# ASEN 5245 – Radar and Remote Sensing Syllabus, Spring 2025

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| Class Lectures: | Tuesdays and Thursdays, 10-11:15am, AERO N240 |
| Office Hours: | Thursday, 11:20am-12:20pm, in-person<br>Zoom: (by appointment) |
| Web page: | Canvas (https://canvas.colorado.edu) |
| Instructor:<br>Email: | Sean T. Peters<br>sean.peters@colorado.edu |
| Teaching Assistant:<br>Email:<br>TA Office Hours: | Anna Casillas<br>anna.casillas@colorado.edu<br>In-person: Tuesday, 12:30pm-1:30pm<br>Zoom: Wednesday 12:30-1:30pm |

## *Course Outline*

The applications of radar are endless: from the detection of targets (such as aircraft) to the estimation of target parameters, electrical properties, wind speed, temperature, and rainfall, to the sensing of space for navigation. The purpose of this class is to provide you with a fundamental understanding of how radar systems operate, their necessary components, and how they are used for remote sensing in aerospace and environmental applications. This course will introduce radar systems using three interconnected perspectives: theory, analysis, and synthesis. The theory portion will consist of lectures covering the mathematical basis and foundation of radar systems. This perspective is the dissemination and acquisition of fundamental radar knowledge needed for a professional to understand the operation of radar systems. The analysis portion will consist of processing and interpreting real radar observations from ground-based, airborne, and space-borne platforms. This perspective applies acquired theoretical knowledge to solve real-life atmospheric science problems. Finally, the synthesis portion will consist of simulating key attributes of radar systems to solidify the understanding between radar theory and application.

## *Course Objectives*

This course will introduce radar systems from a combined theoretical and applied perspective. Students will develop a quantitative understanding of radar system design and radar signal analysis and apply these principles to specific applications in environmental remote sensing via a final project.

The subject of radars is extremely broad, and a wide range of topics will be treated in this course. It is unlikely that any student will be prepared for all topics, but the particular expertise of individual students will be cultivated through a semester project on a particular radar application. The course is intended for any graduate student with a solid background in mathematics, familiarity with electromagnetic (E&M) waves and wave propagation, and a background in undergraduate signal analysis.

By the end of the semester, you will have a good understanding of how a radar system works and their application to environmental remote sensing. This course does not focus on building nor constructing radars; however, students will learn how radar systems can be used to observe the environment and how physically useful information is extracted from such systems.

### *Prerequisites*

The prerequisites for this class include a basic understanding of electromagnetic waves (Physics II), linear system theory including Fourier analysis and some basic understanding of statistics and/or probability. These are all topics that are typically covered in an undergraduate engineering curriculum. Some topics such as electromagnetic waves are covered in more detail by the electrical engineering curriculum however only a basic sophomore Physics II level understanding of the topic is expected for this course.

A working knowledge of MATLAB will be needed as functions written in MATLAB will be provided and homework assignments and projects may require code development in MATLAB. Some problems will require coding skills in a script-type programming language such as MATLAB or Python. If you do not have a background in one these areas, you should expect to spend some extra time on the specific material.

There are many resources, including the library, at your disposal. If you have questions regarding your preparation for the class, you should contact the instructor. Additionally, because radar is a broad topic, it is not unexpected that students may need to do some additional work in specific topical areas to provide a firm base in the fundamentals.

### *Course Content*

The course is divided into several sections, which consist of the following topics:

**Radar fundamentals**
Radar basics; pulsed radar; target ranging; range ambiguity; pulse-to-pulse motion; signal, noise and loss; target detection; receiver components and processing; Doppler radar; Doppler velocity ambiguity

**Radar sensitivity**
Radar power equation: derivation and application for point targets, area targets, and volume targets; radar power losses; radio and receiver noise

**Radar Antenna**
Directivity; gain; illumination; antenna patterns; aperture antennas; phased array antennas

**Scattering Processes**
Radar cross section; Rayleigh; Mie; geometric; Bragg; rough surfaces; polarization, propagation

**Radar Signals**
Transmitter/signal generating characteristics; pulsed waveform; continuous waveform; pulse modulation and compression; complex signals including I and Q signals; digital filtering; Doppler spectrum

**Remote Sensing Applications**
Tracking radars; scanning weather radar; meterological radars, vertically pointing cloud and precipitation radar; airborne radars; space borne radars (e.g., TRMM, GPM, and CloudSat); synthetic aperture radar (SAR); Multiple-input-multiple-output (MIMO) radar

### *Class Web Page – Canvas*

All class communications, including outgoing assignments, incoming submissions, recorded lectures and classes, class announcements, and discussions, will be conducted through the class web page posted on the University of Colorado Canvas service. Access to this web page will be made available to you via your registration confirmation. Also, all email communication will be using @colorado.edu addresses.

Access to the class Canvas web page will expire 2 weeks after the last day of class. Be prepared and download material throughout the semester so that you have a copy of class material after the semester ends.

