Course:	EE360K: Introduction to Digital Communications (Undergraduate)
	EE381K-2: Digital Communications (Graduate)
Semester:	Spring 2022
Lecture Hours:	TTH 12:30-1:45pm
Lecture Location:	EER 1.516
Instructor:	Prof. Jeffrey G. Andrews
Office Hours:	Tue 2-4pm
Office:	EER 6.880
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Unique Course ID:	17635 (360K)
	16695 (381K-2)

TA:	Eunsun Kim
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TA Office Hours:	Mon 7-8:30pm (Zoom Meeting ID: 976 6229 5046)
	Wed 1-2:30pm (In person, office TBD)
TA Office:	TBD

Grader:	TBD
Grader Email:	

COVID-related Comments and Modifications

Lectures will be delivered in person in the above classroom. Although these lectures will be recorded, students are strongly encouraged to attend these lectures in person to maximize their learning experience, their contact with the Professor, to meet other students in the class, and to ask questions. Weekly quizzes will be given in real-time in lecture on Thursday and will not be given remotely unless arrangements are made ahead of time. Exams will also be given in person without a remote option, barring exceptional circumstances.

Of course, this is just the plan. We have learned in the last couple years that all plans are subject to alteration on fairly short notice…. More timely updates will be provided as necessary.

Course Objectives

This course is meant to provide a strong foundation for further study, research and industry practice in the area of communication systems. The main objective of the course is to learn the engineering principles and analytical techniques for the design of reliable high-speed digital communication systems. In particular, the focus of this class is the reliable transmission and reception of finite-alphabet (i.e. digital) symbols over dispersive linear time-invariant (LTI) channels in the presence of noise. In particular we consider baseband and passband modulation and demodulation in additive white Gaussian noise (AWGN), channel equalization, multicarrier modulation (OFDM), and an introduction to information theory and channel coding.

Mobile wireless communication necessarily introduces time-variant channels and multiple access – multiple users sharing the same channel – to the mix: this course does not consider those aspects explicitly, but its sequel EE 381K-11 does. Nevertheless, the models and theory in this course apply equally to wired and wireless channels.

Prerequisites and Background Required

This is intended to be a rigorous (and hopefully inspiring) first or second class on the theory and practice of modern communication systems, accessible to advanced undergraduate students, but also sufficiently deep and comprehensive for first and second year graduate students. As such, the only mandatory prerequisites (equivalent non-UT classes are acceptable) are:

- EE313 Signals and Systems
- EE351K Probability and Random Processes
- M340L, i.e. Linear algebra for EEs, including matrix decompositions

DSP. Although not a mandatory prerequisite, students will find it helpful to also have a strong background in discrete time signal processing, e.g. through EE351M Digital Signal Processing and/or EE445S Real-Time Digital Signal Processing Lab. Students without this background are encouraged to take one of those courses simultaneously to buttress their DSP fundamentals, which will be needed particularly in the second half of the class.

It is also expected that students have some elementary experience with MATLAB: some homework problems and the mini-projects will require MATLAB. Students with a strong preference for Python may use Python instead, but we will not provide explicit Python support, code snippets, solutions, etc.

Course Texts

1. U. Madhow, *Introduction to Communication Systems,* Cambridge University Press, 2014.
2. J. G. Andrews, *Digital Communications Course Reader*, Unpublished Working Draft, 2022.

Web Resources

The online class system is Canvas. All handouts will be distributed on Canvas. We'll send group e-mails and do online grading as well (so you can view your grades there) via Canvas. We will also use Gradescope for grading HWs and Quizzes electronically.

Grading

20%	Midterm 1
20%	Midterm 2
25%	Final Exam
20%	Homework
10%	Mini-project(s), **Grad students only**
10%	Additional 2.5% added to each of the 3 exams and the quizzes, **Undergrad students only**
5%	Weekly Quizzes (lowest two scores dropped)

Furthermore, undergraduate students and graduate students will be graded separately. In particular, students enrolled for the graduate class EE381K-2 will be graded on a curve relative to other students in EE381K-2, while the curve for students enrolled in EE360K will include only other students in that course number.

