ECE 448: Applications of SDRs

Spring 2025

Course description

Have you ever thought about the sheer number of wireless signals surrounding you in the modern world? From cell phones to WiFi to bluetooth - wireless communications enable just about everything you do! In this course, we will take a look at these signals – how they're generated, transmsitted, and received! ECE 447 Communications Theory covers many of the fundamental principles of many methods of communication. This course will focus on the applied aspects wireless communications, specifically using Software Defined Radios (SDRs). This course will introduce SDRs, familiarize the student with the benefits and limitations of various SDRs and the various software packages used to interact with them.

Instructor

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Course Goals

Cadets enrolled in the course shall develop the ability to interact with SDRs, select the best SDR and software package for a certain application, and develop software to transmit/receive wireless signals. Cadets will also:

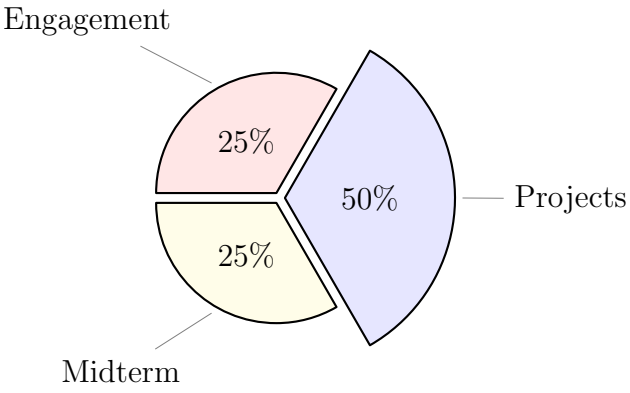
Course Objectives

- Make use of modern software applications to simulate, receive, and transmit signals using modern modulation and encoding techniques.
- Describe the principles of basic signal processing techniques, such as filtering, interpolation, decimation, and matched filtering.
- Implement basic signal processing techniques, such as filtering, interpolation, decimation, and matched filtering in the presence of noise and other non-idealities.

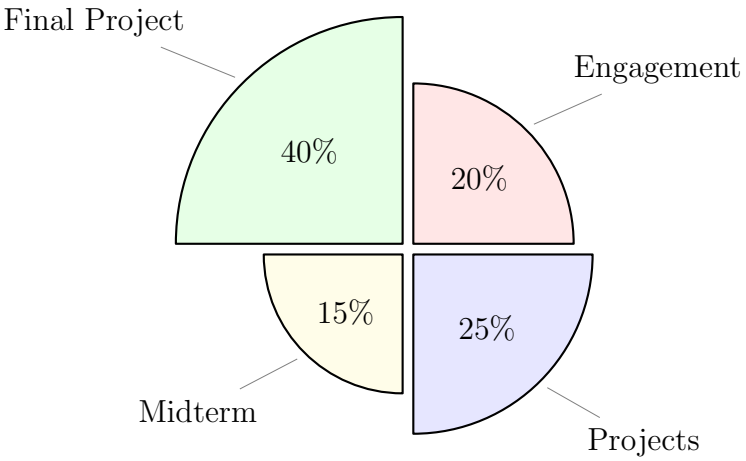
Course Prerequistes by Topic

- **ECE 215/315:** Modulation and demodulation techniques for analog and digital systems.
- **CompSci 206/210/211/212:** Basic programming skills.

Prog Grade Weighting



Final Grade Weighting



Engagement credit will be earned through weekly quizzes on Gradescope, EI, and by instructor prerogative (IP). IP credit will be assigned by my subjective assessment of your level of engagement.

Projects will be assigned for each signal type, and will culminate in a formal final report.

Midterm is an individual effort and will consist of an in-class portion and a practical portion completed outside of class.

Final Project: you will research, design, and implement a wireless communication project. You will produce an IEEE-quality paper as your final report and present your work to the class.