### *Textbook*

A free online book Principles of Modern Radar, Volume I - Basic Principles by Richards, Scheer, and Holm is available via www.knovel.com. You can access it for free using your UCB VPN. To get the VPN working for your account, please, see https://oit.colorado.edu/

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| Title: | **Principles of Modern Radar, Volume I - Basic Principles** |
| Author(s) / Editor(s): | Richards, Mark A.; Scheer, James A.; Holm, William A. |
| Publisher: | SciTech Publishing |
| Copyright Date: | 2010 with updates in 2015 |
| ISBN: | 978-1-891121-52-4 |
| Electronic ISBN: | 978-1-61344-155-8 |
| Online: | www.Knovel.com |

**To access the textbook on Knovel**:

- Go to this CU site: https://libguides.colorado.edu/strategies/ebooks
- Under "Recommended" click the tab for "Sciences".
- Click on "Knovel Library". You may be able to skip the above steps and go straight to this link: https://app-knovel-com.colorado.idm.oclc.org/kn
- You should now see "This Knovel subscription provided by University of Colorado at Boulder" in the upper right of the page, and you can search for and access the textbook (Principles of Modern Radar, Volume I - Basic Principles).

**You can also access the textbook through the IET Digital Library**: https://digital-library.theiet.org/content/books/ra/sbra021e

Principles of Modern Radar (POMR) is a required text, but it is not required that you purchase your copy as an electronic version is available online through an agreement between the University of Colorado and www.knovel.com. Furthermore, class notes and shared lecture recordings cover all the necessary materials you need to succeed in this class. To access the text, you need to access the Knovel web site while your computer has a CU network address. There are two ways for your computer to get a CU network address. Either be physically on campus connected to the internet via the campus's network, or use the CU VPN (Virtual Private Network) to access the CU network. To get VPN on your computer, see https://oit.colorado.edu/. You will need your CU username and identikey password to install the software and every time you login to the VPN. Once connected to the CU network via the VPN, browse to the Knovel website: www.knovel.com and search for 'Principles of Modern Radar'. You will see three volumes of this text. We will use volume 1. You can use the book online, or download individual chapters.

Depending on your specific background, you may wish to draw from other supplementary material to provide more clarity or depth to a topic. One complication of supplying supplemental material is that the notation may change; feel free to reach out if you have a question regarding the changes in notation used in different books. Many books on radar fundamentals are available through the Engineering Library and through www.knovel.com. Some good references include:

- Introduction to Radar Analysis, 2nd Edition, by Majafza
- Introduction to Airborne Radar, 2nd edition, by Stimson
- Radar Principles, by Peyton Z. Peebles, Jr.
- Radar System Principles, by Harold R. Raemer
- Radar Handbook, by Skolink
- Introduction to Radar Systems, by Skolink
- Tools of Radio Astronomy, by Rohlfs and Wilson
- Modern Radar System Analysis, by Marton
- Radio Techniques for Probing the Terrestrial Ionosphere, by Hunsucker
- Fundamentals of Applied Electromagnetics, by Fawwaz T. Ulaby
- Elements of Engineering Electromagnetics, 6th edition, by Rao
- Antenna Theory – Analysis and Design, 3rd edition, by Constantine A Balanis (2005)

Several radar books are available online through an agreement between the University of Colorado and www.knovel.com.

## *Course Grading*

35% Quizzes*

Six (6) quizzes will be given in Canvas during the semester, approximately 1 quiz every 2-3 weeks. The five (5) highest quiz scores will be used to determine your grade. The dropping of one quiz score is to provide built in flexibility for accommodations during the semester.

30% Final Paper

Individual projects about one radar topic or application. Students will prepare a final report in a form of an IEEE conference/letters paper (4 pages). Project instructions and template will be provided in detail separately on Canvas.

20% Labs

Six (6) labs will be given during the semester, approximately 1 lab every 2-3 weeks. The five (5) highest lab scores will be used to determine your grade. The dropping of one lab score is to provide built in flexibility for accommodations during the semester. The labs require using MATLAB code / GUI demos. All lab assignments will be submitted in Canvas and will be penalized 10% for each day late. Each student is permitted to submit a total of two lab assignments up to 3 days late with No Questions Asked. The goal of the labs is to help you to learn how to synthesize the basic concepts, methods, and tools presented in the course curriculum.

15% Homework

Homework will be assigned every other week. Each student needs to submit the homework assignments individually. Homework will be graded for completeness only; solutions for all homework problems will be posted online after the deadline. The homework will prepare PhD students for the preliminary exam. We can discuss any homework problems during office hours. All homework assignments will be penalized 10% for each day late. Each student is permitted to submit a total of 2 homework assignments up to 3 days late with No Questions Asked.

