

**THE AUSTRALIAN NATIONAL UNIVERSITY
DEPARTMENT of ENGINEERING**

**ENGN3226 Digital Communications
[06-11-2008] Course Outline and Assessment Schedule – Semester 2, 2008**

[1] COURSE INFORMATION

1.1 Course Coordinator

Name: Dr. Salman Durrani
Office: E237, Engineering Bldg.
Tel: 6125 6573
Email: salman.durrani@anu.edu.au
Web-Site: <http://engnet.anu.edu.au/DEpeople/Salman.Durrani/>
Drop-in session: Tuesday, 2:00 PM-3:00 PM.

1.2 Lab Supervisor

1. Mr. Ian McRobert (Office: E202) ian.mcrobert@anu.edu.au (Tel: 54885)

1.3 Lab Demonstrator

1. Mr. Akramus Salehin asalehin@rsise.anu.edu.au

1.4 Pre-Requisite

1. ENGN2211 Electronic Circuits
2. ENGN2226 Systems Analysis

1.5 Text Book

1. J. G. Proakis & M. Salehi, "Communications Systems Engineering", 2nd edition, Pearson/Prentice Hall, 2002.

1.6 Web Site

1. <http://webct.anu.edu.au>
It is your responsibility to regularly check the webpage regularly (**at least twice a week**) for course information and announcements.

1.7 Teaching and Learning Activities

	No.	Day	Time	Location
Lectures: (Weeks 1-13)	Lecture 1:	Monday	11:00 AM-12:00 PM	PSYC G08 Lect Theatre
	Lecture 2:	Wednesday	12:00 PM-01:00 PM	PSYC G06 Lect Theatre
	Lecture 3:	Thursday	11:00 AM-12:00 PM	PSYC G06 Lect Theatre
CLabs: (Weeks 4,6,8,10)	Group 1:	Wednesday	2:00 PM-5:00 PM	COP G022 (Building 24)
HLabs: (Week 7,9)	Group 1:	Wednesday	2:00 PM-5:00 PM	Ian Ross Room 103(Hlab1) Ian Ross Room 104(Hlab2)
Project Tutorials: (Weeks 1-4, 6-9, 11-13)	Group 1:	Tuesday	3:00 PM-4:00 PM	ENGN Lect Theatre

[2] COURSE DESCRIPTION

2.1 Course Outline

This course presents the principles and techniques fundamental to the analysis and design of digital communication systems. It focuses on the basic building blocks of a digital communication system (channel encoder/decoder, digital modulator/demodulator and channel characteristics). The emphasis is on mathematical underpinnings of communications theory along with practical applications. Specific topics include:

1. **Probability and Random Processes:** Probability distributions, Random variables, Random processes, Statistical averages, Correlation.
2. **Digital Modulation Techniques:** Signal space analysis, BPSK, QPSK, QAM, bit error rates.
3. **Digital Demodulation & Detection Techniques:** Correlator, Maximum a posteriori detection (MAP), Maximum likelihood detection (ML).
4. **Channel Encoder/Decoder:** Linear block codes, Cyclic codes, Convolutional codes, Viterbi algorithm.
5. **Channel Characteristics:** Wireline vs. wireless channels, Mathematical models for communication channels, Characterization of multipath channels.
6. **Digital Communication Systems:** Multiple Access techniques, TDMA vs. CDMA communication systems.

Simulink is used extensively in the analysis and design.

2.2 Learning Outcomes

Knowledge Base

Having successfully completed this course, students should be able to:-

1. Describe a random process in terms of its mean and correlation functions and characterize special Gaussian and Rayleigh distributions.
2. Identify methods of digital modulation and compare their performance using signal-space analysis.
3. Explain receiver techniques for detection of a signal in AWGN channel.
4. Characterize error-control coding techniques and explain the working of Viterbi algorithm.
5. Explain the mechanism of signal propagation in wireless communication and classify characteristics of multipath propagation channels.

