417mcd2018

Master Course Description for EE-417 (ABET sheet)

Title: Modern Wireless Communications

Credits: 4

UW Course Catalog Description

Coordinator: Payman Arabshahi, Associate Professor, Electrical and Computer Engineering

Goals: To develop an understanding of the fundamental principles of digital communication systems and an appreciation of the limitations imposed by noise, fading, and bandlimited and non-ideal channels in the performance of wireless communication systems.

Learning Objectives: At the end of this course, students will be able to:

1. *Describe* a variety of digital modulation techniques.
2. *Write* computer programs (in Python or MATLAB) to simulate digital modulation techniques.
3. *Determine* the bit error rate of basic modulation formats when operating in an additive white Gaussian noise environment.
4. *Describe* qualitatively and quantitatively, the fundamental impairments to digital transmission across non-ideal channels.
5. *Determine* the advantages of error correcting codes on the performance of digital communication systems.
6. *Design* digital communication systems to operate in noisy and bandlimited channels and to achieve basic system specifications on bandwidth and power usage, data rate, and error rate performance.

Textbook: J.G. Proakis and M. Salehi, *Fundamentals of Communication Systems (2nd Ed.)*, Pearson, 2013. ISBN #: 978-0133354850.

Reference Texts:

1. J. Proakis and M. Salehi, *Digital Communications, 5th Ed.*, McGraw-Hill, 2007. ISBN #: 978-0072957167.
2. R.G. Gallager, *Principles of Digital Communication*, Cambridge University Press, 2008. ISBN #: 978-0521879071.
3. R.W. Heath Jr., and A. Lozano, *Foundations of MIMO Communication*, Cambridge University Press, 2019. ISBN #: 978-0521762281.
4. A. Leon-Garcia, *Probability, Statistics, and Random Processes for Electrical Engineering*, Pearson, 2008. ISBN #: 978-0131471221.

Prerequisites by Topic:

1. Continuous time and discrete time signals and linear systems (EE-235, EE-341).
2. Principles of applied probability and statistics (MATH-390, STAT-390 or IND E 315).
3. Differential and integral calculus
4. Programming experience

Topics:

1. Mathematical models for communication channels
2. Lowpass and bandpass signals- Random processes
   - Wide-sense stationary processes
   - Random processes and linear systems
   - Power spectral density of stationary processes
   - Gaussian and white processes- Digital modulation methods in an additive white Gaussian noise channel
   - Binary and M-ary modulation schemes
   - Optimum receiver structures
   - Probability of error calculations
   - Performance comparisons of modulation methods- Synchronization
   - Carrier phase estimation
   - Symbol timing estimation- Digital transmission through bandlimited additive white Gaussian noise channels
   - Intersymbol interference
   - Signal design for bandlimited channels
   - Linear equalization
   - Decision-feedback equalization- Information theory
   - Source coding
   - Channel capacity
   - Forward error correction coding- RF Link budget analysis and applications

Time permitting overviews of contemporary topics such as multi-carrier modulation and OFDM, or spread-spectrum communication systems may also be provided.

Course Structure: The class meets for two 110 minute sessions a week. There are weekly homeworks, which may include small computer (MATLAB or Python) projects. There is a midterm exam, and a final exam. In the second half of the course students will also work on a major computer project, typically with hardware-in-the-loop (low-cost software defined radio platforms or other transmit/receive devices). The project may be performed individually or in groups of two.

Computer Resources: Computer problems assigned as part of homeworks and the project can be carried out on any personal computer running Windows, macOS, or Linux. Students have access to departmental computing facilities for these, or will use their own desktops/laptops.

Laboratory Resources: Students have access to Departmental Windows computing labs (ECE 137, 361, 365, or Sieg 231) and the Linux Lab (Sieg 118) for homeworks and projects.

Grading: Homeworks: 25%, Midterm exam: 25%, Project: 25%, Final Exam: 25%.

ABET Student Outcome Coverage: This course addresses the following outcomes:

H = high relevance, M = medium relevance, L = low relevance to course.

(1) *An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics* **(H)** The course is highly mathematical in its orientation. Students are asked to both identify and solve appropriate mathematical models, understand and develop mathematical formulations, and perform mathematical derivations and proofs. Engineering judgment is developed through the use of modeling and approximate solution techniques. Some basic principles of physical sciences are occasionally needed to motivate the engineering origins of the problems under consideration. The homeworks involve solving engineering problems identified by the assignments and exemplified by class discussion. The midterm and final exams, and the class project challenge the students to identify the issues and formulate their solutions. Students use MATLAB or Python programming to solve computer assignments in homeworks, and in the class project.

(2) *An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors* (**M**) The class project challenges the students to propose a suitable topic, or work on a challenge posed by the instructor, and in either case to design and implement a software/hardware system (design, build, test). In most cases, this will be implemented in MATLAB or Python together with a hardware platform (e.g. software defined radio) or hardware devices (e.g. speaker and microphone). The class project concerns itself with a basic end-to-end system design, requiring development of modulation, demodulation, error correction coding, synchronization, and equalization modules. The system will be subject to one or more performance criteria (e.g. error probability or data rate at a given signal-to-noise-ratio or range). Students use MATLAB or Python programming to solve computer assignments in homeworks, and in the class project.

(3) *An ability to communicate effectively with a range of audiences* (**M**) The class project inculcates this important skill. Effectiveness in technical writing has a good impact on the final grade. Best practices of good written communications are covered in class. Emphasis in any such communication is placed upon clear descriptions of system design, build, and test steps, analysis of tradeoffs, results of verification and validation, illustrative block diagrams, industry acceptable schematic diagrams, a formal bill of materials with full component (software or hardware) sourcing, and proper discussions and references to engineering design standards.

(4) *An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts* (**L**) Since communication networks form the underpinnings of the information age, ethical issues relating to the Internet (privacy, security, etc.) are discussed briefly in class meetings. Contemporary issues discussed include the latest news and advances in wireless communications, and spectrum and regulatory issues. Professional responsibility topics are addressed in the context of wireless system design under FCC regulatory constraints. In the class project students are asked about the societal relevance of their project focus.

(5) *An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives* (**L**) The class project is conducted either individually or in teams of two. Basic concepts such as task allocation and work breakdown structure are covered. If working in teams, students organize themselves and divide up the work among them.

(6) *An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions* (**M**) The class project focuses on experimentation and analysis and interpretation of data and measurements. For instance, students determine the required sample sizes for statistically reliable Monte Carlo simulations. These techniques are used to solve real-world problems not amenable to analysis and as substitutes for physical experiments. Students also learn about various practical experimental aspects such as channel estimation, compensating for hardware limitations, oscillator drifts, frequency offsets, timing errors, proper sampling strategies, antenna matching, and buffering. Students use MATLAB or Python programming to solve computer assignments in homeworks, and in the class project.

(7) *An ability to acquire and apply new knowledge as needed, using appropriate learning strategies* (**M**) The course emphasizes the rapid change in technologies employed in modern communications and the need for the professional to maintain state-of-the-art knowledge. A variety of references will be required for the class project from web sources, articles, and textbooks. For the project students must consult reference sources and inform themselves concerning different aspects of the design problem. This helps students realize that they need to be able to learn material on their own, and gives them some of the necessary skills.

Prepared By: Payman Arabshahi

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