



THE UNIVERSITY OF  
NEW SOUTH WALES

SCHOOL OF ELECTRICAL ENGINEERING  
AND TELECOMMUNICATIONS

TELE4653

# DIGITAL MODULATION AND CODING

S1, 2009

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## Course Details

**Credits:** The course is a 6 UoC; expected workload is 10-12 hours throughout the 12 week session.

**Contact Hours:** The course consists of 2 hours of lectures per week, one hour of tutorial per fortnight, and three hours of laboratories per fortnight:

Lecture Times:           Thursdays, 2-4pm (ChemSc M11)

Tutorials:                Thursdays 4-5pm (MechEng 202)  
                              Fridays 12-1pm (MechEng 202)

Laboratories:            Fridays 9-12 (EE302, Even and Odd week groups)  
                              Fridays 12-3pm (EE302, Even and Odd week groups)

Note that it is likely that, if enrolment numbers are low, some of the tutorial and lab classes will be closed. These arrangements will be made and finalised in Week 1.

Lectures, Tutorials, and Laboratories all begin in Week 1.

## Course information

**Context and Aims:** Digital communications is today a massive and significant industry, through the enormous growth in mobile cellular communications and wireless computing, to name only the two most prevalent, adding to the already established but always expanding television and radio industries. As the central technical elective in communications in Electrical Engineering at UNSW, this course aims to teach students the fundamental principles of modern digital communication systems, through a combination of thorough theoretical treatment in the lectures and tutorials, and extensive experimentation in the laboratories. It aims to provide the student with the necessary background knowledge, skills and fundamentals to work successfully in the telecommunications industry.

**Aims:** At the successful completion of this course, it is expected that students:

- Understand all the key elements of a digital communication system and at a theoretical level can identify and quantify the factors that determine the performance of a digital communication system.
- Describe the major modulation techniques, their practical considerations, and be capable of quantifying the performance of a generic modulation scheme.
- Explain how the problems of receiver synchronisation can be addressed in digital communications.
- Describe the importance of source coding and compression in communications, and understand the basic principles of how it is implemented in modern practical digital communication systems.
- Understand the importance and rationale of channel coding in communication, and implement and analyse block coding and convolutional coding schemes.

## Relation to Other Courses

This course is a 4<sup>th</sup> year technical elective in the wireless communications discipline. It is aimed at students wishing to specialise in telecommunications in their degree, and possibly, their future careers.

**Pre-requisites:** TELE3113: Analogue and Digital Communications, or equivalent, is required. It is also desirable that students have completed ELEC3104: Digital Signal Processing, as several of the ideas taught in that course lay the foundation in some areas of this subject. In addition, a substantial level of mathematics and statistics is required to adequately master the subject matter.

**Assumed Knowledge:** A basic knowledge and understanding of communication systems and the communication problem, as would be gained from TELE3113, is assumed. Basic knowledge of Fourier theory, digital filters and signal processing is also assumed. Above average competency in the fields of algebra, analysis, and statistics, gained from the second year core mathematics course, commensurate with a student wishing to specialise in telecommunications, will also be required.

The assignments and tutorials will require students to be familiar with MATLAB, or some other equivalent numerical computing platform. The laboratories are to be performed on TIMS, the signal processing platform extensively used in TELE3113 and ELEC3104.

**Following Courses:** As a final year technical elective, it is planned that the standard reached by students at the end of this course would be commensurate with that expected of a graduating telecommunications engineer. There are no follow on courses as such, but students will find that the underlying principles of communication systems taught in this course will provide deeper insight into specialist communications courses in wireless communications, mobile and satellite communications, and optical fibre communications.

## Learning Outcomes

At the end of the course the student should:

- (a) Understand the effects of noise on digital communication systems, and methods for efficient, robust communication in the presence of noise.
- (b) Appreciate the relative merits and disadvantages of a wide variety of different modulation methods.
- (c) Understand the practical considerations and trade-offs in digital receiver design, particularly regarding synchronisation issues.
- (d) Be able to construct appropriate digital codes and their corresponding decoding algorithms to improve communications reliability.

In this regard, this course will contribute to the attainment of the following UNSW graduate attributes:

- *the skills involved in scholarly enquiry*, through the self-directed completion of real-world communication problems in assignments and laboratories
- *an in-depth engagement with the relevant disciplinary knowledge in its interdisciplinary context*, as this is the pinnacle of the technical study of communication systems in the degree, whose thorough treatment necessitates the mutual exchange of concepts with other disciplines
- *the capacity for analytical and critical thinking and for creative problem-solving*, through the problem based learning approach adopted in the lectures, tutorials, laboratories, and assignments.

## Syllabus

Provides detailed understanding of techniques used to process digital information in order to ensure its reliable delivery over noisy channels. Examines the fundamental resources available to telecommunication systems and develops techniques for understanding the implications of different modulation and coding techniques on these fundamental quantities. The course also provides a general understanding of the role of digital modulation and coding in practical digital communication systems.