Engineering Ability

Having successfully completed this course, students should be able to:-

1. Explain in simple words the working principles of basic building blocks of a digital communication system.
2. Model digital communication systems using appropriate mathematical techniques (probability distributions, signal-space analysis, constellation diagrams, trellis graphs, impulse response).
3. Develop an intuitive grasp of random variables and notion of random process and their characteristics.

Practical Skills

Having successfully completed this course, students should be able to:-

1. Simulate digital communication applications using Simulink.
2. Calculate results using Matlab in a knowledgeable and confident manner.
3. Typeset mathematical reports in Latex.

2.3 Library Reserve

1. John G. Proakis, *Digital Communications*, 4th ed, McGraw Hill, 2001. [TK5103.7 P76 2001] <http://library.anu.edu.au/record=b2263191>
2. Bernard Sklar, *Digital Communications: Fundamentals and Applications*, 2nd ed, Prentice Hall, 2001.[TK5103.7.S55 2001] <http://library.anu.edu.au/record=b2089687>
3. Theodore S. Rappaport, *Wireless Communications Principles & Practice*, 2nd ed, Prentice Hall, 2002. [TK5103.2 .R37 2002] <http://library.anu.edu.au/record=b2259071>
4. Simon Haykin, *Communication Systems*, 4th ed, John Wiley, 2001.
5. Andrea Goldsmith, *Wireless Communications*, Cambridge University Press, 2005. (textbook for ENGN4536 Wireless Communications)

[3] POLICIES AND PROCEDURES

3.1 Assessment

There are FOUR components to the assessment for this course:

No.	Component	Marks
1.	Labs	18% (6 Labs, each worth 3%)
2.	Mid-semester Exam	12%
3.	Project	20% (Report = 10%, Lab Demonstration = 10%)
4.	Final Exam	50%

Note:

1. The Mid-semester exam topics include:
 1. Lectures 1-8
 2. Problem Sets 1-3
 3. Text Book Chapters 4.1,4.2,7.1
2. The Mid-semester exam will consist of 3 questions, each worth 10 marks. It will be marked out of 30.
3. The Final exam topics include:
 1. Lectures 9-27
 2. Problem Sets 4-6, 8-10
 3. Associated Text Book Chapters
4. The Final exam will not directly address the topics already covered in Mid-semester exam. Nevertheless, knowledge and understanding of these topics will be assumed.
5. The Final exam will consist of 5 questions, each worth 15 marks. It will be marked out of 75.
6. Past examination papers (2007 onwards) are not available from the library. Sample examination questions may be made available via WebCT before the mid-semester and final exams. Some exam questions will be taken from Problem Set questions as outlined in Section 3.4.

3.2 Permitted Exam Materials

1. A4 page (one sheet) with hand-written notes on both sides.
2. Calculator (Memory cleared for programmable calculators).
3. A list of commonly used formulas will be provided in both the mid-semester and final exams.

3.3 Lecture Notes

1. The lecture notes will be posted on the course web site after each lecture/week.

3.4 Problem Sets

1. At the start of each week, Problem Sets covering the course material will be prepared and posted on the course web-site. The solutions to the Problem Sets will be posted at the end of each week.
2. The Problem Sets are based on relevant material in the textbooks specified in the library reserve.
3. The Problem Sets are assessable as follows:
 - a. ONE question each in the Mid Semester and Final Exams will be taken from the Problem Sets with changes in numerical values. The question wording may be modified as required.
 - b. A further TWO questions in the Final Exam will be similar in nature and difficulty to the Problem Set Questions.

