Carleton University

Department of Systems and Computer Engineering

SYSC 3503 A ***Communication Theory II*** **Winter 2011/12**

Course Outline

Instructor:

Prof. Ian Marsland, Office: 7030 MC, 613-520-2600 ext. 2052, email: ianm@sce.carleton.ca
Office Hours: Wednesdays & Fridays, 1:30-3:00.

Calendar Description:

Amplitude Modulation. Frequency Modulation. Performance of AM and FM in noise. Communication channels, channel models, noise sources, noise models. Digital modulation: ASK, FSK, PSK. Optimal reception, probability of error on the AWGN channel.
Precludes additional credit for SYSC 3501 or SYSC 4600.
Prerequisite: (SYSC 2500 or SYSC 3500) and STAT 2605.
Lectures three hours a week, laboratory, three hours alternate weeks.

Course Overview:

This course provides an introduction to the fundamental principles of communication theory. The basic components of a communication system will be outlined and the concept of modulation will be explained, pointing out the differences between analogue and digital modulation. Important techniques for representing signals in the time and frequency domains will be presented, including signal-space diagrams. Analogue amplitude modulation and frequency modulation will be studied, including their performance in the presence of noise. Amplitude shift keying (ASK), frequency shift keying (FSK), and phase shift keying (PSK), three digital modulation techniques, will be defined, and the fundamental concepts of optimal reception of digitally modulated signals transmitted over an additive white Gaussian noise (AWGN) channel will be emphasized. Techniques for calculating the expected probability of error at the receiver output will be covered.

Learning Objectives:

By the end of this course, students will be familiar with the fundamental terminology and theory behind communication systems, including modulation, signal space representation, optimal reception, and error probability analysis. Students will further develop their understanding of the mathematical tools, including calculus, probability theory, and Fourier transforms, that are required for the course material. Students will acquire the necessary background to study more advanced material in communication theory, as offered in SYSC 4604 – Digital Communication Theory, SYSC 4607 – Wireless Communications, and SYSC 4700 – Telecommunications Engineering.

Instructional Resources:

Lectures: Wednesdays and Fridays, 10:00-11:30 in 3165 ME.

Web Site: http://www.sce.carleton.ca/courses/sysc-3503/w12 – Please check the website regularly, as important announcements will be posted there as the course progresses.

TA: The TA, Mr. Alireza Sharifian, will supervise the labs, and mark the lab reports and assignments.

Instructor: I will be available for discussion during my scheduled office hours (Wednesdays & Fridays 1:30-3:00), but feel free to drop by my office at any time. I am usually free on Monday, Wednesday and Friday afternoons from 1pm to 5pm. Appointments at other times can be arranged if you have trouble finding me. I can also be reached by email, but for help with difficult problems it is usually more productive to meet in person.

Textbook (recommended): S. Haykin & M. Moher, *Communication Systems, 5th Ed.*, John Wiley & Sons, 2009.

References:

1. B. Sklar, Digital Communications, 2nd Ed., Prentice Hall, 2001.
2. L. Couch, Digital and Analog Communication Systems, 7th Ed., Pearson Prentice Hall, 2007.
3. H. Stern and S. Mahmoud, Communication Systems: Analysis and Design, Pearson Prentice Hall, 2004.
4. J. Proakis and M. Salehi, Fundamentals of Communication Systems, Pearson Prentice Hall, 2005.

Assignments:

A total of 6 assignments will be posted on the web site as the course progresses. Assignments are due in the drop box in the 4400 block of Mackenzie Building by 2:00pm on the following days:

Assignment #1	Thursday, January 12th
Assignment #2	Thursday, January 26th
Assignment #3	Thursday February 9th
Assignment #4	Thursday, March 1st
Assignment #5	Thursday, March 15th
Assignment #6	Thursday, March 24th

Late assignments will be accepted until 4pm on the following Monday, but will be penalized by 20%.

Laboratories:

There will be four laboratory exercises throughout the term. Each laboratory exercise requires the completion of a pre-lab component which must be placed in the drop box by 2:00pm on the Wednesday before the lab. Late pre-lab exercises will not be accepted. Lab manuals will be posted on the course website about a week before each lab.

The written lab report must be placed in the drop box by 2:00pm on the Thursday after the lab. Late lab reports will be penalized by 20%. Reports more than three days late will not be accepted.

Lab exemptions will not be granted for this course, and attendance at the scheduled laboratory periods is mandatory. If you are unable to attend a lab due to medical reasons, you must provide a medical note within one week of returning to campus.

Term Project:

There will be a term project, to be completed in teams of 4-6 students. Details of the project will be posted on the course website.

Prerequisites:

STAT 2605 and either SYSC 3500 or SYSC 2500.

Students who have not satisfied the prerequisites for this course must either:

a) withdraw from the course, or

b) submit a prerequisite waiver form online at http://www.sce.carleton.ca/ughelp.

Students without the prerequisites or a prerequisite waiver will be deregistered from the course after the last day to register for courses in the Winter 2012 term.

Examinations:

There will be a written mid-term exam and a written final exam. Both exams will be closed-book, but students will be allowed to bring one 8.5×11" sheet of notes (double sided), and a calculator.

The mid-term exam will be held during the lecture on Friday, March 2nd. The final exam will be held during the University's examination period in April. The precise date should be announced by the end of February. The final exam is for evaluation purposes only and will not be returned to students.

