MURI on the Effects of High Power Microwaves and Chaos in 21st Century Analog and Digital Circuits (Administered by AFOSR)

Summary of Presentations

"Highlights and Research Plans"

presented by Victor Granatstein

Third Annual Review 10/23/04

A. Wave Chaos : SUMMARY

- Direct comparison of random coupling model with
  - -random matrix theory
  - -HFSS solutions
  - -Experiment

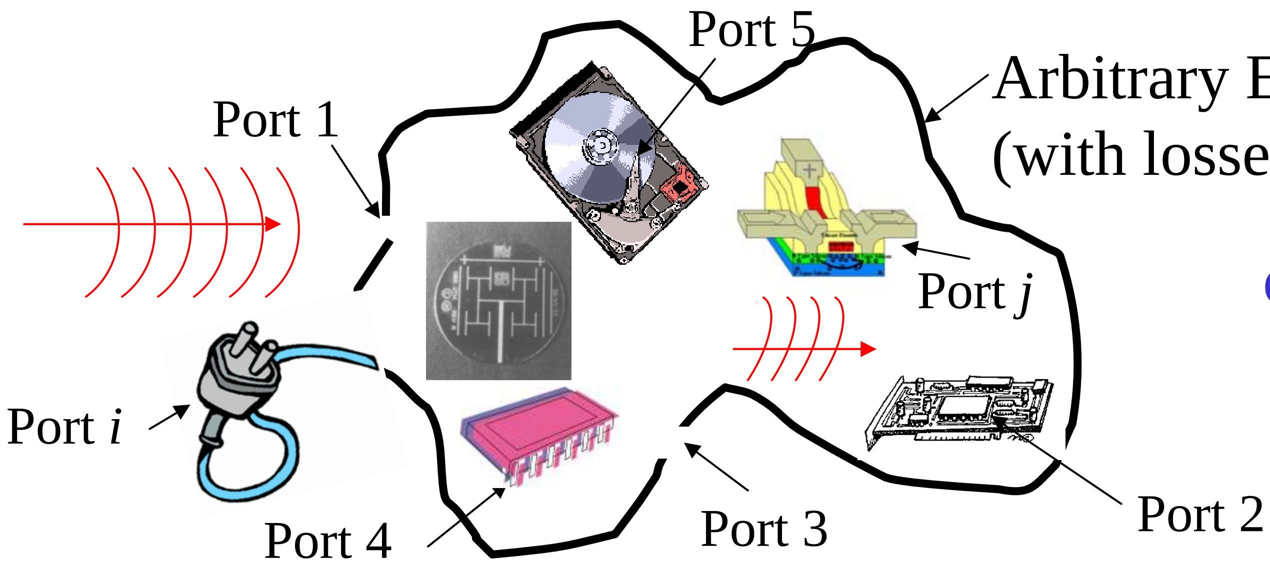
- Exploration of increasing number of coupling ports

- Study losses in HFSS
- Time Domain analysis of Pulsed Signals
  - -Pulse duration
  - -Shape (chirp?)

- Generalize to systems consisting of circuits and fields

Random Coupling Model:
Induced Field Distributions for an Arbitrary Enclosure

Anlage, Antonsen, Ott



Generalized Port Concept

What minimum information do we need to predict the range of voltages on port j because of 1 Watt injected through port i?

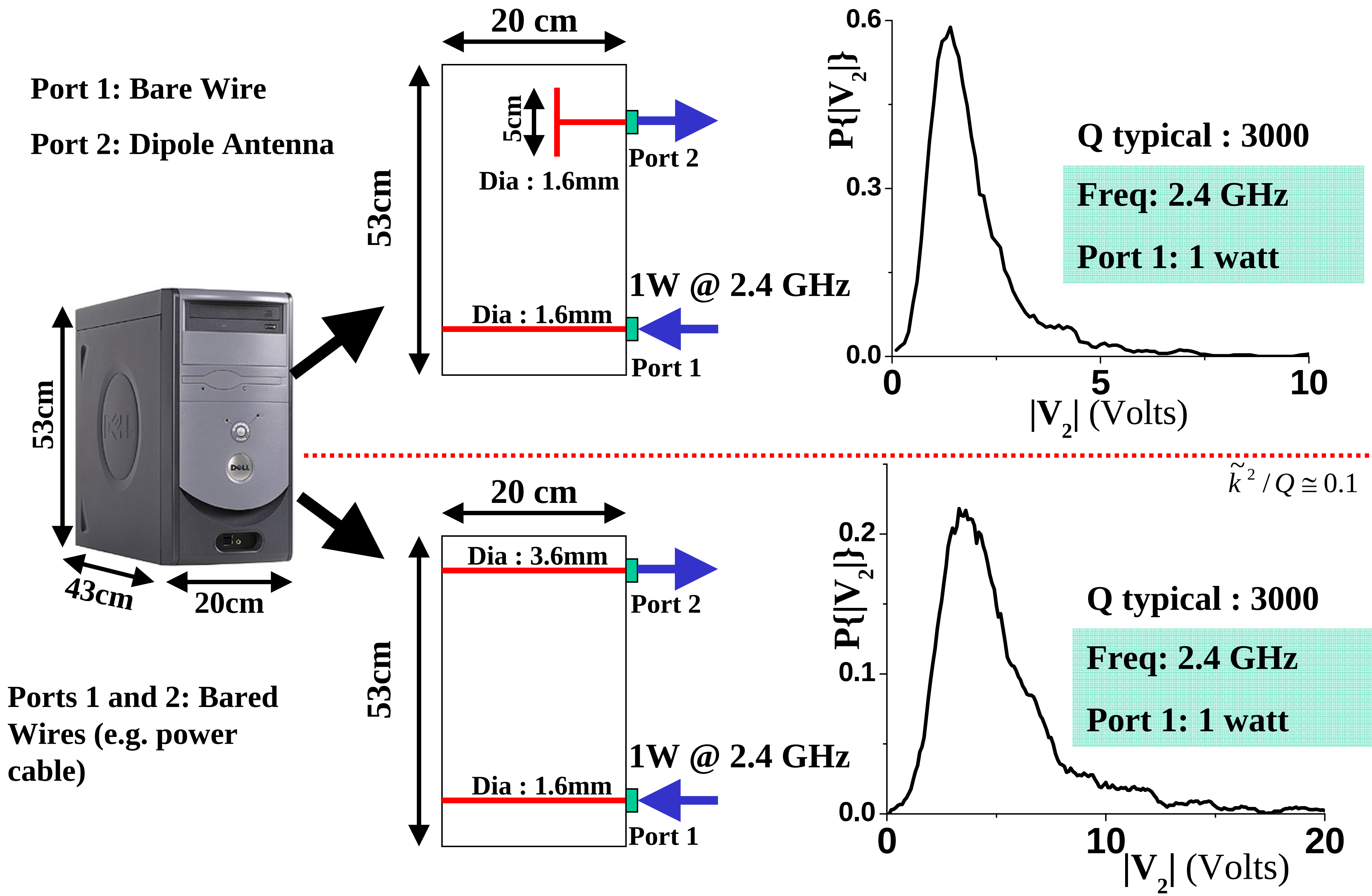
Minimum Information:

- Frequency, Volume
- Losses
- Radiation impedance of the ports

Determine the shape and scales of the Z_{Cavity} and Field PDFs

Application of the Random Coupling Model to a Real Problem

Induced Voltage PDFs in a Computer Enclosure



B. EM Noise Mitigation: SUMMARY

- Using lossy material coating to reduce aperture radiation [Completed]
- Reduction of coupling between cavities using electromagnetic band gap structures [Completed]
- Reducing noise in printed circuit boards using electromagnetic band gap structures

Previous: 1.Concept development

2. Experimental verification

3. Wideband extension

New: 1. Accurate wideband prediction

2. Wideband extension using advanced materials

3. Band gap design

4. Miniaturization

C. Microwave Effects on Devices & Circuits

C1. On-Chip RF Detectors

PROGRESS:

- FIB fabricated Schottky diodes which worked up to 15GHz
- designed and built (MOSIS AMIS 0.5 & 0.35) MOSFET diodes with bias circuit, more sensitive, faster pulse response time than diode but smaller dynamic range
- simulated the effect of adding detector circuits to logic circuits

PLANS:

- design (and implement) RF pulse detectors for system board,
- design (and implement) RF pulse detectors inside chips,
- build full wave rectifier circuits
- alter circuits with FIB
- test sensitivity of RFID tags to deprogramming with RF bursts (seeking industry funding)

C2. Modeling EM Effects on Semiconductor Devices, Gates and IC Interconnects

- Developed Semiconductor simulation tool that models breakdown inside MOS transistors
  - Shows where oxide and avalanche breakdown occurs
  - Can be used to predict the effect of EM radiation of devices not yet built.
  - In contrast to circuit simulator (SPICE), device simulator probes inside transistor to tell exactly where damage occurs.
- Developed Electromagnetic Simulator for Transmission Lines and other Passive Structures on Integrated Circuits (IC’s)
  - Shows precisely where loses occur, and the effects of intrinsic unintentional IC coupling network
  - Extracted modes of propagation in MSIM structures and how they depend on semiconductor doping and geometry:
    - (1) Skin Effect Mode, (2) Slow Wave Mode, (3) Dielectric Quasi- TEM Mode

Microwave Effects &Chaos

C3. RF Upset & Nonlinear Effects in Circuits

PROGRESS:

- Nonlinear junctions (e.g. ESD diodes) have been shown to be the principle cause of upset in circuits. Their high-frequency characteristics are now well understood.
- The extent to which rectification, parasitic resonances and RF gain increase susceptibility has been shown.
- Related scaling and RF susceptibility
- Simple, fast SPICE models (with high-frequency parameters) accurately predict RF effects in circuits.
- Work on systems response well underway.
- Basis for developing high-efficiency HPM sources that generate optimum frequency, bandwidth, modulation and pulse width.

Microwave Effects &Chaos

C3. RF Upset & Nonlinear Effects in Circuits

PLANS:

- Study high-frequency response and scaling in emerging and future device technologies (BiCMOS, LinBiCMOS, Low-Voltage Differential, deep submicron).
- Further investigate nonlinear effects from complex (esp. chirp), chaotic and ultra-wideband modulation.
- Continue development of systems models which include:
  - Voltage-frequency response statistics,
  - RF gain, coupling and cascaded response in interconnected devices
  - Effects from time delay and reflections in transmission line-coupled devices.
- For digital systems, complete study of vulnerability of clock network & characterize data network etc.