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2020

Microwave Circuits

North Carolina Agricultural and Technical State University

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COURSE SYLLABUS

College Name: College of Engineering
Department Name: Department of Electrical and Computer Engineering
Course Name: Microwave Circuits

COURSE INFORMATION

- Course Number/Section: ECEN 625
- Term:
- Semester Credit Hours: 3
- Times and Days:
- Class Location:

INSTRUCTOR CONTACT INFORMATION

- Instructor:
- Office Location:
- Office Phone:
- Email Address:

Faculty must notify students of the approximate time and method they can expect to receive an answer to all communications (e.g., email, phone, course messages). Excluding holidays, the response should be provided within 48 hours.

If there's a graduate teaching assistant assigned to work with this course, please include their names also.

STUDENT HOURS

These are times students may visit the professor without an appointment to request the assistance they need.

NOTE: Students are responsible for reading, understanding, and following the syllabus.

: AM ☐ / PM ☐ – : AM ☐ / PM ☐

Monday ☐ Tuesday ☐ Wednesday ☐ Thursday ☐ Friday ☐

COURSE PREREQUISITES

None.

COURSE DESCRIPTION

This course will cover RF and microwave circuits appropriate for wireless communications and radar sensing. It emphasizes the theoretical and practice aspects of microstrip design of highly integrated systems. Matrix analysis and computer-aided design techniques are introduced and used for the analysis and design of circuits. Impedance transformer, power combiner, couplers, mixers, and calibrated measurements techniques are also covered.

STUDENT LEARNING OBJECTIVES/OUTCOMES (SLO)

Learning outcomes should be specific, measurable, and focused on the content knowledge the students are expected to master and not what the faculty will teach.

If the course is a General Education Course, the SLO should be listed and labeled as "General Education."

SLO 1: Describe the physical meaning of Maxwell's equations, and explain simple wave effects inside a medium, and at the boundaries.

SLO 2: Analyze transmission lines, and characterize wave propagation on transmission lines.

SLO 3: Design matching circuits using lumped and distributed circuit elements. Do impedance matching on Smith chart.

SLO 4: Conduct multi-port network analysis with Z- Y- S- and ABCD parameters.

SLO 5: Analyze and design transformer, couplers, filters, power dividers, attenuators.

SLO 6: Conduct system level analysis (link budget, noise figure, non-linearity) for RF and microwave front-end systems.

SLO 7: Design and analyze microwave circuits using Keysight's ADS software; Measure the S parameters of a microwave device.

REQUIRED TEXTBOOKS AND MATERIALS

Any course-level subscriptions and tools linked in Blackboard Learn learning management system (LMS) should be listed here. The Blackboard LMS must have links to their student data privacy statement.

REQUIRED TEXTS:

Pozar, D. M. (2011). *Microwave engineering*. (4th ed.). Wiley.

REQUIRED MATERIALS:

SUGGESTED COURSE MATERIALS

SUGGESTED READINGS/TEXTS:

SUGGESTED MATERIALS:

GRADING POLICY

ASSIGNMENTS AND GRADING POLICY

94% and above	A		76% - 74%	C
93% - 90%	A-		73% - 70%	C-
89% - 87%	B+		69% - 67%	D+
86% - 84%	B		66% - 64%	D
83% - 80%	B-		63% - 60%	F
79% - 77%	C+			

GRADING ALLOCATION

Course grades are based on a weighted grading scale of 100%. The breakdown for the course is as follows: *[Faculty, please adjust according to your course.]*

Category	# of Activities	Percentage Grade Weight
Discussion Board	8	10%
Assignment	7	30%
Exams	2	40%
Project	1	20%
Total	17	100%

COURSE POLICIES

USE OF BLACKBOARD AS THE LEARNING MANAGEMENT SYSTEM

Blackboard is the primary online instructional and course communications platform. Students can access the course syllabus, assignments, grades, and learner support resources. Students are encouraged to protect their login credentials, complete a Blackboard orientation, and log in daily to the course.

Note: Uploading assignments through Blackboard presents a challenge for Chromebook users in locating the files for submission. If you use a Chromebook, please be sure you also have access to a Mac computer or Windows computer so you can fully participate in your Blackboard class. For more information about student computer recommendations, please visit <https://hub.ncat.edu/administration/its/computer-recommendations.php>.

MAKE-UP EXAMS

See << Update Academic Year >> *Undergraduate Bulletin*:

<https://www.ncat.edu/provost/academic-affairs/bulletins/index.php>

EXTRA CREDIT

LATE WORK

SPECIAL ASSIGNMENTS

Students are expected to attend class and participate on a regular basis in order to successfully achieve course learning outcomes and meet federal financial aid requirements ([34 CFR 668.22](#)). Class attendance in online courses is defined as active participation in academically-related course activities. Active participation may consist of course interactions with the content, classmates, and/or the instructor. Examples of academically-related course activities include, but are not limited to:

- Completing and submitting assignments, quizzes, exams, and other activities within Blackboard or through Blackboard (3rd-party products).
- Participating in course-related synchronous online chats, discussions, or meeting platforms such as Blackboard Collaborate in which participation is tracked.

CLASSROOM CITIZENSHIP

Courtesy, civility, and respect must be the hallmark of your interactions.

COMPLIANCE WITH THE AMERICANS WITH DISABILITIES ACT

North Carolina A&T State University is committed to following the requirements of the Americans with Disabilities Act Amendments Act (ADAAA) and Section 504 of the Rehabilitation Act. If you need an academic accommodation based on the impact of a disability, you must initiate the request with the Office of Accessibility Resources (OARS) and provide documentation in accordance with the Documentation Guidelines at N.C. A&T. Once documentation is received, it will be reviewed. Once approved, you must attend a comprehensive meeting to receive appropriate and reasonable accommodations. If you are a student registered with OARS, you must complete the Accommodation Request Form to have accommodations sent to faculty.

OARS is located in Murphy Hall, Suite 01 and can be reached at 336-334-7765, or by email at accessibilityresources@ncat.edu. Additional information and forms can be found on the internet at <https://www.ncat.edu/provost/academic-affairs/accessibility-resources/index.php>.

Please note: Accommodations are not retroactive and begin once the Disability Verification Form is provided to faculty.

TITLE IX

North Carolina A&T State University is committed to providing a safe learning environment for all students—free of all forms of discrimination and harassment. Sexual misconduct and relationship violence in any form are inconsistent with the university’s mission and core values, violates university policies, and may also violate federal and state law. Faculty members are considered “Responsible Employees” and are required to report incidents of sexual misconduct and relationship violence to the Title IX Coordinator. If you or someone you know has been impacted by sexual harassment, sexual assault, dating or domestic violence, or stalking, please visit the Title IX website to access information about university support and resources. If you would like to speak with someone confidentially, please contact Counseling Services at 336-334-7727 or the Student Health Center at 336-334-7880.

TECHNICAL SUPPORT

If you experience any problems with your A&T account, you may call Client Technology Services (formerly Aggie Tech Support and Help Desk) at 336-334-7195, or visit <https://hub.ncat.edu/administration/its/dept/ats/index.php>.

FIELD TRIP POLICIES / OFF-CAMPUS INSTRUCTION AND COURSE ACTIVITIES

If applicable:

Off-campus, out-of-state, foreign instruction, and activities are subject to state law and university policies and procedures regarding travel and risk-related activities. Information regarding these rules and regulations may be found at <https://www.ncat.edu/campus-life/student-affairs/index.php>.

STUDENT HANDBOOK

<https://www.ncat.edu/campus-life/student-affairs/departments/dean-of-students/student-handbook.php>

STUDENT TRAVEL PROCEDURES AND STUDENT TRAVEL ACTIVITY WAIVER

https://hub.ncat.edu/administration/student-affairs/staff-resources/studen_activity_travel_waiver.pdf

OTHER POLICIES (e.g., Copyright Guidelines, Confidentiality, etc.)

STUDENT HANDBOOK

<https://www.ncat.edu/campus-life/student-affairs/departments/dean-of-students/student-handbook.php>

[Graduate Catalog](#)

SEXUAL MISCONDUCT POLICY

<https://www.ncat.edu/legal/title-ix/sexual-harassment-and-misconduct-policies/index.php>

FAMILY EDUCATIONAL RIGHTS AND PRIVACY ACT (FERPA)

<https://www.ncat.edu/registrar/ferpa.php>

STUDENT COMPLAINT PROCEDURES

STUDENT CONDUCT AND DISCIPLINE

North Carolina A&T State University has rules and regulations that govern student conduct and discipline meant to ensure the orderly and efficient conduct of the educational enterprise. It is the responsibility of each student to be knowledgeable about these rules and regulations.

