

Hands-on Electromagnetics:
Microstrip Circuit and Antenna
Design Laboratories at USU

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Microstrip Circuit and Antenna Design Laboratories at USU

- Objectives
- Courses
- Labs
 - Equipment
 - Lab Projects
- Student Design-based Projects
- Future Work

Objectives

- Complete redesign of electromagnetics curriculum at Utah State University
 - Project-based design experiences
 - Industrially relevant applications
 - Use of state-of-the art equipment and software in hands-on labs
 - Integration of research into the courses.

Utah State University
Electrical and Computer Engineering

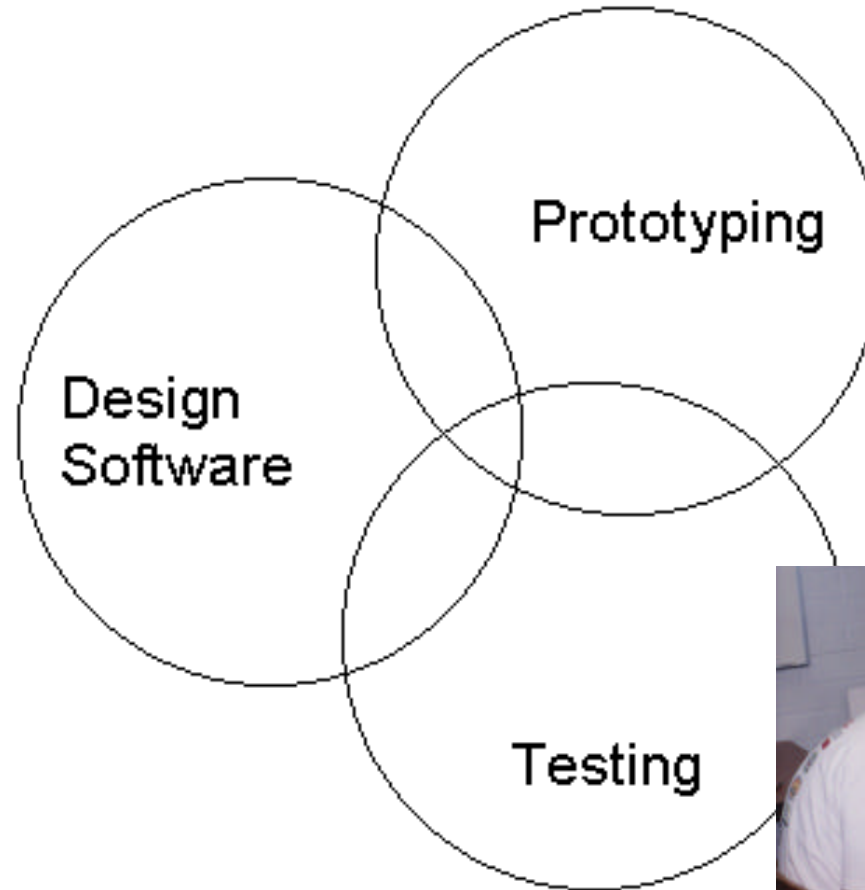
- 250 Undergraduate Students
- 75-100 Graduate Students (mostly M.S.)
- 17 Full time Faculty
- Electrical Engineers (EE) required to take 1 semester (4 credits) of E&M
- Computer Engineers (CEs) have a 2 credit EM option (first half of EE course covering transmission lines, standing waves, etc.)

USU ECE

Electromagnetics Courses

- ECE 3170 Introduction to Electromagnetics
60 students Fall Semester
- ECE 5130 Computational Electromagnetics
20 students Spring Semester
- ECE 6130 Microwave Engineering
22 students Spring Semester
- ECE 6170 Antenna Design
23 students Fall Semester

Facilities



Design Software

- HP/ EEsof Series IV (“Libra”) / ADS
 - Microwave Circuit Design
 - “Momentum” method of moments simulation
 - Microwave Circuit Layout
- XFDTD Finite-Difference Time-Domain
 - General purpose EM design& analysis

Prototyping

- HP/ EEsof Series IV (“Libra”) / upgrading to ADS
 - Microwave Circuit Layout >> HPGL or Gerber File
- Circuit Cam Software
 - HPGL or Gerber file to CAM to LMD file
- LPKF Circuit Board Mill

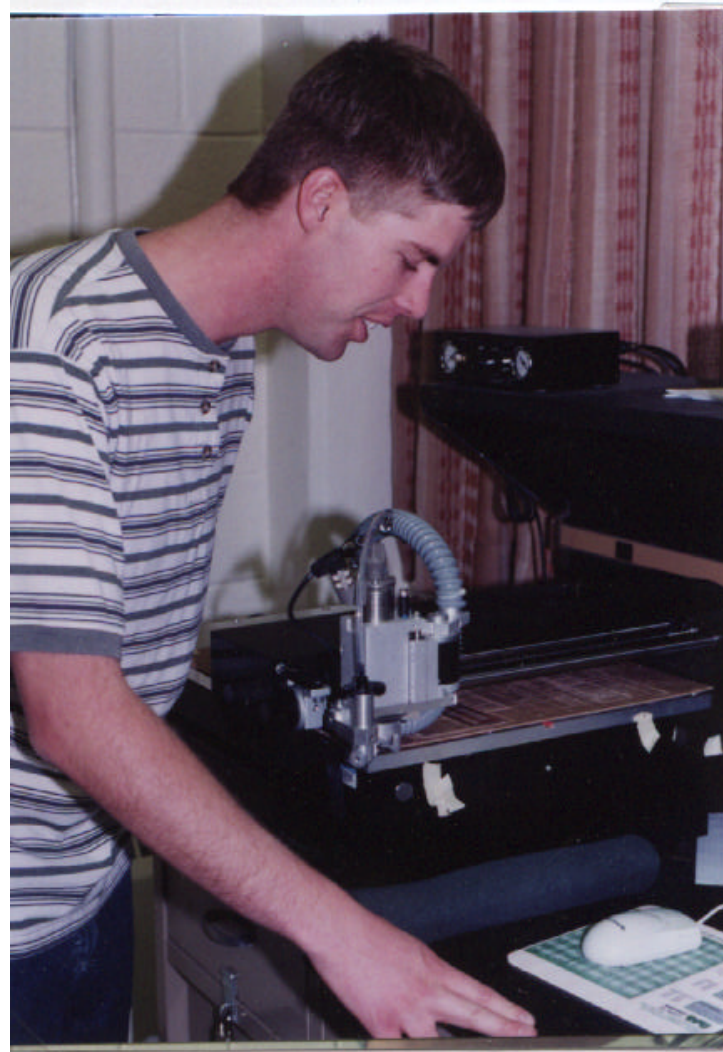
Prototyping Circuit Board Materials

- RT / Duroid
 - [www](#).
 - Requires milling all non-metallic circuit parts
- Gil Laminates
 - [www](#).
 - Circuit outline is milled
 - Remaining non-metal parts are peeled off
(saves expensive milling bits)

