Syllabus

EE 471C / EE 381V Wireless Communications Laboratory

Lecture: Mondays & Wednesdays 9:00-10:15am UTA 1.208

Lab Sections (unique number 17280 / 17360): Friday 9:00am - noon ECJ 1.318
Lab Sections (unique number 17285 / 17365): Thursday 6:30pm - 9:30pm ECJ 1.318

Course URL: http://www.profheath.org/teaching/ee-371c-ee-381v-wireless-communications-lab/

Instructor Information

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Teaching Assistant Information

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Prerequisites for EE 471C (strictly enforced)

EE 445S Real-Time Digital Signal Processing or EE 351M Digital Signal processing or EE 360K Intro to Digital Communications. * Note: there are no pre-requisites for EE 381V, the graduate version. It is suggested though that you have the equivalent of the above courses.

Reading Materials

Required reading will be from the instructor's electronic textbook supplemented by online sources. Chapters will be posted online via Canvas and updated periodically. Note that all chapters include many past homework and exam problems for practice.

Electronic Course Site

Handouts, grading, announcements, and communication via email will be performed using Blackboard http://canvas.utexas.edu. You should be able to log in if you have a valid UT ID and are registered for this class. You will be responsible for checking canvas and your email for notifications about assignments.

Course Introduction

Wireless communication is fundamentally the art of communicating information without wires. In principle, wireless communication encompasses any number of techniques including underwater acoustic communication, semaphores, smoke signals, radio communication, and satellite communication, among others. The term was coined in the early days of radio, fell out of fashion for about fifty years, and was rediscovered during the cellular telephony revolution. Wireless now implies communication using electromagnetic waves -- placing it squarely within the domain of electrical engineering. This brings us to the course at hand.

Wireless communication techniques can be classified as either analog or digital. The first commercial systems were analog including AM radio, FM radio, television, and first generation cellular systems. Analog communication is rapidly being replaced with digital communication. The fundamental difference between the two is that in digital communication, the source is assumed to be digital. Every modern wireless system being developed and deployed is built around digital communication including cellular communication, wireless local area networking, personal area networking, and high-definition television. Thus the spotlight of this class will focus on digital wireless communication.

This class approaches wireless communication from the perspective of digital signal processing (DSP). No background in digital communication is assumed, though it would be helpful. The utility of a DSP approach is due to the following fact: wireless systems are bandlimited. This means that with a high enough sampling rate, thanks to Nyquist's theorem, we can represent the bandlimited continuous-time wireless channel from its samples. This allows us to treat the transmitted signal as a discrete-time sequence, the channel as a discrete-time linear time-invariant system, and the received signal as a discrete-time sequence.

In this class we take an experimental approach to wireless digital communication. We will use a well-known software defined radio platform known as the USRP (universal software radio peripheral) where the radio can be programmed software (in this case LabVIEW) instead of implemented using hardware. The focus will be on the design, implementation, evaluation, and iterative optimization of a digital wireless communication link. A three-hour laboratory period will complement the usual three-hour lecture period each week.

At the end of this class, you will have constructed your own wireless communication link. In this process, you will have achieved the following learning objectives. You should be able to describe the design challenges associated with building a wireless digital communication link. You should be able to define and calculate bit error rates for some common modulation schemes. You should know the difference between binary phase shift keying and quadrature phase shift keying as well as how to implement them. You should understand the connection between pulse-shaping and sampling. You should know how to define excess bandwidth for a raised-cosine pulse. You should understand how to obtain a sampled channel impulse response from a continuous time propagation channel. You should understand how to train and estimate the coefficients of a frequency selective channel. You should understand the various kinds of synchronization required and how to compensate for different sources of asynchronicity. You should be able to explain how to perform equalization using single carrier frequency domain equalization or OFDM modulation. You should be able to justify the use of either zero padding or a cyclic prefix to enable frequency domain equalization. You should be able to perform channel estimation and synchronization in an OFDM receiver. You should be able to explain the key features of the IEEE 802.11a and GSM physical layers to enable channel estimation, equalization, and synchronization. You should be able to define two different modes of operation in a MIMO communication system and explain the difficulty of equalization in fading channels. You should be able to define small-scale fading and large-scale fading. You should be able to calculate the coherence time and coherence bandwidth of a channel. You should be able to create and understand a basic link budget including both small-scale and large-scale fading. You should understand the principle of frequency reuse in cellular systems and be able to calculation the signal-to-interference-plus-noise ratio. You should be able to implement everything you learn on our software defined radio platform.

