EE Breadth Course
EE 4350 Applied Electromagnetics - RF Systems

Catalog Description: **EE 4350** Applied Electromagnetics - RF Systems (3) *Prereq: EE 3320 and 3610*. 2 hrs. lecture; 2 hrs. lab. Analysis and design of RF systems, transmission lines, impedance matching networks, RF filter design, antennas, high speed circuits. Single and multi-port networks and RF modeling.

Prerequisites by topic:
1. Frequency response and frequency limitations of devices
2. Introduction to transmission lines and Smith charts
3. Two-port Networks
4. Signal flow graphs
5. Linear systems analysis
6. Pspice
7. Matlab

Text: Ludwig and Bogdanov, *RF Circuit Design Theory and Applications,* Prentice Hall, 2009 2e

Course Objectives:

This course is intended to provide students with knowledge to analyze and design high frequency components and circuits. This knowledge will prepare students from wireless or high speed electronics design projects in the senior year. This course will educate the student to be able to 1. Analyze circuits using transmission line theory 2. Characterize single and multi-port networks using various network parameters 3. Analyze and design RF filters using discrete components and transmission lines and surface acoustic wave devices 5. Use software packages to simulate and verify design performance 6. Complete labs related to RF topics using a network analyzer including calibration, transmission lines and matching networks

Topics:
1. Introduction to wireless systems
2. The traveling wave
3. Transmission line analysis and design
4. RF component modeling and design
5. RF Measurements and Calibration
6. Smith Charts
7. Single and multi-port network parameters - S, ABCD Parameters
8. Impedance matching networks
9. RF Filter design

Grading Scale: 100-90 A; 89-80 B; 79-70 C; 69-60 D; below 60 F

Assessments:

Homework	10%
Projects and Labs	30%
Midterm Exam	30%
Final Exam	30%

Design Content:

Engineering Design 33%
Engineering Science 66%

Relationship of Course to Program Outcomes:

The course contributes to these outcomes:	How?
an ability to apply knowledge of mathematics, science, and engineering (ABET Criterion 3(a));	Students will use knowledge of Fourier Transforms, transverse wave propagation, Matlab (signal processing applications), and linear systems to analyze and design RF systems
an ability to design and conduct experiments, as well as to analyze and interpret data (ABET Criterion 3(b));	Students will use Matlab and an RF network analyzer as an analysis and design tool for RF systems. Students must be able to use and interpret many of these tools' capabilities to most accurately analyze characterize said systems.
an ability to design a system, component, or process to meet desired needs within realistic constraints (ABET Criterion 3(c));	Students will use Matlab as an analysis and design tool for RF systems, including transmission lines, RF matching networks and RF filters. Students will also design, assemble and test their designs using an RF network analyzer. Limited components and fabrication materials must be chosen to meet the design specifications as best as possible.
an ability to communicate effectively, including conveying technical material (ABET criterion 3(g))	Students will write mini papers on contemporary RF related topics, lab reports must be written clearly. Students will participate in design review presentations, both as a presenter and a reviewer.
an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (ABET Criterion 3(k))	Student will use Matlab and a state of the art RF network analyzer for design and analysis. Students will solder surface mount components and assemble an RF circuits using SMA connectors.
an ability to apply advanced mathematics, including differential equations, linear algebra, and complex variables, to solve electrical engineering problems (Program criteria).	Students must be able to apply linear algebra to compute the two-port parameters of cascaded RF systems. Students must be able to apply Fourier transforms and complex math to analyze RF systems and solve systems using transmission line theory (distributed circuit analysis).

Weekly Course Outline

Week	Lecture	Lab
1	<u>Chapter 1</u> • Introduction to RF Systems, Frequency Spectrum • Behavior of components at RF frequencies • Component Modeling	***LAB 1*** • Introduction to lab equipment • ESD Protection • ESD paper assigned
2	<u>Chapter 2</u> • Transmission line theory • Examples of TL's • The infinitesimal TL segment model • Solving the general transmission line equation	***LAB 2 Transmission Line Characterization Part 1*** • Phase velocity, impulse response, insertion loss, calibration
3	<u>Chapter 2</u> • Traveling voltage and current waves • Microstrip lines • Terminated losses transmission lines • Special termination conditions • Sourced and Loaded transmission lines	LAB 2 continued
4	<u>Chapter 4</u> • One and Two port network parameters basic definitions Z, Y, hybrid parameters • Cascading Networks – ABCD parameters • Scattering parameters – practical measurements	***LAB 3 Transmission Line Characterization Part 2*** • Characteristic impedance, effective permittivity • Parallel plate transmission line design
5	<u>Chapter 3</u> • Smith Charts – graphical representation of reflection and impedance • Impedance transformation • SWR • Admittance transformation – ZY Smith Chart	LAB 3 continued
6	<u>Chapter 3, 8</u> • Parallel and series connections • Introduction to Matching Networks • 2 and 3 element networks T, Pi	***LAB 4 Characterizing the RF behavior of discrete*** components • Air coils, ceramic capacitors • Surface mount inductors and capacitors

7	Chapter 8 • Stub line matching networks • Equivalent circuits and modeling frequency behavior of matching networks • Nodal Quality factor	***LAB 5 Impedance matching Design*** • Discrete component matching • Stub lines • Quarter-wavelength matching • Design Review
8	Midterm Exam • Practical Applications of matching networks	LAB 5 continued
9	Chapter 5 • Introduction to RF filter Design • Filter types, specifications • Filter algorithms	LAB 5 continued
10	Chapter 5 • Denormalization of the Standard LPF • Microstrip Line filters	***LAB 6 Discrete Component Filter design***
11	Chapter 5 • Unit elements and Kuroda's Identities • Microstrip line filter design project • Introduce microstrip line filter design project	LAB 6 continued
12	Chapter 5 • Microstrip line filter fabrication *(No text)* Other High Frequency Filter Implementations • SAW Filters • Transducers – FIR filter design	***LAB 7 Microstrip Line Filter Design*** • Design Review, order boards
13	• How to measure a SAW filter • Characterizing a SAW filter response – a practical application of the Fourier Transform • Other modes of propagation in a SAW	***LAB 8 Surface Acoustic Wave Filter Test***
14	Chapter 5 • Chain Matrix Scattering T-Parameters • Signal flow graph Modeling	LAB 7 Microstrip Line Filter Test

Prepared by: John Scalzo

Updated 22MAR12

Department of Electrical and Computer Engineering
Louisiana State University

EE 4350

Justification:

Applications of wireless communication continue to expand. Electrical engineering students interested in careers or research in this area should have a background in high frequency systems. Low frequency circuit analysis techniques and software are not applicable to the distributed system. This course provides students the necessary theory, analysis, testing, and design approaches to radio frequency (RF) systems. The course will prepare students for electrical and computer engineering senior projects requiring RF systems design. A laboratory already exists for this course. The funds and equipment for this lab were donated in part by alumni and industry.

This course was taught as a special topics lecture course for 3 years and most recently as a lab/lecture course for another 5 years.