University of Florida

Department of Electrical and Computer Engineering

EEL 6509, Section 0522

Wireless Communications

Fall 2021

Course Description

This course introduces fundamental technologies for wireless communications. We will address the following topics:

- Analog and digital modulation
- Propagation, shadowing, fading
- Radio trunking
- Multiple access schemes: FDMA, TDMA, CDMA
- Cellular communications
- Diversity
- Equalization
- Channel coding
- Wireless systems and standards (1G/2G/3G systems)
- OFDM; Multiuser detection; space time coding; smart antenna; software radio, a.k.a., spectrum agile radio or cognitive radio (if time permits)

In the course, students are expected to gain some hand-on experience on W-CDMA systems (3G wireless systems).

Course Prerequisites

- EEL 4514 (Communication Systems and Components) or undergraduate-level communication theory
- EEL 5544 (Noise in Linear Systems) or undergraduate-level probability theory/stochastic processes
- Some exposure to MATLAB or programming languages

Textbook

- T. S. Rappaport, "Wireless Communications: Principles & Practice," 2nd Ed., Prentice-Hall:Upper Saddle River, NJ, 2002, ISBN 0-13-042232-0.

Recommended Readings

- Jon Mark, Weihua Zhuang, "Wireless Communications and Networking," Prentice Hall. ISBN: 0130409057; 2003.
- Andrea Goldsmith, "Wireless Communications," Cambridge University Press, 2005.
- David Tse, Pramod Viswanath, "Fundamentals of Wireless Communications," Cambridge University Press, 2005.
- Harri Holma and Antti Toskala (ed.), ``WCDMA for UMTS : radio access for third generation mobile communications," Chichester ; New York : Wiley, c2000.
- John G. Proakis, ``Digital communications," 4th ed., Boston : McGraw-Hill, c2001.
- J. D. Parsons, "The Mobile Radio Propagation Channel," 2nd Edition, Wiley, 2000.
- G. L. Stueber, ``Principles of mobile communication," 2nd Ed., Norwell, MA: Kluwer, 2001.
- More at http://www.wu.ece.ufl.edu/books/EE/wireless/wireless.html.

Course Information

Instructor:

Dr. Dapeng Oliver Wu
Office: NEB 431
Email: wu@ece.ufl.edu

TA:

Zhuobiao Qiao
Email: zhuobiaoqiao@ufl.edu

Course website: http://www.wu.ece.ufl.edu/courses/eel6509f21

Meeting Time

Monday, Wednesday, Friday, period 9 (4:05 pm - 4:55 pm)

Meeting Room

NEB 102

Office Hours

- Dr. Wu: Monday, Wednesday, period 7 (1:55 pm - 2:45 pm), and by appointment via email.

Structure of the Course

The course consists of 28 lectures, 6 homework assignments, a quiz, and 1 project.

This course is primarily a lecture course. I cover all important material in lectures. Since EEL 5544 is a prerequisite, I assume some previous knowledge about probability theory and stochastic processes, and hence I will cover some material very quickly. Thus, depending on what and how much you recall from earlier study, varying amounts of reading in introductory books on probability theory and stochastic processes (other than the course textbook) may be necessary; these readings are up to the student. I will only give reading assignments from the course textbook.

The class project is described [here].

Course Outline

1. Introduction to current and emerging wireless communication systems (Chaps. 1&2; 3 lecture hours)
2. Frequency reuse, handoff, interference and system capacity, sectorization, cell splitting, spectral efficiency, trunking and grade of service (Chap. 3; 3 lecture hours)
3. Introduction to radio propagation: large- and small-scale effects, multipath, path loss, log-normal shadowing, empirical path loss models (Secs. 4.1, 4.2, 4.6, 4.9, 4.10; 3 lecture hours)
4. Complex baseband model, linear time-varying channels, narrowband signals and Rayleigh fading, Ricean fading, Doppler shift, Doppler spread with uniform scattering (Secs. 5.1, 5.2, 5.6, 5.7; 3 lecture hours)
5. Fade statistics, coherence time, fast vs. slow fading, broadband signals and power delay profile, coherence bandwidth, flat vs. frequency-selective fading, effect on digital transmission (Secs. 5.4, 5.5; 3 lecture hours)
6. Digital and quadrature modulation, error probability with additive Gaussian noise and flat Rayleigh fading, coherent and noncoherent (differential) detection (Secs. 6.4, 6.5, 6.6, 6.7, 6.8, 6.12; 3 lecture hours)
7. Frequency-Shift Keying, coherent and noncoherent demodulation, Minimum-Shift Keying, Gaussian MSK, power and bandwidth efficiencies, Spread spectrum signaling (Sec. 6.9, 6.11; 2 lecture hours)

