ECE 8200
Digital Communication

Class Location/Time	Monday-Wednesday 3:35-4:50 pm, Riggs Hall, #301
Instructor	Fatemeh Afghah (fafghah@clemson.edu), 334 Fluor Daniel Engineering Innovation Building
Office Hours	Mondays and Fridays at 10 am Please write 'ECE 8200 ' in the subject line when you email me about this course. Discussions immediately before and after class are encouraged but may not always be possible.
Grader	NA
Prerequisites	ECE 3300: Signals, Systems, and Transforms ECE 3170: Random Signal Analysis Good Matlab or Phyton programming skills are expected. Familiarity with the following mathematical skills: complex arithmetic, vector and matrix arithmetic, linear algebra integration and differentiation.
Important Dates	• Jan. 15th : No class • Jan. 24th: Last day to drop a class without a W grade • March 18-22th: Spring Break, No class

Course Description:

Upon completion of this course, you should have an understanding of the principles of digital communication including the following: signals and spectra, baseband signaling and detection in noise, modulation and demodulation techniques, and communications link budget analysis.

Course Objectives

This course is a research-based course that focuses on recent advances in wireless technology including LTE, 5G and beyond, IoT communication, UAV communication, and spectrum management. Building on expertise in the mathematical analysis of wireless systems and signals, the lectures, in-class discussions, textbook and scholarly literature readings, homework

assignments, and research projects will foster student learning in fundamental theoretical concepts in wireless communications systems and will familiarize them with related technologies and research challenges in wireless communications. This expertise enables students to be prepared to succeed in the design, analysis, and implementation of specialized wireless systems and is particularly suitable for students with research in wireless systems who plan to pursue professional positions in wireless communications.

Required Materials

Optional textbooks:

1- A First Course in Digital Communications, Ha Nguyen, Ed Shwedyk, Cambridge University Press.
2- Wireless Communications, Andrea Goldsmith, Cambridge University Press, 2005.
3- Introduction to Wireless Systems, Mohama Shankar, John Wiley, 2002.

This course does not require or directly refer to these textbooks, but they do cover the majority of the material. Lectures will occasionally include material not found in the textbooks. You are responsible for all material discussed in class or assigned in the text.

Course Outcomes

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

- Understand the mathematical modeling of wireless channels, and concepts of shadowing and fading.
- Understand the building blocks of wireless networks, digital modulation.
- Understand the basics of information theory and the concept of the capacity of wireless channels.
- Model the signal propagation in an AWGN and fading channels.
- Develop an optimal maximum likelihood receiver for AWGN channels.
- Design an optimal modulation technique to address the system's requirements in terms of probability of error, power consumption, data transmission rate.
- Calculate the probability of bit error in wireless channels.
- Understand the concept of diversity in wireless communication systems.
- Understand different methods of multiple channel access including random channel access.

- Understand the basics of error detection and error correction codes including CRC, RS, Convolutional Codes, LDPC, and Turbo Codes.
- Understand and articulate the terminology, infrastructure, and operation of cellular networks ranging from first-generation analog systems to 5G networks.

- Conduct literature review and in-depth research in their topics of interest including but not limited to mmWave communications, Massive MIMO systems, Passive Wireless Sensor Networks, UAV Networks, Delay intolerant networks, Cognitive Radio Networks, Remote sensing, Green Communications, Network Optimization, Wireless Sensing for Industrial Automation, Fault Tolerant Data Networks, Beamforming, interference management, Network Coding, Big Data in Wireless Networks, IoT, LiFi, Optical and Laser Communications, Deep-Space Communication, Vehicular communication, Spectrum management, Cognitive radio networks, Queuing and Scheduling, Non-terrestrial communication, AI in 5G and Beyond.
- Develop and Simulate Communication protocols in MATLAB Environment.
- Understand the state of the art, the research challenges, and current applications and future trends of wireless communications through intensive scholarly literature review and research-based term projects.
- Read and understand relevant standards and technical specifications of practical systems.
- Conduct a literature review and follow their research topics of interest.

Course Outline:

Although the lectures will generally follow the following list, we will occasionally skip certain material and may include supplementary topics.

- **Overview of Wireless Communication Systems**: History of Wireless Communications, Cellular Networks, Wireless Local Area Networks, Sensor Networks, Spectrum Allocation.

