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

Leader

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Lecturer

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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 communcation, 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 Crypylogy 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 diversty 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 books covers LDPC codes)
- The Theory of Error-Correcting Codes, F. J. MacWilliams & N. J. A. Sloane, North Holland. (covers classical coding theory)

Wireless Communication

- Fundamentals of Wireless Communication, D. Tse & P.Viswanath, Cambridge Univ. Press 2005. (Available free online)
- Wireless Communications, A. Goldsmith, Cambridge Univ. Press 2005.

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

This syllabus contributes to the following areas of the UK-SPEC [4] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

IA2

Demonstrate creative and innovative ability in the synthesis of solutions and in formulating designs.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

D1

Wide knowledge and comprehensive understanding of design processes and methodologies and the ability to

apply and adapt them in unfamiliar situations.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

E4

Understanding of and ability to apply a systems approach to engineering problems.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US4

An awareness of developing technologies related to own specialisation.

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Links
[1] mailto:js851@cam.ac.uk
[2] https://www.vle.cam.ac.uk/mod/book/view.php?id=364101&chapterid=55901
[3] http://teaching.eng.cam.ac.uk/content/form-conduct-examinations
[4] http://teaching.eng.cam.ac.uk/content/uk-spec