EERF 6396
Microwave Design & Measurements

Randall E. Lehmann, PhD
Professor of Instruction
Electrical & Computer Engineering
University of Texas at Dallas

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Recommended Texts:

1. *Microwave Engineering, 3rd Ed.*, by David Pozar, John Wiley & Sons.
2. *Microwave and Wireless Measurement Techniques*, Carvalho & Schreurs, Cambridge University Press

Lecture: Section 001: Mon/Wed 1:00 – 2:15 pm

Lab: Section 301: Mon 10:00 – 12:45 pm (ECSN 2.804)

Instructor: Dr. Randall E. Lehmann
randall.lehmann@utdallas.edu (include "EERF6396" in subject of all emails)
Office: ECSN 4.616
Office Hours: Tue/Thu, 2:30 – 3:30 or by appointment

TA: TBD

Overview

- Course Description:
  - Lectures will cover fundamentals of microwave design and measurements
  - Microwave components will be designed and simulated with various CAD tools
  - Components will be built and measured to compare performance with theory
  - The lab will involve learning the basics of accurate microwave measurements, including:
    - calibration
    - vector impedance (scattering parameters)
    - scalar measurements
    - spectrum analysis

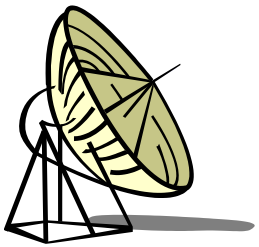
Course Learning Objectives

Objectives

- Ability to apply fundamental RF principles to design of resonant structures
- Ability to design, build and test microwave filters
- Ability to design, build and test microwave directional couplers and power dividers
- Ability to design and implement impedance matching networks for a microwave amplifier

Course Outline

1. Transmission lines and planar circuits
2. Passive components
3. Power dividers
4. Couplers
5. Filters
6. Microwave switches
7. Amplifiers
8. MMICs



Grading

Quiz	5%
Lab projects	45%
Exam #1	15%
Exam #2	15%
Exam #3	15%
Final Project	5%

Late lab reports are subject to 10-point deduction per day.
No extra credit will be given.

General grading standard:

92.50 – 100	A
89.50 – 92.49	A-
86.50 – 89.49	B+
81.50 – 86.49	B
78.50 – 81.49	B-
75.50 – 78.49	C+
67.50 – 74.49	C
<67.50	F

Lab Items

- Monday Lab section will begin meeting Sept 18th (10am).
- Two students per bench
  - Everyone will do all designs and submit design files
  - Lab reports are to be written individually, using measured data from lab.
- Read Safety Manual on class website prior to first lab meeting.
- All lab work must be completed during the assigned lab time.
- Bring USB flash drive to save S-parameter data from VNA measurements.
- Lab reports are due 1 week from the start of your lab time.

Policies

- Homework/Lab Reports/Design Projects are due on eLearning by the specific time and date assigned.
  - Late submissions will be subject to an additional 10-point deduction per day.
  - Unexcused absence from lab will result in a ‘zero’ lab score for that week.

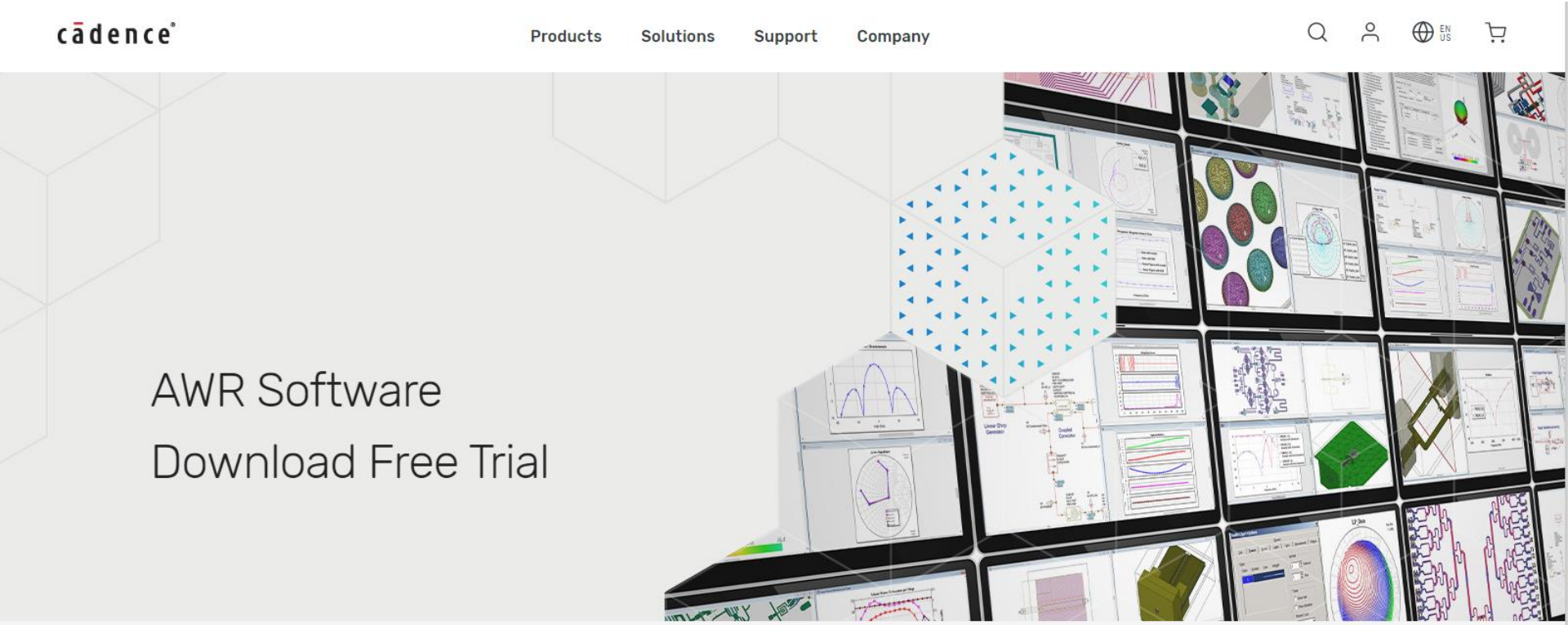
- *Make-up Exams:*
- Any request for change of quiz or exam schedule due to out-of-town work, religious holiday, etc. must be approved in advance.
- No make-up exams to improve scores.

- *Extra Credit:*
- No extra credit will be given.

