This syllabus template is intended to be a customizable template. Formatting should be aligned with your school or department guidelines. Text within brackets is for informational purposes and should be edited to reflect the specifics of your course.
Contact CET for assistance with creating your syllabi, policies, learning objectives, assessments, and course activities. If you are preparing a syllabus for UCOC submission, refer to the Curriculum Office Resources page for a downloadable checklist of required items.

Revised 08/2022

Course ID and Title: EE564, Digital Communication and Coding Systems
Units: 4
Spring 2023 — weekly on Fridays—Time:

Location: [Physical address and/or course-related URLs, etc.]

Instructor: Andreas Polydoros
Office:
Office Hours:
Contact Info:
email:

Teaching Assistant:
Office: [Physical or virtual address]
Office Hours:
Contact Info: [Email, phone number (office, cell), Skype, etc.]

IT Help:
Hours of Service:
Contact Info: [Email, phone number (office, cell), Skype]

Course Description
The course provides a rigorous introduction to modern digital communication with emphasis on wireless systems (radio), which is the key technology behind cellular, IEEE802. 11 (“WiFi”), wireless sensor and mobile *ad hoc* networks (“MANET”), personal-area networks (“Bluetooth”), the Internet of Things (“IoT”), military/institutional systems, etc. The students will be taught both the basic mathematical tools of the field as well as more advanced concepts, such as the impact of digital memory in modulation and demodulation, the role of other important channel parameters and their estimation (such as in carrier and bit synchronization), theoretically optimal approaches to decision making and classification, and so on. They will be exposed to important mitigation techniques for noise and channel distortion, such as forward error correction (FEC) coding, equalization, diversity-reception, and the performance improvement these techniques bring about. They will be prepared to understand in depth, work with and contribute to, the basic building blocks of the ever-expanding wireless revolution.

Learning Objectives
To obtain a systems level understanding of modern digital communication, with emphasis on wireless systems and applications. This includes a basic review of fundamental blocks of transceivers (digital modulation, coding, synchronization, equalization), definition of important parameters (bandwidth, SNR), development of mathematical tools for optimal decisions and related performance, matched filtering and digital receivers. It will also provide a brief introduction of applications, such as spread spectrum and cognitive radio (sensing and localization). Upon successful completion of this course, a student will be well-prepared for a position in industry as a communication systems engineer or, alternatively, to pursue the material in more depth in a doctorate program.

Prerequisite(s): EE503, ?
Co-Requisite(s):
Recommended Preparation:

Course Notes
Teaching will be based mainly on lecture notes, created by the instructor, which will be made available to students (online) right after each lecture. Students get extra credit for making suggestions on improving the lecture notes, identifying any errors and typos, etc.

Technological Proficiency and Hardware/Software Required
No special knowledge of this type is required. Matlab is desirable but not a requirement. Assignments and problems will be mostly conceptual/theoretical in nature.

Attendance
Physical attendance (in-class or remote) is highly recommended but not mandatory.

Description and Assessment of Assignments
Homework assignments are weekly and are due one week later. No late homework submission is accepted. There will also be a final project. For the submission of the final project and related details, see below.

Grading Breakdown
Final grades will be assigned by a combination of student score distribution (curve) and the discretion of the instructor.

Mid-term and final exams will be closed book. Students may bring along a two-page summary (only) *of their own notes*. No make-up exams will be given. If you cannot make the exam dates due to a class conflict, you must notify me by the last day to add/drop a course. If I cannot accommodate your schedule, you must drop the class. In the case of a required business trip or a medical emergency, a signed letter from your manager or doctor is required. This letter must include the telephone number of your doctor or supervisor.

Changes/Information: The student is responsible for all assignments, changes of assignments, announcements, lecture notes etc. All such changes should be posted on the course website.

