USC Viterbi School of Engineering

EE564: Digital Communication and Coding Systems (Spring 2018)

Course Units:	4
Instructor:	Keith M. Chugg EEB 500A (5th floor main office) 213-740-7294 (Voice) chugg@usc.edu – Include 564 in subject
Office Hours:	By appointment (before and after lecture are best) I can also set up Bluejeans video conference/screen-share
Grader:	TBD
TA:	no TA due to low enrollment
Lecture:	Monday and Wednesday, 5:00-6:50 in RTH 105
Discussion:	no discussion due to low enrollment
Webpages:	Piazza Class Page for – All HWs, handouts, solutions will be posted in PDF format with some Matlab, Excel, Python resources USC DEN Desire to Learn for – grades, pad notes, and lecture video. *Student has the responsibility to stay current with webpage material*
Pre-req:	Probability and random vectors (EE503), linear algebra (EE510)
Other Requirements:	Computer programming skills (i.e., plotting, Matlab, C/C++, or Python).
Grading:	20% Homework 40% Midterm Exam (2 hours) 40% Final Project (2 hours)

Exam Dates:

- **Midterm Exam:** March 8, 2018 (last class before Spring Break).
- **Final Exam:** we will have a final project in lieu of a final exam.

Course Objective: To obtain a systems level understanding of modern digital communication and error correction coding systems. This includes design concepts (digital modulation, coding, synchronization, equalization approaches), analysis techniques (computation of bandwidth, SNR, performance), and fundamental limits (information theory limits). 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.

Grading Policies:

- **Final grades** will be assigned by a combination of student score distribution (curve) and the discretion of the instructor.
- **Late HW** will not be accepted. A late assignment results in a zero grade.

- **Make-up Exams:** No make-up exams will be given. If you cannot make the above dates due to a class schedule conflict, you must notify me by the last day to add/drop. If I cannot accommodate your schedule, you must drop the class. In the case of a required business trip or medical emergency, a signed letter from your manager or doctor is required. This letter must include the telephone number of your doctor or supervisor. I must be notified as soon as possible in the case of an emergency.

- **Attendance:** Lecture attendance is encouraged but not mandatory. However, students are responsible for all material presented in lecture.

- **Statement on Academic Conduct:**

  Plagiarism – presenting someone elses ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Section 11, Behavior Violating University Standards https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriate-sanctions/. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct/.

  Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the Office of Equity and Diversity http://equity.usc.edu/ or to the Department of Public Safety http://capsnet.usc.edu/department/department-public-safety/online-forms/contact-us. This is important for the safety whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report, or can initiate the report on behalf of another person. The Center for Women and Men http://www.usc.edu/student-affairs/cwm/ provides 24/7 confidential support, and the sexual assault resource center webpage sarc@usc.edu describes reporting options and other resources.

- **Statement for Students with Disabilities:**

  A number of USCs schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the American Language Institute http://dornsife.usc.edu/ali, which sponsors courses and workshops specifically for international graduate students. The Office of Disability Services and Programs http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, USC Emergency Information http://emergency.usc.edu/will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.

Textbooks:

- **Recommended Textbooks:**

  1. S. Benedetto and E. Biglieri *Principles of Transmission with Wireless Applications* Kluwer Academic, 1999.
  2. B. Sklar, *Digital Communications: Fundamentals and Applications (2nd Edition)*, Prentice Hall, USA, 2001.

- **References:**

1. John G. Proakis and M. Salehi, *Digital Communications, 5th Ed.,* McGraw-Hill, 2008.
2. C. L. Weber, *Elements of Detection and Signal Design,* Springer-Verlag, New York, 1968.
3. H. L. VanTrees, *Detection, Estimation, and Modulation Theory Part I,* John Wiley and Sons, 1968.
4. M. K. Simon, S. M. Hinedi, and W. C. Lindsey, *Digital Communication Techniques – Signal Detection and Design,* Prentice Hall, 1995.
5. E. A. Lee and D. G. Messerschmitt, *Digital Communication, Second Ed.,* KAP, 1994.
6. J. M. Wozencraft and I. M. Jacobs, *Principles of Communications Engineering,* Waveland Press, 1990 (reprint of a 1965 Wiley and Sons book).
7. Stephen G. Wilson, *Digital Modulation and Coding,* Prentice Hall, 1996.
8. S. Lin and D. J. Costello, *Error Control Coding: Fundamentals and Applications*, Prentice Hall, 1983. (2nd edition, 2004).
9. G. C. Clarke, Jr., and J. B. Cain, *Error-Correction Coding for Digital Communications*, Plenum Press, 1981.
10. R. H. Morelos-Zaragoza, *The Art of Error Correction Coding*, Wiley, 2002.
11. Stephen G. Wilson, *Digital Modulation and Coding,* Prentice Hall, 1996.
12. T. Richardson and R. Urbanke, *Modern Coding Theory*, available on-line.
13. K. M. Chugg, A. Anastasopoulos, and X. Chen, **Iterative Detection:** *Adaptivity, Complexity Reduction, and Applications*, Kluwer Academic Press, 2001.
14. Chris Heegard and Stephen Wicker, *Turbo Coding*, Kluwer Academic Publishers, 1998.