3.5 Computer Laboratories

1. There are four computer simulation laboratories (worth 12% of overall assessment):
 - a. CLabs 1-2 are based on Matlab.
 - b. CLabs 3-4 are based on Simulink.
2. **[CLab Groups]** There is only one CLab group (you do not have to sign up for it). Each student will perform the lab individually.
3. **[Pre-Lab]** Preliminary preparation for the laboratories is essential. Read the *Reading, Aims* and *Theory* sections BEFORE coming to the CLab.
4. **[Lab Time]** Complete the *Lab Procedure* section DURING lab time. The Lab tutor will make a note that all procedure steps and measurements have been completed during lab time.
5. **[Lab Reports]** CLab reports will be prepared by every student AFTER completing the lab. A proper CLab report is expected including:-
 - a. Main circuit diagrams,
 - b. Report deliverables (including Simulink/Matlab result figures and calculations/analysis/observations/explanations where requested in the lab manual).
 - c. answers to Evaluation & Review Questions.
 - d. However, no formal introduction or aims or conclusions are required.
6. **[Lab Report Length]**
 - a. Reports should be limited to a maximum of 10 pages (ideally 7-8 pages).
 - b. For typed lab reports, use 11 or 12 point font (Times New Roman or Arial) and all page borders must be at least 1 inch. Reports in excess of 10 pages will have additional pages removed and the report then marked.
 - c. The first page must clearly show the Student Name, University ID and CLab number.
7. **[Lab Report Assessment Criteria]** Each lab report is worth up to 5 marks. All lab reports will be assessed taking into account the following:-
 - a. Report deliverables specified in the lab manual
 - b. answers to the evaluation and review questions and
 - c. the standard of the lab report as outlined in items 5 and 6 above.
8. **[Lab Report Submission]** Reports are due in ENGN3226 submission box at 11 am on Tuesday in the next week i.e.
 - i. CLab1 due week 05: Tuesday 19 Aug., 11am
 - ii. CLab2 due week 07: Tuesday 02 Sep., 11am
 - iii. CLab3 due week 09: Tuesday 16 Sep., 11am
 - iv. CLab4 due week 11: Tuesday 14 Oct., 11am
9. **[Late Submission Policy]** Late reports will be accepted but undergo the following penalty:
 - a. All reports submitted after 12 noon on the due date will be reduced by 0.5 marks for the report per day, including weekends.
 - b. The lab report may be marked at a later date without a late submission penalty only in special circumstances AND if permission is sought in advance.

3.6 Hardware Laboratories

1. There are two hardware laboratories (worth 6% of overall assessment):
 - a. HLab1 is based on TIMS (Telecommunications Instructional Modeling System).
 - b. HLab2 is based on digital electronics (using NAND gates).
2. **[Lab Kit]** Obtain a set of lab components kit (free) from Pam Shakespeare, Student Administrator in WEEK 8.
3. **[HLab Groups]** There is only one HLab group (you do not have to sign up for it). Experiments are conducted by teams of two persons. It is expected that the composition of the teams is maintained for the two hardware experiments.
4. **[Assessment Criteria]** HLabs will be assessed based on the satisfactory completion of tasks outlined in the HLab manuals. The marking will be done during the lab.

3.7 Lab Attendance Policy

1. Any student absent from their HLab or CLab group will receive a 0 mark.
2. For CLabs, the attendance requirement may be waived only in special circumstances AND if permission is sought in advance.

[4] PROJECT

4.1 Aims

1. To acquaint students with modern applications of digital communications.
2. To develop in students the ability to:
 - a. conduct an engineering design project.
 - b. self-learn.
 - c. present lab demonstrations.
 - d. function as an effective team member.
 - e. manage information and communicate via written report.

4.2 Selection of Topic

1. What do you currently know about digital communications?
2. Which digital communications application particularly interests you?
3. How will you research the chosen digital communications topic?

Section 4.10 provides (an incomplete) list of relevant digital communication projects at various levels. This may assist you in selecting and researching your topic.

4.3 Groups

Students should work in *groups of 2*. It is the responsibility of group members to ensure that all members participate in a fair and equitable manner. In general, all members of a group will receive the same mark, though this may be moderated in cases of poor participation. Any group difficulties should be resolved early in the semester.

4.4 Assessment Criteria

The following criteria applies to the overall marking of the project:

1. Level of understanding, analysis and technical details.
2. Matching of measured outcomes with any theory.
3. Actual simulation performance during lab demonstration.
4. Use of “real-time” Simulink results or Matlab Graphical User Interface (GUI).
5. Creativity/originality of simulation implementation.
6. Standard of report formatting and presentation.

