Carleton University Department of Electronics

Winter 2025

ELEC 4600: Radar and Navigation

Introduction

In this course you will learn the principals of Surveillance Radars, Moving Target Indicator (MTI) Radars, Radio Navigation (including VOR, DME, TACAN, ILS), and GPS

Course Description and Requirements

Course Description: Surveillance radar: radar equation, minimum detectable signal, pulse integration, cross-section fluctuations, PRF, range ambiguities, staggered PRF. MTI radars: coherent operation, delay Line cancellers, FFT. Radio navigation: lines of position, NDB, VOR, DME, ILS. GPS: orbits, pseudo-ranges, position determination, GDOP, ionosphere. Geoide, coordinate frames.
Prerequisite(s): fourth-year status in Engineering or permission of the Department.
Lectures: 3 hours per week.
Laboratory and problem analysis: problem analysis 3 hours alternate weeks.

Instructor

Professor: J.S. Wight
Email: jimwight@cunet.carleton.ca
Course Webpage: on Brightspace

Reference Textbook:

1) M. Skolnik, “Introduction to Radar Systems”, McGraw Hill

2) M. Kayton & W.R. Fried, “Avionics Navigation Systems”, Wiley

Lecture Outline

In person, Monday and Wednesday, 4:00 to 5:30

Section I: Radar Fundamentals

Week 1: Radar pulses, range equation. Pulse repetition frequency and unambiguous range, Block diagram: exciter, magnetron, duplexer, antenna, receiver protector, superheterodyne receiver, digital signal processor. Applications: air traffic control, aircraft altimeter, aircraft doppler navigator, ship safety and harbor surveillance, space and remote sensing, tracking.

Week 2: Minimal detectable signal, receiver noise, probability density function, SNR, probability of detection, probability of false alarm, integration of radar pulses, integration improvement factor

Week 3: Target cross section: sphere, cone sphere corner reflector, cross section fluctuations, Swerling classification,

Week 4: Swerling classification effect on S/N and integration improvement factor, multiple pulse repetition frequencies and range ambiguities, cosecant^2 θ contour for antenna elevation beam, beam shape loss, collapsing loss, waveguide loss

Section II: MTI Surveillance Radar

Week 5: Two way Doppler, Moving Target Indicator and Pulse Doppler radars, power oscillator and power amplifier MTI architectures, delay line cancellers, two pulse and three pulse cancellers, multiple and staggered PRFs

Week 6: Digital signal processing, range-gated FFT, improved S/N, improved velocity estimation, constant false alarm rate

Week 7: Example of an MTI processor, clutter attenuation, sub-clutter visibility, clutter visibility factor,

Section III: Radio Navigation

Week 8: Organizations: ICAO, ARINC, RTCA, heading, relative and magnetic bearing, lines of position, NDB (non-directional beacon), ADF (automatic direction finder), VOR (VHF omnirange)

Week 9: Doppler VOR, DME (distance measuring equipment), TACAN, ILS (instrument landing system)

Section IV: GPS

Week 10: Orbits: inclination angle, longitude of ascending node, argument of perigee, semi-major axis, eccentricity, true anomaly, eccentric anomaly, mean anomaly, ECI (earth centered inertial coordinate system), ECEF (earth centered earth fixed coordinate system)

Week 11: Signal format: direct sequence spread spectrum, Fibonacci PN sequence generation, sequence synchronizers, CA code (coarse acquisition code), P code (precision code), clock correction and ephemeris data, almanac data, position calculation, GDOP (geometric dilution of precision)

Week 12: Ionosphere errors, local differential GPS, wide area augmentation, GEOIDE, geocentric latitude, geodetic latitude, meridian radius of curvature, prime radius of curvature, conversion between geodetic and ECEF coordinates

Problem Analysis Sessions

Notes for PA Sessions

- Several problems will be assigned each week as homework to help understand the lecture material, prepare for the midterm exams and final exam. To learn the course material, **IT IS ESSENTIAL THAT YOU ATTEMPT SOLUTIONS FOR THESE PROBLEMS BEFORE THE PA SESSION**. Solutions to these problems will be reviewed in the PA sessions.

Self-Declaration form and Deferred Term work

Students who claim illness, injury or other extraordinary circumstances beyond their control as a reason for missed term work are held responsible for immediately informing the instructor concerned and for submitting a self-declaration form no later than three (3) days after the date/deadline of term work including test/midterm, labs, assignments. Any alternate arrangements made with the instructor for submission of term work should be made as soon as possible but within 3 days of the missed due date. If this is not possible after discussion with the instructor, alternate arrangements must be made before the last day of classes in the term as published in the academic schedule.

