Fall 2023

ECE 644 - WIRELESS COMMUNICATIONS

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ECE 425/644 Wireless Communications: From Fundamentals to 5G

This course is focused on the technical challenges and solutions to physical and link layer design of wireless communication systems. Course topics include characterization of the wireless channel, the cellular concept, digital modulation techniques, spread spectrum, multiple access techniques including CDMA and OFDM, diversity techniques. Advanced techniques such as LTE, MIMO, 5G NR technologies are introduced. Matlab is used for examples and assignments.

Instructor: Alex Haimovich
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Office Hours: By appointment

Pre-requisites:
For 425: ECE 421
For 644: ECE 321 + recommended to have taken a communications systems course such as ECE 421 or ECE 642.

Textbook:
Textbook is not mandatory.
Recommended textbook: Rappaport, *Wireless Communications: Principles and Practice*, 2/e

Class notes and assignments are posted on Canvas.

Course learning outcomes ECE 425

1. Understand the basics of propagation of radio signals
2. Gain an understanding of the design principles of cellular systems
3. Understand how radio signals can be used to carry digital information in a spectrally efficient manner.
4. Gain knowledge of multiple access techniques based on frequency division, time division and code division.
5.
6. Gain insights into how diversity afforded by radio propagation can be exploited to improve performance
7. Gain knowledge of the basics of wireless standards such as LTE and 5G NR.

Course learning outcomes ECE 644

1. Be able to solve design problems related to the effect of the wireless channel on wireless signals.
2. Understand the basics of engineering design of transmit and receive components of the wireless transceiver.
3. Gain knowledge of methods for mapping bits to digital symbols.
4. Gain insight into the evaluation of the performance of wireless systems.
5. Understand the principles of wireless technologies such as CDMA, OFDM and MIMO.

Assessment:

- Class attendance mandatory – missing 3 classes does not require excuse
- Midterm, 2 hours, 35% (equations - one side of one sheet)
- Final, 2 hours, 35% (equations - one side of one sheet)
- ECE 425 Term project 20% Simulation of BPSK communication link
- ECE 644 Term project 20% Simulation of QPSK communication link
- Homework assignments 10%

Homework assignments and midterm project

All the assignments have been posted on Canvas. Check submissions deadlines.

Problem sets associated with a module are to be submitted on Canvas according to the schedule for each assignment. All electronic submissions on Canvas. No hardcopies.

Matlab Basic Matlab skills are required

Syllabus

Module 1 - Pathloss models (class notes, Rappaport book § 4.1, 4.2, 4.6, 4.9, 4.10.3, 4.10.4): Power diagram, dB units, noise figure, sensitivity, free space model, two-ray model, Hata model, shadowing, cell coverage area.

Module 2 - Multipath channel model (class notes, Rappaport book § 5.1-5.6): Rayleigh fading, frequency selective fading, time varying channels – Doppler effect

Module 3 - Cellular concept (class notes, Rappaport book, § 3.1-3.5, 3.6): Cellular concept, hexagonal geometry, number of cells in cluster, SIR calculations

Module 4 - Basics of digital communications (class notes, Rappaport book, §6.6): Match filter, detection theory, probability of error computations, Nyquist pulse shapes.

Module 5 - Digital modulations (class notes, Rappaport textbook § 6.4, 6.7, 6.8.1, 6.83, 6.8.4, 6.9.1, 6.10): Signal space and basis functions, BPSK, constellation mapping, QPSK, MPSK, QAM modulations

Module 6 - Diversity methods (class notes, Rappaport textbook § 7.1, 7.2, 7.10.1-7.10.3, 7.12, 7.13): Diversity methods for Rayleigh fading, BER performance, equalization, channel coding

Module 7 - Spread spectrum, CDMA, 3G (class notes): Direct sequence spread spectrum, suppression of narrowband interference, CDMA, orthogonal codes, near-far problem, 3G WCDMA

Module 8 - OFDM, LTE, 4G (class notes): OFDM, concept of cyclic prefix, LTE: frame structure, DL transmission scheme, reference signals and equalization concept

Module 9 – MIMO (class notes): MIMO channel model, open loop transmit diversity, transmit diversity in LTE, spatial multiplexing, closed loop techniques, layers, codebook coding

Module 10 - 5G NR (class notes): Spectrum and the link budget, DL transmission scheme, UL transmission scheme, MIMO in 5G NR

Course Plan

Classes take place on Mondays 2:30-5:20, Cullimore Lect 1

- Week1, 9/11: Module 1
- Week 2, 9/18: Module1, Module 2
- Week 3, 9/25: Module 2
- Week 4, 10/2: Module 3
- Week 5, 10/9: Module 4
- Week 6, 10/16: Module 4, midterm review
- Week 7, 10/23: Midterm Modules 1-5
- Week 8, 10/30: Module 5
- Week 9, 11/6: Module 6
- Week 10, 11/13: Module 6, Module 7
- Week 11, 11/20: Module 8
- Week 12, 11/27: Module 8, Module 9
- Week 13, 12/4: Module 9
- Week 14, 12/11: Module 10, final review
- Final exam – date to be published by registrar