ECE 8771, Information Theory & Coding for Digital Communications
Summer 2010

Syllabus & Outline (Draft 1 - May 12, 2010)

Instructor: Kevin Buckley, Tolentine 433a, 610-519-5658 (W), 610-519-4436 (F), buckley@ece.vill.edu, www.ece.villanova.edu/user/buckley
Office Hours:

- Mon.& Wed. 1-1:50pm (in T433a)
- by appointment

Prerequisites: ECE 8700 - Communications Systems Engineering and ECE 8072 - Statistical Signal Processing; or instructor permission

Text: *Digital Communications, 5-th edition,* by John Proakis & Masoud Salehi, McGraw-Hill, 2008.

Grading Policy:
* 4 Homeworks (due Mondays 6/4, 6/14, 6/21, 6/28) – 15% each
* 2 Computer Projects: (due Wednesdays 6/16, 6/23) – 20% each

Course Description:
This course covers information theory and coding within the context of modern digital communications applications. We begin with a directed review of probability and digital modulation schemes. We then introduce information theory and employ it to study bounds on source/channel coding and communication channel performance. Source coding is considered because it provides a straightforward example of the utility entropy, an information theory measure. Channel coding is considered because channel capacity, another information theory measure, provides a theoretical bound which is the goal of channel coding. We then proceed with an in depth treatment of block and convolutional channel coding, with both soft and hard decoding. Bit-error-rate performance is studied relative to channel capacity. Advanced topics such as Reed-Solomon codes, space time codes, concatenated codes, turbo coding and LDPC codes are introduced. Bandwidth efficient trellis coded modulation is also overviewed.

ECE 8771, Summer 2010, Lecture Schedule

Lecture 1 (6/2): Review & begin Information Theory;
Course Notes Sections [1] through [4.1]

Lecture 2 (6/7): Information Theory & Source Coding;
Course Notes Sections [4.2] through [5]

Lecture 3 (6/9): Channel Capacity & begin Block Coding;
Course Notes Sections [6] through [7.4]

Lecture 4 (6/14): main Block Coding lecture;
Course Notes Sections [7.5] through [7.6]

Lecture 5 (6/16): Convolution Code descriptions & decoding;
Course Notes Sections [8.1] through [8.3]

Lecture 6 (6/21): Convolution Code performance & Reed Solomon Codes;
Course Notes Sections [8.4] through [8.7], [7.7] through [7.9]

Lecture 7 (6/23): Turbo Codes & LDPC Codes;
Course Notes Section [9]

Lecture 8 (6/28): Space-Time Coding & Trellis Coded Modulation;
Course Notes Sections [10] through [11]

ECE 8771, Course Outline

[1] Introduction (Selected Topics from Chapt. 1 of Course Text)

1.1 Overview of Shannon's contributions to Information Theory

1.2 The digital communication system

2 Selected Topics in Probability, Random Variables & Processes (Selected Topics from Chapt. 2)

2.1 Probability

2.2 Random variables

2.3 Statistical independence & the Markov property

2.4 Gaussian random variables

2.5 Bounds on tail probabilities

2.6 Random processes

[3] Modulation & Detection (Selected topics from Chapts. 3-4)

3.1 Digital modulation

3.1.1 Modulation classification

3.1.2 Signal space representation & the symbol constellation

3.1.3 Linear memoryless modulation scheme examples

3.2 Optimum detection

3.2.1 Correlation demodulator & matched filter

3.2.2 Optimum symbol detectors

3.3 Detector performance for several modulation schemes

[7] Block Codes (Chapt. 7)

- 7.1 Introduction to block codes
- 7.2 A Galios field primer
- 7.3 Linear block codes
- 7.4 Initial comments on performance & implementation
- 7.5 Important binary linear block codes
- 7.6 Binary linear block code decoding & performance analysis
  - 7.6.1 Soft-decision decoding
  - 7.6.2 Hard-decision decoding
  - 7.6.3 Comparison between hard & soft decision decoding
- 7.7 Nonbinary block codes - Reed-Solomon (RS) codes
  - 7.7.1 A GF(2^m) overview for RS codes
  - 7.7.2 RS codes
  - 7.7.3 Encoding RS codes
  - 7.7.4 Decoding RS codes
- 7.8 Techniques for constructing more complex block codes: product codes, interleaving, concatenated block codes
- 7.9 Space-time block codes: multipath fading channels, diversity techniques, spatial/temporal diversity

[8] Convolutional Codes (Sects. 8.1-8)

- 8.1 Linear convolutional codes & their descriptions
- 8.2 Transfer function representation & distance properties
- 8.3 Decoding convolutional codes
  - 8.3.1 Soft-decision MLSE
  - 8.3.2 Hard-decision MLSE
  - 8.3.3 The Viterbi algorithm for MLSE
- 8.4 Performance of convolutional code decoders
  - 8.4.1 Soft-decision decoding performance
  - 8.4.2 Hard-decision decoding performance
- 8.5 Viterbi algorithm implementation issues: RSSE, trellis truncation, cost normalization
- 8.6 Sequential decoding: Stack, Fano, feedback descision decoding
- 8.7 Techniques for constructing more complex convolutional codes

[9] Turbo & Low Density Parity Check (LDPC) Codes (Sects. 8.8-11)

- 9.1 Decoding algorithms which generate extrinsic information
  - 9.1.1 Symbol-by-symbol MAP and the BCJR algorithm
  - 9.1.2 The soft-output Viterbi algorithm (SOVA)
- 9.2 Turbo codes
  - 9.2.1 PCCC with interleaving & iterative decoding
- 9.3 Turbo product codes
- 9.4 Turbo equalization
- 9.5 Low Density Parity Check (LDPC) coding & decoding
  - 9.5.1 Basic graph theory concepts
  - 9.5.2 Graph representation of LDPC codes
  - 9.5.3 Decoding LDPC codes

[10] Space-Time Coding (Sect. 15.4)

- 10.1 Multipath fading channels & diversity techniques
- 10.2 A spatial dicersity technique
- 10.3 Space-time block codes

[11] Trellis Coded Modulation (TCM) (Sect. 8.12)

- 11.1 Introduction
- 11.2 Trellis coding with higher order modulation
- 11.3 Set partitioning
- 11.4 Trellis coded modulation (TCM)
- 11.5 TCM decoding and performance