**What is Electromagnetics?**

- *Electromagnetics* is the study of the effect of charges at rest and charges in motion.

- *Electromagnetics* is described within the context of the theoretical framework of Maxwell’s equations and special cases thereof including circuit theory (Kirchhoff's Laws, Geometric Optics, Physical Optics, etc.)
James Clerk Maxwell (1831-1879)
Maxwell’s Equations and Continuity Equation
In Integral Form

\[ \oint_C \mathbf{E} \cdot d\ell = -\int_S \mathbf{M}_i \cdot d\mathbf{s} - \frac{\partial}{\partial t} \int_S \mathbf{B} \cdot d\mathbf{s} \]

\[ \oint_C \mathbf{H} \cdot d\ell = \int_S \mathbf{J}_i \cdot d\mathbf{s} + \int_S \mathbf{J}_c \cdot d\mathbf{s} + \frac{\partial}{\partial t} \int_S \mathbf{D} \cdot d\mathbf{s} \]

\[ \int_S \mathbf{D} \cdot d\mathbf{s} = \mathbf{Q}_e \]

\[ \int_S \mathbf{B} \cdot d\mathbf{s} = \mathbf{Q}_m \]

Continuity Equation

\[ \int_S \mathbf{J}_{ic} \cdot d\mathbf{s} = -\frac{\partial}{\partial t} \iiint_V q_{ev} dv = -\frac{\partial \mathbf{Q}_e}{\partial t} \]
Why Study Electromagnetics?

- Analyze, model and design:
  1. Antenna systems
  2. RF/Microwave circuits
  3. Fiber optics systems
  4. Electronic packaging; EMI/EMC
Use of Linear Monopole Wireless Mobile Devices
Typical Stub/Monopole on a Cell Phone

Stubby Antenna
No need to handle
Monopole/Stubby Antenna with Meander

The stub is either a helix, usually metallic, or meander, usually flex type.

Typical IFA on a Cell Phone
Bow-Tie Antenna and Feed Network

Increased the dipole length to 20.69 mm
Three-Dimensional Gain Patterns
Surface Current Density
Reflection Coefficient ($S_{11}$) Vs. Frequency

![Graph showing the reflection coefficient ($S_{11}$) vs. frequency. The graph includes a table with points m6 and m7.]

<table>
<thead>
<tr>
<th>Name</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>m6</td>
<td>7.3500</td>
<td>-38.8010</td>
</tr>
<tr>
<td>m7</td>
<td>7.2500</td>
<td>-22.1114</td>
</tr>
</tbody>
</table>
COLLIMATED ANTENNA SYSTEM

Schematic system diagram

Component implementation

54GHz

FSS filter

89 GHz
Three truncated elliptic reflectors

- each contains 99.97% energy of dominating mode.
- Reflection loss 0.005 dB.

Two channels of 54GHz and 89GHz share a common compact range system.

Gaussian beam source

- corrugated horns
- The -8.68dB Beam-width \( \leq 20^0 \)

Total loss in each channel \( \leq 1 \text{ dB} \)

Cross-channel coupling \( \leq -20 \text{ dB} \)
COLLIMATED ANTENNA SYSTEM: FREQUENCY SELECTIVE SURFACE (FSS)

Components
DUAL REFLECTOR ANTENNAS

- F = 30 GHz
- Reflector diameter = 40λ and 100λ
- The source is a Huygens source with radiated electrical field

\[ E_y = N \frac{e^{jkr}}{r} e^{kb \cos \theta} (1 + \cos \theta) \]

If the taper is specified to A dB (A < 0) at the angle \( \theta_0 \), b can be obtained as

\[ b = \frac{20 \log \left( \frac{1 + \cos \theta}{2} \right) - A}{20k(1 - \cos \theta) \log (e)} \]

A = -6dB
SIMULATION RESULTS

Our simulation results

Results from a reference paper
Boeing 757
Discretized Model

Boeing 757
Nose Incidence

\[ f = 100 \text{ MHz (Horizontal Polarization)} \]
INVERSE SYNTHETIC APERTURE RADAR (ISAR)

Hybrid (planar/cylindrical/spherical)
near-field antenna scan system

$s(t) \otimes f(t, \phi)$ : echoes from target

$b(t)$: echoes from support structure

$s_c(t)$: coupling signal
Reflectivity image of object is given as

\[ \sigma(\rho, \phi) = \frac{2\pi}{c} \int_0^\frac{2\pi}{c} \nu \left( \sqrt{\rho_a^2 + \rho^2 - 2\rho\rho_a \cos(\phi - \phi')} \right) d\phi' \]

Measurements at each degree in azimuth, and each has 1024 samples within the 10 nsec time window.
To Be Successful In EM Related Courses:

Requires a solid foundation on the fundamentals of:

- Mathematics
- Physics
- Circuits

EEs are engineers, not technicians.
Prerequisite Courses

- EEE 241: Fundamentals of Electromagnetics
- EEE 202: Circuits I
- Physics 131: University Physics II: Electricity & Magnetism
- Physics 132: University Physics Lab II
EEE 241: Fundamentals of Electromagnetics *fall and spring*
Static and time varying vector fields; boundary value problems; dielectric and magnetic materials; Maxwell's equations; boundary conditions. Prerequisites: EEE 202; PHY 131, 132.
Senior EM Courses