Prototyping

- Professor
 - Provides tutorials and initial demonstration of prototyping facilities
- Students
 - Design and simulate circuits (HP/EEsof Libra)
 - Convert HPGL file to LMD file (Circuit Cam)
- TA or Student Lab Technician
 - Mills circuits (approx. 1 hour for a class of 20)

LPKF Circuit Board Milling



Testing

- Microwave / Antenna Lab
(most-used equipment)
 - HP 8510C Network Analyzer
 - HP 8593E Spectrum Analyzer
 - HP-ESG-3000 Signal Generator
- Anechoic Chamber

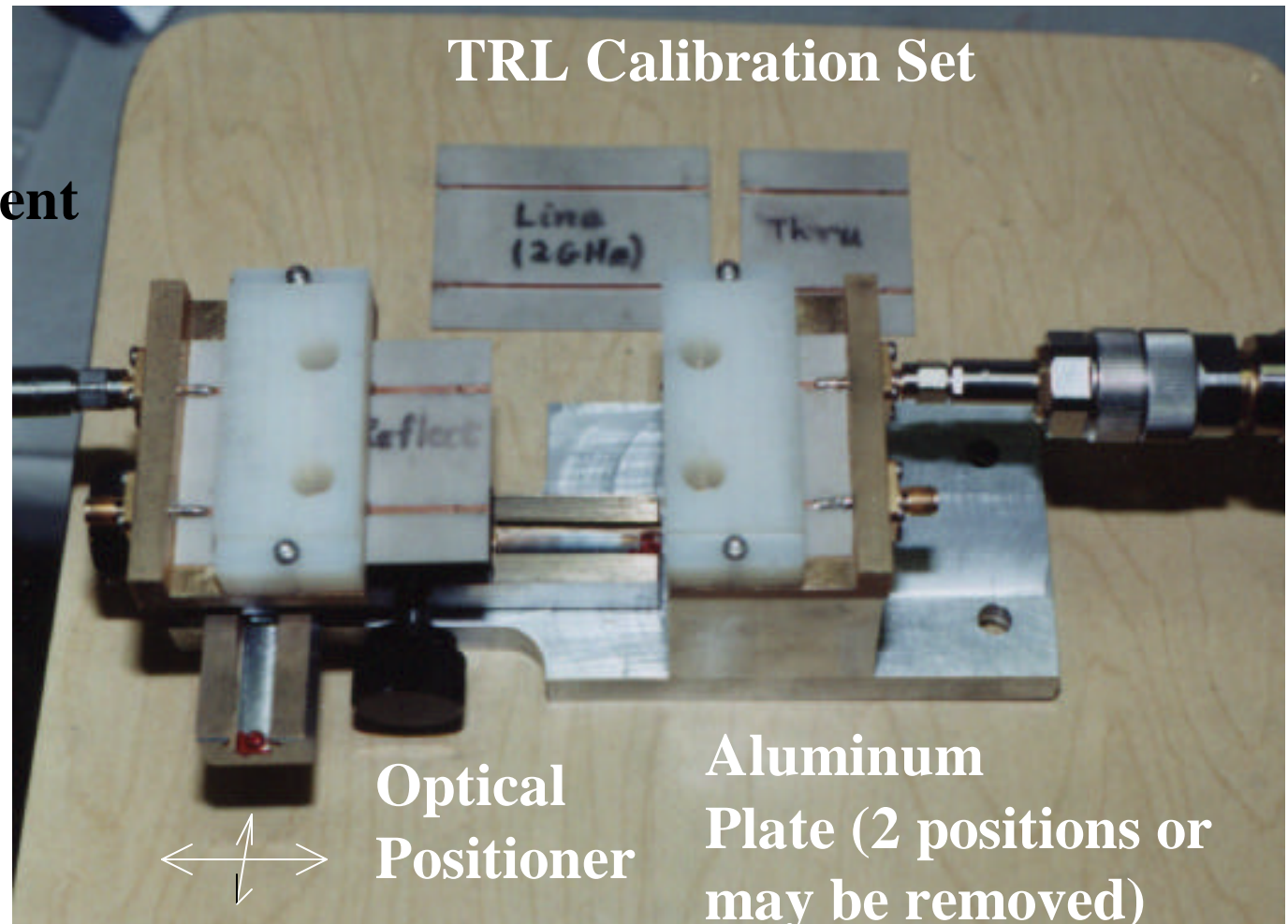
Limited Facilities

(1-2 EM Lab Benches)

- Sequential Labs
 - students sign up for a weekly 2-hour slot
 - TA available 20 hours / week (10 slots, 20 students)
 - After students learn to use the equipment, labs are “open” for them to use independently