Project Design Process

1. Perform theoretical design per specified goals
2. Create circuit on AWR Microwave Office (MWO) and simulate/tune performance over frequency
3. Lay out circuit for printed circuit board (PCB) implementation
4. Simulate design with AWR Axiem electromagnetic (EM) software. Compare to MWO analysis.
5. Send layout files to TA for board fabrication
6. Assemble PCB in lab and RF test; compare to predicted performance.
7. Write (individual) Lab Report

AWR Software
Download Free Trial



- https://www.awr.com/support/academia

DATE	TOPIC/LECTURE	LAB #	LAB ACTIVITY
8/21 **8/23**	Intro to RF RF Fundamentals		(No Lab this week)
8/28 **8/30**	RF Fundamentals RF Fundamentals		(No Lab this week)
9/4 **9/6**	University Holiday (No class) Lab Introduction (Lab #1)		(No Lab this week)
9/11 **9/13**	Scalar & Vector Measurements Quiz (RF Fundamentals)		(No Lab this week)
9/18 **9/20**	AWR Axiem Tutorial Resonant Circuits; SMD Components	2	Scalar Measurements
9/25 **9/27**	AWR Microwave Office Demo Board Layout Tutorial	3	Vector Measurements
10/2 **10/4**	Exam #1 Power Dividers	4	Antenna Measurements
10/9 **10/11**	Directional Couplers Directional Couplers	5	SMD Components
10/16 **10/18**	Filter Design Filter Design	6	Microstrip Resonators
10/23 **10/25**	Transistor Characterization Impedance Matching; Biasing	7	Power Divider
10/30 **11/1**	Exam #2 Amplifier Design; Stability	8	Directional Coupler
11/6 **11/8**	Amplifier Measurements Mixers; Final Project Discussion	9	RF Filters
11/13 **11/15**	PIN Diodes; RF Switch Design MMIC Design	10	RF Amplifier
11/20 **11/22**	Fall Break & Thanksgiving Holiday (No class)		
11/27 **11/29**	MMIC Design Antenna Lab Tour		RF Amplifier (continued if necessary)
12/4 **12/6**	Exam #3 Final Design Project Due: 12/11		

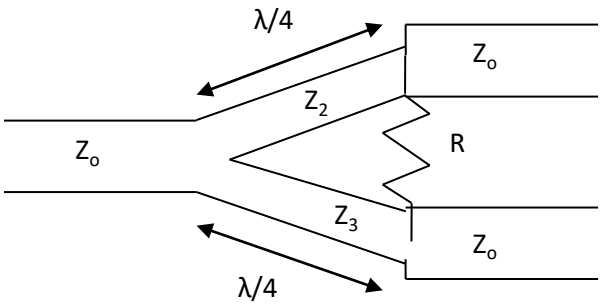
Wilkinson Equal-split Power Divider

Design Goals

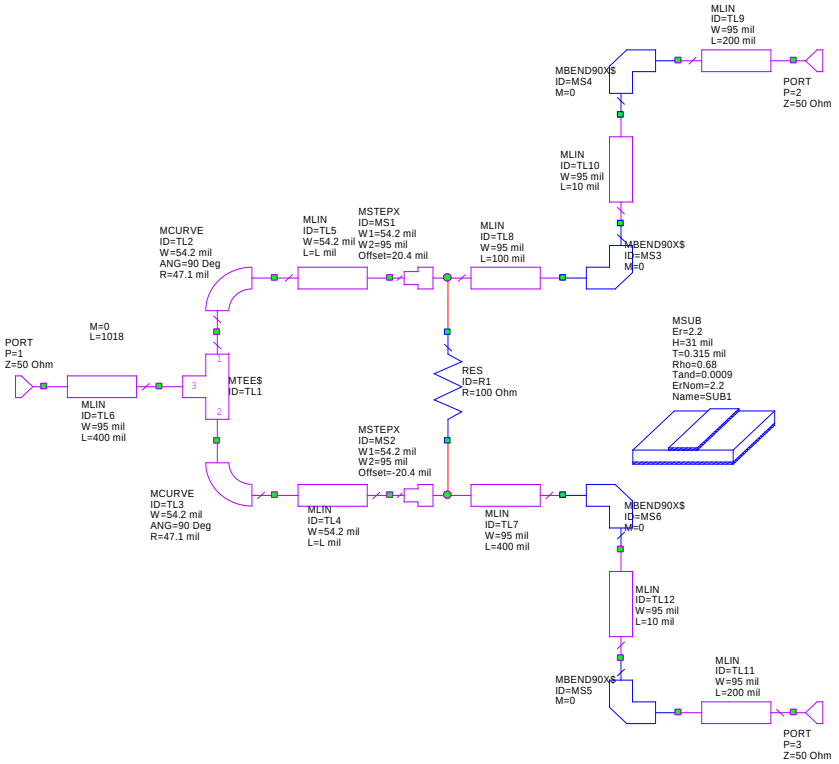
NOTE: Your structure must fit within a board size of 38 x 50 mm.
See RF Test Fixture Drawing for allowed connector (port) locations.

Center frequency = 3 GHz
Return Loss at all ports >15 dB over a 10% bandwidth
Substrate = Rogers 5880 Duroid, $\varepsilon_r = 2.2$
Duroid thickness = 0.787 mm
Conductor = Copper
Conductor thickness = 8 μm
Dielectric loss tangent = 0.0009
Assume Zo = 50 Ω system
Minimum line widths and spacing = 254 μm

