ECE 764
Design of Antennas and Microwave Circuits
Spring 2019

Office Hours: MWF 3:30 to 4:30 (right after our class)
Others by appointment, or when my door is open, or when you can find me in the lab...

Prerequisites: Electronics II (ECE526), Electronics Lab (ECE502), Linear Systems (ECE512), and EM theory (ECE557) - or equivalent from other schools

References: (Texts available in our lab)

"Microwave and RF Design of Wireless Systems" by David M. Pozar, Copyright 2001, John Wiley and Sons, Inc.

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"Planar Microwave Engineering, A Practical Guide to Theory, Measurements and Circuits," by Thomas H. Lee, Copyright 2004, Cambridge University Press.

Chang, Kai, Ed. "Handbook of Microwave and Optical Components, Volume 1," Wiley Interscience, 1989.

Various class handouts. E.g. HP/Agilent "Application Notes" on transmission lines, S-parameters, etc.

Course Description:

This course combines lectures and laboratory work to introduce you to wireless circuits and systems operating at microwave through millimeter wave frequencies (e.g. 1 through 100+ GHz). We will be covering topics including antennas, transmission lines, S-parameters, amplifiers, filters, oscillators, phased-locked loops, mixers, digital signal processing, and microwave measurement techniques and equipment.

The course includes a sequence of labs and project assignments. In the labs, you will learn the essentials of EM signal propagation, antennas, microwave circuits, and test equipment. In the semester project, you will create a Doppler/FMCW radar operating at 5.8 GHz. Such a device could be used for automotive, sports, and many other applications.

A companion course (ECE662) offered in alternate semesters covers the design of HF through UHF circuits for those interested in a more complete exposure to the wireless hardware field. Other recommended courses include ECE660, ECE647, and ECE696. ECE660 covers the mathematical foundations of digital communications, while 647 covers digital signal processing. ECE696 covers IC design, and when combined with other courses, provides a foundation for field of RF integrated circuit (RFIC) design.

Objectives: The primary learning objectives of ECE 764 are:

- to familiarize you with radio waves, antennas, propagation,
- to familiarize you with circuits used in wireless communication and remote-sensing equipment at GHz frequencies,
- to introduce you to performance measures and test equipment used in radio frequency and microwave circuit laboratories, and
- to help you gain a foundation for specifying and designing wireless equipment at the system level.

Homework: Work in this course centers around the design, construction, testing, and documention of real-world antennas, circuits, and systems. There are no classic homework problems. Rather, "homeworks" consist of lab and project assignments and associated documentation you will be required to turn in (plus demos of your project).

Labs/Projects: During the first half of the semester, we will be covering antennas, propagation, and transmission line fundamentals. We will be learning through lectures, lab exercises, and associated writeups. ***The lab exercises will be done in teams of 2 or more*** and will include:

- Lab 1: Experiments and measurement of radio signal propagation in the field
- Lab 2: Antenna design, construction, and performance measurements.
- Lab 3: Familiarization with microwave amplifiers, component parasitics, transmission lines, matching networks, and other "microstrip" components.

During the second half of the semester, we will use what we've learned to design, build, and test a microwave system - a Doppler/FMCW radar operating in the 5.8 GHz Industrial, Scientific, and Medical (ISM) frequency band. The radar will be similar to those now being included in cars for safety enhancement. This will be accomplished in two stages:

- Prototyping of main radar functions (e.g. oscillator, amplifiers, filters, mixer, etc.)
- Full radar product design, construction, and testing.

As with the labs, the project designs will be done in teams (in this case, 3 or 4 person "companies"). Each person within your company will be responsible for a separate part of the design, and the whole company must work out interfaces between sections and get the product functional by the end of the semester.

For the final project demos, we will run tests in the lab to prove that you can measure speed and distance. We may also go out to the street and check the speed of some cars driving by if it is not too cold still at the end of the semester :-)

Exams: The final-exam will be this demonstration of your project plus a company report with each student writing his/her section.

Grading: Your grade in this course will be based on your demonstrated understanding of lecture material, lab assignments, the successful operation of your radar, and on timely completion of the required work. *(See weightings and late work policy below.)*

Weighting of the individual components of your grade will be computed as follows:

- Labs 1 thru 3 — 15% each
- Project prototyping deliverables — 25%
- Demo and documentation of final radar — 30%

Lab/project writeups will be graded on the basis of **completeness**, **correctness**, and overall **quality** (technical and presentation) with 5 points each.

Each lab or project score identified above will be individually scaled to a 100 point range and then your final grade is computed using the weights shown.

The overall semester grading curve is subject to the discretion of the instructor but will generally follow the classical assignment pattern: 90 - 100 = A, 80 - 90 = B, etc. so that you can keep track of your progress.