Circuit Board Holder

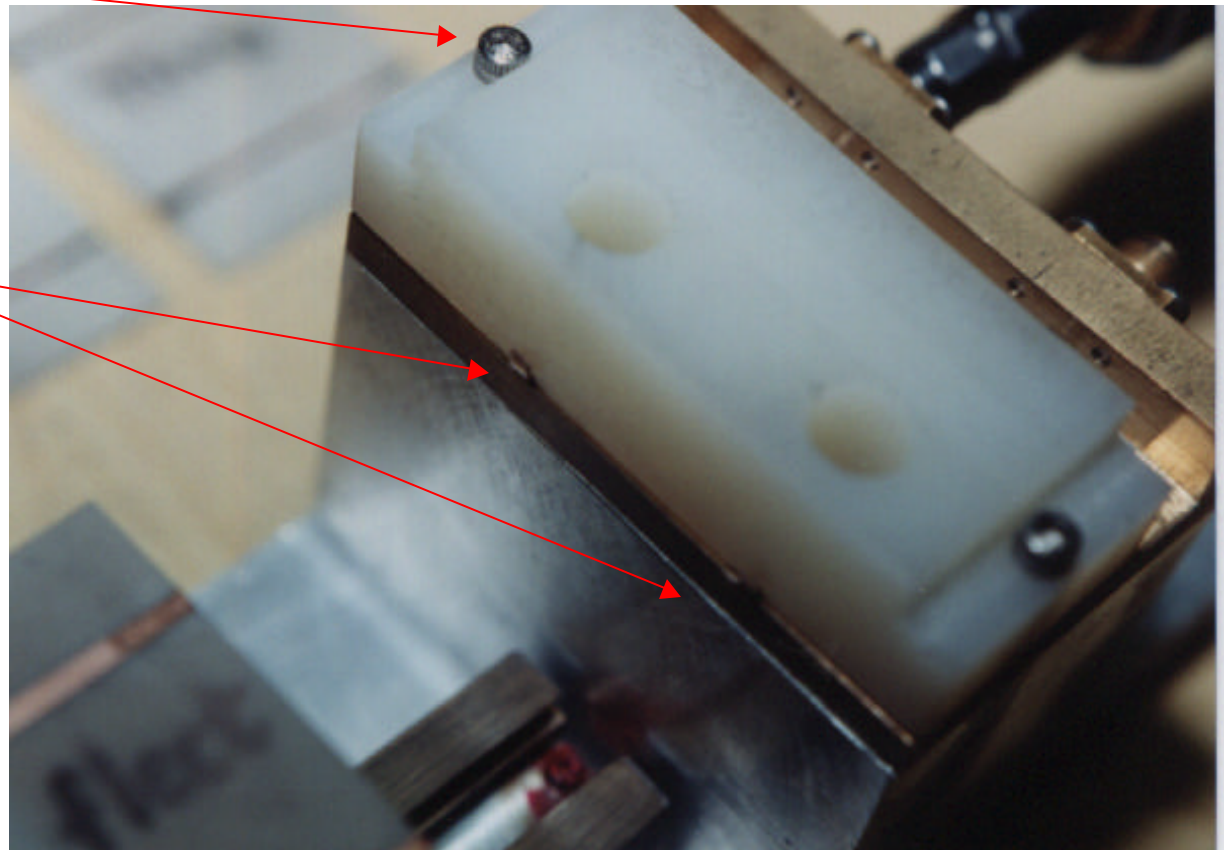
Double Traces
enable measurement
of :
Couplers
BP Filters
Other “odd”
shaped circuits



Circuit Board Holder

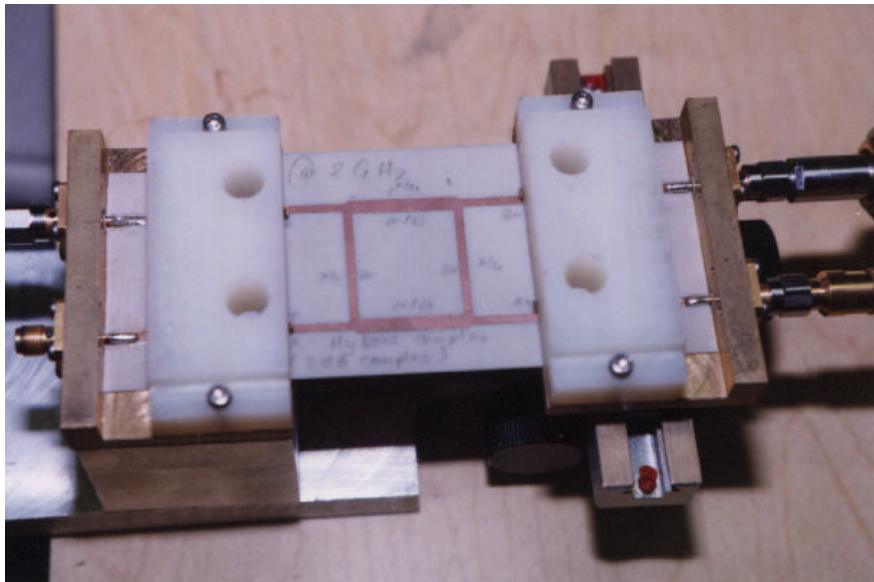
**Screws adjust
pressure**

**“Skis” provide
snap-fit
connection**



Testing

- Microwave Circuit Board Holder
 - Replaces “connectors” that must be soldered to microwave circuits

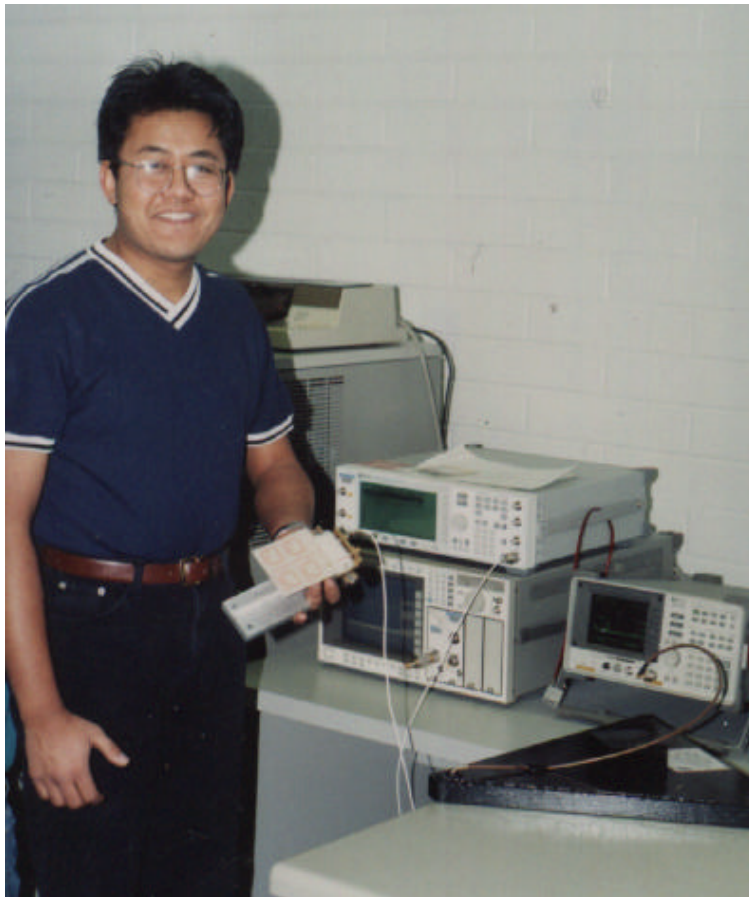


Testing HP 8510C Network Analyzer

**Adjusting a
stub matching
network for
microstrip antenna**



Testing



Agilent ESG3000A Signal Generator
Agilent Spectrum Analyzer
Log Periodic Antenna
Agilent Oscilloscope

