ECE6360 Syllabus

Microwave Design, Spring 2024

M/W, 11:00 am -12:15 pm, Van Leer C340

Class page: https://canvas.gatech.edu

Delivery Mode: In person

Instructor Information

Instructor	Email	Office Hours & Location
Prof. Nima Ghalichechian	nima.1@gatech.edu	1-2 pm, M (or by appointment), TSRB # 534
Teaching Assistant(s)	**Email**	**Office Hours & Location**
TBD	TBD	None

General Information

Description

Project-centered course covering applications of electromagnetic theory to passive microwave components and systems including transmission lines, impedance matching, waveguides, microwave networks, power dividers, couplers, filters, phase shifters and measurement techniques. The course emphasizes deep understanding of applied electromagnetics through design and simulation projects, continuous assignments, and the use of circuit modeling as a complimentary tool.

Pre- &/or Co-Requisites

Undergraduate Semester level ECE 3025 (Introduction to Electromagnetics) or equivalent with a minimum Grade of C. Basic understanding of the theory of electromagnetisms including Maxwell's equations, plane waves, and transmission lines are required.

Course Schedule

- Introduction to radio systems (Week 1)
- HFSS and ADS tutorials (Week 1-6)
- Plane waves (Week 1- 2)
- Transmission line basics (Week 2-4)
- Metallic waveguides (Week 4-7)
- Microstrip, stripline, CPW, and Slotline (Week 8)
- Transitions (Week 8)
- Microwave networks (9-10)
- Smith Chart and matching techniques (Week 10)
- Spring break (Week 11, March 18-22)
- Multi-section transformers and tapered lines (week 12)
- T-junctions and power dividers (week 12)
- Couplers (week 13-14)
- Resonators and filters (week 13)
- mmWave and emerging technologies (Week 13)
- Beamforming networks (Week 13)

- Project presentations (Week, 10 and 14)

Course Goals and Learning Outcomes

1. Develop deep understanding of electromagnetic theory applied to microwave circuits
2. Understand a) practical design techniques for passive microwave circuits and b) theories behind each technique.
3. Develop an intuitive understanding of transmission lines and waveguides.
4. Introduce students to commercially available microwave engineering simulation toolboxes.
5. Understand the tradeoffs between electromagnetic and circuit approaches.
6. Involve the students in a team-oriented design project where they design, fabricate, and test a microwave circuit and present their results to the class.
7. Expose students to emerging topics in microwave engineering.

Course Requirements & Grading

Assignment	Due Date/Frequency	Weight	Notes
Homework	~ weekly	20%	Homework includes reading assignments, problem sets, video tutorials and problem sets
Individual projects	4-5 throughout the semester	20%	Design and simulation using ADS (circuit) and HFSS (EM full wave), short simulation, or MATLAB programming
Midterm 1	2/14/2024	20%	Happy Valentines Day!
Midterm 2	3/27/2024	30%	A week after Spring Break.
Group project	4/25/2024	10%	Tentative
Extra credits	Various	2-4%	

Homework Assignments

Homework assignments are important part of the learning process. Weekly “homework” assignments will be posted throughout the semester that includes reading text, papers, watching instructional videos on how to use HFSS or ADS, short simulations, and MATLAB programing. Please pay attention to the due date. You are expected to work on them on a weekly basis and check your work with the solution that I provide. You may work on these as a group. This is optional. If you do, list the name of your partner(s) when uploading your document. In general, all assignments are submitted through Canvas. In addition to the homework assignments, the lecture notes contain more than 130 exercises. Most of them will be solved in the class, but others will be assigned to you to complete at home.

Midterm #1 and #2

Two midterm exams will take place during the semester. The exam will be closed-book/closed-notes. You will be allowed a single cheat sheet, 8.5” by 11”, with handwritten notes only, on both sides. Do not print or type your cheat sheet. Only hand-written notes are allowed! No internet-enabled devices are permitted. You may bring a simple calculator to the exam.

Projects (Individual and Team)

The core learning component of this course is the projects you will complete throughout the semester. A few simulation-based mini-projects will be assigned throughout the semester. These are designed to complement the class material. Two software are ADS and ANSYS HFSS. Rubrics will be provided for each assignment. Access instructions is available in CANVAS. See also “Additional Materials/Resources” section in

this document. These are submitted as an individual project. However, you may work with your classmates if you prefer.

