Engineering Tripos Part IIB, 4F5: Advanced Communications & Coding, 2017-18

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Timing and Structure
Lent term. 16 lectures. Assessment: 100% exam

Prerequisites
The main pre-requisite is a good background in probability and information theory. 3F1, 3F4 and 3F7 useful.

Aims
The aims of the course are to:

- Introduce students to the principles of algebraic coding and Reed Solomon coding in particular
- Give students an overview of cryptology with example of techniques that share the same mathematical background as algebraic coding.
- Give students an understanding of the challenges inherent in wireless communication, and the tools to design modulation schemes that address these challenges

Objectives
As specific objectives, by the end of the course students should be able to:

- Introduction to applied abstract algebra
- Basic definitions of linear codes and the Reed Solomon code
- Encoding and decoding of Reed Solomon codes for error and erasure channels
- Overview of Cryptology and some algebraic cryptographic techniques
- Be familiar with standard modulation techniques, and be able to analyse their performance in the presence of noise
- Understand the concept of fading in wireless channels and how diversity techniques can be used to combat fading

Content
- The first part of the course will give an introduction to abstract algebra with an eye to practical applications.
In particular, we will study arithmetic over groups and finite fields to a point where students should have the knowledge to implement a practical finite field calculator.

- In the second part of the course, we will introduce the basic concepts of algebraic linear coding and give a spectral presentation of Reed Solomon codes, one of the most commonly used codes in applications as wide as data storage, cellular wireless communications, QR codes and many others.
- The spectral presentation will lead to an easily implementable encoder and decoder structure for both error corrections or erasure recovery.
- In the third part of the course, we will give an overview of the field of Cryptology, or the science of secret and authentic communication. We will then present a number of cryptographic techniques that share the same algebraic fundamentals as linear algebraic coding.
- The final part of the course will cover modulation techniques and wireless communication. We will discuss the phenomenon of fading, a key concept in wireless communication, and look at how to combat fading by using diversity in time/frequency/space.

All the topics will be presented in the context of an integrated end-to-end communication system.

Introduction to practical number theory and algebra (4L)

- Elementary number theory
- Groups and fields
- Extension fields
- 3 equivalent approaches to multiplication in extension fields
- Matrix operations and the Discrete Fourier Transform

Algebraic Coding (3L)

- Linear coding and the Singleton Bound
- Blahut's theorem
- Reed Solomon (RS) codes
- Encoding and decoding of RS codes
- Erasure channel decoding

Introduction to Cryptology (3L)

- Overview of Cryptology
- Stream ciphers, examples
- Block ciphers, examples
- Public key cryptography, basic techniques

Modulation Techniques and Wireless Communication (6L)

- Modulation techniques and their performance over additive Gaussian noise channels
- Modelling a wireless channel: the concept of fading
- Combating fading with diversity in time/frequency/space

Further notes

Booklists
Useful References

Coding Theory

- Modern Coding Theory, T. Richardson & R. Urbanke, Cambridge Univ. Press. (this book covers LDPC codes)
- The Theory of Error-Correcting Codes, F. J. MacWilliams & N. J. A. Sloane, North Holland. (covers classical coding theory)

Wireless Communication


Please see the Booklist for Group F Courses [2] for library holdings.

Examination Guidelines

Please refer to Form & conduct of the examinations [3].

UK-SPEC

The UK Standard for Professional Engineering Competence (UK-SPEC) [4] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the 'Accreditation of Higher Education Programmes' (AHEP) document [5] which sets out the standard for degree accreditation.

The Output Standards Matrices [6] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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