Circuit Board Holder

S-parameters

- 45 MHz - 3 GHz
 - S21 from 0 to -0.75 dB
 - S11, S22 less than -18 dB
- 6 GHz
 - S21 = -10 dB
 - S11, S22 = -3 dB

Project

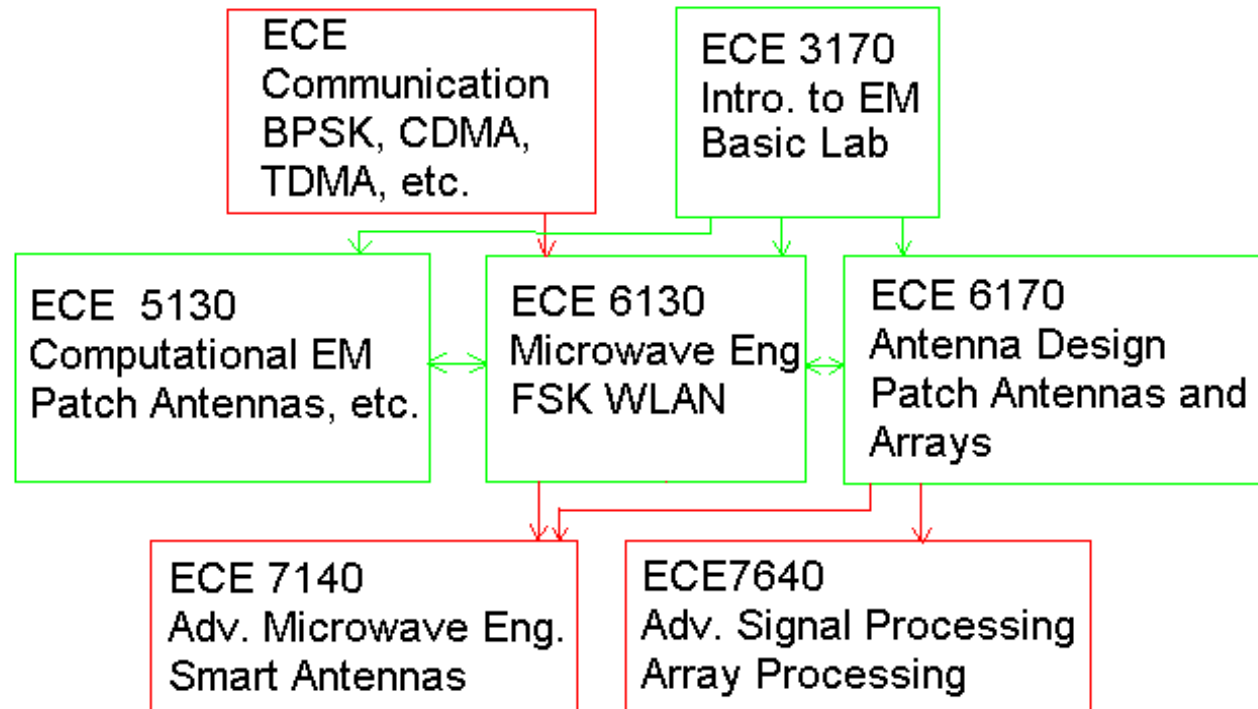
Acknowledgements

- Inspiration
 - University of Southern Florida Larry Dunleavy
<http://www.eng.usf.edu/EE/people/dunleavy.html> (see Teaching)
- WLAN
 - Brigham Young University
Michael Jensen, David Arnold
- Circuit Board Holder Prelim. Design
 - University of Utah Mark Baird

Lab Facility Development Acknowledgements

- Hewlett-Packard Corporation
- Remcom, Inc.
- GIL Laminates
- Panashield, Inc.