A team project will be assigned in the second half of the semester. It will involve literature review, physics of operation, simulations, and an oral presentation. Presentation will be given by all group members towards the end of the semester prior to the final exam week. All members are expected to present. Each team prepares a power point presentation and submit on a due date in CANVAS. Contributions of each individual team member has must be clearly spelled out and listed on the power point. Please see the due date on page 1. Based on the feedback received from class and instructor, students may be asked to revise their project report (power point).

Final Exam

There is no final exam for this class. The focus is on project-based learning. The final exam date (Wednesday, May 3 11:20 AM - 2:10 PM) is reserved as a backup date for project presentation if needed.

Grading Scale

Your final grade will be assigned as a letter grade according to the following scale.

A	90-100%
B	80-89%
C	70-79%
D	60-69%
F	0-59%

Course Materials

Course Website and Other Classroom Management Tools

https://canvas.gatech.edu

Contacting me

Please contact me if you can't attend the office hour but you want to meet me. Also contact me for any other issue. I typically respond within 24 hours (nima.1@gatech.edu). My office is in TSRB room # 534. Show your Buzzard to the security staff at the front desk of TSRB. We can also schedule a virtual meeting if needed.

Course Text

Three textbooks can be used for this course. You don't need all, but one is required. I am aware of the high cost of our engineering textbooks. As a result, I have listed two alternative textbook that are available through Georgia Tech and NC State library for free (electronic version). Reading assignments will be made based on Pozar. Students are required to find the corresponding pages from the other textbooks which is straightforward. Pozar is an excellent text and the popular in this topic for a good reason.

- **Microwave Engineering**, 4th Edition, David Pozar, John Wiley & Sons, 2011. This is a classical microwave engineering textbook with emphasis on passive components. While the 4th Edition is updated and has added chapters on active devices and noise figure, Editions # 2 and 3 are also suitable to be used for our course. Typically, the older editions are less expensive.
- **Principles of RF and Microwave Design**, Matthew A. Morgan, Artech House, 2020, ISBN 13: 978-1-63081-649-0. Download the electronic version for free from GT Library as one PDF file. This book covers similar ground as Pozar and has a lot of similarity. It does explain some concept more in depth and sometimes explanations become lengthy or redundant, especially, for PhD-level audience. Overall, it is a good textbook.
- **Microwave and RF Design,** Michael Steer, Third Edition, 2019, NC State University. This is a 5-volume open access book. A link to the PDF copy of the book is available on the course page. Each

volume can also be downloaded from NC State open access library: https://repository.lib.ncsu.edu/handle/1840.20/36776?show=full

- **Foundations of Microwave Engineering,** Robert Collin, 2nd Edition, 1992. This is a classic microwave engineering textbook. The material in all modern texts such as Pozar are based on this book. IEEE made it available through IEEE Xplore in 2001. Access using this link https://ieeexplore.ieee.org/book/5265446.
- **Foundations of Applied Electromagnetics**, Kamal Sarabandi, University of Michigan Publishing, 2022. This book is published by Michigan Publishing under an agreement with the author. It is made available free of charge in electronic form to any student or instructor interested in the subject matter. Excellent graduate-level applied EM textbook. A link to the PDF copy of the book is at https://services.publishing.umich.edu/publications/ee/#foundations-applied-electromagnetics. You may review this book to refresh your basic EM knowledge. Chapter 6/7 covering rectangular/circular waveguides are particularly interesting.
- **Other texts and reading material listed on my slides:** Throughout the semester, several other valuable readings materials are provided on Canvas and listed on the slides. One example is Ulaby that is a good undergraduate EM textbook to refresh your learning in that course.

Numerical Simulation Tools

Preferred simulation tools

1. **Circuit: ADS**
2. **Electromagnetic: HFSS**

- **ADS:** Pathway Advanced Design System (ADS) from Keysight (formerly known as Agilent or HP) is a simulation tool for microwave circuits. It is the best tool available for microwave circuit design. Full-wave electromagnetic simulation is also possible in ADS but somewhat clunky. I highly recommend that you "play" with the Smith Chart toolbox and other capabilities in ADS and perform several impedance matching practices. Instructional videos will be provided on Canvas. This software is available through ECE labs: https://help.ece.gatech.edu/software/keysight/ads
- **ANSYS HFSS:** The actual name is Ansys EM Desktop Suite. A few years ago, the software was acquired by ANSYS and become a part of their package. HFSS uses frequency-domain finite element method and is the most popular full-wave simulation tool for passive microwave circuits and antennas. It is more user-friendly than other tools. HFSS is available through the ECE Computer Support Group https://help.ece.gatech.edu/software. Don't forget to check out the examples and tutorials. Instructional videos are posted on Canvas.