Table 1 Grading Breakdown

Assessment Tool (assignments)	Points	% of Grade
Homework		25%
Mid-term (2 hours)		25%
Final (2 hours)		25%
Final project		25%
TOTAL		100%

Grading Scale

Table 2 Course Grading Scale

Letter grade	Corresponding numerical point range
A	90-100
A-	85-89
B+	80-84
B	75-79
C	60-74
F	59 and below

Grading Timeline and Policy

Each homework will be graded as "pass" – "fail"; no letter grade will be provided for each homework. No submission of a given homework will correspond to a "fail". Submission is considered valid if at least 4 out of 5 problems have been addressed at some depth. Submission is a "pass" if approx. 80% of *submitted* answers are correct. In sum, at least 2 out of every 3 given problems must have been answered correctly for a "pass". Final homework grades are as per the Table above: 90%+ of submitted homework solutions being a "pass" corresponds to an A, etc. (percentages properly rounded to nearest integers). Important: the notation of submitted solutions must follow *exactly* the notation developed in class, even though some assigned problems from the textbook or from other suggested textbooks may follow a different notation. Violation of the class-notes notation is a "fail".

Grade Adjustment

If you dispute any scoring of a problem in an exam (mid-term or final), you have three days from the date of the returned-graded mid-term exam, or until May 12 for the final exam, to request a review. All requests for a review must be submitted in writing (by email), along with an explanation for the request. A reply will be provided by email and will be a final decision. Homework grades cannot be disputed (they are already generous as is).

Course Specific Policies

By the time of the mid-term exam, a set of projects will be posted on the Blackboard. The projects consist of reviewing and presenting specific Journal papers of importance. Students will have two weeks thereafter to decide on their project, in agreement with the instructor. Projects are individual (no teams allowed), although more than one student can choose the same project/paper. The deliverable consists of a summary presentation in Powerpoint form, not to exceed 15 slides (typical length of a conference presentation). The projects can be submitted no later than the end of session, May 10, 2023. They should convey the essential points of their assigned paper, and they

must include the notation developed in class (not the notation of the assigned paper). Additional results (from other related papers) and Matlab simulations are a plus, but not necessary. The purpose of the project is to motivate the students to look at a specific topic on their own, understand its essence and be able to present it in their own brief format and style.

Required Text
A. F. Molisch, *Wireless Communications* (Third Ed.), Wiley, 2022.

Other Suggested References (not required)
Note: The list of excellent textbooks on the topic is very long. Below is just a short select list, reflecting the instructor's preferences (in chronological order):

W. Davenport and W. Root, *Random Signals in Noise*, McGraw-Hill, 1958.

J. Wozencraft and I. Jacobs, *Principles of Communications Engineering*, Wiley, 1965 (reprinted, Waveland Press, 1990).

H. Van Trees, *Detection, Estimation, and Modulation Theory*, *Part I*, Wiley, 1968.

M. Simon, J. Omura, R. Scholtz and B. Levitt, *Spread Spectrum Communications*, Computer Science Press, 1985.

B. Sklar, *Digital Communications: Fundamentals and* Applications, Prentice Hall, 1988.

E. Lee and D. Messerschmitt, *Digital Communication*, Kluwer, 1988.

J. Proakis, *Digital Communications*, 2nd Ed., McGraw-Hill, 1989.

R. Giltin, J. Hayes and S. Weinstein, *Data Communications Principles*, 2nd Ed., Plenum Press, 1994.

H. V. Poor, *Signal Detection and Estimation*, 2nd Ed., Springer-Verlag, 1994.

M. Simon, S. Hinedi and W. Lindsey, *Digital Communication Techniques – Signal Detection and Design*, Prentice Hall, 1995.

H. Meyr, M. Moeneclaey and S. Fechtel, *Digital Communication Receivers: Synchronization, Channel Estimation and Signal Processing*, Wiley, 1998.

S. Benedetto and E. Biglieri, *Principles of Transmission with Wireless Applications*, Kluwer, 1999.

K. Chugg, A. Anastasopoulos, and X. Chen, *Iterative Detection: Adaptivity, Complexity Reduction, and Applications*, Kluwer, 2001.

A. Goldsmith, *Wireless Communications*, Cambridge U. Press, 2005.

D. Tse and P. Viswanath, *Fundamentals of Wireless Communication*, Cambridge U. Press, 2005.

Course Outline

Notes: Topics outlined as "advanced" will be mentioned briefly and can become parts of students' projects. Also, some of the topics in Part IV may need to be compressed, depending on overall pace.