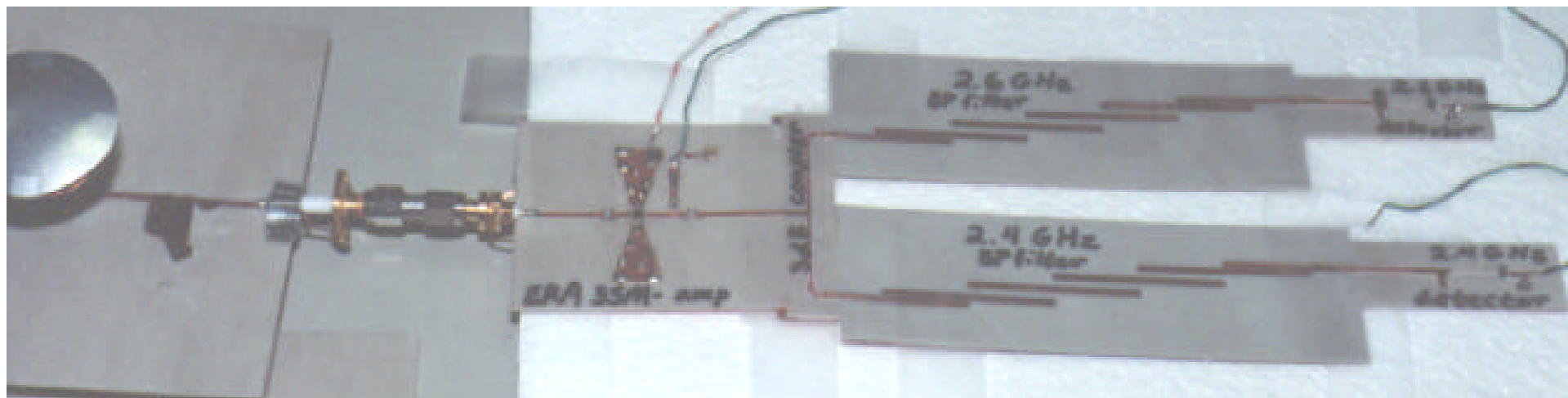
Project Cluster



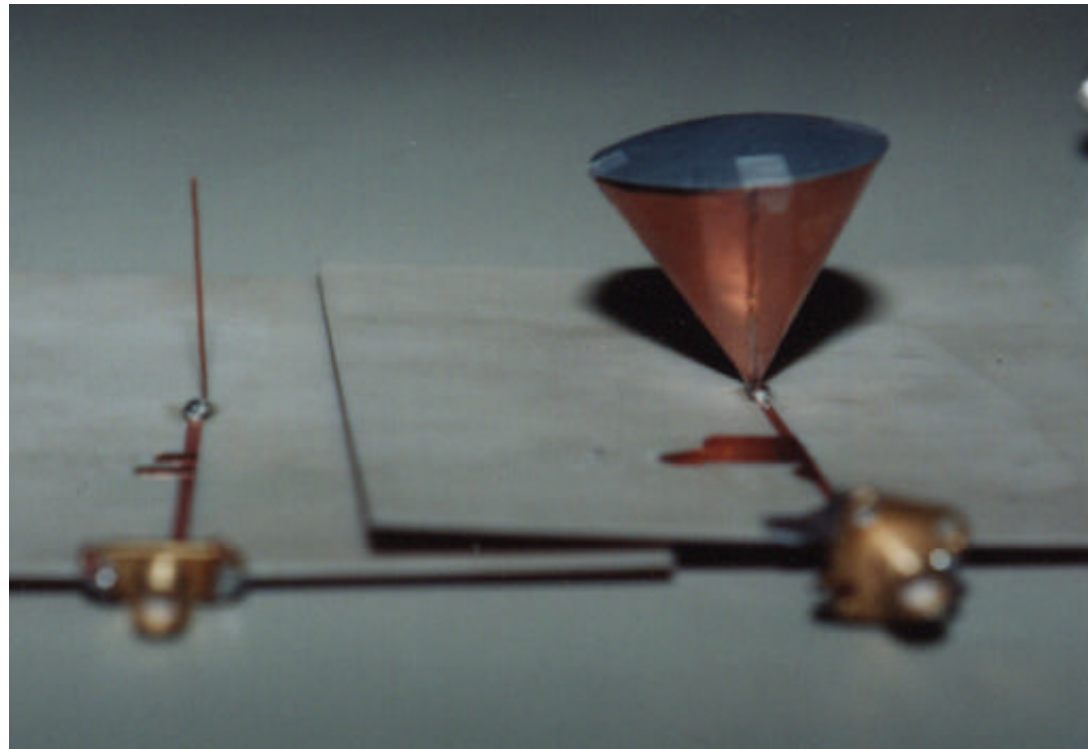
ECE 3170 -- Basic Labs

- Standing Waves (Slotted Line)
- Time Domain Reflectometry
- Single Stub Matching (HP/EEsof Libra Software)
- Antenna Measurements
 - Impedance, Matching (using their single stub system), Polarization, Rad. Pattern

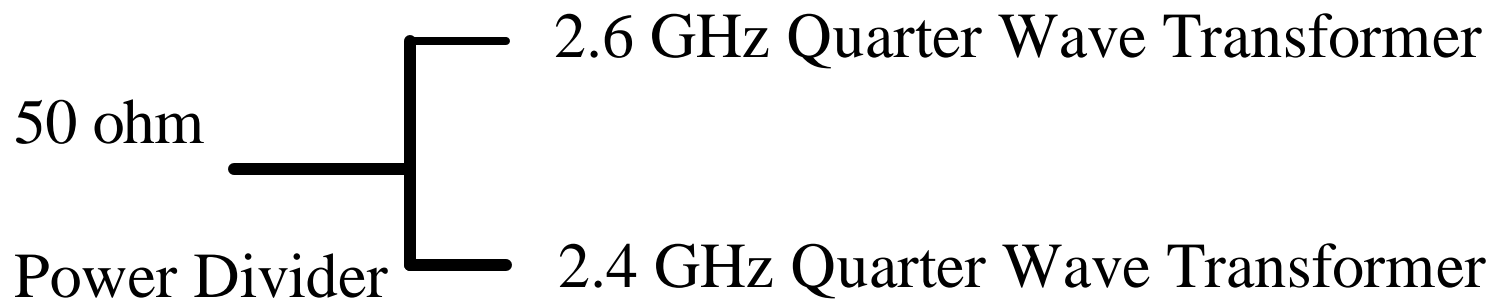
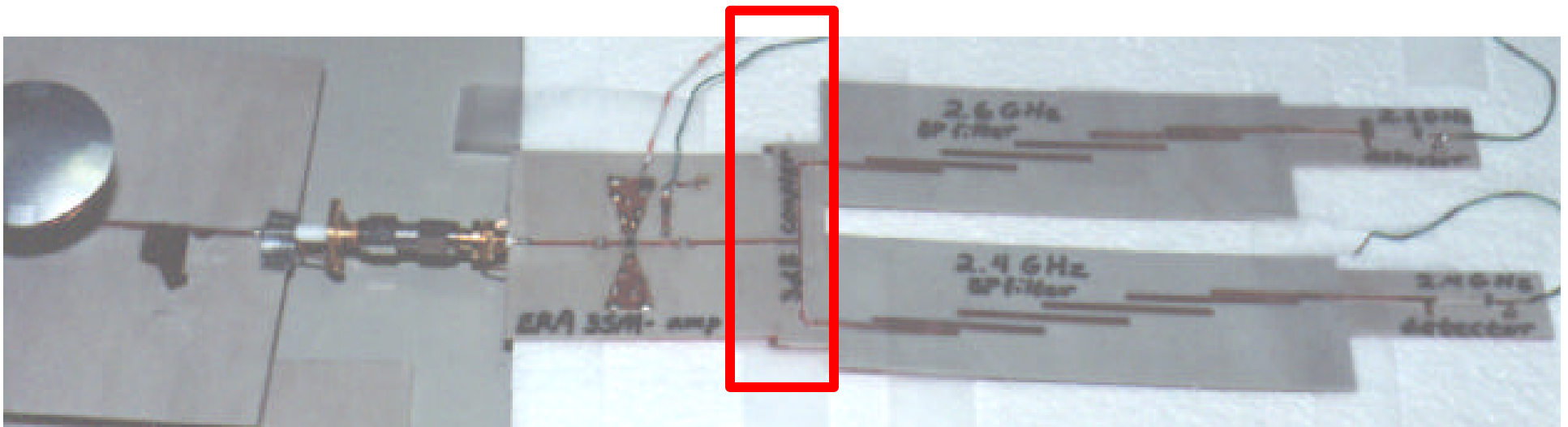
ECE 6130 -- Microwave Engineering WLAN Project