Other simulation tools

- **Feko from Altair:** https://www.altair.com/feko/ is a good microwave/antenna simulation toolbox that uses method of moments. Students can download the free student edition at https://altairuniversity.com/free-altair-student-edition, but there are campus wide licenses at Georgia Institute of Technology for full version of Feko, if you need. The student version (for personal use) has limitation. For example, max number of mesh elements is 25k. Feko has a lot of educational material- much better than HFSS and CST. Here is one example https://altairuniversity.com/46078-antenna-modeling-and-simulation-techniques-webinar. Check Canvas resource tab for more information on Feko. In my experience, setting up ports in Feko is somewhat tricky, otherwise, it's easy to use.
- **CST Microwave Studio**: Also known as CST Studio Suite is a powerful full-wave program with several types of solvers. Time-domain, frequency domain, integral, etc. For electrically large antennas or circuits or wide-band structures it makes sense to use a time-domain solvers. CST is great in this area. Examples includes arrays or Vivaldi antennas. It also offers other types of solvers as well. Many years ago, my research group used exclusively HFSS. Nowadays, most students use

CST instead. Software is available at ECE https://help.ece.gatech.edu/software. The difference with HFSS is that the students will need to read the ECE EULA for each respective software before access is granted https://eulas.ece.gatech.edu/CST/.

- **MATLAB:** For certain HW assignments and projects you will need to use MATLAB. In addition to the core program, MATLAB has an RF Toolbox that is useful for visualization of polar plots for gain patterns, S-parameters, Smith Chart, and others https://www.mathworks.com/products/rftoolbox.html. MATLAB's Phased Array Systems Toolbox is useful for quick analysis of arrays https://www.mathworks.com/products/phased-array.html. For toolbox installation check here.

Additional Materials/Resources

- https://www.microwaves101.com: Quick entry-level source for various microwave components.
- www.antenna-theory.com: Great web page for learning about Smith Chart, impedance matching and antennas. The approach is intuitive and practical. Review sections related to Smith Chart and impedance matching if you feel less comfortable with these topics.
- IEEE Microwave Theory and Technology Society also known as MTT-S https://mtt.org
- IEEE Microwave Magazine available using IEEE Xplore. Contains great educational and review material that serves well as a starting point of research providing an overview of the topic. References of each article can used for deeper understanding of the topics.
- Other publication: Please see MTT-S publication list using the listed link above.

Attendance and/or Participation

Class attendance is highly recommended. During the class, it is recommended that you take notes. The learning process starts by these notes! While supplementary lecture notes will be posted on CANVAS, the notes are not to be considered as a direct replacement for you own class notes and participation. I will not post any additional notes. Discussions during lectures are important part of the learning for this course. If you miss a lecture, review the suppletory lecture notes on CANVAS and contact your classmates for discussion notes. Complete the reading assignments and attend the office hours.

Collaboration & Group Work

Students are encouraged to work together on homework assignments and simulation projects. However, you must submit your own version of the assignment. You are expected to complete the midterms yourself, without any external help or communication.

Extensions, Late Assignments, & Re-Scheduled/Missed Exams

The dates of the 2 midterms exams are announced in this document. Please note these dates and make the necessary arrangements to attend. If you can't attend the exam, notify me as soon as possible. No makeup exam will be given unless there is a special arrangement or documented emergency. Outside emergencies, any missed assignment or exam will result in a zero grade. Late submission of any type of assignment is not accepted and will result in zero.

Academic Integrity

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit http://www.catalog.gatech.edu/policies/honor-code/ or http://www.catalog.gatech.edu/rules/18/.

Any student suspected of cheating or plagiarizing on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for

violations. Violating Georgia Tech's Academic Honor Code may result in the grade of zero for the assignment.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404) 894-2563 or http://disabilityservices.gatech.edu/, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible to set up a time to discuss your learning needs.

Student-Faculty Expectations Agreement

At Georgia Tech we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See http://www.catalog.gatech.edu/rules/22/ for an articulation of some basic expectation that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.

Information Related to Covid-19

Students are expected to be familiar with and abide by the Institute guidelines, information, and updates related to Covid-19. Find campus operational updates, Frequently Asked Questions, and details on campus surveillance testing and vaccine appointments on the Tech Moving Forward site.