Important Dates

Midterm 1: TBD
Midterm 2: TBD

Final: Set by Registrar; however we may have it before finals or as a take-home

Course Lecture Schedule (subject to change)

Key:

- [M3.2] = Madhow, Chapter 3, Section 2
- Topics with Andrews writeups. You can use Madhow as a supplement for these parts if you would like additional detail. In the event of conflicts/contradictions, ignore Madhow.
- Andrews writeups, still in progress

Introduction, Fast-Paced Review

1. Introduction to analog and digital communications [M1]
2. Key signals, Correlation and Matcher Filter Receivers, Fourier transforms, Energy spectral density [M2.1-2.5]

Passband Signals and Analog Communication

3. Passband signals and bandwidth [M2.6-2.7]
4. Complex baseband signal representation [M2.8]
5. Amplitude modulation and demodulation, FM, SSB, Phase locked loops [M3.2, 3.5]

Probability and random processes for digital communications [Madow Ch. 5]

6. Gaussian random variables, Gaussian noise, vector AWGN channels
7. WSS Random processes, autocorrelation and power spectral density
8. Noise models for baseband and passband, filtering and correlation in noise

Digital Modulation and Demodulation

9. Pulse shaping, baseband digital modulation, Nyquist criterion [M4.2-4.3]
10. MAP detection, maximum likelihood (ML), receiver statistics [A1, M6.1-6.2]
11. Reception of M-ary digital signals: Union Bound, Nearest Neighbor Union Bound
12. Constellation analysis: SNR and Eb/No, Probability of symbol and bit error in AWGN for PAM, QAM, PSK
13. Applications to link budgets and communication system design [M6.5]

Information theoretic fundamentals for communications

14. Introduction to information theory: entropy and mutual information over discrete and continuous alphabets
15. Capacity of discrete memoryless channels (i.e. "the Shannon limit") and the channel coding theorem
16. AWGN Channel Capacity interpretations, parallel Gaussian channels and waterfilling

Communication in dispersive channels

17. Introduction to ISI channels: matched filter receivers, eye diagrams, mean-square distortion, intro to equalization
18. Linear Equalization I: zero forcing IIR and FIR equalization
19. Linear Equalization II: MMSE IIR and FIR equalization
20. Analog Multicarrier Modulation: the multicarrier concept
21. OFDM via the geometric channel model, frequency domain equalization
22. Understanding OFDM in the time and frequency domains, relationship to single carrier frequency domain equalization (SC-FDE)
23. OFDM case studies: Wi-Fi (802.11a, g, n, ac) and cellular (LTE and 5G NR)

Introduction to Channel Coding

24. Intro to Coding: Concepts, Repetition Codes, Convolutional Codes

25. Maximum Likelihood Sequence Detection (Viterbi decoding); system design with codes

Other Information

Homework will typically be assigned on the second lecture day of the week, due one week later by the start of class. Students are strongly encouraged to try the homework problems on their own, and then refine their understanding and solution with another student or group of students. There will be TA and faculty office hours to further assist. Late homework will be accepted only in extraordinary circumstances.

Short (10 minute) quizzes will be given most weeks at the end of second class day (e.g. Wednesday or Thursday). They will not figure heavily in your grade, but will help both you and the professor assess whether you are learning the key concepts presented in lecture. The quizzes will be worth 10 points each and your two lowest quiz grades will be dropped when computing the final grades. There are no make-up quizzes.

Regrade Policy

All requests for regrades, on homework or exam, must be submitted in writing within a week of their return to you. No verbal complaints will be considered. Mistakes can be made in the grading process and we will correct those, but it is unlikely that more partial credit will be given. The basic idea here is that we don't want to indirectly penalize those students who don't ask for regrades, since grading is on a curve.

College Drop/Add Policy

An engineering student must have the Dean's approval to add or drop a course after the fourth class day of the semester.

Students with Disabilities

The University of Texas at Austin provides upon request appropriate academic accommodations for qualified students with disabilities. For more information, contact the Office of the Dean of Students at 471-6259, 471-4641 TDD or the College of Engineering Director of Students with Disabilities at 471-4382