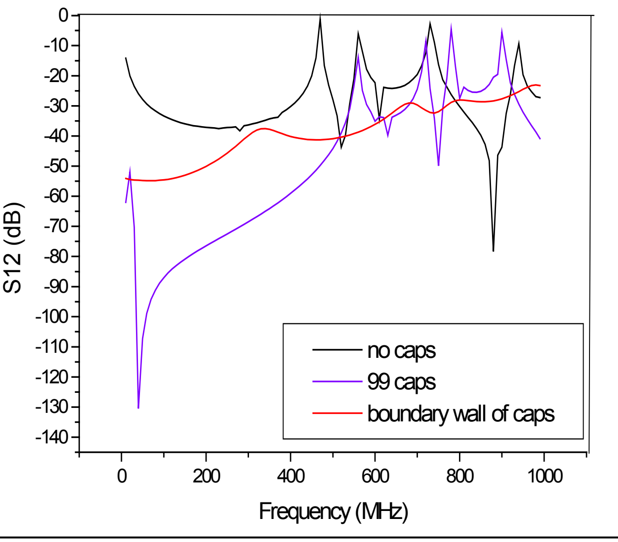
NOT Effective

Numerical Validation and Results



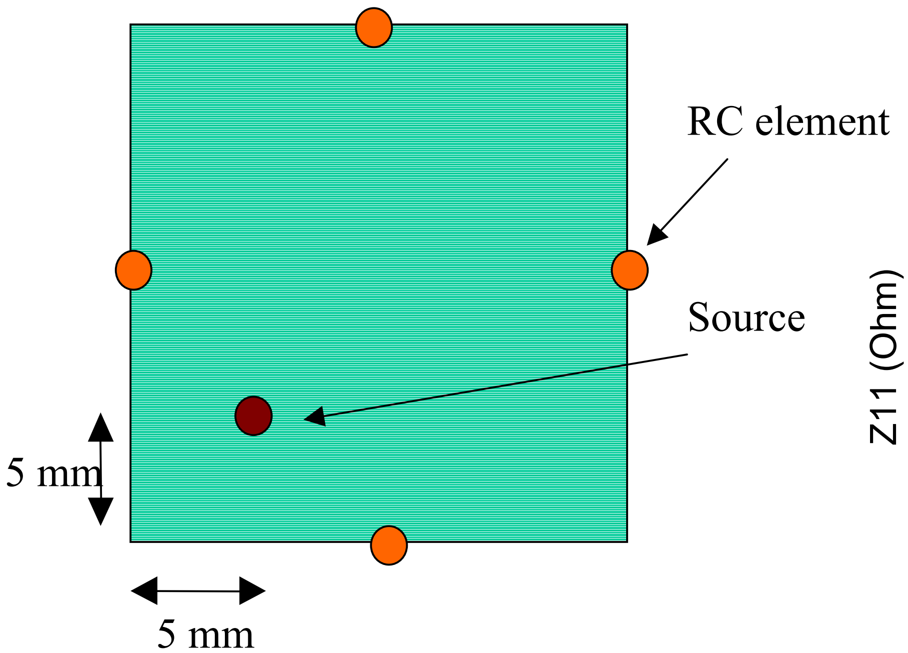




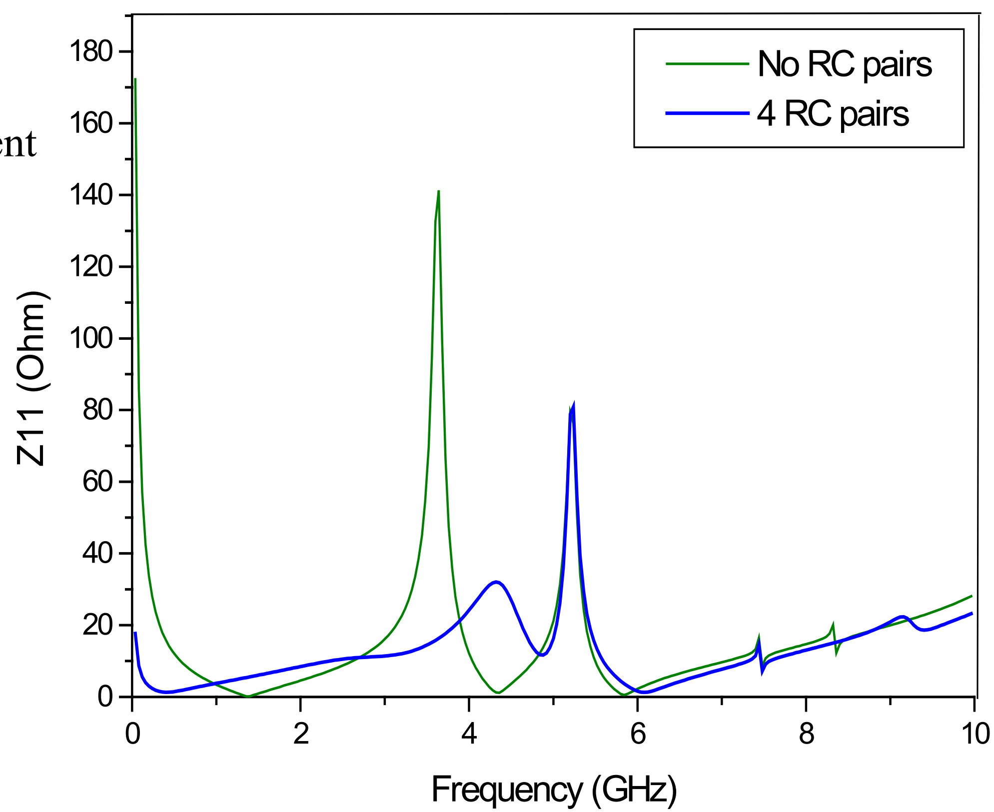


Numerical Validation and Results

- 2cm x 2cm Package with and without RC pairs



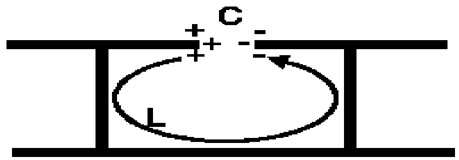
RC element: R=0.6 Ω, C=50 pF

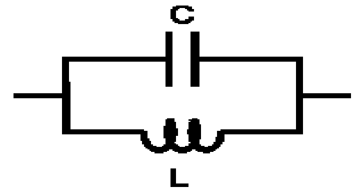


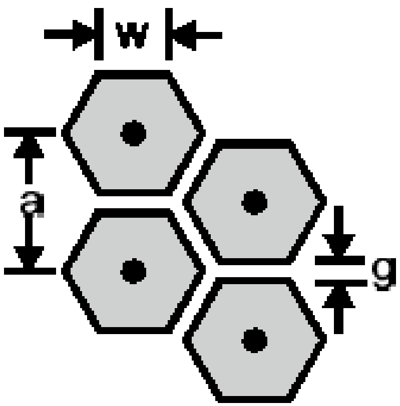
Novel Material: Do they have any thing to offer in *Noise Reduction*?