The project report and lab demonstration assessment sheets are available in project page in WebCT.

4.5 Due Dates

No.	Week	Due Date	Description
1	04	Fri. 15 Aug	Two page project description.
2	12	Tue. 28 Oct., 11am	Project Report due (ENGN3226 submission box).
3	12	Tue. 28 Oct., 11am	Deadline for Electronic Submission.
4	13	Mon. 27 Oct. 11-12am	Lab demonstrations (schedule to be announced later)

4.6 What is expected in two page project plan

The first page should specify:

1. the digital communications project you wish to implement.
2. names of group members and the responsibilities of each member.
3. the context in which the application/technology is used.
4. Performance measures and relevant theory to be used.
5. 1 or 2 key references.

The second page (& if required third page) should list:

1. Block diagram of the overall implementation
2. Detailed Simulink diagram(s) for implementation.

4.7 What is expected in the report

1. Up to 10 pages in length (including title page and excluding appendix).
2. Clear discussion of the digital communication application and its context. Should be comprehensible to a non-technical person.
3. Clear discussion of how digital communication theory is used in the application. Should be comprehensible to other students in the class.
4. All source material must be fully acknowledged and documented. Students are reminded of the University's plagiarism policy: *copying of material from books, magazines, internet or anywhere else is strictly prohibited*. What you write must be in your own words.
5. Quality professional standard presentation using word processor.

Suggested Report format is as follows:-

1. Title
2. Abstract
3. Introduction/Background
4. Theory/Design (include system block diagram)
5. Implementation (include main Simulink block diagram)
6. Results
7. Conclusions
8. References (typically 3-5)
9. Appendix A: Simulink sub-system block diagrams
10. Appendix B: Matlab code

Groups must also submit the following by email or by bringing the files on USB:

1. A pdf or doc copy of Final report
2. All Simulink/Matlab files.

4.8 What is expected in the lab demonstration

1. 15 min duration.
 - a. 5-7 min demonstration and
 - b. 5-10 mins for interactive discussion and questions
 - c. More interactive than a formal presentation
2. What is the goal of your project
 - a. How did you design your simulation
3. Demonstration of Simulink block diagram performance.
4. Suitable material (Printouts) to support the demonstration:
 - a. Block diagrams
 - b. Measured results
 - c. Key theory equations

Sign-up sheet for lab demonstration will be made available at a later date.

4.9 Use of Scheduled Tutorial Time

This is up to you. It can provide a minimum amount of contact among group members. I will be available for consultation during these times. Here is what I recommend:

- Weeks 1 – 4
 - form groups
 - discuss possible topics and methods for research
 - discuss technical issues
- Weeks 6 – 9
 - In-depth research of topic
 - Simulink implementation
- Weeks 11-12
 - Preparation of report and lab demonstration

Please note there is no tutorial meeting in Weeks 5 and 10.

4.10 Project Ideas

The following is a list of projects completed by students in 2007, which are unavailable in 2008:

1. Generation and detection of Direct Sequence Spread Spread (DS-SS) coherent BPSK.
2. Implementation of Channel Encoders (from first principle) for Digital Communication Systems.
3. BPSK and PAM Digital Receiver with MATLAB Implementation of MAP Detector.
4. Simulation of Digital Modulation Techniques in Non-ideal Noisy Environments.

Some ideas for projects, to get you started thinking, are given below:

1. Minimum Shift Keying (MSK) modulation and demodulation.
2. Non-coherent detection of Binary Phase Shift Keying (BPSK).
3. Trellis coded modulation.
4. Simulation of Rician/Nakagami fading channels (amplitude and phase).
5. Turbo coding.
6. Low Density Parity Check coding.
7. Alamouti scheme for two transmit antennas.