Please consult the following about specific policies such as academic dishonesty, cell phones, change of grade, disability services, disruptive behavior, general class attendance, grade appeal, incomplete grades, make-up work, student grievance procedures, withdrawal, etc.:

- Undergraduate Bulletin
<https://www.ncat.edu/provost/academic-affairs/bulletins/index.php>
- Graduate Catalog
<https://www.ncat.edu/tgc/graduate-catalog/index.php>
- Student Handbook
<https://www.ncat.edu/campus-life/student-affairs/departments/dean-of-students/student-handbook.php>

ACADEMIC DISHONESTY POLICY

Academic dishonesty includes but is not limited to the following:

1. Cheating or knowingly assisting another student in committing an act of cheating or other academic dishonesty;
2. Plagiarism (unauthorized use of another's words or ideas as one's own), which includes but is not limited to submitting exams, theses, reports, drawings, laboratory notes or other materials as one's own work when such work has been prepared by or copied from another person;
3. Unauthorized possession of exams or reserved library materials; destroying or hiding source, library or laboratory materials or experiments or any other similar actions;
4. Unauthorized changing of grades, or marking on an exam or in an instructor's grade book or such change of any grade record;
5. Aiding or abetting in the infraction of any of the provisions anticipated under the general standards of student conduct;
6. Hacking into a computer and gaining access to a test or answer key prior to the test being given. N.C. A&T reserves the right to search the emails and computers of any student suspected of such computer hacking (if a police report of the suspected hacking was submitted prior to the search); and
7. Assisting another student in violating any of the above rules.

A student who has committed an act of academic dishonesty has failed to meet a basic requirement of satisfactory academic performance. Thus, academic dishonesty is not only a basis for disciplinary action, but may also affect the evaluation of a student's level of performance. Any student who commits an act of academic dishonesty is subject to disciplinary action.

In instances where a student has clearly been identified as having committed an act of academic dishonesty, an instructor may take appropriate disciplinary action, including loss of credit for an assignment, exam, or project; or awarding a grade of "F" for the course, **subject to review and endorsement by the chairperson and dean.**

ASSIGNMENTS AND ACADEMIC CALENDAR

Include topics, reading assignments, due dates, exam dates, withdrawal dates, pre-registration and registration dates, all holidays, and convocations. *

THE WEEK OF (MM/DD/YY)	SUBJECT	UNIT LEARNING OUTCOMES (ULO)	READING IN TEXT, ACTIVITY, HOMEWORK, EXAM
	Unit 1: Electromagnetic Theory -I	<p>ULO 1: Explain the physical meaning of Maxwell's equations. (SLO 1)</p> <p>ULO 2: Compute simple differential and integral operators (SLO 1)</p> <p>ULO 3: Relate Kirchhoff circuit laws to the static or low frequency Maxwell's equations. (SLO 1)</p>	<p>1. Read Textbook: Pozar, D. M. (2011). <i>Microwave engineering</i>. (4th ed.). Wiley. a. Chapter 1: Electromagnetic Theory</p> <p>2. Complete: Discussion #2: Electromagnetic Wave Phenomena (ULO 1)</p>
	Unit 2: The pn junction diode and its applications	<p>ULO 1: Calculate simple plane wave propagation in media and its key parameters. (SLO 1)</p> <p>ULO 2: Calculate simple power transmission for plane EM waves. (SLO 1)</p> <p>ULO 3: Explain the concept of phase velocity, intrinsic impedance, skin depth, loss tangent, etc (SLO 1)</p> <p>ULO 4: Explain the basic boundary conditions (SLO 1)</p>	<p>1. Read Textbook: Pozar, D. M. (2011). <i>Microwave engineering</i>. (4th ed.). Wiley. a. Chapter 1: Electromagnetic Theory</p> <p>2. Complete: Assignment #1: Plane Waves (ULO 1-4)</p>
	Unit 3: Transmission Lines and Waveguides I	<p>ULO 1: Formulate the transmission line equations (SLO 2)</p> <p>ULO 2: Determine the key parameters of a transmission line (SLO 2)</p> <p>ULO 3: Analyze the wave propagation on a</p>	<p>1. Read Textbook: Pozar, D. M. (2011). <i>Microwave engineering</i>. (4th ed.). Wiley. a. Chapter 2: Transmission Line Theory b. Chapter 3: Transmission Lines and Waveguides</p> <p>2. Complete: Discussion Board #3 Transmission Lines (ULO 1-4)</p>