Outline

Part I: communication systems: physical layer description and related important parameters

- Classification of services: broadband, institutional-military, sensors, IoT; related parameters
- Transceiver chain; separation theorem; simplified diagrams and equivalent channels
- Introduction to power, bandwidth, noise, SNR
    - Link budget example
    - Introduction to limits in throughput (capacity) and accuracy (estimation)
    - The critical role of error-correction coding: block, convolutional, modern codes
        - *Advanced*: modulation-constrained capacity
    - The many versions of SNR: in/out, bit/symbol/word, modulation/information
- Introduction to channels
    - LoS/AWGN, fading (with and without selectivity), dynamics, imperfections
- Brief review of linear systems (references, handouts)
- Brief review of random variables-processes; Gaussian vectors and processes (handouts)
    - statistical inference: definitions, metrics, Least-Squares
        - *Advanced*: Wiener process/white noise, stochastic calculus (Ito)

Part II: transmission

- Signal space concepts; constellations
    - In-phase/quadrature (I/Q) representation
- Pulse shapes and their use (bandwidth and self-interference control)
- Linear versus non-linear modulations
    - PSK, FSK, QASK, orthogonal, offset
        - Sketch of OFDM
            - *Advanced*: peak-to-average-power ratio and mitigation techniques
    - Modulation with memory: CPM, MSK, GMSK
        - *Advanced*: Rimoldi representation and Laurent expansion
- Spectral analysis of randomly modulated signals
    - Cyclo-stationarity: first glimpse of applications
        - *Advanced*: spectrum of signal times signal
- Complex Envelopes (CE); Hilbert transforms; Single Sideband; Bedrosian's theorem
    - Connection with I/Q
    - The transmitter-channel CE cascade

Part III: Reception

Part III.A: basic concepts

- Single-shot, binary scalar transmission: motivating the Likelihood Ratio (LR)
    - Performance: introducing the Q(.) function; bounds
    - The M-ary version
- General vector-based hypothesis testing
    - Criteria (Bayes, Neyman-Pearson), formal LR's
        - The Gaussian example
    - Introduction to composite hypotheses
    - *Advanced*: Error bounds

Part III.B: communicating with waveforms in AWGN

- Formal derivation of Likelihood Functionals
    - Karhunen-Loeve derivation
    - Sampling derivation
    - Sufficient statistics
- The critical role of the matched filter
    - Approximations
    - Nyquist sampling and all-digital receivers
- Bandpass modulation and I/Q reception: motivation; total transceiver diagram
- Classic modulations (PSK, FSK, QASK) in AWGN; performance and comparisons
- Composite hypothesis: the noncoherent receiver
- Hard versus soft demodulation

Part III.C: communicating through random/unknown/dispersive channels

- Brief review of random channels
    - Flat fading: performance of linear modulations
    - Frequency-selective fading (ISI): simple versus Viterbi equalizers
        - *Advanced*: the optimal receiver and the Forney - Ungerboeck metrics
        - *Advanced*: Kailath's optimal estimator-correlator

Part IV: special topics

- Learning an unknown channel: synchronization
    - Phase/Timing/Frequency: basic versus digital-likelihood approaches
    - Practical performance versus bounds
- Countering noise, channel randomness and interference
    - Codes and their performance
    - Diversity in fading
- Spread spectrum for time/frequency selective interference
    - Like-user interference: joint detection
        - *Advanced*: sphere decoders for array reception
- Cognitive radio
    - Distributed Sensing
    - *Advanced*: Distributed Localization