Late Work: To receive full credit, ***you must turn in your work by close-of-business (COB) on the due dates specified***. Assignments turned in late (without documentation of illness, or other significant circumstances outside your control) will be pro-rated as follows:

- 0 - 48 hrs. — 90 % maximum credit
- 48 - 96 hrs. — 70 % maximum credit
- > last week of semester — 0 % credit

The demonstration/documentation of the final radar system operation for the final exam must be done on time, of course...

Lab Hours: The Communications Circuits Laboratory (Engineering Hall Room 3097) will generally be open during normal business hours (8 a.m. - 5 p.m., Monday - Friday, excluding holidays.) It is also possible to work after hours thanks to key-card access.

Project Kit: You will need to purchase a project kit that contains the core components required to complete the labs/project. This kit may be obtained from the ECE shop and is in two parts. ***Each student*** *needs to purchase* ***one individual kit*** *and* ***one-quarter of a 4-person group kit***. Some of the larger parts as well as fabrication of PCBs will be available with proof-of-purchase.

Tools: Soldering stations, solder, and drilling equipment is provided in the lab. Please be careful and neat as you use these, since we are all sharing the same construction benches.

In particular, ***be certain soldering irons are always stowed in their holders and always turned off before you leave the room (regardless of whether you are the one who turned them on or not !)***

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Academic Honesty:

This is a challenging course in which collaboration with other students is both desired and inevitable. You are encouraged to seek help from your teammate(s) or fellow classmates to understand the basic theory and troubleshoot problems as you do labs and project assignments. However, in order to provide equitable grading, ***certain activities must be completed on your own***. These include:

- Your lab/project *design*s.
- The portion of the lab write-ups you are responsible for.
- Your section of the project writeups

While collaborating to perform lab experiments and to understand the fundamental concepts is permitted and even expected in many cases,
each student must do their own individual designs, measurements, and writeups.

K-State's Honor System (the legalese):

"Kansas State University has an Honor System based on personal integrity, which is presumed to be sufficient assurance that, in academic matters, one's work is performed honestly and without unauthorized assistance. Undergraduate and graduate students, by registration, acknowledge the jurisdiction of the Honor System. The policies and procedures of the Honor System apply to all full and part-time students enrolled in undergraduate and graduate courses on-campus, off-campus, and via distance learning. The honor system website can be reached via the following URL: www.k-state.edu/honor .

A component vital to the Honor System is the inclusion of the Honor Pledge which applies to all assignments, examinations, or other course work undertaken by students. The Honor Pledge is implied, whether or not it is stated: "On my honor, as a student, I have neither given nor received unauthorized aid on this academic work." A grade of XF can result from a breach of academic honesty. The F indicates failure in the course; the X indicates the reason is an Honor Pledge violation. "

Disabilities: If you have any condition, such as a physical or learning disability, which will make it difficult for you to carry out the work as outlined or which will require academic accommodations, please notify me in the first two weeks of the course. In particular, ***if you have concerns about constructing circuits with (really, really, small) surface - mount components, please let me know.***

Additional information from the university:

"Any student with a disability who needs a classroom accommodation, access to technology, assistance during an emergency evacuation, or other assistance in this course should contact Disability Support Services and/or the instructor. DSS serves students with a wide range of disabilities including, but not limited to, physical disabilities, sensory impairments, learning disabilities, attention deficit disorder, depression, and anxiety ."

ECE 764 Spring 2019 Schedule

(Tentative)

Week	*Material*	*Assignments*
1	Introduction to comm systems, frequencies, and wavelengths Calculating and measuring received signal strengths with spectrum analyzer	Verify you have lab access Lab 1 assigned
2	EM theory review Antenna theory	Purchase lab kit (before lab 2)
3	Basic antenna types: dipoles, monopoles, patches, arrays Antenna characterisitics: polarization, patterns, and impedance	Lab 1 due
4	Measurement of antenna patterns and signal reflection/transmission Transmission lines and reflection coefficient	Lab 2 assigned
5	Introduction to Smith Charts, plotting of impedance/admittance Simulation with Agilent ADS	
6	Lambda/4 lines and impedance transformations with microstrip Microstrip components and coupled-line microwave filters	Lab 2 due
7	PC board design, layout, and parasitics Two-port circuit theory review and introduction to S-parameters	Lab 3 assigned
8	Circuit analysis and simulation with S-parameters Amplifier insertion gain, matching, stability, noise figure, and compression specs	Lab 3 due
9	Project discussion (microwave plus baseband, ADC and DSP functions) Basic mixer concepts and hybrid-ring microstrip implementations	Project assigned
10	Voltage controlled oscillators Frequency multipliers	Prototype design/layouts due
11	Project discussions (pads, RF connector test points, test planning)	Probotype boards back
12	Frequency synthsizers and phase-locked loops	
13	Project testing/debugging discussions	Test, debug, respin boards Submit final board layouts
14	Analysis and design of directional antennas: Array theory Dish antennas and antenna feeds: e.g. helix, horn, and patch antennas Antenna simulations with ADS, EZNEC and other tools	
15	Additional radar and wireless performance issues	
16	***Final Exam***:	Radar demos and writeups

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