		transmission line for various loads (SLO2) ULO 4: Design transmission line stubs and impedance transformers (SLO2)	
	Unit 4: Transmission Lines and Waveguides II	ULO 1: Explain the operation principles of rectangular waveguides (SLO 2) ULO 2: Design rectangular waveguides. (SLO 2) ULO 3: Explain the principle of Smith Chart. (SLO 2) ULO 4: Utilize Smith Chart for transmission line analysis (SLO 3)	1. Read Textbook: Pozar, D. M. (2011). Microwave engineering. (4th ed.). Wiley. a. Chapter 2: Transmission Line Theory b. Chapter 3: Transmission Lines and Waveguides 2. Complete: Assignment #2: Transmission Line Theory and the Smith Chart (ULO 1-4)
	Unit 5: Microwave Network Analysis-I	ULO 1: Characterize a multi-port network using Z, Y, ABCD parameters (SLO 3) ULO 2: Characterize an arbitrary multi-port network using S parameters. (SLO 3) ULO 3: Determine the reciprocity and lossless condition for various networks. (SLO 3)	1. Read Textbook: Pozar, D. M. (2011). Microwave engineering. (4th ed.). Wiley. a. Chapter 4: Microwave Network Analysis 2. Complete: Discussion Board #4: S Parameters (ULO 1-2)
	Unit 5: Microwave Network Analysis-I	ULO 1: Characterize a multi-port network using Z, Y, ABCD parameters (SLO 3) ULO 2: Characterize an arbitrary multi-port network using S parameters. (SLO 3) ULO 3: Determine the reciprocity and lossless condition for various networks. (SLO 3)	1. Read Textbook: Pozar, D. M. (2011). Microwave engineering. (4th ed.). Wiley. a. Chapter 4: Microwave Network Analysis 2. Complete: Discussion Board #4: S Parameters (ULO 1-2)

	Unit 6: Microwave Network Analysis-II	<p>ULO 1: Conduct network analysis using signal flow chart and S parameters (SLO 3)</p> <p>ULO 2: Convert between different network parameters. (SLO 3)</p> <p>ULO 3: Explain the principles of the network measurement. (SLO 3)</p>	<p>1. Read Textbook: Pozar, D. M. (2011). Microwave engineering. (4th ed.). Wiley.</p> <p>a. Chapter 5: Impedance Matching and Tuning</p> <p>2. Complete: Assignment #3: Microwave Networks (ULO 1-3)</p>
	Unit 7: Impedance Matching-I	<p>ULO 1: Design simple lumped matching circuits (L-, T-, Pi- networks) (SLO 4)</p> <p>ULO 2: Design lumped matching circuit using smith chart. (SLO 4)</p> <p>ULO 3: Design matching circuits using transmission lines and stubs. (SLO 4)</p>	<p>1. Read Textbook: Pozar, D. M. (2011). Microwave engineering. (4th ed.). Wiley.</p> <p>a. Chapter 5: Impedance Matching and Tuning</p> <p>2. Complete: Discussion #5: Pros and Cons of different matching circuits (ULO 1-3)</p>
	Unit 8: Impedance Matching-II	<p>ULO 1: Design matching circuit using Smith Chart (SLO 4)</p> <p>ULO 2: Synthesize multi-section impedance transformers for broadband matching. (SLO 4)</p> <p>ULO 3: Explain the broadband matching limits (SLO 4)</p>	<p>1. Read Textbook: Pozar, D. M. (2011). Microwave engineering. (4th ed.). Wiley.</p> <p>a. Chapter 5: Impedance Matching and Tuning</p> <p>2. Complete: Assignment #4: Impedance Matching (ULO 1-2)</p> <p>3. Complete: Exam #1: Mid Term Exam (ULO 1-2)</p>
	Unit 9: Passive Components I	<p>ULO 1: Describe the design tradeoff in a three-port device. (SLO 5,7)</p>	<p>1. Read Textbook: Pozar, D. M. (2011). Microwave engineering. (4th ed.). Wiley.</p>