EE 381V Graduate Course Only: *Part of the final grade for this course will consist of a final term project, due at the end of the course. There are three possible term projects, which you can choose based on your interests. You are encouraged to consult with Prof. Heath during the selection of your project topic as well as your research advisor (if you have one).*

(1) System Implementation Here the final deliverable is an implementation of a wireless communication system of your choice. The idea is that the implementation will deal with either a different system than we considered in class, or a similar system with enhancements such as space-time coding, MIMO, or more advanced transceiver design. This project will require code that is well documented, can be made available online, and appropriate written documentation. Demo and all related code will be turned in.

(2) Survey Paper Here the final deliverable is a research paper in the format of a journal or conference paper that provides a survey of a given topic. This project should have a detailed survey component and a simulation component for full credit. The paper will be graded as a conference or journal paper. You will be able to choose the format that suits your project and I will grade accordingly. Final project report must be written in ***LaTeX****. Possible topics include a broad survey of software-defined radio or more detail surveys of specific areas including synchronization, channel estimation, OFDM, MIMO, millimeter wave, visible light communication, and channel estimation.*

(3) Research Paper Here the final deliverable is a research paper in the format of a journal or conference paper. This project should contain some element of innovation, even if it is small or incremental. The paper will be graded as a conference or journal paper. You will be able to choose the format that suits your project and I will grade accordingly. Final project report must be written in LaTeX. Possible topics include synchronization, implementation architectures, channel estimation, distributed antenna systems, small cells, MIMO, millimeter wave cellular, massive MIMO, beamforming, etc.

Outline of Experiments

- Introduction to LabVIEW and the National Instruments RF Hardware
- Baseband QAM Modulation
- Baseband QAM Demodulation
- Channel Estimation
- Synchronization
- Frequency Offset Estimation and Correction
- OFDM Modulator and Demodulator
- OFDM Synchronization, Frequency Offset, and Channel Estimation

Course Organization

The course consists of two lectures per week and a single laboratory session. The lecture will cover the theory of wireless communication to prepare you for implementation in the lab. Lectures will be supplemented by homework assignments every couple weeks, consisting of a few problems to test what you learned in class. The laboratory sessions will consist of two parts: a prelab that you conduct at home before the lab begins and the lab itself. Doing the prelab ahead of time is very important and is mandatory for your participation in the lab. After the labs you will summarize your lab findings in lab reports.

Technical Area Fulfillment (EE 471C)

This course counts as a technical area elective for the Communications / Networking technical area and the Signal / Image Processing technical area. Consult your academic advisor to see if it can count as a technical elective in other areas.

Course Policies

Prelabs – Every lab session will have a prelab that is due at 7pm on Blackboard. The prelab includes a mixture of problems and programming to prepare you for that week's experiment. You may work on the prelab with your lab partner but not with other students but all work must be your own. You may not participate in the lab without a prelab. Copying another student's prelab is considered cheating and the appropriate action will be taken. Prelabs, homeworks, tests, and solutions from previous offerings of this course or offerings of related courses on the Internet are off limits. Use of these materials will be considered cheating and appropriate action according to the Academic Dishonesty Policy listed below will be taken.