100% Total

**Quizzes will be open book, open note, but time limited. You will have several days to start a quiz, but you will have a finite amount of time to complete it. Quizzes won't be posted during your spring break, and your last one will be one week before the end of the semester ensuring you have enough time to prepare for other finals.*

## *Quiz Format and Planned Due Dates*

Quizzes will be administered through Canvas. A quiz will be available on Canvas on Friday and will be due by 11:59 pm the following Thursday. Once you start the quiz, you will have 1 hour and 15 minutes to complete the quiz. All quizzes will require an uploaded file to be submitted to Canvas. Your work can either be hand drawn using pen or pencil on paper, scanned, and then uploaded to Canvas. Or, your work can be done electronically and then uploaded to Canvas. The quizzes will require the sketching of diagrams and writing of equations. An hour and 15 minutes is allocated to take the quiz and 15 minutes is allocated to upload scanned files to Canvas.

**Planned Quiz tentative dates:**

| Quiz # | Date Available | Due Date | Material "In Play" |
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| 1 | Friday, 24-Jan | Thursday, 30-Jan | Weeks 01-02 |
| 2 | Friday, 07-Feb | Thursday, 13-Feb | Weeks 01-04 |
| 3 | Friday, 21-Feb | Thursday, 27-Feb | Weeks 01-06 |
| 4 | Friday, 14-Mar | Thursday, 20-Mar | Weeks 01-09 |
| 5 | Friday, 11-Apr | Thursday, 17-Apr | Weeks 01-12 |
| 6 | Friday, 25-Apr | Thursday, 1-May | Weeks 01-14 |

## University & Aerospace Engineering Sciences Policies: Spring 2025

### *Honor Code*

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the Honor Code may include but are not limited to: plagiarism (including use of paper writing services or technology [such as essay bots]), cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. Understanding the course's syllabus is a vital part in adhering to the Honor Code.
All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution: StudentConduct@colorado.edu. Students found responsible for violating the Honor Code will be assigned resolution outcomes from the Student Conduct & Conflict Resolution as well as be subject to academic sanctions from the faculty member. Visit Honor Code for more information on the academic integrity policy.

### *Acceptable Use of AI in this Class*

You may use gen AI tools only on homework and lab assignments in this course. Gen AI use is permitted for the purpose of (1) grammar checks but not for rewriting sections of the assignment, (2) generating ideas or outlines but the final work must be student-generated, and (3) summarizing or synthesizing concepts, with proper critical evaluation and original analysis as outlined for each individual homework and lab assignment. If you use gen AI tools on assignments in this class, document your usage with clear attribution and explanation of AI's role in the completion of the assignment, and with the Chicago Manual of Style or appropriate citation guidelines for this course. You may NOT use gen AI tools on any quizzes in this course.

### *Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation*

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671

or DSinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

If you have a temporary illness, injury or required medical isolation for which you require adjustment**,** please notify the instructor as soon as possible so that appropriate accommodations can be made. Because of FERPA student privacy laws, you are not required to state the nature of your illness when alerting me nor provide a "doctor's notes" for classes missed due to illness.

### *Department of Aerospace Accommodations Policy and Procedure*

Students should expect to receive accommodations for a timed assessment (e.g., exam) only if their faculty instructor(s) receive the student's accommodations letter at least 5 business days before the assessment, as a departmental policy, in order to facilitate administering the assessment.

### *Accommodation for Religious Obligations*

Campus policy requires faculty to provide reasonable accommodations for students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. Please communicate the need for a religious accommodation in a timely manner. In this class, please let the instructor know of any religious observances that interfere with due dates posted in this syllabus on or before the end of January, which is before the first quiz is due in Canvas so that the instructor can plan to schedule quizzes appropriately.

See the campus policy regarding religious observances for full details.

### *Preferred Student Names and Pronouns*

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

### *Classroom Behavior*

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, marital status, political affiliation, or political philosophy.

For more information, see the classroom behavior policy, the Student Code of Conduct, and the Office of Institutional Equity and Compliance.

### *Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation*

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits protected-class discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner abuse (dating or domestic violence), stalking, and related retaliation by or against members of our community on- and off-campus. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who have been subjected to misconduct can contact OIEC at 303-492-2127 or email CUreport@colorado.edu. Information about university policies, reporting options, and OIEC support resources including confidential services can be found on the OIEC website.

Please know that faculty and graduate instructors are required to inform OIEC when they are made aware of incidents related to these concerns regardless of when or where something occurred. This is to ensure that individuals impacted receive outreach from OIEC about their options and support resources. To learn more about reporting and support for a variety of concerns, visit the Don't Ignore It page.

### *Mental Health and Wellness*

The University of Colorado Boulder is committed to the well-being of all students. If you are struggling with personal stressors, mental health or substance use concerns that are impacting academic or daily life, please contact Counseling and Psychiatric Services (CAPS) located in C4C or call (303) 492-2277, 24/7.

Free and unlimited telehealth is also available through Academic Live Care. The Academic Live Care site also provides information about additional wellness services on campus that are available to students.