THE UNIVERSITY OF ADELAIDE
AUSTRALIA

EXAMINATION FOR THE DEGREE OF B.E.

Semester I June 2005

101902 COMMUNICATIONS IV (ELEC ENG 4035)

Official Reading Time:	10 mins
Writing Time:	120 mins
Total Duration:	130 mins

Instructions:

- This is a closed book examination.
- Attempt **ALL FOUR** questions.
- All questions carry equal marks; part marks are given in brackets where appropriate.
- **Explanations are expected where requested, and marks will be given for these.**
- Begin each answer on a new page.
- Examination materials must not be removed from the examination room.
- **ANSWERS TO QUESTIONS SHOULD BE EXPRESSED CLEARLY AND WRITTEN LEGIBLY. THESE ASPECTS OF PRESENTATION WILL BE TAKEN INTO ACCOUNT IN ASSESSMENT.**

Materials:

- One Blue book
- The use of calculators is permitted, this equipment to be supplied by the candidate. No pre-recorded material nor calculator instruction book is permitted, and calculators with remote communication links are not permitted.

Attachments:

- Fourier Transform Sheet
- Table of the Q Function
- Communications IV Data Sheet

DO NOT COMMENCE WRITING UNTIL INSTRUCTED TO DO SO

Total number of pages (including attachments) = 11

Question 1 follows on page 2.

Question 1

1a) A message signal m(t) = cos(2000 πt) + 2 cos(4000 πt) modulates a carrier c(t) = 100 cos(2πf_ct) (where f_c = 20 kHz) to produce a double sideband suppressed carrier modulated (DSBSC) signal v(t) = m(t) c(t).

(i) Calculate an expression for v(t). **(1 mark)**

(ii) Calculate the spectrum (fourier transform) M(f) of m(t) and sketch it, showing clearly the magnitudes of the various components. **(2 marks)**

(iii) Calculate the spectrum (fourier transform) V(f) of v(t) and sketch it, showing clearly the magnitudes of the various components. **(3 marks)**

(iv) Determine an expression for the upper sideband component of v(t). Note that this is a real signal. **(2 marks)**

(v) Determine an expression for the spectrum of the upper sideband component of v(t) and sketch it, showing clearly the magnitudes of the various components. **(2 marks)**

[Your sketches should show appropriate values on the frequency axis].

1b) A signal x(t) is a stationary random process with power spectral density $S_{xx}(f)$. This is passed through the system shown in Figure 1 and the output is y(t).

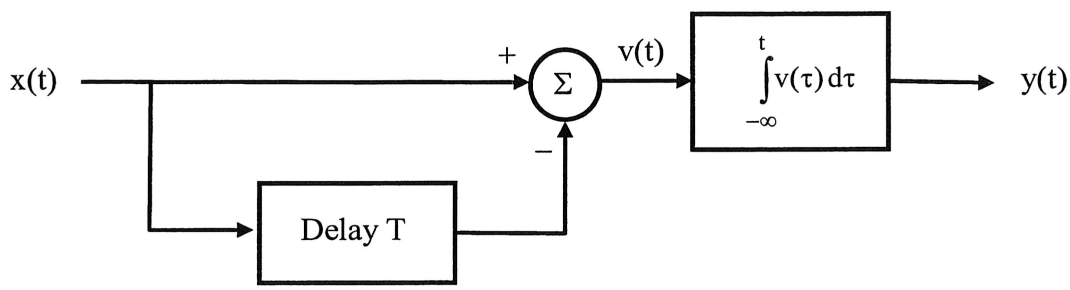

Figure 1

(i) Express the output y(t) in terms of x(t). **(2 marks)**

(ii) Calculate the transfer function H(f) of the system. **(3 marks)**

(iii) Calculate the power spectral density $S_{yy}(f)$ of y(t) and sketch it for $S_{xx}(f)$ = 1. **(3 marks)**

(iv) When $S_{xx}(f)$ = 1, what frequency components are absent in the output? **(2 marks)**

Question 2 follows on Page 3

Question 2

2a) In a broadcast communication system the transmitter power with modulation is 75 kW, the channel attenuation is 80 dB, the noise power spectral density is $S_{nn}(f) = N_o/2$ with $N_o = 10^{-10}$ W/Hz and the normalised baseband message signal m(t) has a bandwidth of 10 kHz, $|m(t)| \le 1$ and a mean square value $\langle m^2(t) \rangle = 0.1$.

(i) If the modulation used is amplitude modulation (AM) with a modulation index a = 0.90, calculate the predetection signal to noise ratio (SNR_p) and the output signal to noise ratio (SNR_o), stating any assumptions you make. **(3 marks)**

(ii) If the modulation used is double sideband suppressed carrier (DSBSC), calculate the predetection signal to noise ratio (SNR_p) and the output signal to noise ratio (SNR_o), stating any assumptions you make. **(3 marks)**

(iii) If the modulation used is frequency modulation (FM) with peak frequency deviation 75 kHz, calculate the predetection signal to noise ratio (SNR_p) and the output signal to noise ratio (SNR_o), stating any assumptions you make. **(5 marks)**

[All signal to noise ratios should be expressed in decibels.]