Table 3 Course schedule
Note: schedule is indicative

	Topics
Week 1	Communication systems: description, important parameters, equivalent diagrams Stochastic descriptions (review), linear systems (review), introduction to channels
Week 2	Power, bandwidth, SNR, introduction to inference and related theoretical limits (capacity, parameter estimation), introduction to coding
Week 3	Signal space, constellations, pulse shaping, Nyquist criterion
Week 4	Linear and nonlinear digital modulation (CPM), OFDM
Week 5	Spectral analysis, complex envelope, Hilbert Transform, single sideband modulation
Week 6	Single-shot binary transmission, likelihood ratio, M-ary transmission, performance in white noise
Week 7	Vector-based hypothesis testing, criteria (comms, radar), composite hypotheses, general likelihood ratios and properties, performance bounds
Week 8	Mid-term and general review of material
Week 9	Continuous-time likelihood functionals, sufficient statistics, matched filtering, sampled digital receivers
Week 10	Bandpass modulation, total transceivers, classic modulations (PSK, FSK, QAM), performance
Week 11	Composite hypothesis, incoherent reception, hard versus soft demodulation
Week 12	Random-unknown-fading channels: performance, equalization
Week 13	Learning of important parameters: synchronization (phase, frequency, timing)
Week 14	Performance of coded systems, diversity reception, degrees of freedom (MIMO)
Week 15	Spread spectrum systems, cognitive radio
FINAL	

Classroom norms
[Classroom norms describe the behaviors that are encouraged and discouraged during class. They can be a powerful tool for establishing a supportive learning environment. Refer to the CET resource, A menu of discussion norms.]

Zoom etiquette
["Netiquette" or "internet etiquette," describes the recommended communication and behavior of online communication. Having a Zoom netiquette policy for your course can help minimize the chances of miscommunication and perceived disrespect. It is also recommended that you encourage students to contact you with questions or concerns about complying with a policy. For instance, if a student is unable to keep their camera on during the synchronous Zoom session, encourage them to contact you prior to the class session.]

Academic Integrity
[The first 5 paragraphs are required to be included on your syllabi.]
The University of Southern California is foremost a learning community committed to fostering successful scholars and researchers dedicated to the pursuit of knowledge and the transmission of ideas. Academic misconduct is in contrast to the university's mission to educate students through a broad array of first-rank academic, professional, and extracurricular programs and includes any act of dishonesty in the submission of academic work (either in draft or final form).

This course will follow the expectations for academic integrity as stated in the USC Student Handbook. All students are expected to submit assignments that are original work and prepared specifically for the course/section in this academic term. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s). Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity.

Other violations of academic misconduct include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

[Note to Faculty: Include common examples of activities and assignments that might occur in your class. See the following example.]
[Please ask me if you are unsure about what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.
Collaboration. In this class, you are expected to submit work that demonstrates your individual mastery of the course concepts.
Group work. Unless specifically designated as a 'group project,' all assignments are expected to be completed individually.

Computer programs. Plagiarism includes the submission of code written by, or otherwise obtained from someone else.]

[Note to Faculty: Include information regarding grade outcomes a student may expect if found in violation. See the following example]
[If found responsible for an academic violation, students may be assigned university outcomes, such as suspension or expulsion from the university, and grade penalties, such as an "F" grade on the assignment, exam, and/or in the course.]

Course Content Distribution and Synchronous Session Recordings Policies
USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. (Living our Unifying Values: The USC Student Handbook, page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via email, on the internet, or via any other media. (Living our Unifying Values: The USC Student Handbook, page 13).

Course Evaluations
[Course evaluation occurs at the end of the semester university-wide. It is an important review of students' experience in the class. The process and intent of the end-of-semester evaluation should be provided. In addition, a mid-semester evaluation is recommended practice for early course correction.]

Course Schedule
[Provide a detailed course calendar that includes a list of deliverables (homework assignments, examinations, etc.) broken down on a weekly basis. The format may vary, but the content must include:

- Subject matter (topic) or activity
- Required preparatory reading or tasks (e.g., viewing videos)
- Deliverables and when each deliverable is due. A blanket statement that there will be a deliverable due at a specified frequency (e.g., there will be homework due weekly) may obviate the need to state when certain deliverables are due

IMPORTANT: In addition to in-class contact hours, all courses must also meet a minimum standard for out-of-class time, which accounts for time students spend on homework, readings, writing and other academic activities. Standard fall and spring sessions (001) require a final summative experience during the University scheduled final exam day and time.]

Statement on Academic Conduct and Support Systems

Academic Integrity:
The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, comprises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline - 988 for both calls and text messages – 24/7 on call
The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress

24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL) – 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - (213) 740-5086
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - (213) 740-0776
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention - (213) 740-0411
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion - (213) 740-2101
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call
Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice - (323) 442-2850 or otfp@med.usc.edu
Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.