ECE 430/630 and CS 429/629: Software Defined Radio Laboratory - 3cr
Course Syllabus

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Office Hours
By appointment only.
All communication should be via email. Please use your Drexel email address.

Course Meetings
Mondays 2-5 PM, In person (3101 Market, room 223) and Zoom remote synchronous

Course Description
This laboratory course takes a Software-Defined Radio (SDR) implementation approach to learn about modern analog and digital communication systems. Software defined radio uses general purpose radio hardware that can be programmed in software to implement different communication standards. We will begin by discussing the basic principles of wireless radio frequency transmissions and leverage this knowledge to build analog and digital communication systems. Knowledge of these techniques and systems will provide a platform that can be used in the class project for further exploration of wireless networking topics such as cybersecurity, cognitive radio, smart cities, and the Internet of Things. Some topics that will be covered are:

- Wireless radio frequency communication fundamentals
- Introduction to Software Defined Radio
- Analog communication: Amplitude modulation (AM), Frequency modulation (FM)
- Digital communication: binary phase shift keying (BPSK), quadrature amplitude modulation (QAM)
- Wireless networking physical layers (PHY) using Orthogonal Frequency Division Multiplexing
- Wireless networking medium access control (MAC) layer, Link layer, and Network layer
- Wireless jamming

Pre-requisites
This class is meant for junior/senior undergraduates and graduate level students in electrical and computer engineering and computer science. While there are no formal coursework requirements given the intended diversity of students and use of team based assignments and projects, successful completion of the class will require the development and application of a basic understanding of time and frequency domain concepts, signal processing, as well as python and C++ programming in a Linux environment.

Course Policies
This course meets for 3 hours every week at the time and location mentioned above. It is strongly suggested that students do not miss class without an excuse (e.g. sickness). These 3 hours will be split into lecture and lab components. The lecture component will take place during the first 30-40 minutes. The rest of the meeting time is reserved for the lab component of this course. During the lecture component and through out-of-class pre-lab assignments,
students will be introduced to the concepts they would need to understand and complete the lab. The lab component of this course is where students will have a chance to have hands-on-experience with the software and the hardware. Students will be provided Ubuntu environment for completing labs and should be comfortable with Linux, Python/C++, MATLAB/Simulink or be prepared to learn these tools. All hardware components (antennas, radio boards, USRPs) will be provided during the lab and on a time-share basis beyond lab hours for projects and homework. Refer to the schedule below for detailed description of labs and topics.

The course website will be run through BBLearn, where all related content will be posted. Any homework or project submission will be done using BBLearn also. It is highly recommended that students check this website regularly to not miss any important announcements or assignments.

By the end of the course, students will be proficient in:
- Understanding how SDRs work
- Making changes to hardware design of SDRs and modifying the host-side software
- Transmitting and receiving wireless signals using SDRs
- Wireless networking physical layer techniques
- Wireless networking MAC, link, and network layer techniques

This course aligns with the below Drexel Student Learning Priorities (DSLP):
- Self-directed Learning
- Technology Use
- Creative and Critical Thinking
- Research, Scholarship, and Creative Expression

Textbook

There is no required textbook. The course will be leveraging published papers, online resources, and technical manuals as references. Students may refer to these textbooks as references:
- “Modern Digital and Analog Communications” (ISBN: 978-0195331455)

Grading

Final grades for this course will be based on timely completion of lab work. Labs will be graded based on the timely completion of checkpoints in assignments as well as a short lab report on each completed lab. A final project will be released towards the end of the term and will replace the final exam. The project will involve leveraging technical papers and online resources to conduct a laboratory project relevant to the topics in the class. The final grade breakdown is shown below.

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Lab</td>
<td>50%</td>
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<tr>
<td>Reports</td>
<td>20%</td>
</tr>
<tr>
<td>Final Project</td>
<td>30%</td>
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</tbody>
</table>

Final letter grades will be assigned based on the following grading matrix. There may or may not be a curve in determining these final grades. This will be determined based on overall student performance.
<table>
<thead>
<tr>
<th>Date</th>
<th>Week</th>
<th>Lectures</th>
<th>Labs</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/27</td>
<td>1</td>
<td>Lecture 1; Project description</td>
<td>Lab 1 – SDR Intro</td>
</tr>
<tr>
<td>6/27</td>
<td></td>
<td>Course drop deadline</td>
<td></td>
</tr>
<tr>
<td>7/4</td>
<td>2</td>
<td>Lecture 2; Analog</td>
<td>Lab 2 – Analog Communications (AM/FM)</td>
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</tbody>
</table>

**Academic Integrity**

Don’t cheat. Drexel’s policy on academic dishonesty, which applies to this course, may be read at [http://www.drexel.edu/provost/policies/academic_dishonesty.asp](http://www.drexel.edu/provost/policies/academic_dishonesty.asp). All incidents of cheating will be reported using official methods. For the purposes of this course, examples of cheating are (but not limited to) copying code from someone else, sharing solutions during quizzes. The penalty for academic dishonesty in this course is at the discretion of the instructor and may include warnings to the student, along with loss of points or failing grade in the course. In certain cases, students might be expelled from the University.