8. Equalization techniques: linear/nonlinear/adaptive equalization (Secs. 7.2 -- 7.9;   4 lecture hours)
9. Diversity combining techniques: selection, max-ratio, equal-gain; RAKE (Secs. 7.10 -- 7.11;   3 lecture hours)
10. Error control coding techniques: block codes, convolutional codes, Turbo codes (Secs. 7.12 -- 7.18;   3 lecture hour)
11. Multiple access techniques: FDMA, TDMA, CDMA, ALOHA, Slotted ALOHA, CSMA   (Chap. 9;   4 lecture hours)
12. Wireless systems and standards: AMPS, IS-136, GSM, IS-95, WCDMA (11.1 -- 11.4;   3 lecture hours)
13. Advanced topics: OFDM, Multiuser detection, space time coding, smart antenna, software radio (1 lecture hours)

Course Objectives

Upon the completion of the course, the student should be able to

- distinguish the major cellular communication standards (1G/2G/3G systems)
- characterize the tradeoffs among frequency reuse, signal-to-interference ratio, capacity, and spectral efficiency
- characterize large-scale path loss and shadowing
- characterize small-scale fading in terms of Doppler spectrum, coherence time, power delay profile, and coherence bandwidth
- analyze the error probabilities for common modulation schemes
- analyze the performance of trunked radio systems
- describe different types of diversity and how they improve performance for mobile radio channels
- describe simple equalization schemes
- characterize TDMA, FDMA and CDMA

Handouts

Please find handouts here.

Requirements

Course Policies

- **Attendance:**

- o Perfect class attendance is not required, but regular attendance is expected.
  - o It is the student's responsibility to independently obtain any missed material (including handouts) from lecture.
- **During lecture, cell phones should be turned off.**
- **No late submissions of your homework solution, and project proposal/report, are allowed unless U.F. approved reasons are supplied and advance permission is granted by the instructor.** Excused late submissions must be consistent with university policies in the Graduate Catalog (https://catalog.ufl.edu/graduate/regulations) and require appropriate documentation. Additional information can be found here: https://catalog.ufl.edu/graduate/regulations/
- **Software use**
  - o All faculty, staff and student of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.
- **Announcements:**
  - o All students are responsible for announcements made in lecture, on the student access website, or via the class email list.
  - o It is expected that you will check your email several times per week for possible course announcements.
- **Students Requiring Accommodations**
  - o Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting https://disability.ufl.edu/students/get-started/. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.
- **University Honesty Policy**

UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (https://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Students are encouraged to discuss class material in order to better understand concepts. All homework answers must be the author's own work. However, students are encouraged to discuss homework to promote better understanding. What this means in practice is that

students are welcome to discuss problems and solution approaches, and in fact can communally work solutions at a board. However, the material handed in must be prepared starting with a clean sheet of paper (and the author's recollection of any solution session), but not refer to any written notes or existing code from other students during the writing of the solution. In other words, writing the homework report shall be an exercise in demonstrating the student understands the materials on his/her own, whether or not help was provided in attaining that understanding.

All work submitted in this course must be your own and produced exclusively for this course. The use of sources (ideas, quotations, paraphrases) must be properly acknowledged and documented. For the copy of the UF Honor Code and consequences of academic dishonesty, please refer to http://www.dso.ufl.edu/sccr/honorcodes/honorcode.php. Violations will be taken seriously and are noted on student disciplinary records. If you are in doubt regarding the requirements, please consult with the instructor before you complete any requirement of the course.

Course Evaluation

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/.