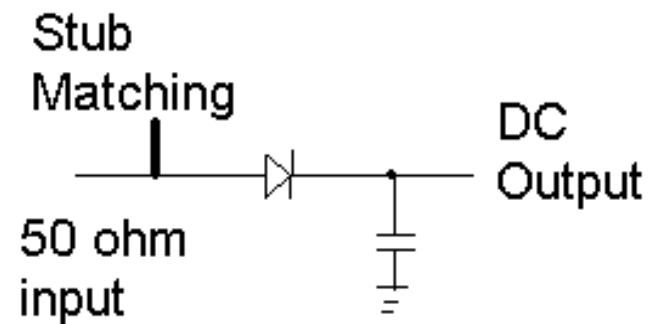
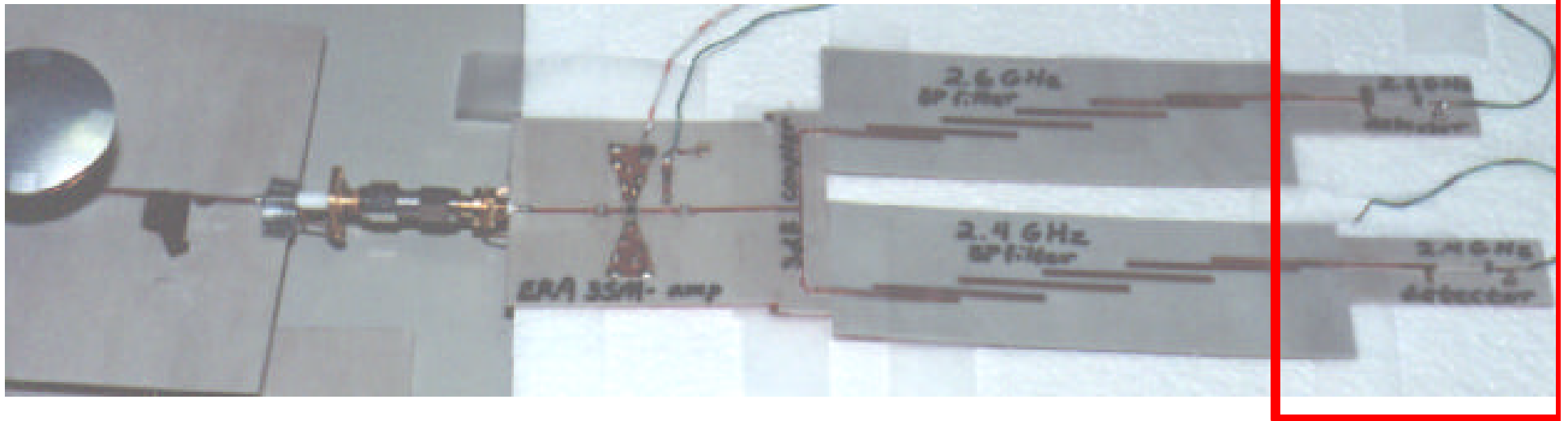
Lab 1 -- Antenna Matching Single and Double Stub