- Meta-material
- Negative Permittivity material
- High Impedance Ground Planes
- Photonic Band Gap material
- Textured Surface
- …

High Impedance Surface
As a Series of Parallel LC Resonators







$$C = \frac{W(\varepsilon_1 + \varepsilon_2)}{\pi} Cosh^{-1}\left(\frac{a}{g}\right)$$

L depends primarily on the length of the via

$$Z = \sqrt{\frac{L}{C}}$$

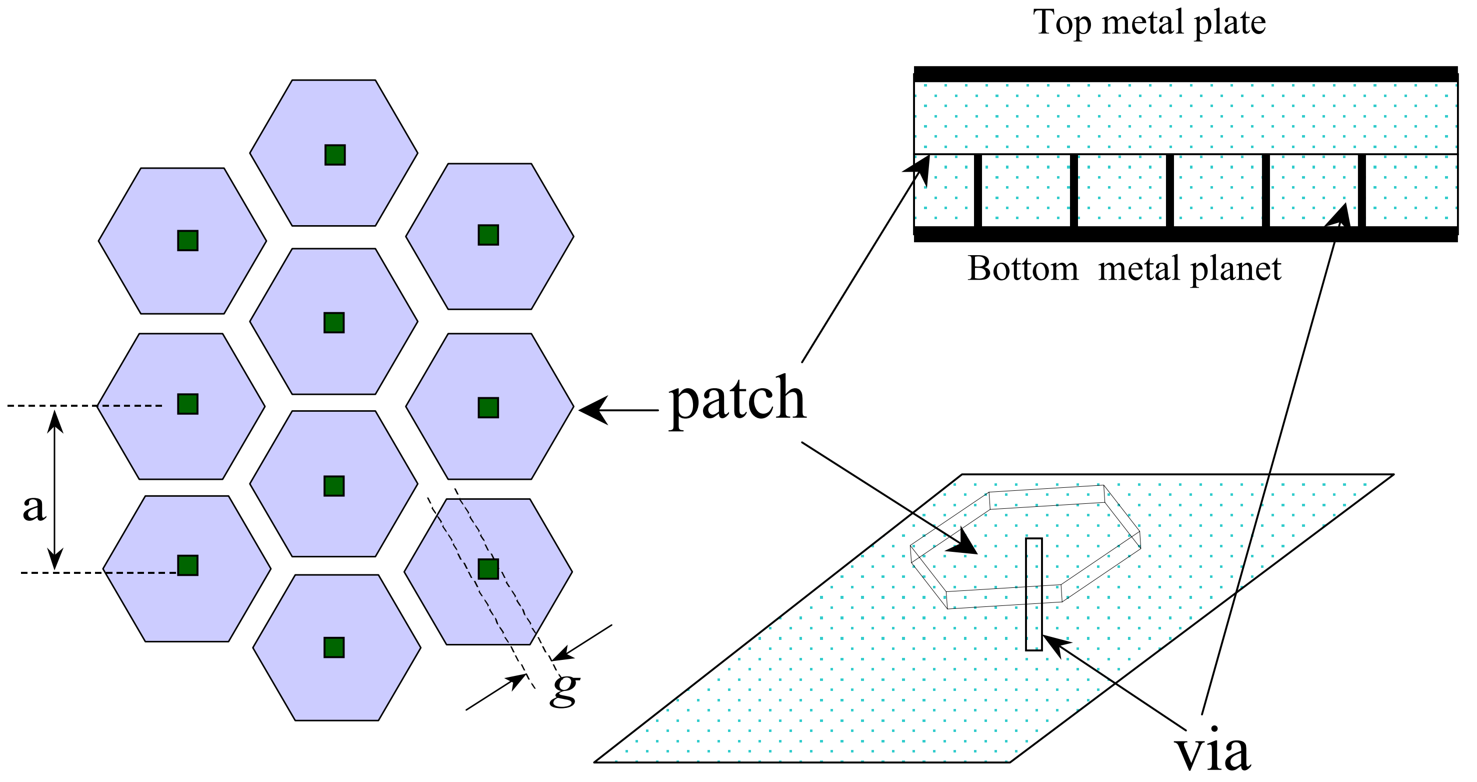
$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}}$$