In-Class Recording

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A "class lecture" is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To "publish" means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class

section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

• Your academic advisor or Graduate Program Coordinator

• Jennifer Nappo, Director of Human Resources, 352-392-0904, jpennacc@ufl.edu

• Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu

• Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: http://registrar.ufl.edu/catalog0910/policies/regulationferpa.html

Campus Resources:

Health and Wellness

Covid-19 Protocols:

•   You are expected to wear approved face coverings at all times during class and within buildings even if you are vaccinated. Please continue to follow healthy habits, including best practices like frequent hand washing. Following these practices is our responsibility as Gators.

•   If you are sick, stay home and self-quarantine. Please visit the UF Health Screen, Test & Protect website about next steps, retake the questionnaire and schedule your test for no sooner than 24 hours after your symptoms began. Please call your primary care provider if you are ill and need immediate care or the UF Student Health Care Center at 352-392-1161 (or email covid@shcc.ufl.edu) to be evaluated for testing and to receive further instructions about returning to campus. UF Health Screen, Test & Protect offers guidance when you are sick, have been exposed to someone who has tested positive or have tested positive yourself. Visit the UF Health Screen, Test & Protect website for more information.

U Matter, We Care:

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: https://counseling.ufl.edu, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)

Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.

Academic Resources

E-learning technical support, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling. https://www.crc.ufl.edu/.

Library Support, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

Student Complaints Campus: https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf.

On-Line Students Complaints: http://www.distance.ufl.edu/student-complaint-process.

Grading:

Grades	Percentage	Due Dates
Homework	30%	see calendar
Project proposal	10%	4pm, October 27
Quiz	10%	December 8
Project report	50%	4pm, December 15

The project report consists of

1. (50%) A written report for your project
2. (25%) Computer programs that you develop for your project
3. (10%) Powerpoint file of your presentation
4. (15%) Your presentation/demo video on YouTube

Grading scale:

Top 25% students will receive A. Average score will be at least B+.

More information on UF grading policy may be found at:
https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx

Homework:

- Due dates of assignments are specified in the course calendar.
- **No late submissions** are allowed unless U.F. approved reasons are supplied and advance permission is granted by the instructor. Excused late submissions must be consistent with university policies in the Graduate Catalog (https://catalog.ufl.edu/graduate/regulations) and require appropriate documentation. Additional information can be found here: https://catalog.ufl.edu/graduate/regulations/
- If you wish to dispute a homework grade, you must return the assignment along with a succinct written argument within one week after the graded materials have been returned to the class. Simple arithmetic errors in adding up grade totals are an exception, and can normally be handled verbally on-the-spot during office hours of the TA. For all other disputes, the entire homework may be (non-maliciously) re-graded, which may result in increase or decrease of points.

Class Project:

The class project will be done individually (that is, teaming with other students is not allowed). Each project requires a proposal and a final report. The final report is expected to be in the format of a conference paper plus computer programs and a Powerpoint file. On October 27, the project proposal (up to 2 pages) is due. On December 15, the final report (up to 10 pages) is due. For details about the project, please read here.

Suggested topics for projects are listed here.

Course calendar can be found here.

Related courses in other schools:

[Helsinki University of Technology, S-72.238: Wideband CDMA systems](#)

[Northeastern University, COM3525: Wireless Networks](#)

[Stanford University, EE359: Wireless Communications](#)

[Stanford University, EE360: Advanced Topics in Wireless Communications](#)

[University of California, Berkeley, EE 224B: Fundamentals of Wireless Communication](#)

[University of Texas, Austin, Wireless communications](#)

[University of Texas, Austin, Multiuser wireless communication](#)

MATLAB

- [MATLAB Tutorial](#)
- [MATLAB Central](#)

Standards:

- [IEEE 802.16 (WiMAX)](#) [[Introduction](#)]
- [3GPP LTE (Long Term Evolution)](#)

Online Calculator for Erlang-B formula

- [http://personal.telefonica.terra.es/web/vr/erlang/eng/mcerlb.htm](#)

Software:

- Advanced Design System (ADS) from [Agilent](#)
- **[Learning by simulations](#)**

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