Lab 2 -- Power Divider and Quarter Wave Transformers

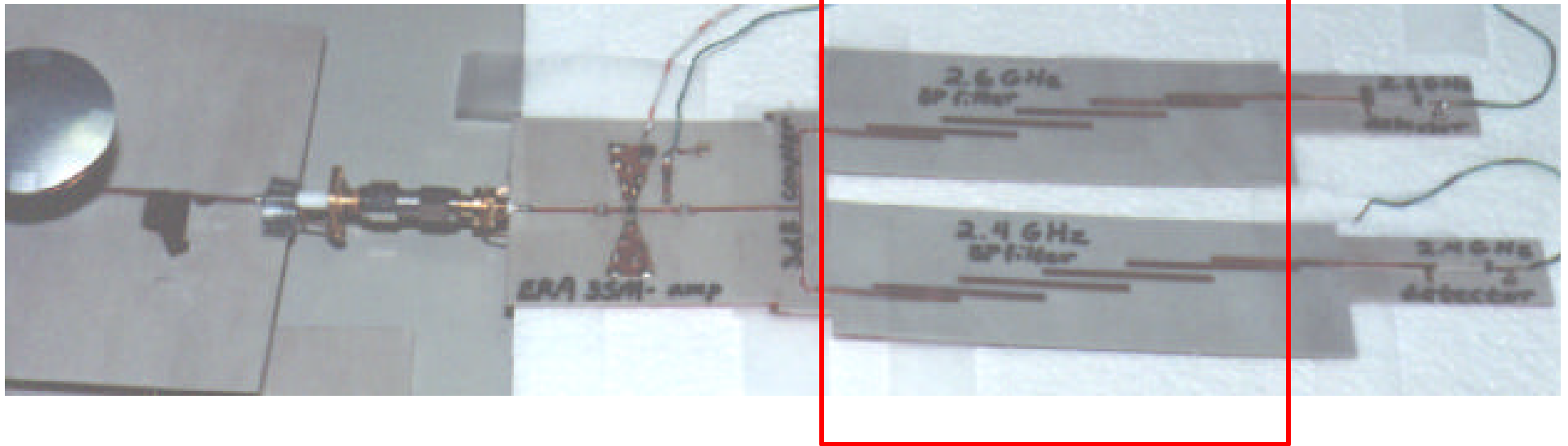


Lab 3 -- Diode Detectors



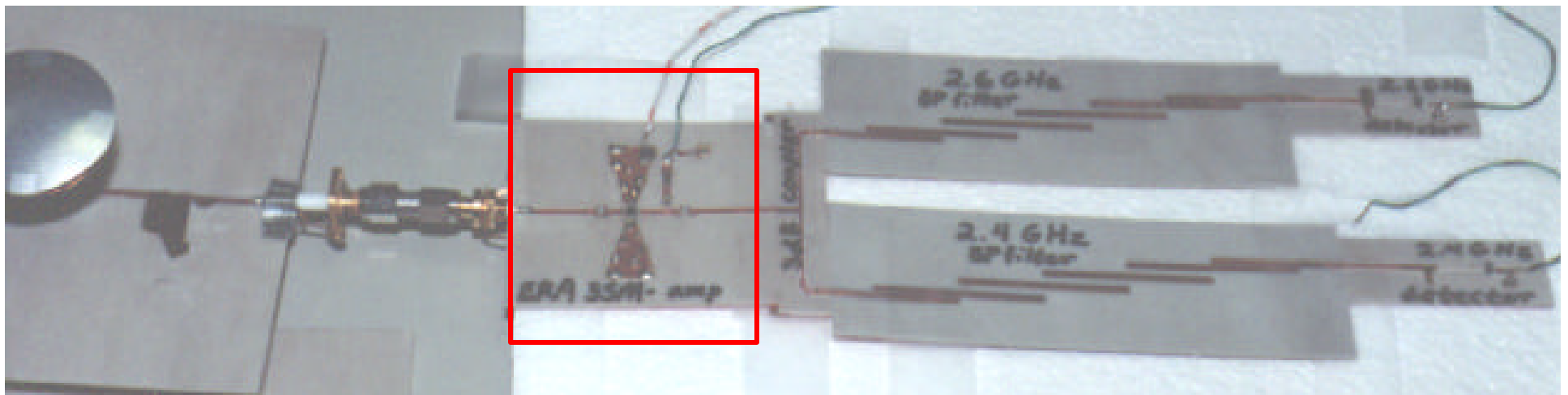
Lab 4 -- Coupled Line Filters

Pass 2.6 GHz, Reject 2.4 GHz



Pass 2.4 GHz, Reject 2.6 GHz

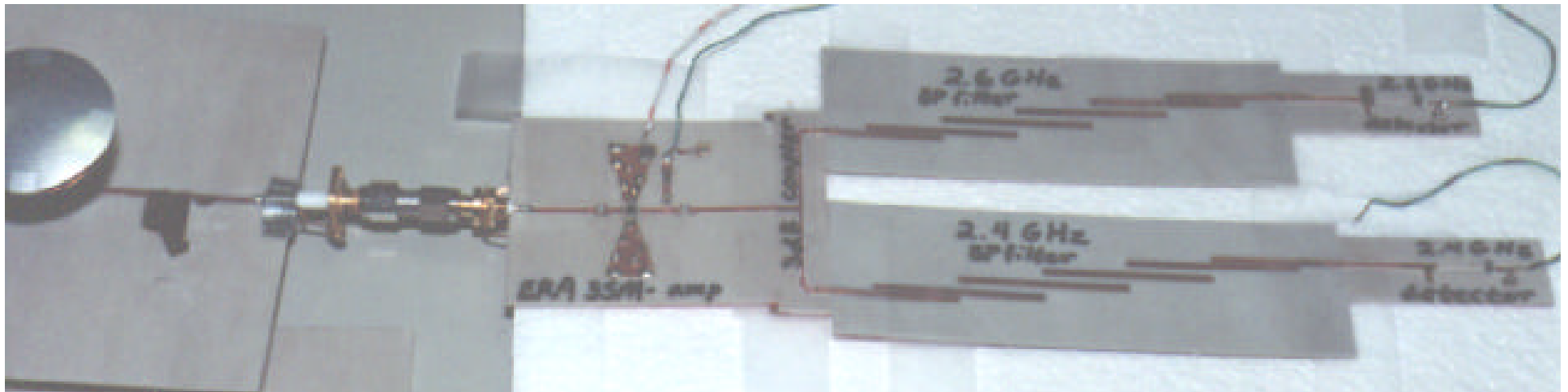
Lab 5 -- Amplifiers



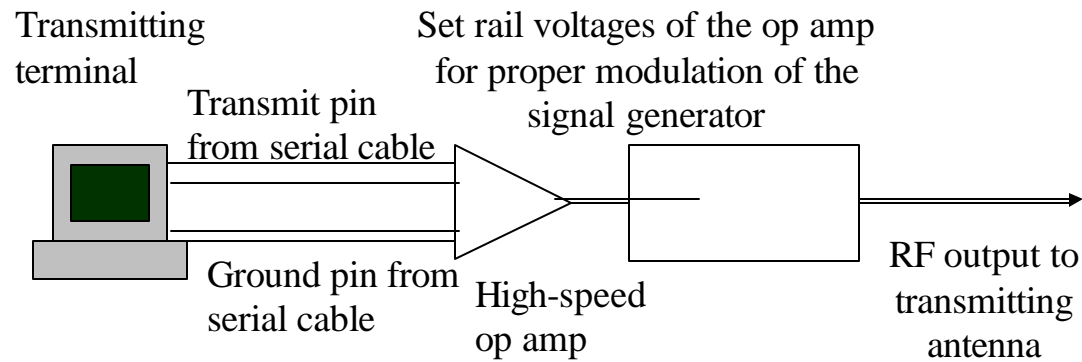
Minicircuits Amplifier ERA-35M
Students provide Bias,
Decoupling Caps
Grounding

Lab 6 -- System Testing

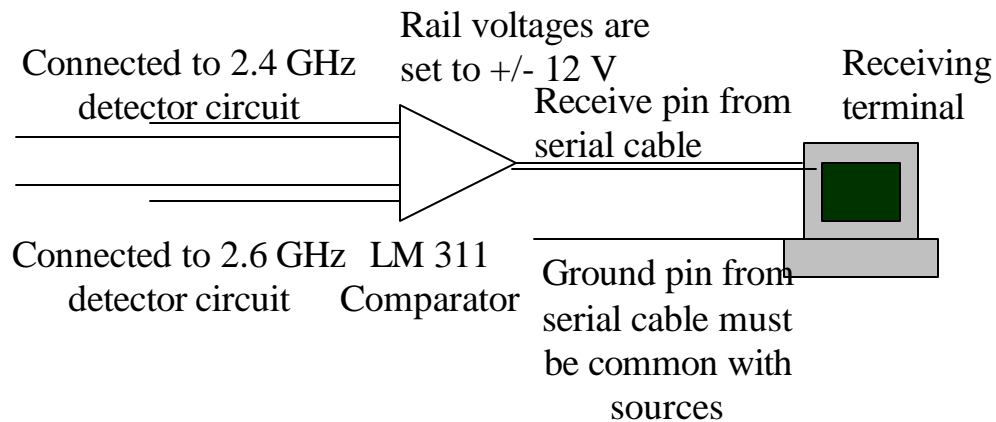
- **Elements Connected with Copper Tape**
- **Test diode detector and work towards antennas**
- **Student antennas are also connected with copper tape. (This shows the demo antennas, which have connectors for easy interchange.)**



Lab 7 -- Computer Interface Transmitter



Lab 7 -- Computer Interface Receiver



ECE 5130 -- Computational EM

- Numerical Integration / Differentiation
- Matrix Solution (Gauss Elim. & SOR)
- Finite Difference Frequency Domain (FD)
 - microstrips, striplines, capacitance
- Finite Difference Time Domain (FDTD)
 - quarter-wave transformer, time and frequency domains

