

ASEN 5245: Radars and Remote Sensing, Spring 2023

Class Lectures: Tuesdays and Thursdays Time=TBA
In-person and via Zoom in real-time + uploaded video for asynchronous students

Office hours: Thu 10-11am, zoom link:
And by appointment, in-person N440B or via zoom

Webpage: <https://canvas.colorado.edu>

Instructor: Sebastijan Mrak, Sebastijan.mrak@colorado.edu

Course outline:

This course will introduce radar systems from a combined theoretical and applied perspective. Students will develop a quantitative understanding of radar components, radar system design, and radar signal analysis, and apply these principles to specific applications in environmental remote sensing via 2 group projects and a final individual 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, and familiarity with electromagnetic (E&M) waves, E&M propagation, and digital signal processing.

The applications of radars are endless; from the detection of targets such as aircraft to the estimation of the target's parameters, electrical properties, and kinematics, to sensing the space for navigation. The purpose of this class is to provide you with a fundamental understanding of how radar systems operate, what are the necessary components, and how are they used for remote sensing in aerospace and environmental applications.

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 EM 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. I will provide pre-recorded lectures covering EE materials including radio-frequency circuits, EM propagation, and digital signal processing.

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

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 the 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.

Textbook:

Class notes, shared pre-recorded lectures, and my notes cover all the necessary materials you need to succeed in this class. In addition to these notes, 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/>

Course grading

50% Quizzes: I will prepare 6-8 quizzes posted on canvas every 2-3 weeks. These quizzes are open-book, “take-home” exams with a limited time to upload answers. Quizzes won’t be posted during your mid-terms, and your last one will be one week before the end of the semester ensuring you have enough time to prepare for other finals.

20% Group projects (5% each): I will share data from a pulsed-doppler radar (project 1) and from CWFM radar (project 2). The class will be split into N groups, each one with 3-4 students. Each group will need to process the data themselves and submit a report.

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).

Extra 5% for in-class engagement: I will be asking questions during lectures and will give points for engagement with the discussion, and engaging in extracurricular activities supporting this class.

Homework will be rolled out every other week, with solutions published online with a 14-day delay. The homework will prepare PhD students for the preliminary exam. We will discuss problems during office hours.

Course content

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

2) Radar Signals: Transmitter/signal generating characteristics; pulsed waveforms; continuous waveforms; pulse modulation and compression; complex signals; digital filtering; Doppler spectrum

3) Radar Sensitivity: Radar power equation: derivation and application for point targets; Radar power equation for area targets; Radar power equation for volume targets; radar power losses; radio and receiver noise

4) E&M propagation and radar antennas: Radiation and propagation of radio waves, radar antennas, directivity, gain, antenna patterns; aperture antennas; phased array antennas

4) Scattering Processes: Radar cross-section; Rayleigh, Mie, Bragg scattering, rough surfaces

6) Remote Sensing Applications: Tracking radars, meteorological radars, incoherent scatter radar, synthetic aperture (SAR) radar, massive input massive output (MIMO) radar.

Some applications will be covered by invited speakers.

University Policies for Spring 2023

Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail 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, political affiliation or political philosophy. For more information, see the policies on [classroom behavior](#) and the [Student Conduct & Conflict Resolution policies](#).

Requirements for COVID-19

As a matter of public health and safety, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to [Student Conduct and Conflict Resolution](#). For more information, see the policy on [classroom behavior](#) and the [Student Code of Conduct](#). If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the “Accommodation for Disabilities” statement on this syllabus.

CU Boulder currently requires masks in classrooms and laboratories regardless of vaccination status. This requirement is a precaution to supplement CU Boulder’s COVID-19 vaccine requirement. Exemptions include individuals who cannot medically tolerate a face covering, as well as those who are hearing-impaired or otherwise disabled or who are communicating with someone who is hearing-impaired or otherwise disabled and where the ability to see the mouth is essential to communication. If you qualify for a mask-related accommodation, please follow the steps in the “Accommodation for Disabilities” statement on this syllabus. In addition, vaccinated instructional faculty who are engaged in an indoor instructional activity and are separated by at least 6 feet from the nearest person are exempt from wearing masks if they so choose.

If you feel ill and think you might have COVID-19, if you have tested positive for COVID-19, or if you are unvaccinated or partially vaccinated and have been in close contact with someone who has COVID-19, you should stay home and follow the further guidance of the [Public Health Office](#) (contacttracing@colorado.edu). If you are fully vaccinated and have been in close contact with someone who has COVID-19, you do not need to stay home; rather, you should self-monitor for symptoms and follow the further guidance of the [Public Health Office](#) (contacttracing@colorado.edu). **If you test positive or you are identified as a close contact after attending class in person, please send an email to me (Sebastijan.mrak@colorado.edu) immediately. I will notify the department and send a notification to class via Canvas without**

revealing the person's identity. This will give a heads up to everyone in order to facilitate self-testing and, if necessary, self-isolation.

Accommodation for Disabilities

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.

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.

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code academic integrity policy. Violations of the Honor Code may include, but are not limited to: plagiarism, 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. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu; 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found on the [Honor Code website](#).

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. The university will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by or against members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or email cureport@colorado.edu. Information about university policies, [reporting options](#), and the support resources can be found on the [OIEC website](#).

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive

information about their rights, support resources, and reporting options. To learn more about reporting and support options for a variety of concerns, visit [Don't Ignore It](#).

Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. See the [campus policy regarding religious observances](#) for full details. Please let me know of any religious holidays by the end of January so I can plan to schedule quizzes appropriately.