ELEC 4503: RF Lines & Antennas

Fall 2025 Academic Term

1 Introduction

Welcome to the Antenna Course, a dynamic and immersive learning experience designed to empower students with the theoretical foundations and practical expertise needed to excel in antenna design, simulation, fabrication, and measurement. This course offers a carefully structured progression through a series of hands-on laboratories, fostering a deep understanding of the core concepts that drive modern communication systems. From mastering electromagnetic simulation tools to exploring real-time tuning and array performance analysis, the curriculum integrates cutting-edge techniques with actionable skills. The course delves into essential antenna concepts, including the design principles of horn, patch, and slot-waveguide antennas, while emphasizing critical measurement methodologies such as Vector Net- work Analyzer (VNA) operations and radiation pattern assessments. Through engaging lab experiences, students will develop a robust skill set, encompassing PCB layout preparation, impedance matching anal- ysis, and the application of the Friis transmission equation. This hands-on approach not only reinforces theoretical learning but also cultivates problem-solving abilities and innovative thinking. Beyond the classroom, the Antenna Course opens doors to exciting future career opportunities in electrical engineering and telecommunications. Graduates will be well-prepared for roles in wireless communication design, RF engineering, and advanced research, where their expertise in antenna technologies will be highly sought after. This journey is an invitation to explore the forefront of wireless technology, equipping you with the knowledge and confidence to shape the future of connectivity.

2 Course Description and Requirements

2.1 Course Description

Introduction to distributed circuits, travelling and standing waves, reflection coefficient, SWR, impedance transformation, Smith charts. Introduction to transmission lines; coaxial, rectangular waveguide, resonators, optical fibers. Introduction to antennas; gain, directivity, effective area. Introduction to linear arrays.

Includes: Experiential learning activity
Prerequisite(s): ELEC 3909
Lectures: Three hours a week
Laboratory: Course Labs three hours alternate weeks

2.2 Instructor

Professor: Shulabh Gupta
Email: Shulabh.Gupta@carleton.ca
TA: Alex Szabo, AlexSzabo@cmail.carleton.ca
Course Webpage: On Brightspace

2.3 Textbook

1. M. Sadiku, “Elements of Electromagnetics”, 6th or latest edition. (recommended, typical cost of about $280 online).
2. David Pozar, “Microwave Engineering", 4th or latest edition.

Note: Contact the bookstore for current pricing of required textbooks.

3 Laboratory Sessions

Three hours every week as per schedule and location posted on Brightspace.
Note 1: All sessions are mandatory, and attendance will be taken. Zero will be assigned for the corresponding lab reports in case of absence.
Note 2: All HFSS/lecture-related questions must be posted on the Brightspace forum only, to avoid repetitions and so that everyone benefits.

3.1 Notes for Labs

- There are a total of 5 course labs and 1 lab dedicated for project work.
- All labs will be in ME4140 in the Mackenzie building, except the first lab in MC6030 (Minto), which may be revised based on available resources.
- All lab reports must be prepared using LaTeX only, using the templates provided, and submitted as a PDF file, with suggested section headings and specified page limits. The LaTeX template will be provided in advance.
- No entry in the hardware labs after 10 mins of the allocated time.
- Any unsafe practice, irresponsible usage of the equipments inside the lab, and any careless damage to components and equipments, judged by the course instructor and the teaching assistant will lead to immediate suspension from the labs, and the students will be barred to enter the labs until re-instated.
- The prepared document must be electronically submitted on Brightspace within 10 days.
- Reports must be named according to the following format:
  `Lastname_Firstname_ELEC_4503_Fall_2025_Lab_ #.pdf`

4 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. **No make up labs will be possible, and for missing the labs with a valid reason, the lab weight will be transferred to the final exam.**

Requirement: Contact the instructor with the completed self-declaration form no later than 3 days after the date/deadline of term work, including tests/midterms, labs, or assignments.

Note: In engineering courses, the grade from a deferred examination replaces the final examination grade in the published grading scheme and the grade from deferred term work replaces the grade for that term work in the published grading scheme. Students who defer either term work or the final examination are evaluated using the same grading scheme as all others in the course.

5 Evaluation and Grading Scheme

The cumulative course grade will be determined as follows:

- **Course Labs (Labs 1–5)**: 25% of the overall grade (25 marks total).
- **Course Project (Lab 6)**: A final report focusing on the design and simulation performance of a passive phased array is due on December 5, 2025. The report must include an appendix covering all measurements conducted during Course Lab 6. 15% of the overall grade (15 marks total).
- **Mid-term exam:** 10% of the overall grade, November 11th, 2025 during lecture hours (10 marks total)
- **Closed-book Final Exam (During normal exam period)**: 50% of the overall grade.

5.1 Final Exam

- Scheduled during the examination period at the end of the Fall term.
- Traditional 3-hour closed-book format, in-person on campus.
- For evaluation purposes only and will not be returned.

- Students who miss the final exam may be granted permission to write a deferred examination. See the Undergraduate Calendar for regulations on deferred examinations.