**Student Resources**

Students are encouraged to read the University policies on academic integrity, plagiarism, cheating, course drop, and course withdrawal. These can be found at:

- [http://www.drexel.edu/provost/policies](http://www.drexel.edu/provost/policies)
- [http://www.drexel.edu/provost/policies/course_drop.asp](http://www.drexel.edu/provost/policies/course_drop.asp)
- [https://drexel.edu/provost/policies/course-withdrawal/](https://drexel.edu/provost/policies/course-withdrawal/)

**Accommodations**

Student with disabilities requesting accommodations and services at Drexel University need to present a current Accommodation Verification Letter (AVL) to faculty before accommodations can be made. AVL’s are issued by the Office of Disability Resources (ODR). For additional information, contact ODR at [www.drexel.edu/odr](http://www.drexel.edu/odr), James E. Marks Intercultural Center, 3225 Arch St, Street, Suite 011, Philadelphia, PA 19104, 215.895.1401 (V), or 215.895.2299 (TTY).

**Course Calendar**

The course runs over 10 weeks of meetings and an additional week to allow for final project completion, totaling up to 11 weeks. A detailed schedule is show in the table below. For lab topic details, refer to the next section.
Remote asynchronous only)

<table>
<thead>
<tr>
<th>Date</th>
<th>No.</th>
<th>Lab Details</th>
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<tbody>
<tr>
<td>7/11</td>
<td>3</td>
<td>Lecture 3 – DragonRadio PHY and MAC</td>
</tr>
<tr>
<td>7/18</td>
<td>4</td>
<td>Radio Wars Episode I</td>
</tr>
<tr>
<td>7/25</td>
<td>5</td>
<td>Lecture 4</td>
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<tr>
<td>8/1</td>
<td>6</td>
<td>Lecture 5</td>
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<tr>
<td>8/8</td>
<td>7</td>
<td>Radio Wars Episode II</td>
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<tr>
<td>8/8</td>
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<td>Course withdraw deadline</td>
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<tr>
<td>8/15</td>
<td>8</td>
<td>Lecture 6</td>
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<tr>
<td>8/22</td>
<td>9</td>
<td>Radio Wars Episode III</td>
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<tr>
<td>8/29</td>
<td>10</td>
<td>Radio Wars Episode III</td>
</tr>
<tr>
<td>8/29</td>
<td></td>
<td>Last day of classes</td>
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<tr>
<td>8/15</td>
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<td>Final Project Report</td>
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Lab Details

Labs:

**Lab #1: Introduction to Software Defined Radio**: In this lab, students will create accounts on the Drexel Grid SDR Testbed, learn the fundamentals of Linux containers and how to access the software defined radios. The lab will culminate in students using their accounts to create a radio frequency tone on one radio and receiving the tone and observing its signal spectrum at a receiver.

**Lab #2: Analog Communications**: In this lab, students will first learn the fundamentals of analog communication and experimentally demonstrate amplitude modulation and frequency modulation signal transmission and reception using software defined radios programmed with GNU Radio Companion (GRC) flowgraphs. While the signals used in the lab experiments will not be standards compliant with commercial AM and FM radios, the system developed by the students could be extended to receive signals these standards.

**Lab #3: Introduction to DragonRadio: PHY and MAC**: In this lab, students will explore DragonRadio, a sophisticated SDR platform built at Drexel, starting with its physical (PHY) layers. They will tune parameters of the OFDM PHY and write a simple TDMA scheduler and then use DragonRadio’s introspection capabilities to explore how these changes affect radio performance.
Lab #4: Digital Communication: In this lab, students will use gnuradio companion flowgraphs to demonstrate digital communication techniques. Specifically, they will prototype binary phase shift keying (BPSK) and Quadrature Amplitude Modulation (QAM). They will also demonstrate an OFDM radio transmitter and receiver using gnuradio companion flowgraphs. OFDM is central to many modern wireless standards. They will also learn about wireless channel estimation techniques.

Lab #5: DragonRadio: MAC and Frequency Hopping: In this lab, students will develop a frequency-hopping MAC. They will also make use of a jammer, a radio that attempts to interfere with other radios’ transmissions, and use their MAC to evade the jammer.

Lab #6: DragonRadio: The Link Layer: In this lab, students will work with the link layer of DragonRadio and learn about Automatic Repeat-reQuest (ARQ) and Adaptive Coding and Modulation (ACM), both mechanisms for optimizing throughput in the presence of packet transmission errors. Students will modify the ACM mechanism to use different packet metrics to control the modulation and coding scheme and measurement the performance impacts of their choices.

By the end of these sets of labs, students will be familiar with the basics of SDR programming and be able to use these radios to prototype communication systems that are analogous to those used in commercial analog and digital communication standards. They will also be equipped to extend these radio designs to consider modern research topics in wireless communications and networks, cognitive radios, cybersecurity, and the Internet of Things.

Final Project

The final project will consist of a series of “Radio Wars” competitions that will be completed in teams of two.

In the first competition entitled “Radio Drag Race”, students will modify parameters of the DragonRadio physical layer in a competition to transfer data in file faster than their peers in a single link network. Students will need to report on the modifications that they made to the radio, the differences in performance that various design options achieved, and the results of their timed trials.

In the second competition entitled “Radio Jamming” students will repeat the “Radio Drag Race” competition in a single link network in the presence of a TA/instructor driven jammer of known and pre-shared operating characteristics. Students can modify the radio in real time using the DragonRadio interactive mode interface and will again report on the modifications they made to the radio, the differences in performance that various design options achieved, and the results of their timed trials.

In the third and final competition “Collaborative Intelligent Radio Network”, student teams will each operate the radios to maximize the transfer of data concurrently in a multi-link network that must adapt both to the transmissions of other teams’ signals but also to the presence of jammers of unknown location and capability. Student teams can collaborate with one another verbally using the interactive mode of DragonRadio and a version of the “Collaboration intelligent radio network” (CIRN) language developed for the DARPA Spectrum Collaboration challenge. A final report will document the performance of the team radio and performance during the competition.

A write-up on the project will be due on the last day of classes in the term.