THE UNIVERSITY OF ADELAIDE
AUSTRALIA

EXAMINATION FOR THE DEGREE OF B.E.

Semester I June 2006

# 101902 COMMUNICATIONS IV (ELEC ENG 4035)

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| 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

**Q1a)** A band pass signal $x(t) = 20\ \text{sinc}(200t)\cos(2\pi 1000t)$ is applied to an ideal band pass filter centred at 1000 Hz and of bandwidth 100 Hz. The passband gain is unity.

**(i)** Calculate the fourier transform X(f) of x(t) and sketch X(f) showing clearly the amplitude and frequency scales. **(3 marks)**

**(ii)** Sketch the frequency response of the filter and find an expression for its transfer function H(f). **(2 marks)**

**(iii)** Calculate the impulse response h(t) of the bandpass filter. **(2 marks)**

**(iv)** Calculate the output y(t) of the bandpass filter. **(3 marks)**

**Q1b)** A binary PAM system generates a signal

$$s(t) = \sum_{k=-\infty}^{\infty} A\, a_k\, p(t - kT)$$

where $A = 10$, $a_k = \pm 1$ is random uncorrelated binary data, the pulse shape is $p(t) = \Delta(t/T)$ and $T = 1$ ms is the bit period.

**(i)** The signal s(t) is cyclostationary. Explain clearly what this means in relation to the mean and autocorrelation function of s(t). **(2 marks)**

**(ii)** Sketch the signal s(t) for $0 \le t \le 4T$ if the data is $a_k = [-1\ \ +1\ \ +1\ \ -1\ \ +1]$ for $0 \le k \le 4$. **(3 marks)**

**(iii)** Calculate the power spectrum $S_{ss}(f)$ of s(t) and sketch it showing clearly the amplitude and frequency scales (use the result on data sheet, derivation is not required). **(3 marks)**

**(iv)** Calculate the autocorrelation function $\overline{R}_{ss}(\tau)$. **(2 marks)**

**Question 2 follows on Page 3**

# Question 2

**Q2a)** In a broadcast communication system the carrier power is 90 kW, the channel attenuation is 80 dB, the noise power spectral density is $S_{nn}(f) = N_o/2$ with $N_o = 1.5 \times 10^{-10}$ W/Hz and the normalised baseband message signal m(t) has a bandwidth of 15 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 following for a receiver with bandwidth equal to that of the signal:

The bandwidth of the signal
The predetection signal to noise ratio ($SNR_p$) in decibels
The output signal to noise ratio ($SNR_o$) in decibels **(4 marks)**

**(ii)** If the modulation used is frequency modulation (FM) with peak frequency deviation 75 kHz, calculate the following for a receiver with a bandwidth given by Carson's rule:

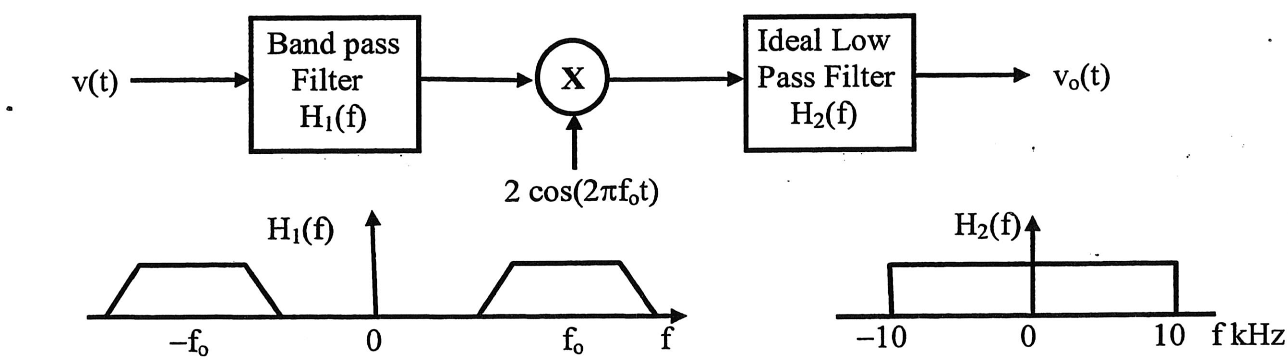
The (approximate) bandwidth of the signal
The predetection signal to noise ratio ($SNR_p$) in decibels
The output signal to noise ratio ($SNR_o$) in decibels **(5 marks)**