ECE 5130 -- Computational EM

- Method of Moments (MoM)
 - Wires (straight and curved). Expand to antennas.
- Finite Element Method (FEM)
 - Waveguides and ducts

ECE 5130 -- Final Projects

- **FD**

- Electrotherapy for Pain Control
- Multilayer microstrips

- **FDTD**

- PEMF Bone Healing
- Radar for Snow Pack
- Microstrip Antennas
- Geophysical Wells
- Lightning Coupling to Radio Tower
- Microwave Heating
- Optical Matching Layers
- Plasma Modeling

- **FEM / MoM**

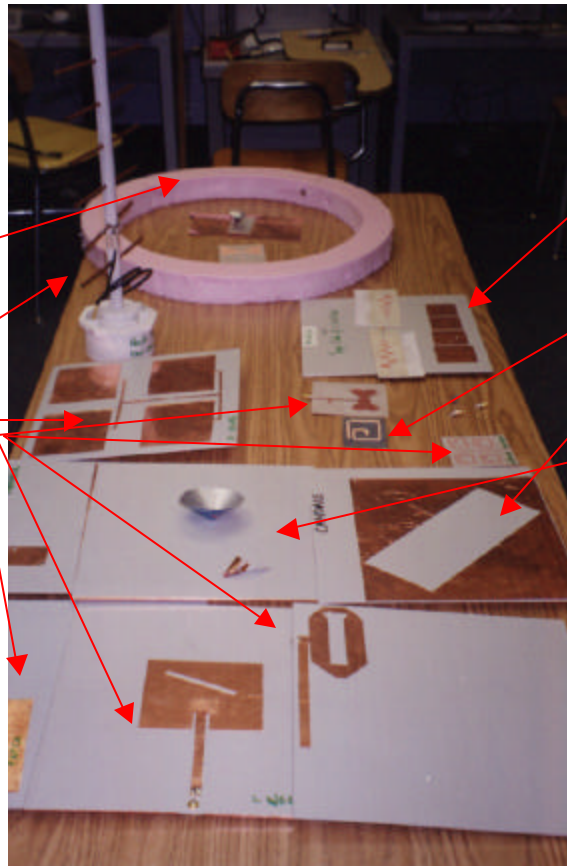
- Comparison for Duct Potentials
- Grid Generator

ECE 6170 -- Antennas

- Labs
 - Impedance Measurement and Matching
 - Radiation Pattern and Polarization
 - Dipole Design and Measurement
 - Array Design and Measurement

ECE 6170 -- Antenna Projects

Imaging Array
Hand-Held Yagi
Satellite Antennas

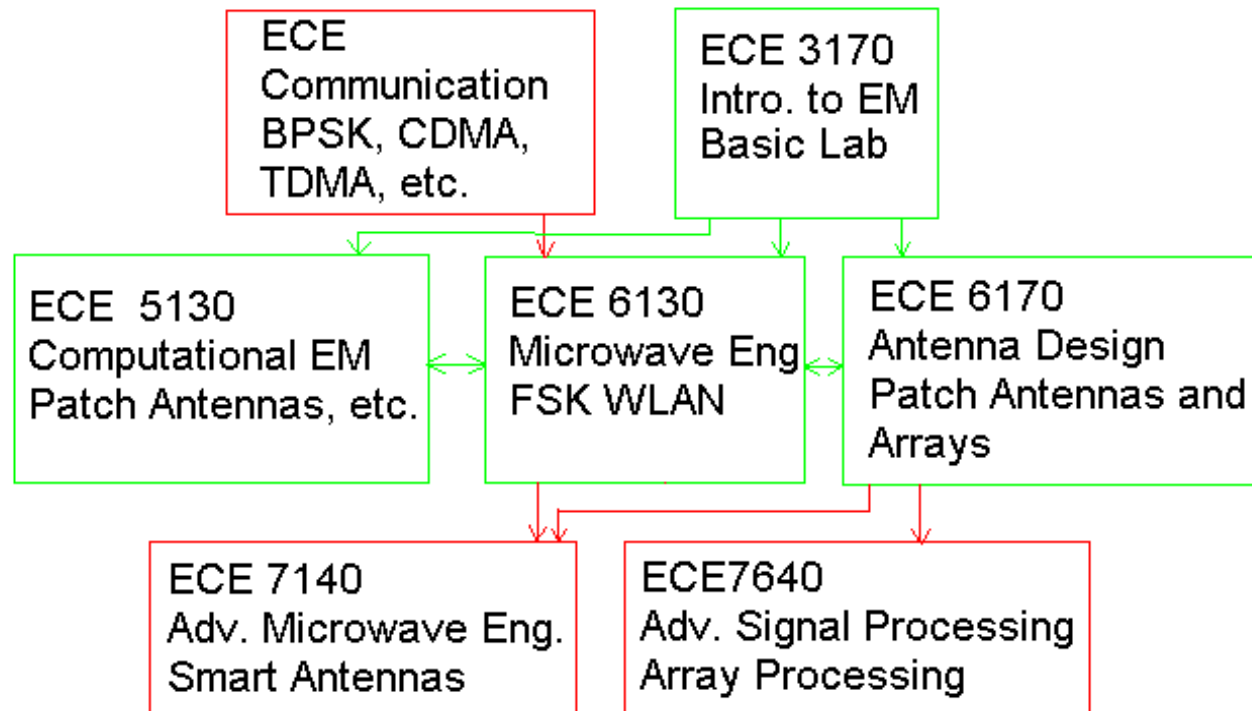


Radar Antennas
(Distance Measurement)
Medical Implant Ant.
Dielectric Measurement
WLAN Antennas

Do Labs Help You Understand the Material?

- “Yes! Yes! Yes!”
- “Absolutely. I loved the project.”
- “I’ll never forget it - especially the dumb mistakes we made!”
- “The labs are great.”
- “Add more labs.”
- “They took a lot of time, but it was worth it.”

Conclusion -- Making Progress, but More Fun Yet to Come ...



On Line Access

- <http://www.engineering.usu.edu/ece/faculty/furse/index.html>
- Courses (continually being updated)
- Tutorials
 - HP/EEsof, XFDTD, Measurement Equip., misc.
- Engineering is Fun!
 - Precollege and Cool Stuff Links