Review of Fourier Transform and introduction to random signals; the basic problem of digital baseband communication through AWGN channels; Pulse shaping and matched filters; Nyquist criterion and ISI; ML and MAP detectors; Digital Modulation Schemes: M-ASK, QPSK, FSK, CPM; spectral analysis of modulated signals; signal space methods and bit error rate analysis; Digital Receivers: carrier and clock synchronisation; Information theory: entropy and source coding, channel capacity; Channel Coding: block codes and convolutional codes.

## Teaching Strategies

The material of this course will be presented through a combination of lectures, tutorials, laboratories, and assignments.

**Lectures:** The lectures will focus on the theoretical analysis of digital communication systems. The focus will be on explaining the underlying principles of the topic addressed (modulation, synchronisation, compression, and forward error control coding). These principles will be illustrated through a combination of fundamental derivations and practical system illustrations. Attendance at the lectures is compulsory, and moreover students are expected to prepare for the lecture in advance, as the formal notes will be available prior to each lecture.

Important announcements regarding the course, such as rescheduled classes due to public holidays, assignment submission dates, details of the final examination, will be made during the lectures. Students who miss lectures and so miss these announcements do so at their own risk – it is the obligation of the student to ensure they obtain the necessary information, and it is not the obligation of the lecturer to inform each student personally of any course developments.

**Tutorials:** The tutorials aim to provide students with practical quantitative analysis of communication systems. The tutorials will take students through the important topics in the course, and aim to develop analytical and problem solving skills.

Tutorials will begin in week 1. The first tutorial will be revision of fundamental, elementary mathematical ideas, and all students are welcome to attend, even outside their assigned tutorial times. It is compulsory that students attend a tutorial every second week. However, each tutorial will cover slightly different questions every week, so students may wish to attend tutorials every week, particularly if they are struggling with a certain concept.

**Laboratories:** Students must attend the laboratory every fortnight at their allotted time. If students find they must miss a lab session for any reason (illness, family or work commitments), they are required to contact the lecturer and make alternative arrangements PRIOR TO the lab session in

question. Students who have not done so will receive a mark of 0 for the missed lab session – there will be no exceptions. Some lab periods may need to be rescheduled due to public holidays, and the announcement of alternative arrangements will be made during the lectures.

A satisfactory performance (70% or above) in the lab component is a requirement to passing this course. Students must be marked off by a lab demonstrator at the end of each lab session and have their mark recorded by the demonstrator. It is the responsibility of the student to make sure this is done. If no mark is recorded at the end of the lab for whatever reason, a mark of 0 will be given – once again, there will be no exceptions.

Students are required to maintain a laboratory journal, and the marks obtained directly correspond to the quality of this journal. The journal should record all equipment settings and connections, as well as any measurements and observations made. It is important for all engineers to accurately document all experimental work, and emphasis is placed on the lab journal in this course to ensure that students develop this important attribute of a professional engineer.

There are 6 experiments to complete in total. All experiments will be performed on the TIMS systems in EE302, in part using the MATLAB interface. The lab sheets will be made available on the course website prior to each lab, and students are expected to have performed the pre-work and familiarised themselves with the concepts addressed before coming into the lab.

At the beginning of each lab session there will be a small quiz that will be performed on Vista (beginning at the 2<sup>nd</sup> lab, in Week 3). The quiz will consist of 8 multiple choice questions, from topics covered in the most recent lectures and tutorials. These quizzes will only be available at the beginning of the lab period. Students who are late and miss the quiz for any reason will receive an automatic mark of 0 for that quiz – there will be no exceptions.

**Assignments:** In parallel with the lab program there will be fortnightly assignments, to be submitted to the lecturer at the beginning of each lecture, beginning in Week 3. These assignments will require the students to construct simulations in MATLAB, in parallel with and to support their work in the labs and lectures/tutorials. To a lesser this work will also be supported by analytical problems.

Each assignment will be comparatively small, and is designed to be completed in roughly 3 hours work (corresponding to a lab period). Each assignment will build on previous assignments, and work as a whole to construct a MATLAB simulation of an entire communication system.

The assignments are compulsory and form an important assessment component of this course. Late assignments will suffer a late penalty of 10% reduction in the maximum attainable mark per day late, including weekends, with the submission date taken from the time when the assignment physically reaches the lecturer's hand. The assignments are to be submitted to the lecturer at the beginning of the lecture, and not put in the assignment box.

## Assessment

There are four components of assessment in this course:

Final Examination:	55%
Labs:	20%
Assignments:	20% (Due weeks 3,5,7,9,11,and 13)
Lab Quizzes:	5% (online quizzes at the beginning of lab classes)

**Final Examination:** The exam in this course is a standard closed-book 3 hour examination, managed centrally by the exam unit. The examination will test analytical and critical thinking and the general understanding of the course material. Equal weight will be given to course topics in regard to the proportion of marks available. More details will be discussed during lectures, and past exam papers will be made available on the course website.

**Laboratory Work:** As discussed above, marks here will be awarded at the end of each fortnightly lab session based on the quality of each student's lab journal. A satisfactory performance in the

lab (at least 70%) is necessary to pass this course. This requirement reflects the importance of every graduating engineer to be able to understand practical experimental issues.