  (Reading: Chapter 1, Wireless Communications, Goldsmith)

- **Overview of Signals and LTI Systems Characterization**

  Overview of signals representations, Properties of signals, Fourier transform, Linear time-invariant signals, Impulse Response.

  (Reading: Chapter 2, A First Course in Digital Communications, Ha Nguyen)

- **Probability Theory, Random Variables and Random Processes**

Random variables, Expectations of random variables, Random processes, Statistical properties of joint random processes, Gaussian distribution.

(Reading: Chapter 3, A First Course in Digital Communications, Ha Nguye

- **Sampling and Quantization**

  Sampling of continuous-time signals, Quantization, Pulse-code modulation (PCM)

  (Reading: Chapter 4, A First Course in Digital Communications, Ha Nguyen)

- **Baseband Communication and Optimum Receiver**

  Geometric representation of signals, Representation of noise, Optimum receiver, Baseband signaling schemes, Error performance

  (Reading: Chapter 5 & 6, A First Course in Digital Communications, Ha Nguyen)

- **Digital Modulation and Detection**: Signal Space Analysis, Geometric Representation of Signals, Maximum Likelihood Detection, Passband Modulation Principles, Amplitude Modulation, Phase modulation, Quadrature Amplitude Modulation, Frequency Modulation, Minimum Shift Keying.

  (Reading: Lecture notes; Chapter 5, Wireless Communications, Goldsmith)

  (Reading: Chapter 8, A First Course in Digital Communications, Ha Nguyen)

- **Path Loss and Shadowing**: Overview of Signal and Linear Systems, Radio Wave Propagation, Signal Models, Path Loss Models, Ray Tracing, Shadow Fading, Outage Probability, Cell Coverage Area.

  (Reading: Lecture notes; Chapter 2, Wireless Communications, Goldsmith)

- **Statistical Multipath Channel Models**: Channel Response, Multi-path Fading, Narrowband Fading, Wideband Fading, Power Delay Profile, Doppler Spread, Coherence Bandwidth, Delay Spread, Coherence Time.

  (Reading: Lecture notes; Chapter 3, Wireless Communications, Goldsmith)

- **Performance of Digital Modulation over Wireless Channels**: Error probability for different modulation techniques including BPSK, MPAM, MPSK, MQAM and FSK over AWGN and fading channels.

(Reading: Lecture notes; Chapter 6, Wireless Communications, Goldsmith)

- **Coding Techniques**: Source coding, Channel coding, Generator Matrix, Parity-Check Matrix, Linear Block Codes, Cyclic Codes, Trellis Diagram, Convolutional coding, Concatenated codes, Turbo codes, LDPC codes.

  (Reading: Lecture notes; Chapter 8, Wireless Communications, Goldsmith)

  This chapter will be offered if we had enough time.

- **Multiple User Communication Systems**: Time-Division Multiple Access (TDMA), Frequency-Division Multiple Access (FDMA), Code-Division Multiple Access (CDMA), Space-Division Multiple Access (SDMA), Space-Time Coding, Orthogonal Frequency Multiple Access (OFDM), Throughput Calculation, and Random Access Techniques including ALOHA, slotted ALOHA, CSMA, and DSMA.
  (Reading: Lecture notes; Chapter 14, Wireless Communications, Goldsmith)

- **Cellular Networks**: Fundamentals of Cellular Networks, Frequency Reuse, Channel Assignments, Cellular Technologies including GSM, IS-95, EDGE, UMTS, LTE, 5G.
  (Reading: Lecture notes; Chapter 15, Wireless Communications, Goldsmith)

Grading

We use two grading options for this course:

1_With a final exam:

Final grades will be based on the following weights:
Homework: 15%
Mid-term test (open-book): 20% (tentative date: April 3rd)
Final Test (comprehensive, closed-book): 30%
Project proposal, literature review, and final paper: 35% (the project could be based on a literature survey on a topic related to wireless communications).
The project can be graded for up to 65% of the final grade (15% extra credit) if the quality of the final paper meets the expectations for a journal paper.

1_Without a final exam:

Final grades will be based on the following weights:
Homework: 10%
Mid-term test (open-book) : 20% (tentative date: April 3rd)
Project proposal, literature review, and final paper: 70%.