Course outline: (Benedetto Chapter/Section for reference)

1. Overview of digital communication and coding systems (Ch. 1, Ch. 3)
   (a) Basic ideas from information theory
   (b) Block diagram of digital communication system
   (c) Role of error correction (FEC, CRC, ARQ)
   (d) High-level description of modulation and coding techniques
2. Digital communication signals and channels (2.1-2.5)
   (a) Common methods of digital modulation (Amplitude, frequency, phase shift keying)
   (b) Passband signal models. Complex baseband equivalent.
   (c) Pulse shaping and power spectral density
   (d) Signal space representation and dimensionality
   (e) Additive White Gaussian Noise (AWGN) channel
   (f) Intersymbol interference (ISI) channels
3. Optimal demodulation and decoding (2.6 and handouts)
   (a) MAP decision rule and optimality
   (b) Continuous time likelihood for AWGN channel
   (c) Sufficient statistics and reversibility
   (d) Composite hypothesis testing
   (e) Soft-out measures and formats
4. Uncoded, memoryless modulations over the AWGN channel (Ch. 4)
   (a) QASK formats (PAM, QAM, PSK)
   (b) Orthogonal and related modulations
   (c) Performance analysis and bounding techniques
   (d) Phase noncoherent differential methods and
   (e) Spectral efficiency considerations
5. Classical coding (Ch. 10, Ch. 11)
   (a) Linear block codes
      i. Error correction capabilities
      ii. Syndrome based decoding
      iii. Performance bounds
      iv. Example codes
   (b) Convolutional codes
      i. FSMs, state diagrams, trellises, graphical models

   ii. Decoding via Viterbi and Forward-backward algorithm
   iii. Performance bounds
   iv. Tables of best convolutional codes
   v. Parity check trellis for block codes

6. Modern coding (11.3 and handouts)
   (a) Code constructions and variations (LDPC, concatenated convolutional codes, etc.)
   (b) Iterative decoding
      i. Rules of iterative decoding
      ii. Graphical representations and message-passing interpretation
      iii. Analysis and design methods (uniform interleaved analysis and threshold prediction)

7. Uncoded modulations over ISI channels (Ch. 7 and handouts)
   (a) Linear ISI-AWGN channel model
   (b) Viterbi/FBA detection for ISI-AWGN channel
   (c) Linear and decision feedback equalization
   (d) OFDM
   (e) Single carrier FDE

8. Synchronization and peak-to-average power considerations (Ch. 9, Ch. 6, and handouts)
   (a) Maximum Likelihood parameter estimation
   (b) Frame synchroniztion
   (c) Symbol synchronization
   (d) Phase lock loops
   (e) CPM and offset modulations

9. Case study of a modern digital communication system (handouts)
   (a) Examples from WiFi, cellular, and satellite systems

Course schedule:

- Week 1: Overview of digital communication and coding systems
- Week 2: Digital communication signals and channels
- Week 3: Digital communication signals and channels
- Week 4: Optimal demodulation and decoding
- Week 5: Optimal demodulation and decoding
- Week 6: Uncoded, memoryless modulations over the AWGN channel
- Week 7: Uncoded, memoryless modulations over the AWGN channel

- Week 8: Review and Midterm
- Week 9: Classical coding
- Week 10: Classical coding
- Week 11: Modern coding
- Week 12: Modern coding
- Week 13: Uncoded modulations over ISI channels
- Week 14: Synchronization and peak-to-average power considerations
- Week 15: Case study of a modern digital communication system (handouts)