**Assignments:** The six fortnightly assignments will together account for 20% of a student's final grade. These assignments will be primarily MATLAB programming and simulations. Marks will be awarded based on the quality of a student's programming, their understanding and interpretation of the simulation results, and the competency of any analytical solutions.

**Lab Quizzes:** The five multiple choice quizzes conducted on Vista ([vista.elearning.unsw.edu.au](http://vista.elearning.unsw.edu.au)) will together make up 5% of the final grade in this course. Each quiz will consist of 8 multiple choice questions and will be closed book. The motivation of these quizzes is to encourage students to keep up to date with the course material and concepts, and as such has a relatively small weight in the final grade.

## Resources for students

**Lecture Notes:** A comprehensive set of typed lecture notes will be handed out at each lecture. These typed lecture notes will take the role of the textbook, since no available textbook quite covers all the course material at the depth required of this course. These lecture notes are the reference of examinable material – they effectively play the role of the detailed course syllabus.

In addition, the lecturer will make available the set of slides/overheads used in each lecture on the course website, for additional reference.

**Textbooks:** No available textbook covers all course topics; however several textbooks would still be extremely useful to students for reference:

**Recommended Texts:** (one of the following)

- J. Proakis & M. Salehi, "Communication Systems Engineering", Prentice-Hall, 2<sup>nd</sup> Edition, 2002.
- S. Haykin, "Communication Systems", Wiley, 4<sup>th</sup> Edition, 2001.
- S.G. Wilson, "Digital Modulation and Coding", Prentice-Hall, 1996.
- R.G. Gallager, "Principles of Digital Communication", Cambridge University Press, 2008.

**Reference Books:** The following list of books will provide reference for various parts of the course, and can be found at the library as required:

- B. Lathi, "Modern Digital and Analog Communication systems", Holt Saunders, (most recent edition).
- L.W. Couch II, "Digital and Analog Communication Systems", Prentice-Hall, 5<sup>th</sup> Edition, 1997.
- H. Taub & D.L. Schilling, "Principles of Communication Systems", McGraw Hill, 1986.
- B. Sklar, "Digital Communications", Prentice Hall, 1988.
- H. Stark & F.B. Tuteur, "Modern electrical communications", Prentice Hall, 1988.
- M. Rice, "Digital Communications: A Discrete-Time Approach", Pearson-Prentice Hall, 2009.
- N. Benvenuto, R. Corvaja, T. Erseghe, & N. Laurenti, "Communication Systems", Wiley, 2007.
- R.B. Wells, "Applied Coding and Information Theory for Engineers", Prentice Hall, 1999.

## Course Website:

Course Webpage: <http://subjects.ee.unsw.edu.au/tele4653>

Lecture Notes, tutorial solutions, assignments, and past exam papers can be downloaded from the course webpage.

Vista: <http://vista.elearning.unsw.edu.au>

WebCT Vista will be used for the on-line quizzes at the beginning of the laboratory sessions, and also for the release of assignment marks.

## Other Matters

### Academic honesty and plagiarism

Plagiarism is a serious issue at UNSW. Students should all be familiar with the university wide policy for plagiarism and academic honesty. This can be found at [www.lc.unsw.edu.au/plagiarism](http://www.lc.unsw.edu.au/plagiarism).

### Continual Course Improvement

Students are advised that the course is under constant revision in order to improve the learning outcomes of its students. Please forward any feedback (positive or negative) on the course to the lecturer or via the CATEI course evaluation. Your comments and feedback are always greatly appreciated and highly valued.

### Administrative Matters

On issues and procedures regarding such matters as special needs equity and diversity, occupational health and safety, enrolment, rights, and general expectations of students, please refer to the School policies: <http://scoff.ee.unsw.edu.au>

## Course Schedule (tentative)

Week	Topic	Tasks
1	Baseband Signalling Principles (AWGN, Matched filter, pulse shaping, ISI)	Lab 1 (Baseband Signalling)
2	Baseband Signalling Principles (continued)	Lab 1
3	Bandpass Signalling and Signal Space Methods	Lab 2 (Noise Performance of Communication Channels) Assignment 1 (Communication Channels in MATLAB)
4	Modulation Techniques (QASK, PSK, FSK)	Lab 2
5	Modulation Techniques (continued)	Lab 3 (ASK, FSK, PSK) Assignment 2 (Modulation in MATLAB)
6	Receiver Synchronisation and digital receiver design	Lab 3
7	Receiver Synchronisation (continued)	Lab 4 (Carrier recovery) Assignment 3 (Coherent and Non-coherent receivers)
8	Information Theory I (Entropy and Source Coding)	Lab 4
9	Information Theory II (Channel Capacity and the Promise of Coding)	Lab 5 (Bit clock recovery and synchronisation) Assignment 4 (Source Coding)
10	Linear Block Coding	Lab 5
11	Convolutional Coding	Lab 6 (QASK) Assignment 5 (Channel Coding)
12	TCM and Revision	Lab 6 Assignment 6 (due week 13 – communication system performance)