		ULO 2: Design various power dividers, such as T Junction, Wilkinson power divider, etc. (SLO 5,7)	<ul style="list-style-type: none"> a. Chapter 7: Power Dividers and Directional Couplers 2. Complete: Discussion #6: Analysis Technique for Power Dividers (ULO 1-2)
	Unit 10: Passive Components II	<p>ULO 1: Design and analyze four-port devices, such as the 90-degree hybrid, 180-degree hybrid, coupled line directional coupler, and magic T (SLO 5,7)</p> <p>ULO 2: Analyze symmetric four-port devices using even-odd mode analysis and using ABCD and S parameters. (SLO 5,7)</p>	<ul style="list-style-type: none"> 1. Read Textbook: Pozar, D. M. (2011). Microwave engineering. (4th ed.). Wiley. a. Chapter 7: Power Dividers and Directional Couplers 2. Complete: Assignment #5: Passive Devices (ULO 1-2)
	Unit 11: Microwave Filters I	<p>ULO 1: Design filters using lumped elements. (SLO 5,7)</p> <p>ULO 2: Transform low-pass filters into high-pass, band-pass, and band-stop responses. (SLO 5,7)</p> <p>ULO 3: Design filters using insertion loss method, for maximally flat and equal-ripple responses. (SLO 5,7)</p> <p>ULO 4: Convert lumped-element filters into distributed filter designs. (SLO 5,7)</p>	<ul style="list-style-type: none"> 1. Read Textbook: Pozar, D. M. (2011). Microwave engineering. (4th ed.). Wiley. a. Chapter 8: Microwave Filters 2. Complete: Discussion #7: Design Techniques in Microwave Filters (ULO 1-2)
	Unit 12: Microwave Filters II	<p>ULO 1: Design low-pass filters using stepped-impedance multi-section transmission lines. (SLO 5,7)</p> <p>ULO 2: Design band-pass filters using coupled lines. (SLO 5,7)</p>	<ul style="list-style-type: none"> 1. Read Textbook: Pozar, D. M. (2011). Microwave engineering. (4th ed.). Wiley. a. Chapter 8: Microwave Filters

		ULO 3: Recognize different filter configurations. (SLO 5,7)	2. Complete: Assignment #6: Microwave Filters (ULO 1-3)
	Unit 13: Microwave Network Analysis-I	<p>ULO 1: Explain the noise figure and non-linearity of RF devices. (SLO 7)</p> <p>ULO 2: Explain the basic architecture of a direct-conversion RF transceiver. (SLO 7)</p> <p>ULO 3: Analyze the noise and nonlinearity performance of RF systems consisting of cascaded devices, such as filters, amplifiers, mixers, etc. (SLO 7)</p> <p>ULO 4: Conduct link budget and receiver sensitivity calculation. (SLO 7)</p>	<p>1. Read Textbook: Pozar, D. M. (2011). Microwave engineering. (4th ed.). Wiley.</p> <p>a. Chapter 10: Noise and Nonlinear Distortion</p> <p>b. Chapter 14: Introduction to Microwave System</p> <p>2. Complete: Discussion #8: An Example of RF System (ULO 1-4)</p>
	Unit 14: RF and Microwave Simulation and Measurement	<p>ULO 1: Design and simulate a microwave device using ADS. (SLO 7)</p> <p>ULO 2: Conduct S parameter measurement of microwave devices using VNA. (SLO 7)</p> <p>ULO 3: Run simple EM simulation of microwave devices using ADS Momentum. (SLO 7)</p>	<p>1. Read Textbook: Pozar, D. M. (2011). Microwave engineering. (4th ed.). Wiley.</p> <p>a. Chapter 4: Network Analysis</p> <p>b. Chapter 8: Microwave Filters</p> <p>2. Complete: Assignment #7: Noise and Nonlinear Distortion (ULO 1-2)</p> <p>3. Complete: Design Project #1 (ULO 1-2)</p>
	Unit 15: Final Review	<p>ULO 1: Develop an overall view of this course. (SLO 1-7)</p> <p>ULO 2: Connect the dots between different lectures. (SLO 1-7)</p>	<p>1. Read Textbook: Pozar, D. M. (2011). Microwave engineering. (4th ed.). Wiley.</p> <p>a. Chapters 1–5, 7–8, 10, 14</p>

		ULO 3: Solve professional microwave engineering problems using the techniques covered throughout the course. (SLO 1-7)	2. Complete: Exam #2: Final Exam (ULO 1-2)
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** These descriptions and timelines are subject to change at the discretion of the instructor.*