- General course representative of all EM areas:
  EEE 341: Engineering Electromagnetics

- Specialized courses in EM areas (need EEE 241 and 341)
  1. Antennas: EEE 443: Antennas for Wireless Communications
  3. Optics & Lasers: EEE 448: Fiber Optics
Senior EM Courses

- EEE 443: Antennas for Wireless Com’s
  (fundamental parameters, dipoles, loops, arrays, smart antennas, microstrips, measurements)
- EEE 445: Microwaves
  (devices, sources, impedance matching, measurements)
- EEE 448: Fiber Optics
  (principles of fiber optics communications)
GRADUATE COURSES

EEE 540 – Fast Computational Electromagnetics
EEE 541 – Electromagnetic Fields and Guided Waves
EEE 543 – Antenna Analysis and Design
EEE 544 – High Resolution Radar
EEE 545 – Microwave Circuit Design
EEE 546 – Advanced Fiber Optics
EEE 547 – Microwave Solid-State Circuit Design I
EEE 548 – Coherent Optics
EEE 549 – Lasers
EEE 641 – Advanced Electromagnetic Field Theory
EEE 643 – Advanced Topics in Electromagnetic Radiation
EEE 647 – Microwave Solid State Circuit Design II
**Graduate School**

- **MS:**
  1. Somewhat specialized
  2. Applications oriented
  3. Often the most marketable degree for pursuing a career industry or government

- **PhD:**
  1. Very specialized – one ends up knowing quite a bit about one area/topic.
  2. Research and development (R & D)
  3. Usually required for university position
CAREER OPPORTUNITIES

• Academia (need PhD)

  Teaching, research (grant proposals, papers, reviewing papers of others, supervising graduate students, etc.), consulting (so you can pay the bills).

• Industry, Government (BS, MS, PhD)

  Applications of EM in antennas, RF and microwave communications, radar or remote sensing systems, fiber optics communications systems, and electronic packaging.
Job Opportunities

• Industry

Boeing, General Dynamics, Northrop-Grumman, L-3 Com, Lockheed-Martin, Motorola, Intel, Rockwell International, Raytheon, Honeywell, Texas Instruments, IBM, Qualcomm, Broadcom, United Technologies, Bell Helicopters, Andrew Corporation, etc.

• Government/Government National Laboratories

Electromagnetic Anechoic Chamber (EMAC) – antenna and radar cross section measurements.
Wireless Communications Circuits Lab:
mixed signal measurements for Antenna/RF/Microwave systems.
Facilities

Laboratory for Wave-Material Interactions
EM Faculty

- James T. Aberle (PhD: Univ. of Mass.)
- Constantine A. Balanis (PhD: Ohio State)
- Rudy Diaz (PhD: UCLA)
- Joseph C. Palais (PhD: Univ. of Mich.)
- George Pan (PhD: Univ. of Kansas)
James T. Aberle
Associate Professor of EE

- Research interests include antennas, computational electro magnetics, metamaterials, RF and microwave circuit design, software-defined radio.
- PhD from UMass (Amherst)
- Dave Pozar was PhD advisor
- ASU Professor since 1989
- Extensive experience with industry – working for start-up, consulting – as well as basic research on government-funded grants and industry consortia.
- More info: [http://faculty.engineering.asu.edu/~aberle](http://faculty.engineering.asu.edu/~aberle)
Research interests include smart antennas, computational electromagnetics, high intensity radiated fields

PhD from Ohio State University (1969)
Prof. Leon Peters, Jr. was PhD advisor
ASU Professor since 1983
Experience with industry and government
1. Worked for government
2. Consulted for government and industry
3. Performed basic research on government-funded grants, and industry contracts and consortia.

More info:
http://balanis.faculty.asu.edu
FULLWAVE MODELING + EXPERIMENTAL VALIDATION APPROACH TO UNDERSTANDING THE INTERACTION OF EM WAVES WITH ENGINEERED MATERIAL STRUCTURES

<table>
<thead>
<tr>
<th>Frequency [GHz]</th>
<th>TM Surface wave propagation [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>-20</td>
</tr>
<tr>
<td>3</td>
<td>-15</td>
</tr>
<tr>
<td>4</td>
<td>-10</td>
</tr>
<tr>
<td>5</td>
<td>-5</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

Characterization of Materials at RF

Design of Photonic Antennas for sub 30nm resolution

Artificial Magnetic Conductors for ultrathin antennas

Magnitude of Electric Field above Si Substrate
Joseph C. Palais
Professor of Electrical Engineering

- Fiber Optic Communications
- Fiber Optic Sensors
Research interests include computational electromagnetics, electronic packaging and signal integrity, 60 GHz antenna systems.

- PhD from University of Kansas, 1984
- PhD advisors: Adrian K. Fung
- ASU faculty member since 1995
- Conducted research contacts/projects for US government and industry

http://engineering.asu.edu/people/75035