Wilkinson Power Divider Design

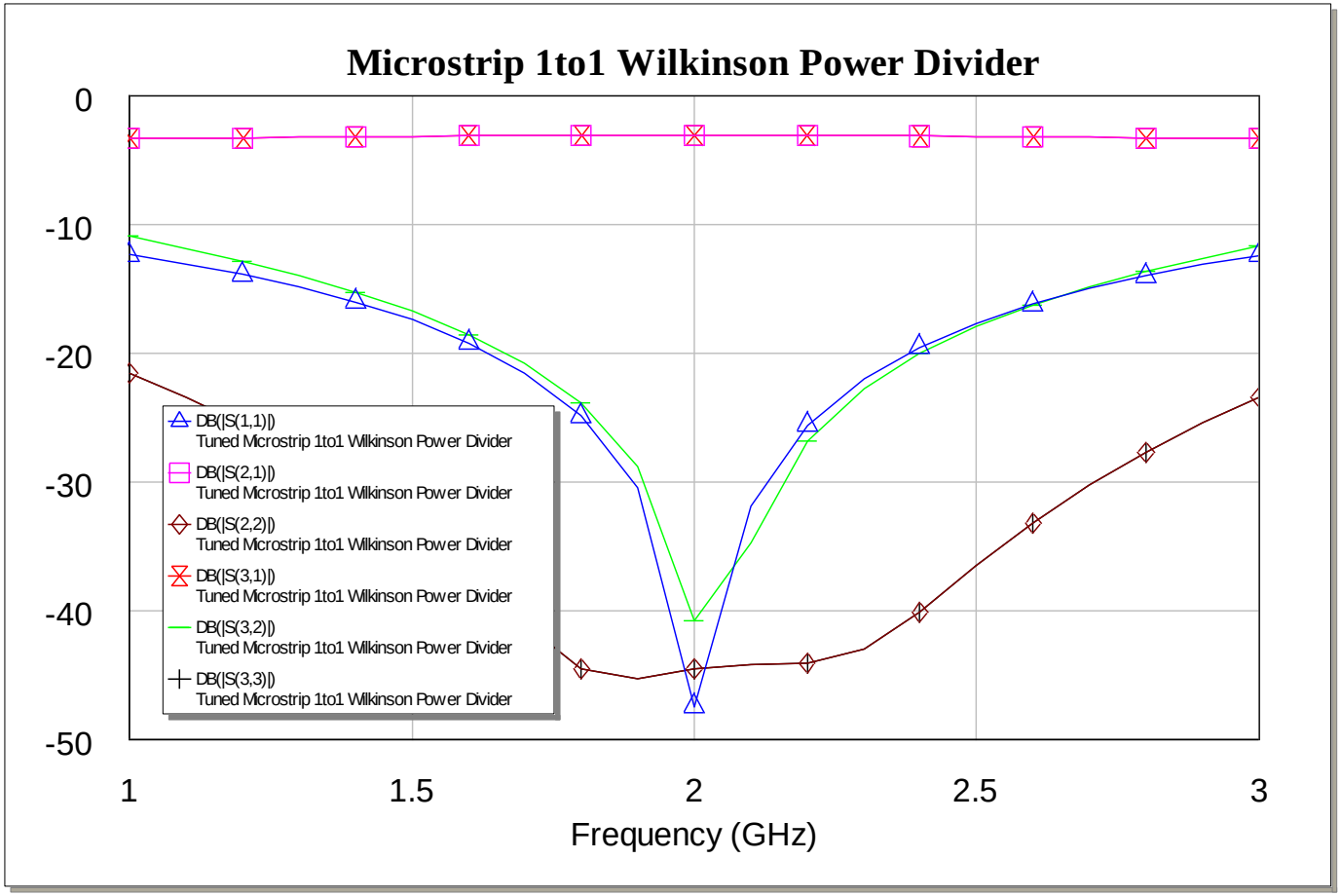


Theory

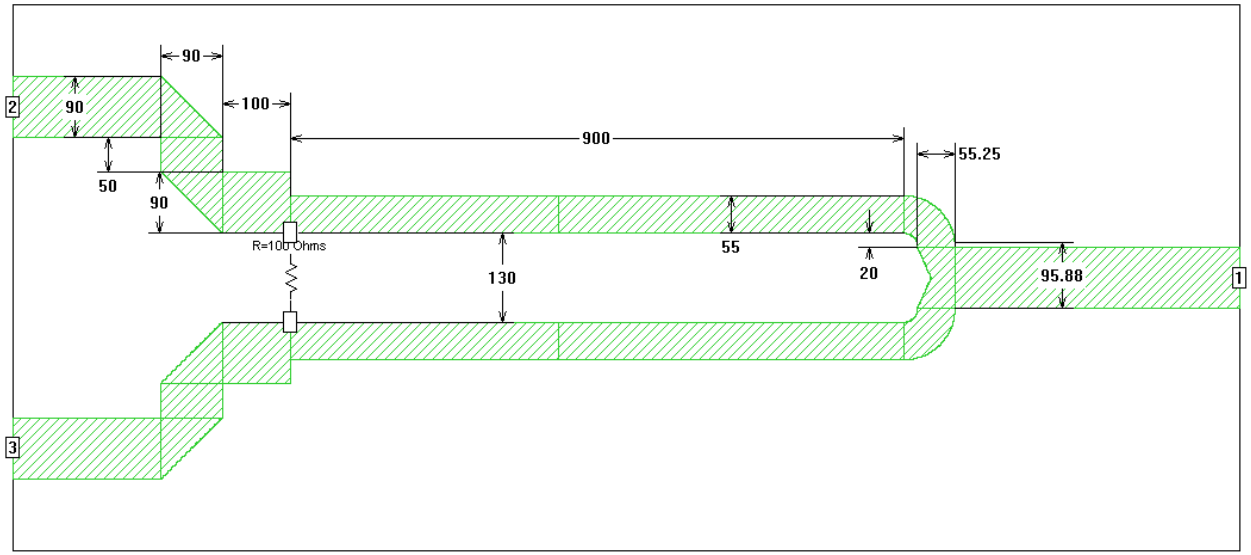


MWO Circuit

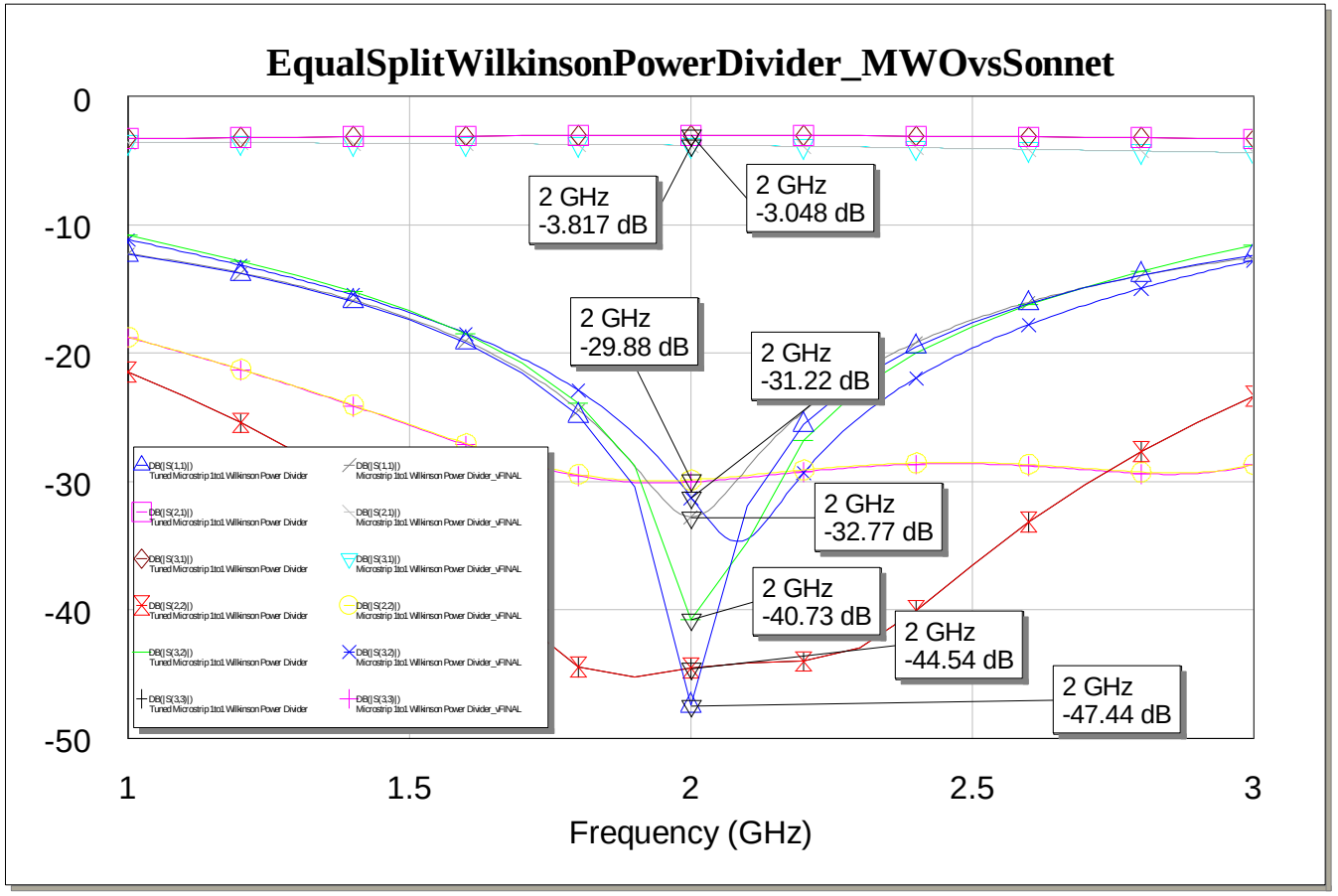
MWO Predicted Performance



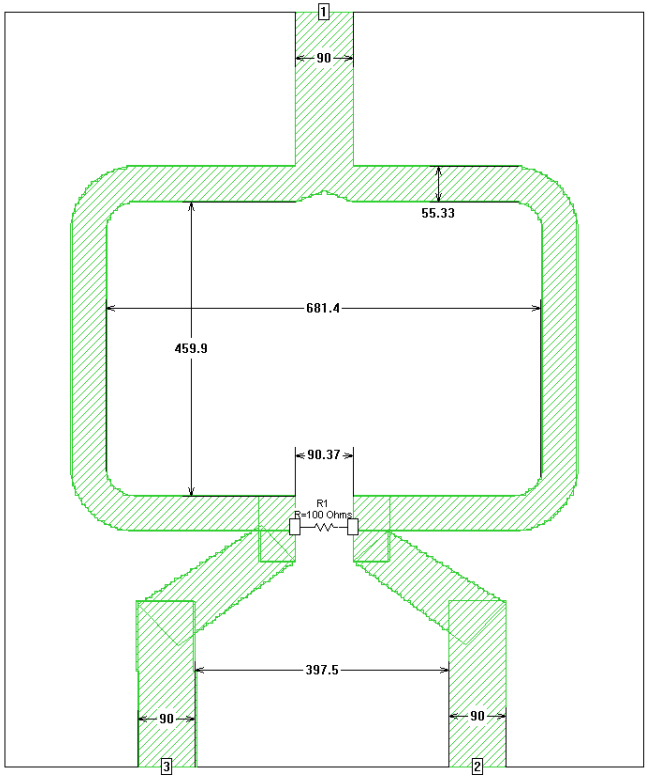