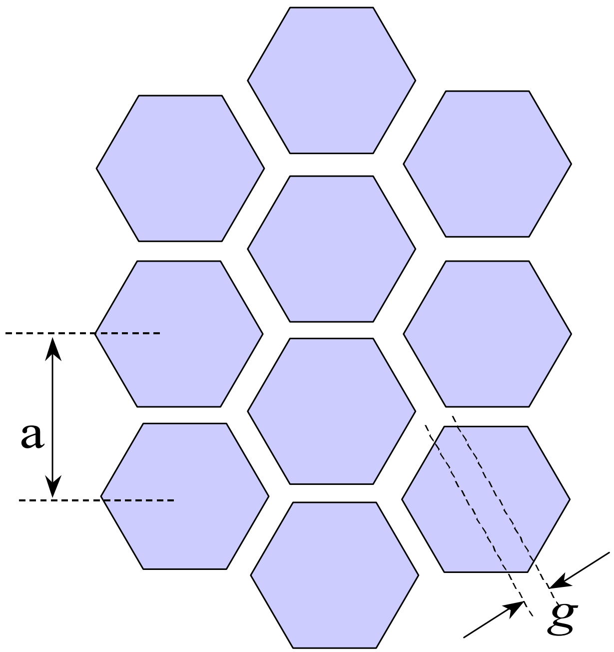
$$BW = \frac{\Delta\omega}{\omega_0} = \frac{Z}{Z_0}$$

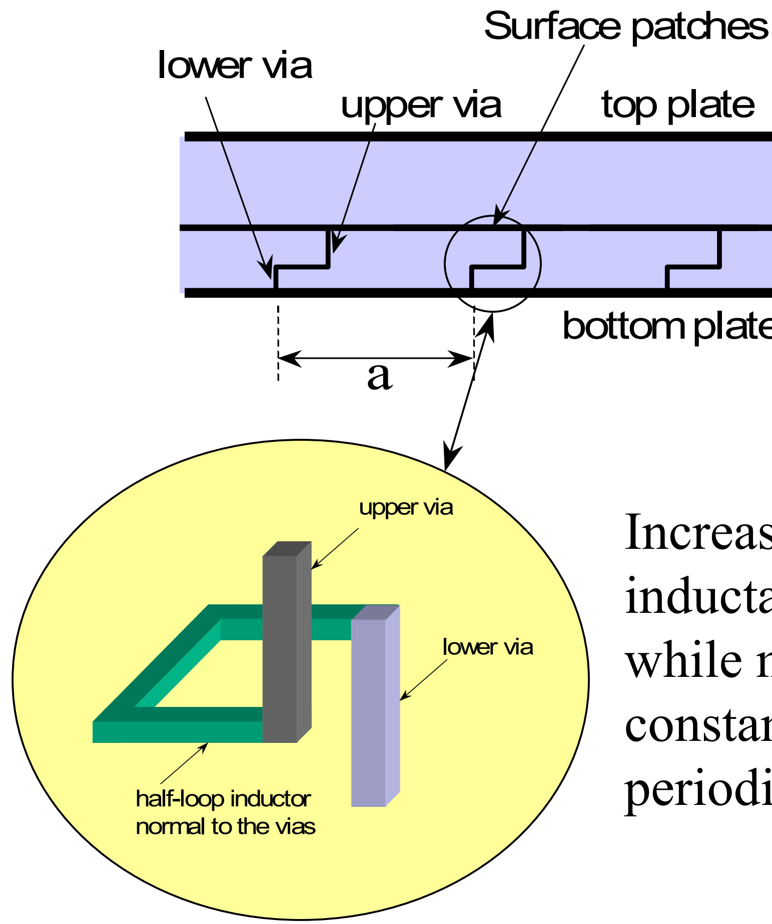
increasing either L or C can decrease the center frequency.
But increasing L will also help increase the relative bandwidth.
The constraint on the board thickness is therefore one of the fundamental limit on achievable low frequencies.

