THE UNIVERSITY OF ADELAIDE AUSTRALIA

SUPPLEMENTARY EXAMINATION FOR THE DEGREE OF B.E.

Semester I July 2004

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) = sinc(2000 t). A modulated signal v(t) is generated, where:

$$v(t) = \mathrm{Re}\left\{m^{+}(t)e^{j2\pi f_o t}\right\}$$

and $m^{+}(t)$ is the analytic signal and f_o = 10 kHz.

(i) Calculate the spectrum (fourier transform) M(f) of m(t) and sketch it. **(2 marks)**

(ii) Calculate the spectrum (fourier transform) of z(t) = $m^{+}(t)e^{j2\pi f_o t}$ sketch it. Is z(t) an analytic signal (explain your answer)? **(3 marks)**

(iii) Calculate the spectrum of v(t) and sketch it. **(3 marks)**

(iv) Derive an expression for v(t) in terms of m(t) and its Hilbert transform $\hat{m}(t)$.
(3 marks)

[Your sketches should show appropriate values on the axes].

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).

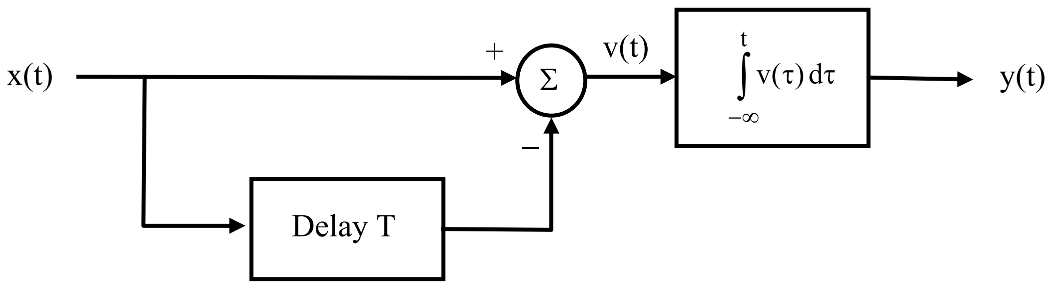

Figure 1

(i) Express the output y(t) in terms of x(t). **(3 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)**

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, $|m(t)| \leq 1$ 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) with $|m(t)| \leq 1$, $\langle m^2(t) \rangle = 0.05$ and bandwidth W = 12 kHz. 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? **(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, explaining the values of the coordinates of the various symbols. **(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 which transmits 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, indicating the important frequencies. **(3 marks)**

Question 4 follows on Page 5

Question 4

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

(i) Calculate the minimum required average (binary) code word length required to transmit these symbols. **(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 QPSK (quartenary phase shift keyed) digital transmission system transmits data at 10^6 bits/sec and has a probability of a bit error equal to $p = Q\left\{\sqrt{E_S / N_O}\right\}$, 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 (15,11) Hamming block coding.

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

(ii) If the uncorrected bit error probability is $p = 10^{-4}$, calculate the bit error probability with error correction. (NB. The transmitted bit rate in the channel does not change, and hence E_s remains the same but the message bit rate is reduced). **(3 marks)**

(iii) If the QPSK system is redesigned so that the transmitter power is the same but the Hamming coded transmitted data rate is increased so that the message bit rate is 10^6 bits/sec, calculate the corrected probability of a bit error. (NB. The transmitted bit rate is increased, resulting in a decrease in E_s). **(5 marks)**

End of Questions

Data Sheets follow on Pages 6 – 11