5.2 Midterm

- Occurs during the course lecture, in-person on **November 11th, 2025.**
- Open-book format. Students may bring any textbook material.
- No discussions between students allowed. Evidence of cheating will have serious consequences.
- Missing the midterm without a valid medical certificate or reason results in a mark of zero. With justified explanation, the midterm weight will be moved to the final exam.

5.3 Passing Requirements

To pass the course, you need:

1. Minimum term course grade of 50% **AND**
2. Minimum grade of 50% in the final exam.

6 Additional Requirements

- Students must review assignment and quiz grades as soon as they are returned. Any marking concerns must first be addressed to the TA. If clarifications are insufficient, bring the issue to the instructor's attention before December 10, 2025, for an informal appeal and re-marking.
- Course materials (including the course outline, slides, notes, videos, labs, projects, assignments, quizzes, exams, and solutions) are for personal use and may not be reproduced or redistributed without prior written permission from the instructor.
- Consult Section 5 of the undergraduate regulations: `https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/grading/`

6.1 Generative Artificial Intelligence (AI)

Students may use AI tools for sharing ideas, clarifying challenging concepts, or getting started on projects. Some acceptable uses include:

1. Students may use AI tools for basic word processing and formatting functions, including grammar and spell checking, basic formatting and design suggestions.
2. Creating outlines (e.g., using AI to structure an essay or presentation flow).
3. Providing definitions or explanations of complex concepts (e.g., using AI to explain a difficult theory).
4. It is required to document your use of AI in this course, using the following guidelines:
    - Clearly identify and cite AI-generated text (e.g., 'The following paragraph was generated by ChatGPT/Microsoft Word's Researcher tool'). Please consult resources on the Library website.
    - Review, edit, and ensure the accuracy and originality of final submissions.
    - AI-generated content should not exceed 30% of the total work deliverable length.

This policy supports the use of AI as a supplementary tool, helping students develop ideas and structure their work while emphasizing the importance of transparency and personal engagement with the content. AI can be used for inspiration and foundational support, and can encourage students to critically assess and refine AI-generated material.

As our understanding of the uses of AI and its relationship to student work and academic integrity continue to evolve, students are required to discuss their use of AI in any circumstance not described here with the course instructor to ensure it supports the learning goals for the course.

Note: Students can also access resources related to citing Generative AI on the MacOdrum Library website. Additional resources are also available on https://carleton.ca/ai/.

Important: While the AI tools maybe used following these guidelines, the ownership of the work must belong to the students only, and they should be able to describe their work deliverables satisfactorily. In case, it is demonstrated that any submitted work was generated by AI and the student is unable to explain the work, a grade penalty of 50% will be applied.

6.2 Exam Format and E-Proctoring

Engineering courses shall have on-campus and proctored final examinations.

7 Learning Outcomes

Below is a list of 10 detailed learning outcomes tailored to the Antenna Course labs, reflecting the skills and knowledge students will gain from the hands-on activities described in the laboratory manual:

1. **Master Electromagnetic Simulation Tools**: Achieve proficiency in using ANSYS HFSS to simulate antenna designs, including setting up models, defining boundary conditions, and analyzing performance metrics such as return loss (S11) and radiation patterns.
2. **Develop Antenna Design Expertise**: Gain a comprehensive understanding of various antenna types (e.g., horn, patch, slot-waveguide) and their design principles, including geometry, material properties, and operational frequency considerations.
3. **Acquire PCB Layout Skills**: Build foundational skills in preparing PCB layouts for antenna feeds, including exporting designs to PCB software and generating Gerber files for fabrication.
4. **Enhance VNA Measurement Techniques**: Master the calibration and operation of a Vector Network Analyzer (VNA) to accurately measure S-parameters and extract dielectric properties of materials using ring resonators.
5. **Understand Impedance Matching and VSWR**: Develop expertise in measuring and interpreting Voltage Standing Wave Ratio (VSWR) to evaluate antenna impedance matching and optimize performance across specified frequency ranges.
6. **Master Practical Antenna Fabrication**: Acquire hands-on skills in fabricating antennas, such as custom patch antennas using copper tape, and understanding the impact of substrate materials on antenna performance.
7. **Develop Real-Time Tuning Capabilities**: Gain techniques for real-time resonance tuning by physically adjusting antenna dimensions, enabling precise alignment with desired resonance frequencies.
8. **Apply Radiation Pattern Analysis**: Achieve a thorough understanding of antenna radiation patterns and their measurement methodologies using table-top setups, including interpreting directional characteristics.
9. **Utilize the Friis Transmission Equation**: Learn to apply the Friis transmission equation to predict and verify power transfer between antennas, enhancing skills in power measurement and analysis.
10. **Evaluate Antenna Array Performance**: Develop a comprehensive understanding of antenna array behavior, including measuring gain and beamwidth, and comparing performance differences between single antennas and arrays.

These outcomes align with the lab objectives and descriptions, providing a structured progression of skills from simulation and measurement to practical design and analysis.

8 Academic Integrity and Plagiarism

1. 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.
2. 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.).

9 Academic Accommodations

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

1. **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 here.
2. **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.
3. **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).
4. **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 here.
5. **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. See here.