Power Divider Layout

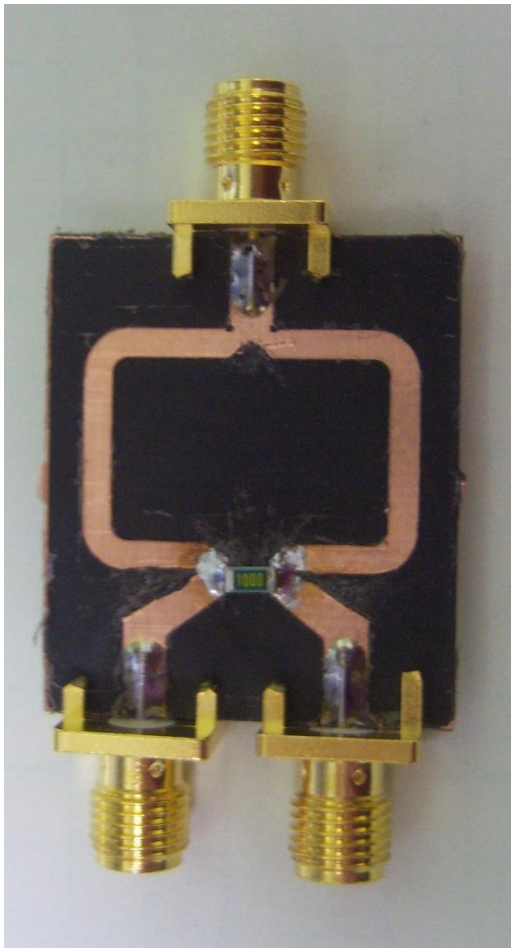


Circuit vs. EM Simulation

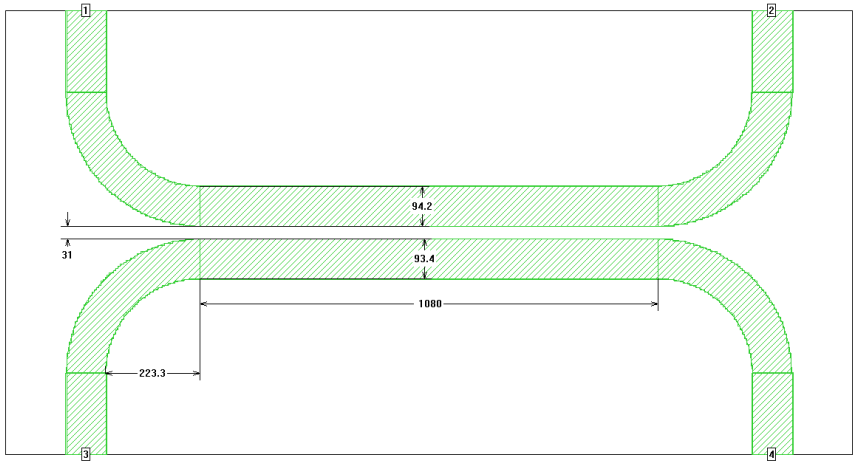


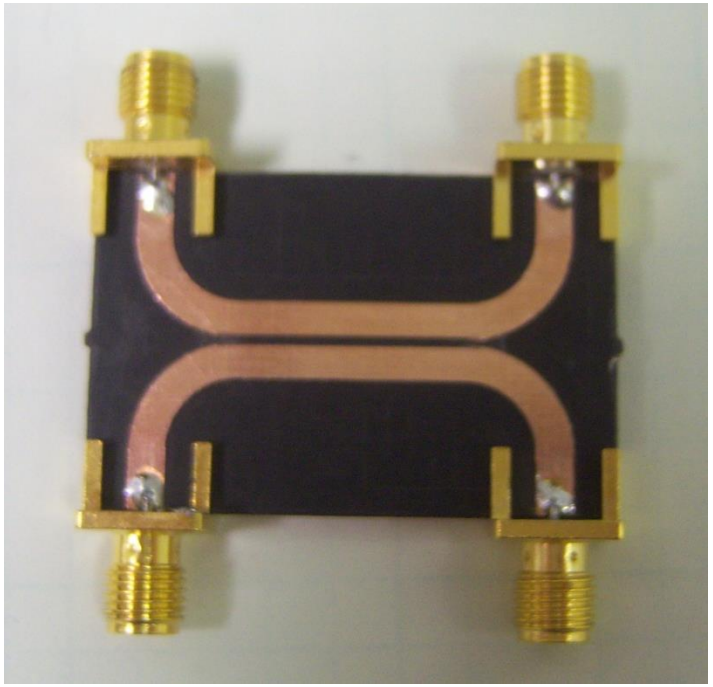
Wilkinson Power Divider



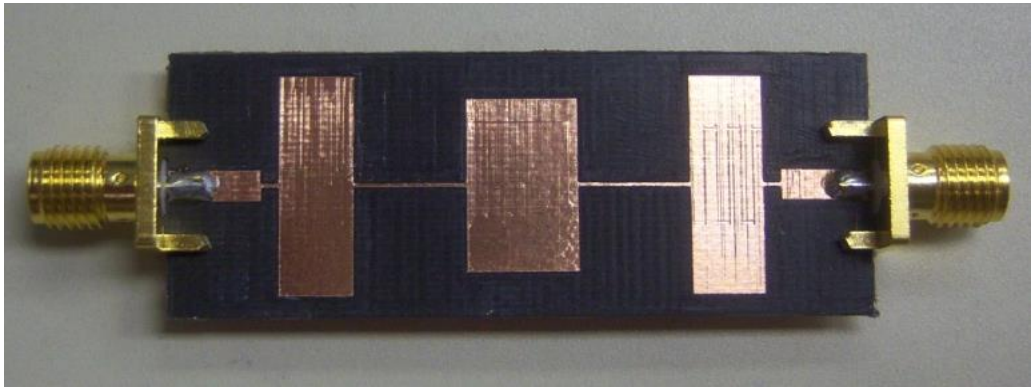


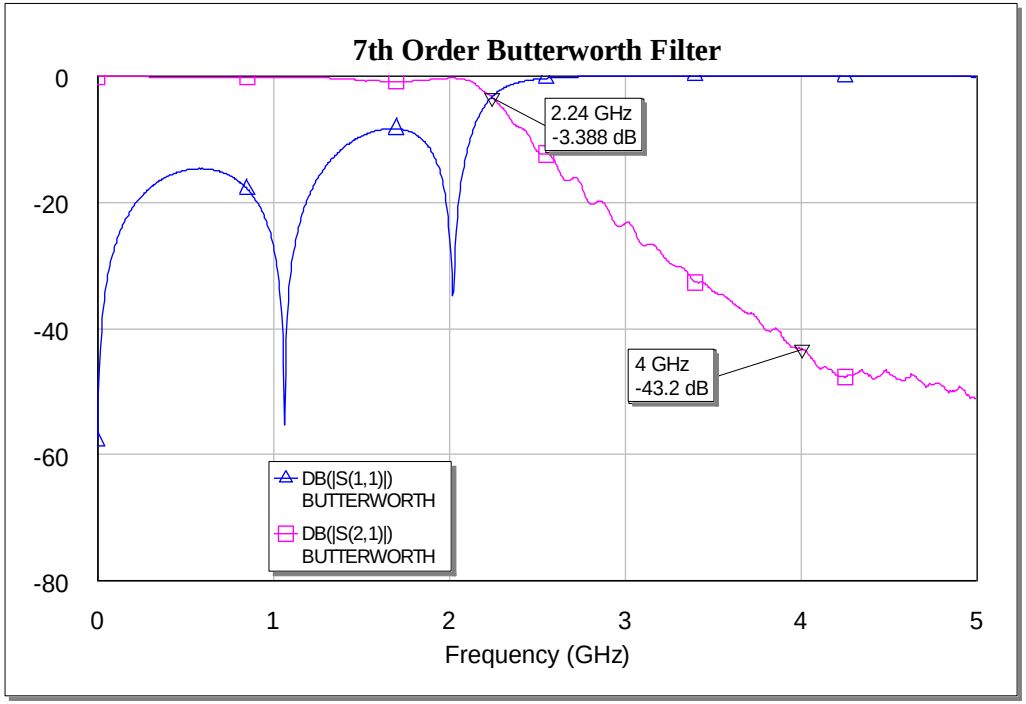
Microwave Directional Coupler



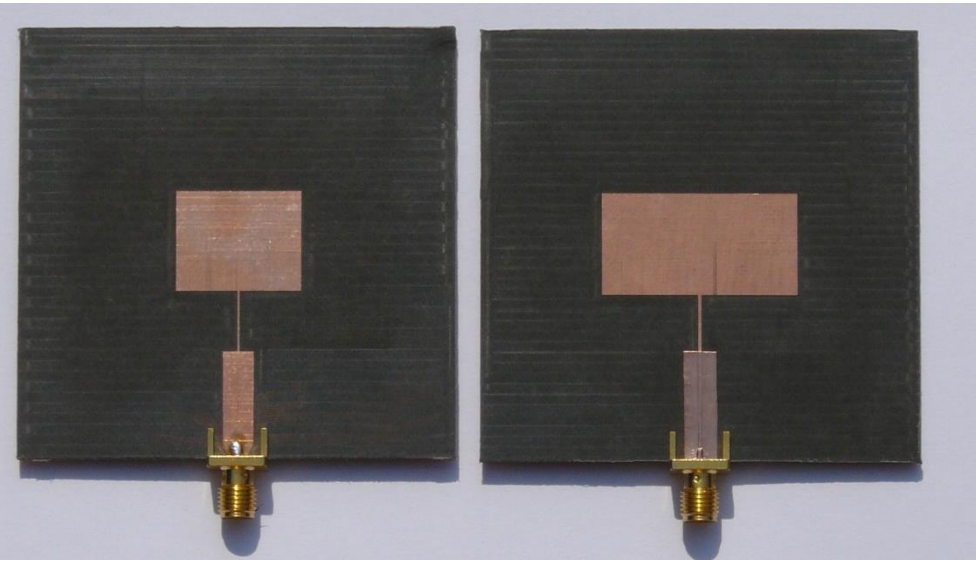


Microwave Low Pass Filter

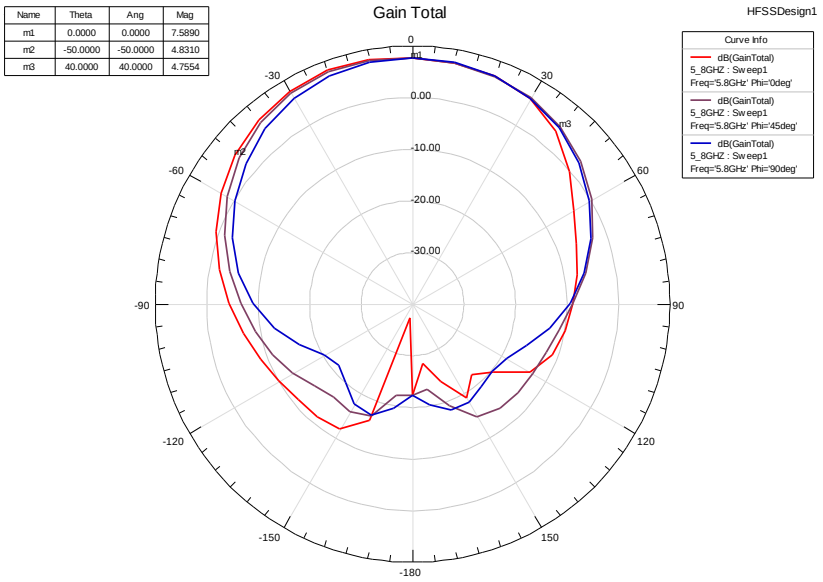


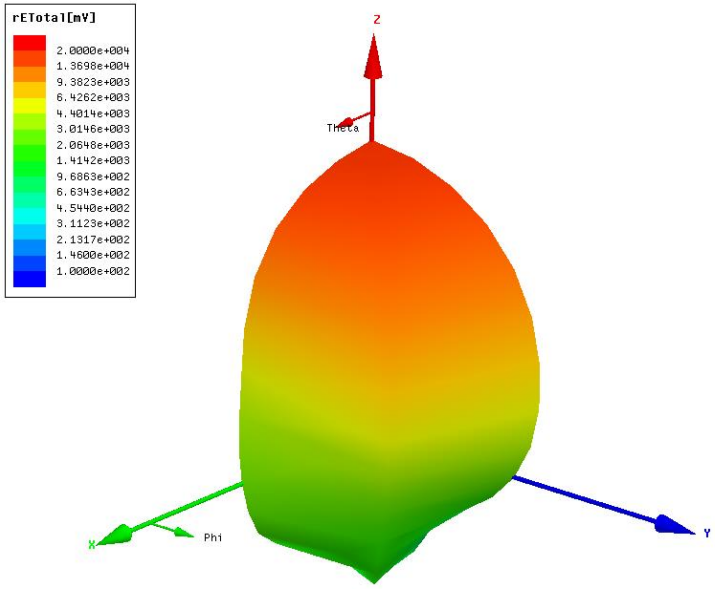