A Novel Power Plane with Integrated Simultaneous Switching Noise Mitigation Capability using High Impedance Surface



Increasing Band Gap by increasing inductance without affecting board thickness or periodicity

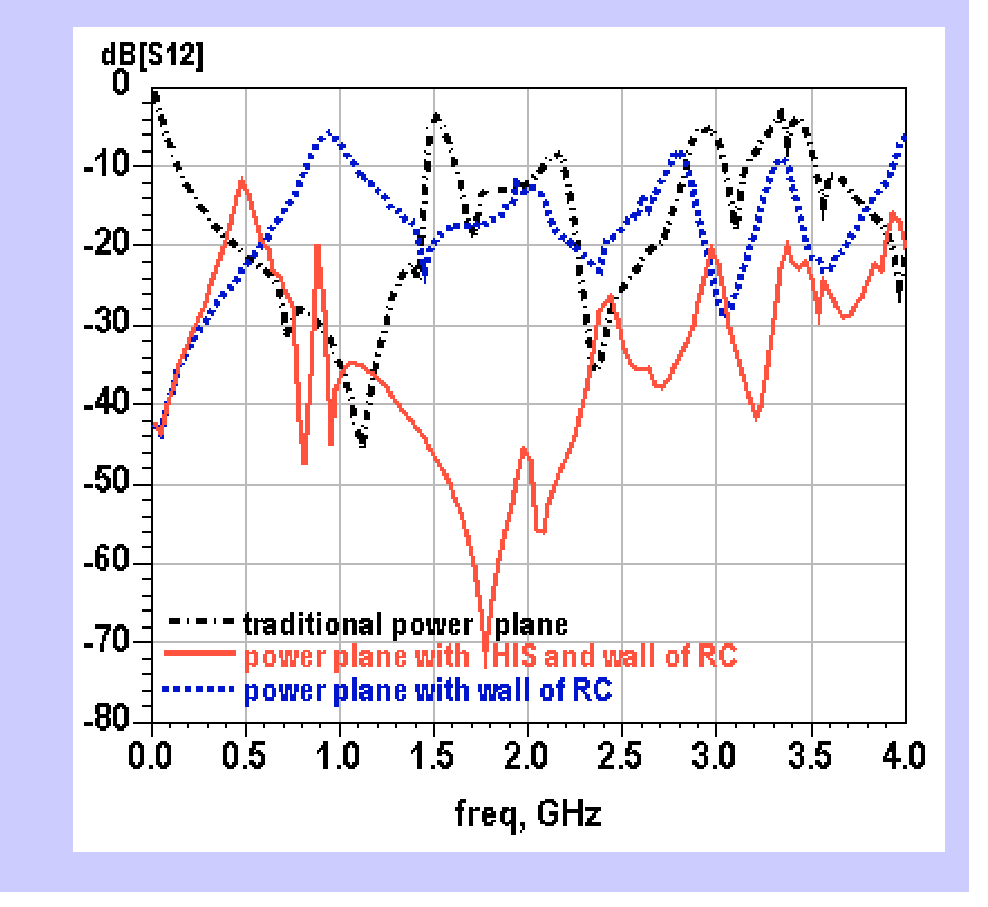




Increasing inductance while maintaining constant periodicity

Numerical Simulation Results using HFSS

Achieved a 3.2 GHz –20 dB bandwidth!



Summary

1. Developed S-parameter extraction methodology for Finite-Difference Time-Domain Simulation of resonant structures
2. Developed a technique for reducing aperture radiation by using external conductive coating
3. Developed fast numerical algorithm for switching noise simulation in printed circuit boards
4. Developed two new concepts for noise mitigation in circuit boards and from apertures using high impedance surfaces (photonic band gap material)