The *Academic Regulations of the University* permit instructors to specify requirements that must be satisfied for students to be eligible to write the final examination or, where circumstances warrant, apply to the Registrar's Office for deferral of the final examination.

- All students are encouraged to write the final examination.
- Students who miss the final exam, but completed all labs and assignments, and attempted the midterm, will receive the grade ABS. These students are eligible to apply for deferral of the final examination. For more information, see the current Undergraduate Calendar, *Academic Regulations of the University*, Section 2.2, The Course Outline; Section 2.3, Standing in Courses/Grading System; and Section 2.5, Deferred Final Examinations.
- Students who miss the final exam, and did not complete all labs and assignments or missed the midterm exam, will receive the grade FND. These students are ineligible to write the deferred final exam.

Grading Scheme:

To pass the course, students must attend all the labs. For these students, the final grade will be calculated by weighting the course components according to whichever of the following schemes yields the highest grade:

	Scheme #1	Scheme #2
Assignments:	10%	0%
Pre-lab Exercises:	5%	5%
Lab Reports:	5%	5%
Term Project:	15%	15%
Mid-term Exam:	10%	0%
Final Exam:	55%	75%

Attendance:

Students are expected to attend all lecture and lab periods. The Faculty of Engineering and Design requires its students to have a conflict-free timetable, so requests to accommodate missed exams, assignment due dates, etc., because of conflicts with other courses, jobs or vacation plans will not be considered.

Students with Disabilities:

Students with disabilities who require academic accommodations in this course should contact the Paul Menton Centre for Students with Disabilities (PMC) (UC 500) to complete the necessary forms. After registering with the PMC, make an appointment with your instructor to discuss your specific needs at least two weeks prior to the mid-term exam. This will allow sufficient time to make the required arrangements. Please note that the deadline for submitting completed forms to the PMC for accommodations for formally scheduled final exams is March 7, 2011.

Academic Accommodation for Religious Obligations

Students who require accommodations due to religious obligations must follow the procedures described in Section 2.10 of the *Academic Regulations of the University*.

Health and Safety:

Every student should have a copy of our Health and Safety Manual. An electronic version of the manual can be found at http://www.sce.carleton.ca/courses/health-and-safety.pdf.

Week-by-week Outline:

The following week-by-week outline is a preliminary guideline only and is subject to change:

Week 1: January 4th – January 6th:

Introduction and overview of communication theory and systems: General model of a communication system. Examples of communication systems. Analogue vs. digital modulation.

Review of signals: Classifications of signals: Energy vs. power, deterministic vs. random, periodic vs. aperiodic. Fourier series and Fourier transforms. The Dirac delta (impulse function). Energy spectral density of energy signals. Signal bandwidth.

Review of systems: Classification of systems: Linear vs. nonlinear, time invariant vs. time-variant, realizable vs. non-realizable. Impulse and frequency response of linear time-invariant systems. Transmission of signals through linear time-invariant systems. Convolution.

Weeks 2-3: January 9th – January 20th:

Analogue modulation schemes: Amplitude modulation (AM): definition, time domain waveform, modulation index and modulation efficiency, spectrum, bandwidth, envelope detection and coherent demodulation, superheterodyne receiver. Double-sideband suppressed carrier (DSB-SC) AM: definition, time domain waveform, spectrum, bandwidth, coherent demodulation. Single sideband (SSB) and vestigal sideband (VSB) modulation (brief). Frequency modulation (FM): definition, time domain waveform, modulation index, spectrum, bandwidth, demodulation.

Week 4: January 23rd – January 27th:

Performance of analog modulation schemes in the presence of noise: Noise sources and noise models, additive white Gaussian noise (AWGN) channel model, signal-to-noise ratio (SNR), noisy receiver model for analog modulation, performance measures for analogue modulation.

Week 5: January 30th – February 3rd:

Digital transmission of analog signals: Bandlimited signals, sampling theorem for bandlimited signals, pulse amplitude modulation (PAM), quantization, pulse code modulation (PCM), line codes.

Week 6-7: February 6th – February 17th:

Digital signalling: Geometric representation of signals: signal space diagrams, Gram-Schmidt orthogonalization. Binary and M-ary signaling. Baseband and bandpass signalling. Amplitude shift keying (ASK), phase shift keying (PSK), and frequency shift keying (FSK). Spectral characteristics of baseband and bandpass signals.

Week 8: February 27th – March 2nd:

Review of probability theory: Discrete and continuous random variables. Probability distributions and probability density functions. Bernoulli and Gaussian random variables. Expected values. Mean and variance. Discrete-time and continuous time random processes. Wide-sense stationary random processes. Autocorrelation function and power spectral density of random processes.

Week 9: March 5th – March 9th:

Optimal receivers: Matched filters (to maximize output SNR). Optimal detection in the presence of AWGN: Maximum a posteriori (MAP) and maximum likelihood (ML) decision rules to minimize the probability of error.

Weeks 10-11: March 12th – March 23rd:

Probability of error analysis: Probability of symbol and bit errors for digital communication systems in the presence of AWGN. Union bound on the probability of error.

Weeks 12-13: March 26th – April 5th:

Digital transmission through bandlimited channels: Communication system model, Nyquist criterion for no intersymbol interference (ISI), pulse shaping.