The project report and contributions should meet the expectations for an IEEE/ACM conference paper.

A – 90% - 100%; B – 80 to < 90%; C – 70 to < 80%; D – 60 to < 70 & F – < 60%

Additional Policies

Course Structure and Evaluation Mechanisms:

This course offering will consist of several elements: Lectures that meet two hours and a half per week to present and discuss topics relating to wireless networks, readings from the textbooks, papers and other closely related material that support and expand on lecture themes, homework assignments that will sharpen students' understanding of the material, and research projects that provide a chance to gain a more in-depth understanding of a topic of interest as well as designing a new wireless system by applying concepts from lectures. The main emphasis will be on in-class discussions. We will not only focus on theoretical aspects but also explore the actual implementations and current technologies. The students frequently will be provided with materials out of the textbooks. There will often be important material in the text that we will not have time to cover in class.

Term Project: Students will be involved in mandatory term projects. Each final project will include a study of a specific aspect of wireless networks based on the student's interest. Students are welcome to discuss with the instructor to select a project or develop their own projects after getting approval from the instructor. Each student is supposed to prepare a project proposal to define the problem statement, submit a comprehensive literature review to study the recent literature and other online resources on the adopted topic, and provide a comprehensive summary of the problem, its importance, current solutions, and future direction to solve the remaining challenges and a final paper describing the mathematical modeling, developed algorithms and solution and simulation and experimental results. The project is broken down to the following assignments:

i) **Proposal (5 points): The** proposal tentative is a one-page (single column) document to define the problem statement, why this project is interesting for the student and relevant to the course topics, and what aspects the student plans to investigate related to this topic.
Proposals are due on Feb. 14th, 2024.

ii) **Review assignment (10 points):** In this assignment, the instructor assigns an IEEE/ACM journal paper related to the selected project to each student to review or the student can select a paper that is related to the research project and will be used as one of the main references of his/her research. The goal of this assignment is for

the student to evaluate the scientific hypotheses and findings of the paper by answering the following questions:

- What hypothesis or question is motivated in this paper?
- Why is the proposed method needed?
- Are the assumptions of the model reasonable?
- Is the proposed method novel?
- What evaluation methods are used to verify the method?
- Is the proposed method well supported by the results?
- What are the aspects that the authors have not discussed?
- How the proposed method could be improved?
- How do you plan to use this paper in your research?

The review assignment is a three-page (single-column) document and is due on Feb. 28th.

iii) **Literature review (10 points):** a three-page (single-column) document and is due on March 15th. The goal of this assignment is for the student to review between 10-15 recently published related papers published in reputable IEEE/ACM venues to present a comprehensive review of the recent advances in the field related to the selected topics and discuss future research directions in this domain. Each student will present a 10-minute presentation followed by 5-minute questions to present his/her proposal and literature review after the Spring break (March 25, and 27) and describe the plan for his/her research project.

iv) **Final paper & presentation (25 points):** a 5-page double-column IEEE conference format paper. For students working on survey research, the paper should include the abstract, introduction, related work, and a discussion on the student's evaluation of the technology and its future direction. Research papers should include For students working on research papers, the paper should include the abstract, introduction, related work, proposed method, evaluation, and experimental results and conclusions. The final papers are due on April 26th. The final presentation is due as a 20 min presentation followed by 5-minute questions and discussions. The final presentations are during the last two weeks of the class.

STUDENT ACCESSIBILITY SERVICES

Clemson University values the diversity of our student body as a strength and a critical component of our dynamic community. Students with disabilities or temporary injuries/conditions may require accommodations due to barriers in the structure of facilities, course design, technology used for curricular purposes, or other campus resources. Students who experience a barrier to full access to this class should let the instructor know and make an appointment to meet with a staff member in Student Accessibility Services as soon as possible. You can make an appointment by calling 864-656-6848, by emailing studentaccess@lists.clemson.edu, or by visiting Suite 239 in the Academic Success Center building. Appointments are strongly encouraged – drop-ins will be seen, if at all possible, but there could be a significant wait due to scheduled appointments. Students who have accommodations are strongly encouraged to request, obtain, and send these (Links to an external site.) to their instructors via SAS as early in the semester as possible so that accommodations can be made in a timely manner. It is the student's responsibility to follow this process each semester.
You can access further information at the Student Accessibility website (Links to an external site.). Other information is at the university's Accessibility Portal (Links to an external site.).