Due dates and late policy – All prelab assignments will be due at 7pm in on Tuesday in Blackboard. No late prelabs will be accepted, as you need to be prepared for the lab. All homework assignments will be due at 5pm on Thursday in the box outside Prof. Heath's office. Homework received after 5:05pm will count for 50% of the grade you receive until 5:00pm on Friday when it will be 0. Lab reports are due in your lab section the week they are due. Electronic submissions via email are also acceptable.

Exams - There will be two midterm exams and a final exam based on topics covered in the lecture and the lab.

Participation – Attendance in the laboratory session is mandatory. Attendance in the lecture is at your discretion but highly encouraged. There will be surveys on some assignments. Completion of occasional anonymous surveys through blackboard is mandatory.

Questions and discussion in class are encouraged. Participation will be noted. Please raise your hand if you would like to respond to a question.

Evaluations - Course and instructor evaluations will tentatively occur the third week of November.

Messaging - Receiving and placing cellular calls during class is prohibited. Interactive text messaging, checking email, etc. is distracting and discouraged.

Grading – Note that this course is cross-listed as both an undergraduate and a graduate course. The graduate course requires a different project. Graduate and undergraduate students are graded <u>differently</u> to maintain fairness according to the schedule below.

Grading EE 471C Undergraduate Course

- 10% Homework
- 50% Lab
    - 30% Lab experiments
    - 10% Pre-labs and participation
    - 10% Lab Reports
- 10% Each midterm exam
- 20% Final exam

Grading EE 381V Graduate Course

- 10% Homework
- 30% Lab
    - 20% Lab experiments
    - 5% Pre-labs and participation
    - 5% Lab Reports
- 10% Each midterm exam
- 20% Final exam
- 20% Final project

Academic Dishonesty

Faculty in the ECE Department are committed to detecting and responding to all instances of scholastic dishonesty and will pursue cases of scholastic dishonesty in accordance with university policy. Scholastic dishonesty, in all its forms, is a blight on our entire academic community. All parties in our community - faculty, staff, and students - are responsible for creating an environment that educates outstanding engineers, and this goal entails excellence in technical skills, self-giving citizenry, and ethical integrity. Industry wants engineers who are competent and fully trustworthy, and both qualities must be developed day by day throughout an entire lifetime. Scholastic dishonesty includes, but is not limited to, cheating, plagiarism,

copying, collusion, falsifying academic records, or any act designed to give an unfair academic advantage to the student. The fact that you are in this class as an engineering student is testament to your abilities. Penalties for scholastic dishonesty are severe and can include, but are not limited to, a written reprimand, a zero on the assignment/exam, re-taking the exam in question, an F in the course, or expulsion from the University. Don't jeopardize your career by an act of scholastic dishonesty. Details about academic integrity and what constitutes scholastic dishonesty can be found at the website for the UT Dean of Students Office and the General Information Catalog, Section 11-802.
Note: Copying in any form is considered cheating, whether from another student or the solution manual.

Documented Disability Statement for Syllabus

Students with disabilities may request appropriate academic accommodations from the Division of Diversity and Community Engagement, Services for Students with Disabilities, 471-6259, *http://www.utexas.edu/diversity/ddce/ssd/*

Note about Feedback

Feedback is an important part of any kind of learning. Without feedback on how well you understand the material, it is more difficult for you to make significant progress. During this course you will give me feedback on your learning in informal and formal ways, such as assignments or exams. I want you to let me know when something we discuss is not clear. This kind of communication will enable me to provide additional information when needed or to explain a concept in different terms.

In addition to feedback on your learning, I will ask for feedback from you about how my teaching strategies are helping or hindering your learning. This kind of feedback is very important to me as I continually strive to be the best teacher I can be. Some of this feedback will be gathered from online anonymous surveys. I encourage you to respond to these surveys so that together we can create an effective teaching and learning environment.

Religious Holidays

By UT Austin policy, you must notify me of your pending absence at least fourteen days prior to the date of observance of a religious holy day. If you must miss a class, an examination, a work assignment, or a project in order to observe a religious holy day, you will be given an opportunity to complete the missed work within a reasonable time after the absence.