Grade Scale

F	D	C-	C	C+	B-	B	B+	A-	A
$\leq 60\%$	70%	73%	77%	70%	83%	87%	90%	93%	100%

Deliverables

1. **General Submission Standards**
   - All work will be available through Teams, the course website, or Gradescope.
   - All submissions must be complete, error-free, and neatly organized.
   - Work should be organized using the **Known/Given, Find, Solution, Answer** method.
   - Answers should be clearly indicated by a box.
   - Use engineering notation with proper units.
   - Work will be submitted on Gradescope, unless directed otherwise by your instructor. Scans/uploads must be of excellent quality, neat, and legible.
   - In general, I am looking for *understanding of concepts* - you may indicate this through combined use of equations, explanations, diagrams, plots, etc.
   - Guessing will not earn partial credit.
   - Blank submissions and submissions with a clear lack of effort will automatically earn a zero, with no opportunity for revision/retake.
2. **Report Quality** In this course, you will produce many technical reports. This is an opportunity to develop your technical writing skills. The following guidance will help you develop those skills.
   - Avoid passive voice – use active voice and take credit for your work!
   - Avoid overly colloquial language, but also avoid overly formal language. Good technical writing strikes a balance between the formal and informal.
   - Wordiness does not equate to completeness. Say what you mean, concisely.
   - Don't be "that" person – eliminate unnecessary words such as "that" and "the" as much as possible.
   - Use the correct words when describing processes or systems.
   - When using technical jargon, clearly define terms at least once.
   - Be specific in your language; I should not have to guess or infer meaning when reading your report.
   - Reread and revise your work; even better – ask a peer to review your work and provide corrections/suggestions.
   - Formatting matters – your report format should aid the reader, not hinder them. Do not overuse indents (Microsoft Word loves to do this), use bold and italics sparingly, and justify your paragraphs.

3. **Midterm Grading Specifications**

   In general, work will receive one of the following scores. Note, specifications may be tailored to specific assignments.

   - 1: Problem answer meets or exceeds expectations of the assignment. Understanding of concepts is evident. There are no nontrivial errors. Communication (i.e. description of methodology) is clear and complete.
   - 0.5: Partial understanding of concepts is evident but significant gaps remain. Improved communication (i.e. description of methodology) and/or significant revisions are needed.
   - 0: No work provided or minimal effort on the problem.

4. **Engagement Credit** (EC) will be graded out of a total amount available (number TBD) and is earned in several ways:
   - Weekly quizzes will be offered on Gradescope. Each quiz will be worth 1 EC. Revisions will be allowed.
   - You will earn 1 EC for each EI session you schedule and attend.
   - Reviewing/revising a colleague's report/deliverable will earn 1 EC.
   - For EI and peer revision, you **must** request your EC through the running Gradescope assignment. If you do not request EC in a timely manner or do not provide sufficient evidence, the EC may not be granted.

5. Each **Project Report** will clearly articulate your accomplishments in the course of each project. There is no page limit, but one page is typically not enough to completely describe your work. Reports should follow guidance on

6. Your **Final Project** is an extensive part of the final grade – it should be treated as such. You **WILL NOT** succeed in this project without sustained, consistent effort over the semester. The final project is self-scoped and culminates in a IEEE-quality report and presentation/demonstration of your communication system.

   Checkpoints for each part of the project are identified in the course schedule. Each checkpoint will be graded on a binary scale (0 or 1), with revisions accepted according to course policy. The goal of each checkpoint is to develop a section of your final report, and to indicate you are making progress towards your final goal.

   - You must first submit a **project proposal**, which will identify *what* you want to build, *why* you believe it is meaningful and feasible, and clearly identify your endstate for A-, B-, and C- level submissions.
   - The **Background Research** will include a survey of previous work upon which you will base your project. You must include at least 4 high quality sources and discuss its relationship to your project.

- Your **Design Description** describes your initial design, including critical components and their functions, use cases, test plan, and any progress made.
- The **Prototype Description** will capture results of your design build and test, along with your plan for completion of the project.
- The **final project submission** consists of a IEEE-quality report and a 5-minute project presentation/demonstration. No page requirement is given for the final report, but typical reports are at least 7-10 pages, including diagrams, photos, tables, etc. as necessary. The final report should completely document every aspect of the project development. Any code should be published to a github repository.

7. **Final Project Presentation** Must be engaging and descriptive, capturing the story of your project, including information from your checkpoints and lessons learned.

Instructor Philosophy

You have chosen one of the most difficult majors at USAFA - I applaud your commitment! My role in your journey is to enable your success. My intent is to do this by creating an inclusive environment and putting in the work *with* you. If you work hard and communicate with me, I will do everything in our power to make sure you succeed. Have questions? Ask – I genuinely believe there's no such thing as a stupid question. Have concerns, especially about your learning environment? Let's talk. You face many challenges here at USAFA; I am in your corner – so let's go!