Microstrip Patch Antenna



Name	Theta	Ang	Mag
m1	0.0000	0.0000	7.5890
m2	-50.0000	-50.0000	4.8310
m3	40.0000	40.0000	4.7554

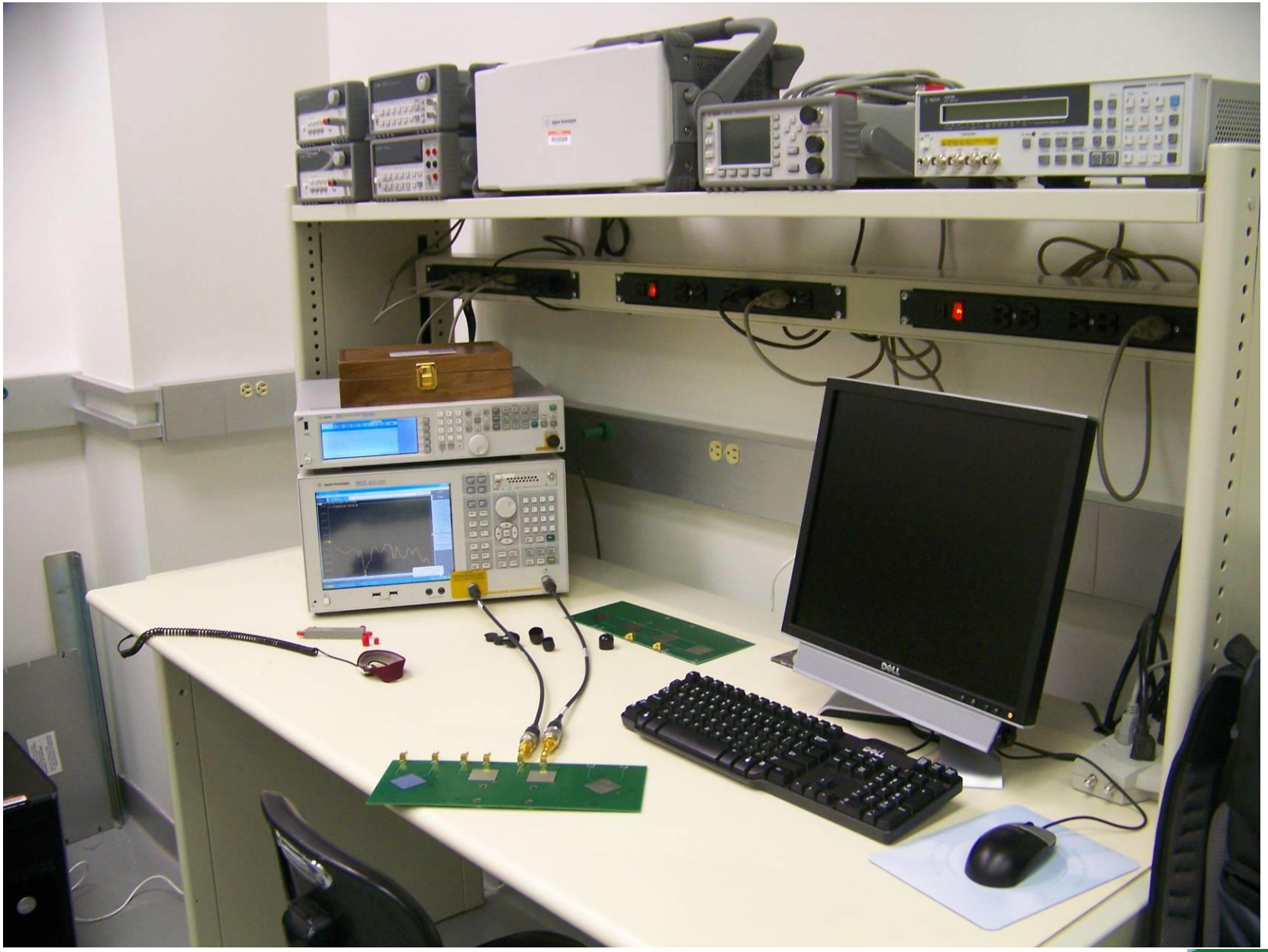




RF/Microwave Teaching Lab

•Five stations each equipped with the following:

- ✓8.5 GHz Vector Network Analyzer
- ✓6 GHz Signal Generator
- ✓6 GHz Spectrum Analyzer
- ✓Dual-channel Power Meter
- ✓100 KHz LCR Meter
- ✓Function Generator
- ✓Power Supplies
- ✓PC to access CAD tools:
  - Agilent ADS
  - AWR Microwave Office and VSS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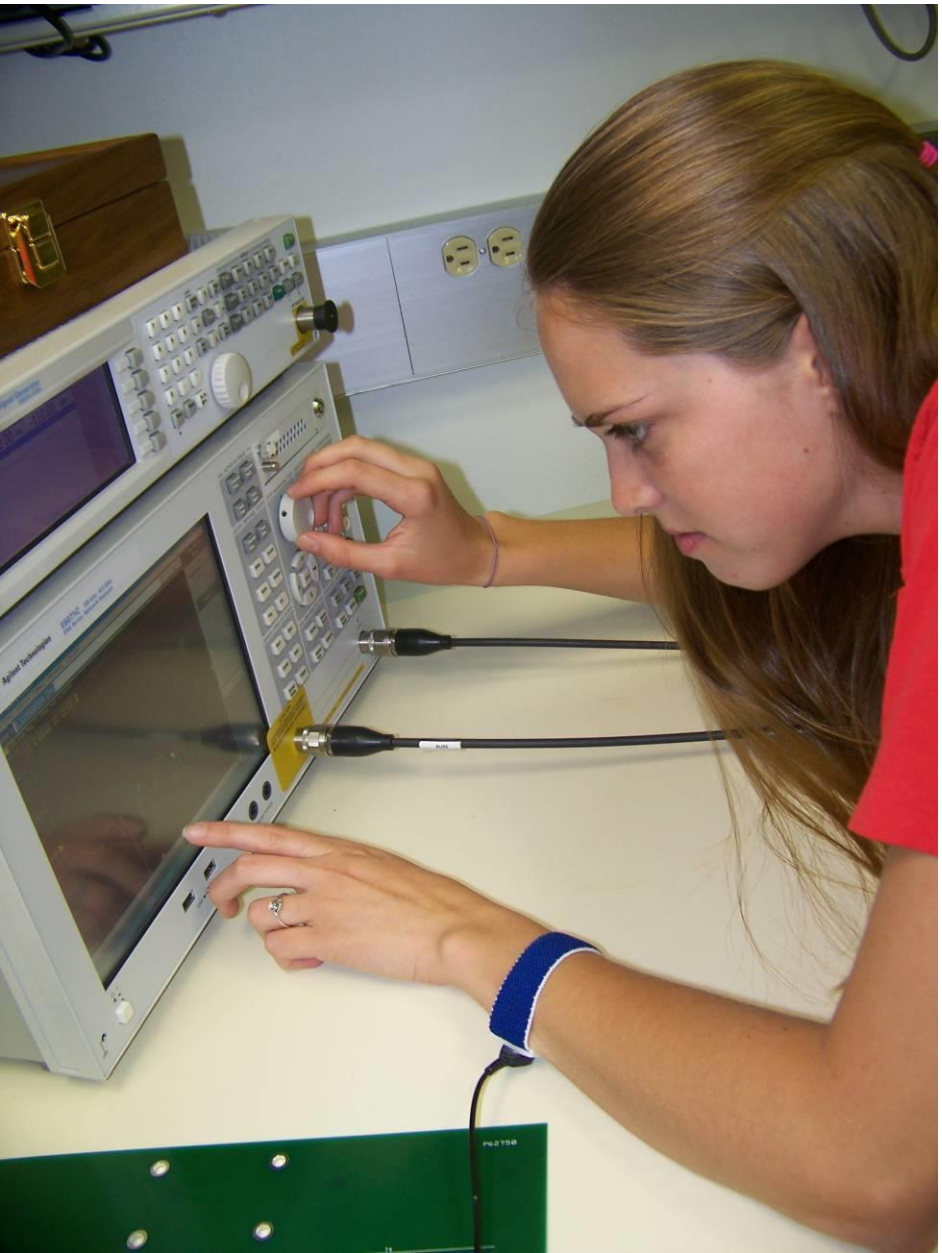
RF/Microwave Teaching Lab

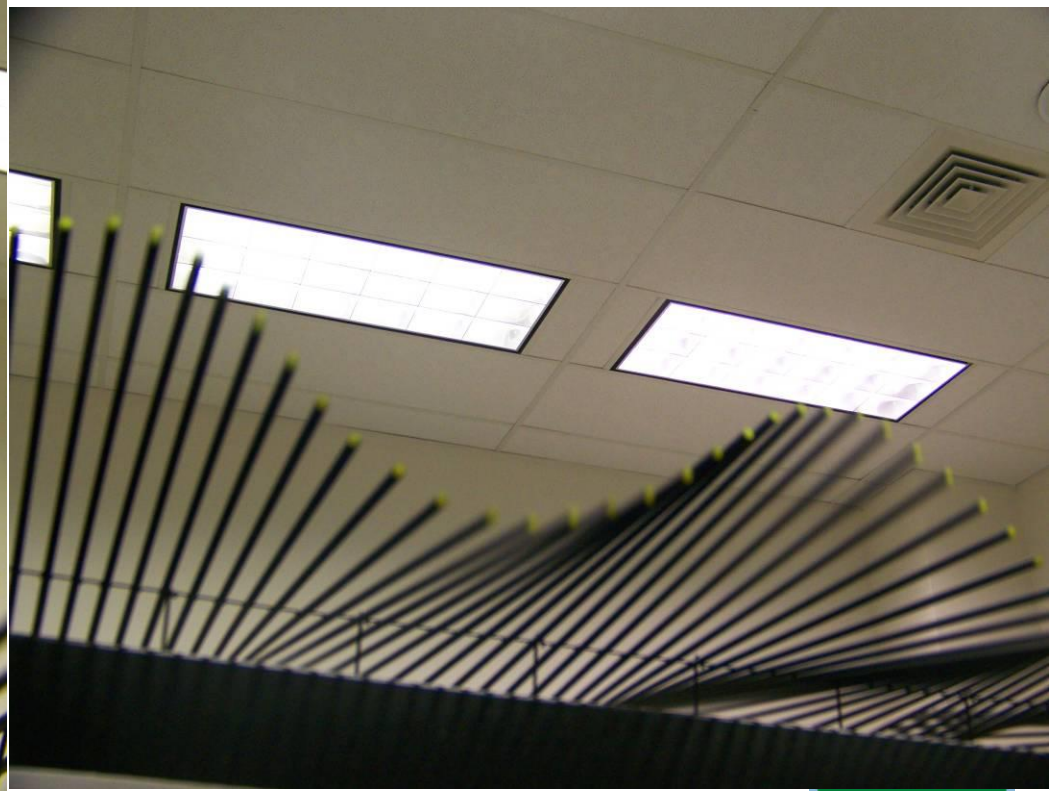


- Topics
- ✓ RF safety
- ✓ Connector and cable care
- ✓ ESD
- ✓ Transmission lines/wave propagation
- ✓ LCR Measurements
- ✓ Scalar Measurements
- ✓ Vector Impedance (S-parameters)
- ✓ Power Measurements
- ✓ Device DC & RF Characterization
- ✓ Spectrum Analysis

Wave Motion

Principles of:

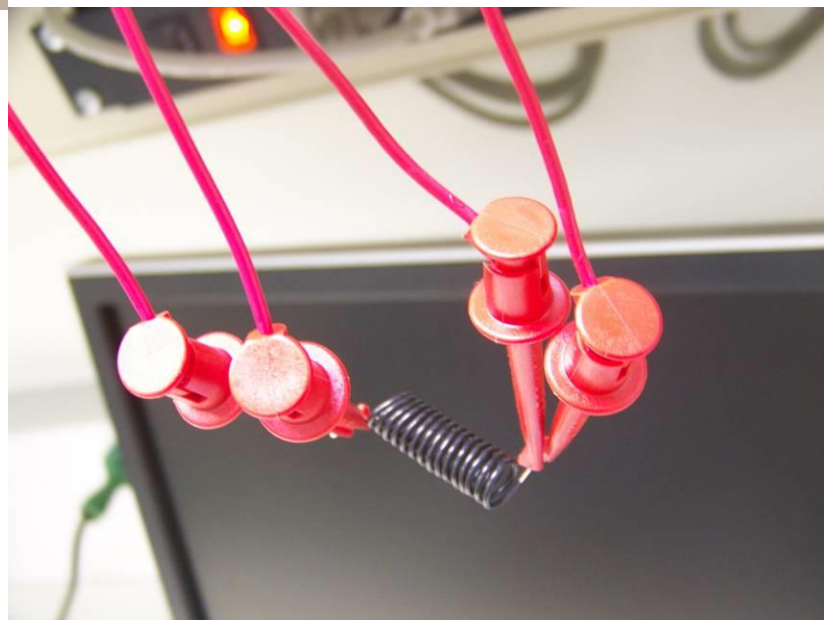
- Electromagnetic wave propagation
- Standing waves
- Reflection coefficient
- Impedance matching



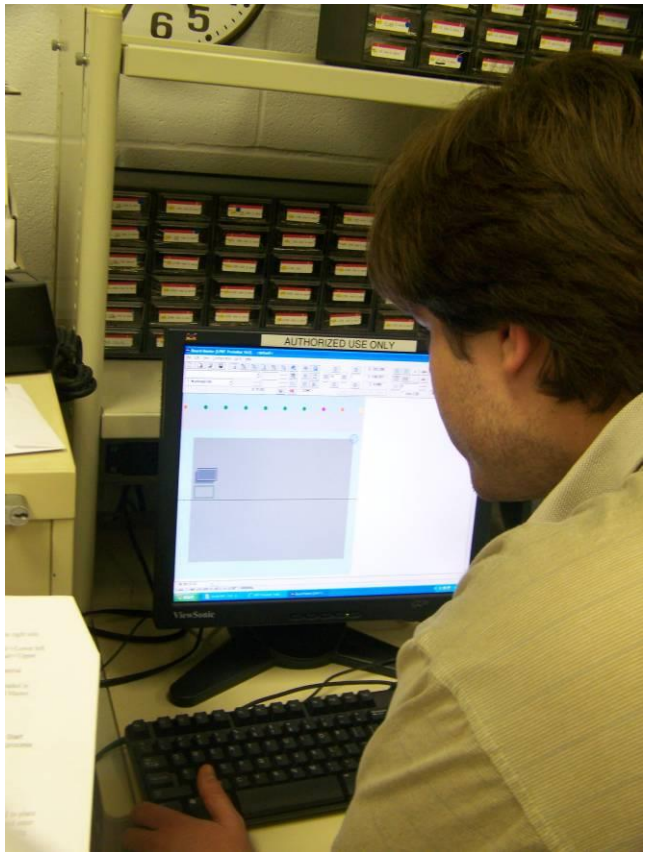
LCR Measurements

Lab Exercises

- Design hand-wound RF coils
- Design RF resonant circuits
- Confirmation that passive components do behave differently at RF

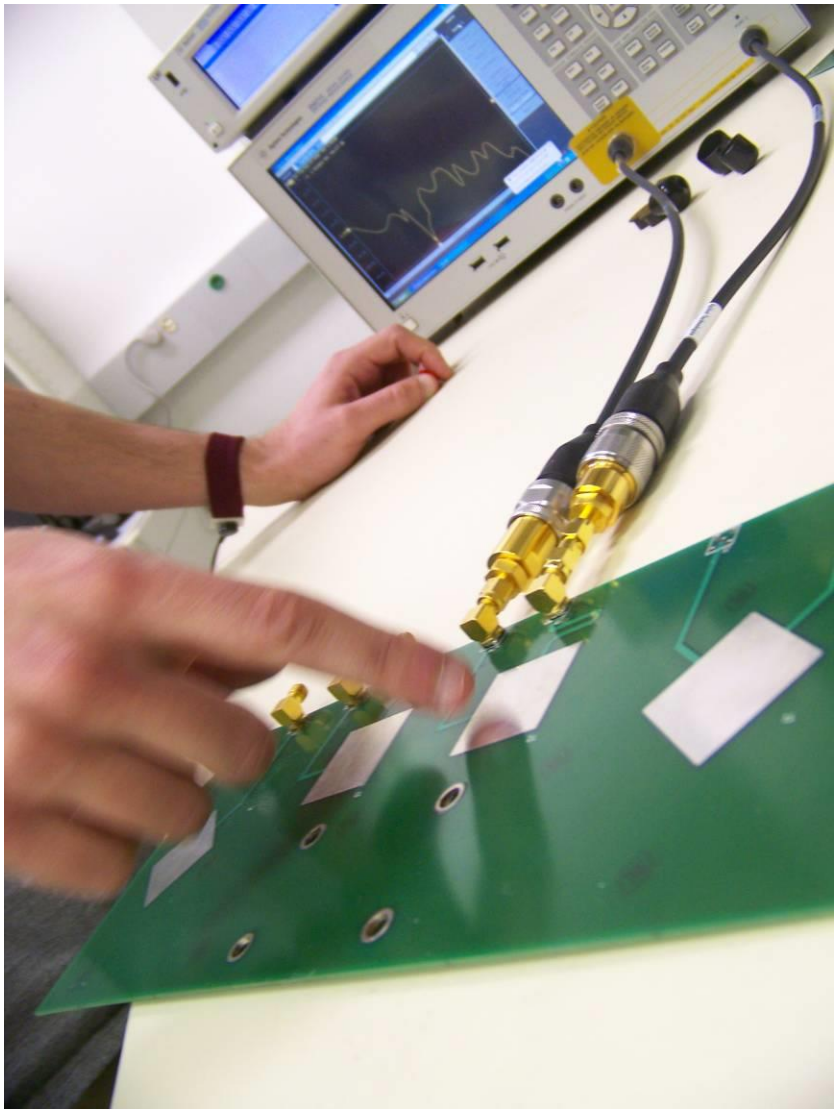


Circuit Board Prototyping Machine



- Rapid prototyping
- FR4, Duroid substrates
- Min. line width or space = 4 mils
- Resolution = 0.01 mils (0.25μm)
- 62,000 rpm

Vector Network Analysis



- Accurate calibration techniques
- Reference plane extensions
- S-parameters for characterization & design

Antenna Design and Measurements