2b) A communication channel has a bandwidth of B = 200 kHz. This channel is used to transmit a message signal m(t) of bandwidth W = 12 kHz with $|m(t)| \le 1$, $\langle m^2(t) \rangle = 0.05$. At the receiver, the signal is received accompanied by white noise of power spectral density $S_{nn}(f) = N_o/2$ and the average received power is +30 dB relative to N_oW (the noise power in a bandwidth W).

(i) If amplitude modulation (AM) with modulation index a = 0.95 is used, calculate the output signal to noise ratio (SNR_o) in decibels. **(3 marks)**

(ii) If frequency modulation (FM) is used so that the whole bandwidth is utilised, calculate the output signal to noise ratio (SNR_o) in decibels. **(4 marks)**

(iii) Is the FM system in part (ii) above threshold? (Show relevant calculations). **(2 marks)**

Question 3 follows on Page 4

Question 3

3a) In a digital communication system three message symbols s_1, s_2 and s_3 are used.

$$s_1(t) = \begin{cases} 1 & ;\ 0 \le t \le 0.5T \\ 0 & ;\ \text{elsewhere} \end{cases} \qquad s_2(t) = \begin{cases} 1 & ;\ 0.5T \le t \le T \\ 0 & ;\ \text{elsewhere} \end{cases} \qquad s_3(t) = \begin{cases} 1 & ;\ 0 \le t \le T \\ 0 & ;\ \text{otherwise} \end{cases}$$

(i) Determine the values of c_1 and c_2 required so that suitable normalised (ie. unit energy) basis functions are $\psi_1(t) = c_1\, s_1(t)$ and $\psi_2(t) = c_2\, s_2(t)$. Verify that $\psi_1(t)$ and $\psi_2(t)$ are orthogonal. **(4 marks)**

(ii) Draw the signal constellation for these signals, showing clearly the coordinates of the constellation points. **(3 marks)**

(iii) If the decision regions are such that the boundaries are equidistant from adjacent symbols, sketch these on the constellation diagram. Why is this optimum? **(3 marks)**

(iv) Which of the three message symbols is more likely to be received in error? (Explain your answer). **(2 marks)**

3b) A voice band telephone channel passes frequencies in the range 300 Hz to 3300 Hz. It is desired to design a modem using Nyquist pulses and which is capable of transmitting digital data at a symbol rate of 2400 symbols/sec and a data rate of 4800 bits/sec.

(i) Select an appropriate QAM (quadrature amplitude modulation) signal constellation, a suitable sub-carrier frequency (ie. in the range 300–3300 Hz) and an appropriate roll-off factor ρ for Nyquist pulses, assuming the whole frequency band is utilised. **(5 marks)**

(ii) Sketch the spectrum of the transmitted signal, showing clearly the carrier frequency and the frequencies where the Nyquist roll-off begins and ends. **(3 marks)**

Question 4 follows on Page 5

Question 4

4a) A source X has an alphabet {A, B, C, D, E} with corresponding probabilities {0.10, 0.15, 0.20, 0.20, 0.35}.

(i) Calculate the source entropy H(x) in bits and explain what this means. **(3 marks)**

(ii) Design a binary Huffman code for these symbols, and calculate its efficiency. **(5 marks)**

(iii) Explain why it is possible to uniquely decipher a Huffman code. **(2 marks)**

4b) A BPSK (binary phase shift keyed) digital transmission system transmits data at 10^6 symbols/sec and has an uncorrected probability of a bit error equal to $p = Q\left\{\sqrt{2E_S / N_O}\right\} = 10^{-4}$, where E_S is the energy per transmitted symbol and $N_o/2$ is the spectral density of the accompanying additive white gaussian noise. Error correction is achieved by using a (15,11) Hamming block code.

(i) Calculate the value of E_s/N_o. **(1 mark)**

(ii) How many errors can the code correct in each block of 15? **(1 marks)**

(iii) What is the minimum bandwidth required to transmit the signal? **(2 marks)**

(iv) Calculate the bit error probability after error correction. **(3 marks)**

(v) If the BPSK system is redesigned so that the transmitter power is the same but the transmitted symbol rate with the Hamming coding is increased to $(15/11) \times 10^6$ symbols/sec so that the message bit rate is 10^6 bits/sec, calculate the corrected probability of a bit error. (Hint: Calculate the reduced value of E_s/N_o, and hence the new value of p, the uncorrected probability of a bit error). **(3 marks)**

End of Questions

Data Sheets follow on Pages 6 – 11