Module Title: 4C7 Information and Communication Theory

Code: EEU4C07

Level: Senior Sophister (Optional module)

Credits: 5

Lecturer: Prof Nicola Marchetti (marchetn@tcd.ie)

Module Organisation

<table>
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<tr>
<th>Semester</th>
<th>Start Week</th>
<th>End Week</th>
<th>Associated Practical Hours</th>
<th>Lectures</th>
<th>Tutorials</th>
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Total Contact Hours: 48

Module Description
The objective of the 4C7 Information and Communication Theory module is to develop the fundamental theory to enable students to design and analyse digital communication systems, and the related information and communication theoretical aspects. The module builds on the material covered in the 3C1 Signals and Systems and 3C5 Telecommunications modules.

Learning Outcomes
On successful completion of this module the student will be able to:

1. Design a matched filter for detecting a known signal in additive white Gaussian noise.
2. Design a baseband pulse transmission system to combat the effects of inter-symbol interference.
3. Use signal space analysis to design a maximum likelihood decoding scheme for the coherent detection of signals in additive white Gaussian noise.
4. Determine the bit error rate for coherent binary phase-shift keying and quadriphase-shift keying systems.
5. Understand the information theoretical aspects of Gaussian communication channels.
6. Use linear block, cyclic, convolutional and turbo codes for error-control coding.
7. Understand the fundamentals of advanced coding techniques, such as Low Density Parity Check (LDPC) and Polar codes.
8. Understand multiuser information and communication theory, in relation to its extension to fading channels, multiuser diversity and multiple antenna systems.
Module Syllabus

- **Brief review of random processes**
  Stationary processes; Mean, correlation, and covariance functions; Ergodic processes; Transmission of a random process through a linear time-invariant filter; Power spectral density; Gaussian Process; Narrowband noise.

- **Baseband pulse transmission**
  Matched filter; Error rate due to noise; Inter-symbol interference; Nyquist's criterion for distortionless baseband binary transmission; Correlative-level coding; Baseband M-ary PAM transmission.

- **Signal space analysis**
  Conversion of the continuous AWGN channel into a vector channel; Likelihood functions; Coherent detection of signals in noise: Maximum likelihood decoding; Correlation receiver; Probability of error.

- **Passband digital transmission**
  Binary phase-shift keying; Error probability of binary phase-shift keying; Generation and detection of coherent quadrature phase-shift keying signals; Error probability of quadrature phase-shift keying.

- **Information theoretical aspects of Gaussian channel**
  Gaussian channel definitions; Bandlimited channels; Parallel Gaussian channels; Channels with coloured Gaussian noise; Gaussian channels with feedback.

- **Applications of information theory to error-control coding**
  Linear block codes; Cyclic codes; Convolutional codes and their performance; Turbo codes.

- **Advanced coding theory**
  Message passing algorithms; LDPC codes; Polar codes.

- **Network information theory**
  Capacity of multiple access, broadcast and fading channels; Capacity of multiple antenna channels; Multiuser diversity; Opportunistic scheduling.

Recommended Texts


Teaching Strategies

This module is taught using a combination of lectures and problem-solving tutorials. Two software-based lab sessions will demonstrate some of the concepts covered in class.

Assessment

Continuous assessment will be adopted. The final marks for the module will be calculated according to:

- Two in-class quizzes (25% each);
- End-of-year written examination (50%).