1. **Absences**
   In the event of an absence, communicate with me **beforehand.** If a cadet will miss any graded event due to a scheduled absence such as an SCA, sport team trip, or scheduled medical procedure, a makeup plan should be in place **before** the absence occurs. In the even of bedrest, please notify me **via email** ASAP after receiving approval.
2. **Academic Honor**
   Your honor is extremely important. The course's academic security policies are designed to help you succeed in meeting academic requirements while practicing the honorable behavior our country rightfully demands of its military. Do not compromise your integrity by violating academic security or by taking unfair advantage of your classmates.
3. **Assignment Availability**
   All work will be available through Teams, the course website, and/or Gradescope. A 24-hour grace period is generally observed, after which 25% of available points will be deducted for each calendar day (the first calendar day being anywhere from one minute, to 24 hours after the assignment is due) the graded assignment is late. I may waive part or all of this penalty for legitimate, pre-coordinated (if possible) extenuating circumstances.
4. **Authorized Resources**
   If applicable to this course, GRs and the Final Exam are individual effort. No collaboration is allowed while taking these exam. Although electronic devices may be authorized for viewing reference materials, use of internet, Teams, and generative AI tools is **not** allowed during GRs and final exams.
5. **Collaboration**
   Collaboration (not copying) on practice problems and assessments is highly encouraged, unless your instructor provides direction otherwise. A good litmus test to distinguish between copying and collaboration is as follows: students must be able to explain every step indicated on their submitted work to be considered collaboration and not copying. All help received on work submitted for grading must be documented in accordance with the course documentation policy.

6. **Documentation**
   In accordance with the Dean's policy for documentation, all ECE assignments must have a documentation statement. For group projects, you are not required to document collaboration within your own team, as such collaboration is expected and authorized. The documentation statement should be clearly identified with the word "Documentation." If you did not collaborate, then the statement "Documentation: None," is appropriate. Assignments without a documentation statement are incomplete and may be returned to the student for completion. The assignment will then be assessed the appropriate penalty according to the late work policy. Your instructor may assess a 1-day-late penalty (up to 25%) in lieu of returning the assignment. In this case, a documentation statement must still be received, before the grade can be posted.

7. **Extra Instruction**
   EI is one of the best and easiest ways to succeed in this class; EI is recommended early and often. Walk-in EI is not generally available, so please book with me at the following link:

8. **Generative AI**
   Your instructors are pro-AI; however, we expect you to use generative AI platforms (ChatGPT, etc) as a tool rather than to complete your assignments for you. It will become clear to us quickly if you are using AI irresponsibly: ChatGPT often generates incorrect solutions to the challenging mathematical problems given in this course and many times offers methods of completing the problems that do not align with your specific course objectives. If you utilize generative AI on any assignment, include a documentation statement as outlined in the Documentation Policy.

Lesson	Topics	Notes
1	Course Overview & Introduction	
2	Noise Figure & Link Budget	
3	Signal Space	
4	PAM Theory	
5	ASCII/PAM	**PAM Project Due**
6	ASCII/PAM	
7	ASCII/PAM	
8	GRC: OOT Modules	
9	GRC: Custom Blocks	**Theory Project Due**
10	GRC: Custom Blocks	
11	CW	
12	CW	**Custom Block Project due**
13	CW	
14	DTMF	
15	DTMF	**CW Project Due**
16	Flex Day	**Final Project Intro**
17	FHSS - Tx	
18	FHSS - Rx	**DTMF Project Due**
19	Midterm (in-class portion)	
20	Flex day	

Lesson	Topics	Notes
22	RF Reverse Engineering	**Final Project Proposal due**
23	RF Reverse Engineering	
24	RF Reverse Engineering	
25	Flex day	**RF RE Project Due**
26	ADS-B	
27	Project Work Day	**Background Research due**
28	ADS-B	
29	ADS-B	
30	AIS	
31	AIS	**Design Description due**
32	WBFM Radio	**ADS-B/AIS Project**
33	HD Radio	
34	HD Radio	
35	Project Work Day	**Prototype Description due**
36	QAM	
37	QAM /OFDM	
38	QAM /OFDM	
39	Project Day	
40	Final Project Presentations	**Final Project due**