**(iii)** What is the maximum channel attenuation (in decibels) allowed if the FM system in (ii) is to be above threshold? **(3 marks)**

**Q2b)** An AM system has a received signal of the form:

$$v(t) = A\left[1 + am(t)\right]\cos(2\pi f_o t) + n(t)$$

where A = 100 µV, m(t) has a bandwidth of 10 kHz with $|m(t)| \leq 1$ and $\langle m^2(t) \rangle = 0.1$, the modulation index is a = 0.9, the carrier frequency is $f_o$ = 1.6 MHz and n(t) is white noise of power spectral density $S_{nn}(f) = 2.5 \times 10^{-15}$ V²/Hz. The receiver has the form shown in the figure below.




The a pass band gains are 1, the flat parts of $H_1(f)$ are 20 kHz wide centred at $\pm f_o$ with transitions at each end of 5 kHz width (ie. the total bandwidth is 30 kHz, noise bandwidth = 23333 Hz).

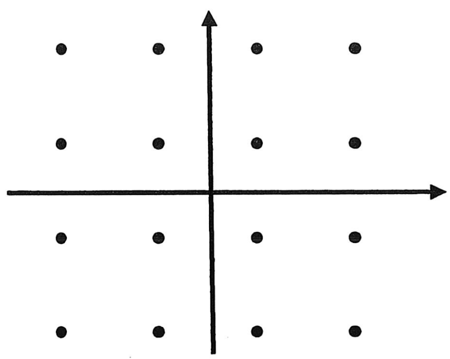
**(i)** Calculate the predetection signal to noise ratio (ie. at the output of $H_1$) in decibels. **(4 marks)**

**(ii)** Calculate the output signal to noise ratio in decibels (ie. at the output of $H_2$). **(4 marks)**

**Question 3 follows on Page 4**

# Question 3

**Q3a)** A 16QAM system uses the constellation shown below such that the symbols are equally spaced by d both horizontally and vertically and are symmetrically placed with respect to the origin. The system transmits 2400 symbols/sec (ie. 9600 bits/sec) at a carrier frequency of 1 MHz. The receiver impedance is R = 50 ohm.



**(i)** Determine the minimum bandwidth required for transmission. **(2 marks)**

**(ii)** Calculate the average energy per bit (in $V^2s$) for the constellation in terms of the separation distance d (the horizontal and vertical separation of the symbols). (Note that the energy of each symbol in the constellation is given by the square of its distance from the origin). **(3 marks)**

**(iii)** If the average received power $P = 1.200 \times 10^{-6}$ W, determine the symbol spacing d. **(3 marks)**

**(iv)** If outermost corner symbols have an energy of $9.000 \times 10^{-10}$ J and $N_o = 1.000 \times 10^{-11}$ W/Hz, determine the probability of selecting an adjacent symbol in error during demodulation. (Assume a matched filter receiver). **(4 marks)**

**[Hint:** Convert watts to volt$^2$ and joules to volt$^2$ sec by multiplying by the resistance R].

**Q3b)** A BPSK (binary phase shift keyed) system is used to transmit the same bit rate as in part a):

**(i)** Determine the minimum bandwidth required for transmission. **(2 marks)**

**(ii)** For an average received power $P = 1.200 \times 10^{-6}$ W and noise spectral density $N_o = 1.000 \times 10^{-11}$ W/Hz, determine the probability of error for a matched filter receiver. **(4 marks)**

**(iii)** Comment on the differences between BPSK and 16 QAM as revealed by your answers. **(2 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 on a 50 MHz carrier and has an uncorrected probability of a bit error equal to $p = Q\left\{\sqrt{2E_c / N_o}\right\} = 10^{-4}$, where $E_c$ is the energy per transmitted channel bit 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 $E_c/N_o$. **(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) × $10^6$ 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 $E_c/N_o$, 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**