4.11 Software Packages

The software packages which are required for this course are available on all Info Commons computers:

1. Matlab 2007b (Matlab version 7.5 and Simulink version 7.0)
2. Latex (Winedt and MikTeX)

Please note the following regarding Simulink file versions:-

1. Simulink files in this course will be made available in Simulink version 6.0 (older) format. This allows them to be run in any higher version.
2. Any Simulink version 7.0 files created by you in the CLabs may get corrupted if you try to edit them (e.g. at home) using older Matlab version such as Matlab 2007a. If that happens, the quickest solution is to create a fresh Simulink file.

The following are additional (optional) software packages also available on all Info Commons computers:

1. Mathematica 6.0 (for symbolic integration)
2. Microsoft Visio 2003 (due to ANU licencing restrictions, Visio 2003 is available only on the 20 PCs in the Law G17 computer lab. Law G17 has the same software as the Engineering lab)

[5] TENTATIVE COURSE SCHEDULE

Week	Lectures	Textbook	Prob. Sets	Tutorials	Labs
1 (21Jul-27Jul)	L01 Intro to ENGN3226	Chapter 1 (1.1–1.2)	P01 Random Variables	✓: 1 st Project Meeting	
	L02 Digital Comm. System				
	L03 Random Variables (Matlab Demo)				
2 (28Jul-03Aug)	L04 Important RVs (Mathematica Demo)	Chapter 4 (4.1–4.2,4.4)	P02 Random Processes	✓	
	L05 Functions of RVs				
	L06 Random Processes				
3 (04Aug-10Aug)	L07 Noise Model	Chapter 7 (7.1–7.4)	P03 Signal Space	✓	
	L08 Signal Space				
	# (Mathematica Demo)				
4 (11Aug-17Aug)	L09 PAM (Intro. To Simulink Demo)	Chapter 7 (7.1–7.4)	P04 Modulation	✓: 2 page Project plan due	CLab1 R.V. & R.P.
	#				
	L10 BPSK and QPSK				
5 (18Aug-24Aug)	#	Chapter 7 (7.5–7.6)	P05 Detection Theory	Midsem-Exam: Tue 19 Aug	CLab1 due
	L11 QAM (Simulink Demos)				
	L12 Correlator Demodulator				
6 (25Aug-31Aug)	#	Chapter 7 (7.5–7.6)	P06 Correlator	✓: Project Meetings Resume	CLab2 QPSK
	L13 Detection Theory				
	L14 Generalized Detection				
7 (01Sep-07Sep)	#	Chapter 7 (7.5–7.6)	P07 BER ?	✓	HLab1 QPSK CLab2 due
	L15 BER				
	# (Simulink Demos)				
8 (08Sep-14Sep)	L17 Channel Coding	Chapter 9 (9.4–9.7)	P8 Block Codes	✓	CLab3 Coding
	L18 Block Codes				
	#				
9 (15Sep-21Sep)	L19 Hamming Codes	Chapter 9 (9.4–9.7)	P9 Conv. Codes	✓	HLab2 Coding CLab3 due
	L20 Cyclic Codes				
	L21 Convolutional Codes				
10 (22Sep -28Sep)	L22 Properties of Conv. Codes	Chapter 9 (9.4–9.7)	P10 Viterbi Algorithm	No Project Meeting	CLab4 Conv. Coding
	L23 Viterbi Algorithm				
	#				
Semester break					
11 (13Oct-19Oct)	L24 Channel Models	Chapter 1 (1.3–1.4)	P11 Channel ?	✓: Project Meetings Resume	CLab4 due
	L25 Multipath Fading				
	# (Simulink Demos)				
12 (20Oct-26Oct)	L26 Digital Comm. Systems	Chapter 4 (4.4)		✓: Project Report due	
	L27 Final Exam				
13 (27Oct-02Nov)		Chapter 10 (10.4)		Project Demonstrations	
Final Exam : Friday, 7 Nov. 2008, 9:15am – 12:30 pm (Sports Hall)					

Note:

All assessable item due 11am on Tuesday of that week in ENGN3226 Assignment Box.

(# = lecture topic continues)

(✓ = project tutorial meeting)

(red color = assessment item due)