TITLE IX

The Clemson University Title IX statement: Clemson University is committed to a policy of equal opportunity for all persons and does not discriminate on the basis of race, color, religion, sex, sexual orientation, gender, pregnancy, national origin, age, disability, veteran's status, genetic information or protected activity in employment, educational programs and activities, admissions and financial aid. This includes a prohibition against sexual harassment and sexual violence as mandated by Title IX of the Education Amendments of 1972. This Title IX policy (Links to an external site.)is located on the Campus Life website. Ms. Alesia Smith is the Clemson University Title IX Coordinator, and the Executive Director of Equity Compliance. Her office is located at 223 Brackett Hall, 864.656.0620. Remember, email is not a fully secured method of communication and should not be used to discuss Title IX issues.

ACADEMIC INTEGRITY

As members of the Clemson University community, we have inherited Thomas Green Clemson's vision of this institution as a "high seminary of learning." Fundamental to this vision is a mutual commitment to truthfulness, honor, and responsibility, without which we cannot earn the trust and respect of others. Furthermore, we recognize that academic dishonesty detracts from the value of a Clemson degree. Therefore, we shall not tolerate lying, cheating, or stealing in any form.

All infractions of academic dishonesty by undergraduates must be reported to Undergraduate Studies for resolution through that office. In cases of plagiarism instructors may use the Plagiarism Resolution Form.

See the Undergraduate Academic Integrity Policy (Links to an external site.) website for additional information and the current catalog (Links to an external site.) for the policy. For graduate students, see the current graduate student handbook (Links to an external site.) for all policies.

EMERGENCY PREPAREDNESS STATEMENT

Emergency procedures have been posted in all buildings and on all elevators. Students should be reminded to review these procedures for their own safety. All students and employees should be familiar with guidelines from the Clemson Police Department. Visit here for information about safety. (Links to an external site.)

ACADEMIC SUCCESS CENTER

The Academic Success Center (Links to an external site.) (ASC) offers a variety of free learning and success services for all undergraduate students that include

Mastery of course content

- Tutoring – students can expect a 1:1 meeting with a trained undergraduate peer leader (who made an A or B in the course and was recommended by a faculty member) during which the student can share specific questions they have about course content with the tutor focused on helping the student, through questioning techniques and identification of helpful learning strategies, and master course concepts. Tutors do not help with homework or other class assignments.
- Peer-Assisted Learning (PAL) – students can expect collaborative and active group learning and study sessions focused on mastery of course content and learning strategies that is facilitated by a trained undergraduate peer leader (who made an A or B in the course and was recommended by a faculty member). PAL leaders do not help with homework or other class assignments.

Learning and Success Strategies

- Academic coaching - students can expect a 1:1 meeting with a trained professional academic coach during which the coach helps students see themselves, their skills, and their study habits from a fresh perspective through one-on-one sessions focused on learning and personal success strategies.
- Success strategy workshops – students can expect 30-45 minute workshops on college success skills, time management and organizational skills, test-taking strategies, study strategies, finals preparation, life skills, and academic resources.

- College success skills course (CU 1010) – students experiencing academic difficulty can expect a course focused on academic and personal skill building taught by instructors who wish to work with this student population

ASC services are designed to equip students with strategies and resources they can use to:

- Succeed in their courses
- Become more confident, independent, and skillful learners
- Engage in more productive and effective study and learning strategies
- Manage their time more effectively

Location: The Class of 1956 Academic Success Center building is located in the center of campus adjacent to Cooper Library and the Watt Family Innovation Center.

TECH SUPPORT

If you have trouble with Canvas or another university system, check here first: Clemson System Status.

CCIT's IT Support Center offers a wide range of support options and hardware repair with several contact methods to help you answer your questions as quickly as possible:

- Phone: (864) 656-3494
- Email: ITHelp@clemson.edu
- Chat: Live Online Chat (Links to an external site.)
- Web Form: Help Request Form (Links to an external site.)
- Troubleshoot: Knowledge Base (Links to an external site.)
- Everything CCIT Does: Browse Services

Copyright Statement

The instructor reserves the rights to make changes to the syllabus at any times.