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

Introduction to Presentations by

University of Maryland, College Park (UMCP)

and Boise State University (BSU)

"Overview of Research Progress"

presented by Victor L. Granatstein

Third Annual Review 10/23/04

MAIN TOPICS

A. Using wave chaos concepts to predict statistically wave coupling into complex RF enclosures.

B. EM noise mitigation in circuit boards and cavities

C. RF effects on semiconductor devices, circuits and systems

(a)Modeling from basic equations of physics

(b) Experimental studies of chaos and nonlinear RF effects in high speed circuits and digital systems

D. Boise State Univ. studies of gate oxide stress

A. Wave Chaos : Overview

FACULTY: Steven Anlage, Thomas M. Antonsen Jr., Edward Ott
GRAD STUDENTS: James Hart, Sameer Hemmady, X. Henry Zheng

- **Model gives statistical ensemble of scattering matrices describing coupling into and out of irregular enclosures (Random Coupling Model)**
- **RCM requires only generic input parameters (e.g., cavity Q & impedance of ports)**
- **Predictions of RCM verified in microwave cavity with "chaotic" ray paths (1/4 bow tie cavity)**
- **<u>Revolutionary new way to predict statistical properties of microwave fields in irregular enclosures</u>.**

A. Wave Chaos: Interactions/Transitions

- **Ongoing interaction with NRL groups studying nonlinear circuit response and RF effects**
- **Participation in Ad-hoc DOD Working Group on Nonlinear & Chaotic Effects (UMCP hosted meeting and presented wave chaos work there)**
- **2 journal papers (Phys. Rev. E & IEEE Trans. CS)**

4 papers submitted (Phys. Rev. Lett., Electromagnetics)

1 paper in conference proceedings

Talks at DEPS, EUROEM, APS, UNM. Site visits by AFRL

T. Antonsen received Faculty Outstanding Research Award

B. EM Noise Mitigation: Overview

FACULTY: Omar Ramahi

CURRENT GRAD STUDENTS: S. Shaparia, M. Kerman

STUDENTS GRADUATED: B. Mohajer-Iravani (M.S.)
Lin Li (PH.D.), Xin Wu (Ph.D.)

- **Developed new concept for noise mitigation in circuit boards using high impedance surfaces (electromagnetic band gap material)**
- **Developed new aperture coating technique that substantially reduces aperture induced resonance**

B. EM Noise Mitigation: Interactions/Transitions

- **Invited presentations at IBM (Res.Triangle Pk., NC), Sun Microsys. (Burlington, MA), Hewlitt Packard (Marlborough, MA), Inco Corp (Toronto, Can) & E-tenna (Laurel, MD)**
- **4 papers published in refereed journals**

  11 papers in conference proceedings
- **Excellent Paper Award at EMCD '04**

C. RF Effects on Semiconductor Devices, Circuits and Systems: Overview

FACULTY: Victor Granatstein, Neil Goldsman, Agis Iliadis, Bruce Jacob, John Melngailis, John Rodgers

GRAD STUDENTS: Vincent Chan, Cagdas Dirik, Todd Firestone, Woochul Jeon, Kyechong Kim, Laise Parker, Bo Yang

- **Simulated EM effects in devices, gates and interconnects; provides input parameters for SPICE based on physics eqs. instead of measurements on existing devices.**
- **Identified major mechanism for RF upset of ICs ; viz., ESD devices demodulate RF and induced voltages cause bias shift, bit errors, latch, oscillations, noise, etc.; spurious resonances can amplify induced voltages**
- **Improved on-chip microwave sensors; e.g. Schottky diode compatible with CMOS operating at 15 GHz**

C. Microwave Effects on Devices & Circuits Interactions/Transitions

- **Interaction with Lab of Physical Sciences (NSA) to develop 3-dimensional models of ICs**
- **Working with ARL to simulate details of wide bandgap semiconductor device operation**
- **Provided Titan-Jaycor with num. & exper. data on RF characteristics of wide range of device families; used to benchmark code for predicting RF effects in DOD systems**
- **Inst. of Defense Analysis funded study of data recovery using RF probing of smart card chips**
- **2 papers published and 2 papers submitted to refereed journals, 8 papers in conference proceedings**
- **Patent pending "Sense and Protect Circuit", #MR2833-15**

Research at Boise State University

FACULTY: R. Jacob Baker, William B. Knowlton,
(6 grad students incl. 1 MS completed)

- **Collaboration with J. Melngailis on CMOS compatible Schottky diode**
- **Demonstrated significant degradation in MOSFET and inverter circuit operation resulting from gate oxide pulsed stress**
- **Cooperation with Micron Technology, Cypress Semiconductor and International SEMATECH (Austin, TX)**
- **6 papers in conference proceedings**

Presentations

PART A. WAVE CHAOS

2. Wave Chaos Theory: "Statistical Properties of Wave Chaotic Scattering & Impedance Matrices"
----- Presenter: Tom Antonsen

3. Wave Chaos Experiments: "Universal Field, Impedance and S-Matrix Statistics of Metallic Enclosures"
----- Presenter: Steve Anlage

PART B. RF INTERFERENCE MITIGATION

4. "EM Noise Mitigation in Circuit Boards and Cavities" ----- Presenter: Omar Ramahi

Presentations

PART C. RF EFFECTS on DEVICES & CKTS.

5. "On-Chip Schottky Diodes and MOSFET RF-Detectors and Focused Ion Beam Post-Processing"
   ------ Presenter John Melngailis

6. "Experimental Investigation of Microwave Vulnerabilities in CMOS Inverters"
   ------- Presenter:Agis Iliadis

7. "Modeling EM Effects on Semiconductor Devices, Gates & IC Interconnects"
   ----- Presenter: Neil Goldsman

Presentations

8. " Studies of RF Upset and Nonlinear Effects in Circuits" ------ Presenter: John Rodgers

9. "RF Interference and Circuit Integrity in Digital Systems' ---- Presenter: Bruce Jacob

D. RESEARCH at BOISE STATE UNIVERSITY

10. "Degradation in Gate Oxides: Experimental Studies of Stress in Devices and Circuits" ----- Presenter: Bill Knowlton