Instructors can require (or not) the student to submit the self-declaration form. Include the following statement if you require the student to submit a completed self-declaration form:

> **Consult with the instructor no later then 3 days after any missed course work or midterm examination.**
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> or
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> **Contact the instructor with the completed self-declaration form no later than 3 days after the date/deadline of term work including test/midterm, labs, assignments.**

Evaluation and Grading Scheme

The cumulative course grade will be determined as follows:

Two Midterm exams at 20% each

Final Exam at 60%

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a) Final Exam: **Final exams are for evaluation purpose and will not be returned to students.**

> Final Exams ae Closed-book with a Sheet of Equations provided, Scientific calculator required, no Scranton Sheet allowed.
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> Deferred Final Examinations
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> Students who are unable to write the final examination because of a serious illness/emergency or other circumstances beyond their control may apply for accommodation by contact the Registrar's office. Consult the Section 4.3 of the University Calendar (https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/examinations/)

c) Exam format

> **Engineering Courses shall have on campus and proctored final examinations.**

Learning Outcomes

Upon successful completion of this course, students will be able to:

Comprehend, design, and evaluate Surveillance Radars, MTI Radars, Radio Navigation Systems (including VOR, DME, TACAN, and ILS), and Global Navigation Systems (including GPS, GLONASS, Galileo)

Graduate Attributes

The Canadian Engineering Accreditation Board requires graduates of undergraduate engineering programs to possess 12 attributes: Graduate-Attributes.pdf (engineerscanada.ca) or GA's. Courses in all four years of our programs evaluate students' progress towards acquiring these attributes. Aggregate data (typically, the data collected in all sections of a course during an academic year) is used for accreditation purposes and to guide improvements to programs. Some of the assessments used to measure GAs may also contribute to final grades; however, the GA measurements for individual students are not used to determine the student's year-to-year progression through the program or eligibility to graduate. Accreditation metrics are based on courses common to all students in a program.

Graduate attributes are not assessed in this elective course.

Academic Integrity and Plagiarism

a) Please consult the Faculty of Engineering and Design information page about the Academic Integrity policy and our procedures: https://carleton.ca/engineering-design/current-students/fed-academic-integrity. Violations of the Academic Integrity Policy will result in the assignment of a penalty such as reduced grades, the assignment of an F in a course, a suspension or, expulsion.

b) One of the main objectives of the Academic Integrity Policy is to ensure that the work you submit is your own. As a result, it is important to write your own solutions when studying and preparing with other students and to avoid plagiarism in your submissions. The University Academic Integrity Policy defines plagiarism as "presenting, whether intentionally or not, the ideas, expression of ideas or work of others as one's own." This includes reproducing or paraphrasing portions of someone else's published or unpublished material, regardless of the source, and presenting these as one's own without proper citation or reference to the original source.

Examples of violations of the policy include, but are not limited to:

- Any submission prepared in whole or in part, by someone else;
- Using another's data or research findings without appropriate acknowledgment;
- Submitting a computer program developed in whole or in part by someone else, with or without modifications, as one's own;
- Failing to acknowledge sources of information through the use of proper citations when using another's work and/or failing to use quotations marks; and
- Unless explicitly permitted by the instructor in a specific course, the use of generative AI and similar tools to produce assessed content (such as text, code, equations, images, summaries, videos, etc.).

Academic Accommodations

You may need special arrangements to meet your academic obligations during the term. For an accommodation request the processes are as follows:

Pregnancy obligation: Contact us with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For accommodation regarding a formally-scheduled final exam, you must complete the Pregnancy Accommodation Form (click here).

Religious obligation: Contact us with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details click here.

Academic Accommodations for Students with Disabilities: The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send us your Letter of Accommodation at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, contact us, if needed, to ensure that accommodation arrangements are made.

You should request your academic accommodations in the Ventus Student Portal, for each course at the beginning of every term. For in-term tests or midterms, please request accommodations at least two (2) weeks before the first test or midterm.

Please consult the PMC website for the deadline to request accommodations for formally-scheduled exams (if applicable).

Survivors of Sexual Violence: As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: https://carleton.ca/equity/sexual-assault-support-services

Accommodation for Student Activities: Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation will be provided to students who compete or perform at the national or international level. Contact us with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist: https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf