The University of Adelaide
Examination for the Degree of B.E.
June 2003

ELEC ENG 4020 Communication Theory (7192)

Time: 1 hour and 30 minutes

There will be a ten minute reading time prior to the commencement of the examination.

Attempt ALL THREE questions.

All questions carry equal marks, part marks are indicated in brackets.

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 link capabilities are not permitted.

Attachments:

   Communication Theory Data Sheet.
   Table of Fourier Transforms.
   Table of the Q Function.

This is a closed book examination. Answers to questions should be expressed clearly and written legibly. These aspects of presentation will be taken into account in the assessment.

Question 1 follows on page 2
Question 1

An analog communication system transmits a baseband signal \( m(t) \) with \(|m(t)| < 1\), \( \langle m^2(t) \rangle = 0.1 \) and a bandwidth of 10 kHz on a carrier frequency of 5.60 MHz. The path loss to the receiver is 166 dB, and the received noise has a power spectral density \( S_{nn}(f) = N_0/2 \) where \( N_0 = 8.00 \times 10^{-20} \text{ W/Hz} \).

a) For this part the modulation used is amplitude modulation (AM) or double sideband suppressed carrier modulation (DSBSC).

(i) How many such AM channels could be fitted into a spectrum allocation of bandwidth 1 MHz? \( \text{(2 marks)} \)

(ii) With an \underline{unmodulated} transmitter power of 10 kW and a modulation index of \( a = 0.95 \), calculate the output signal to noise ratio of the AM receiver in decibels. \( \text{(3 marks)} \)

(iii) If instead of AM, double sideband suppressed carrier (DSBSC) modulation is used, calculate the output signal to noise ratio if the \underline{peak} transmitter power is 10 kW. \( \text{(3 marks)} \)

(iv) In comparing the answers to parts (ii) and (iii), explain why DSBSC would be better than AM. \( \text{(2 marks)} \)

b) For this part the modulation used is frequency modulation (FM) with a modulation index \( \beta = 5 \).

(i) Define the modulation index of an FM system. \( \text{(2 marks)} \)

(ii) How many such FM channels could be fitted into a spectrum allocation of bandwidth 1 MHz? \( \text{(2 marks)} \)

(iii) With an unmodulated transmitter power of 10 kW, calculate the output signal to noise ratio of the FM receiver. \( \text{(3 marks)} \)

(iv) The threshold of an FM system occurs at a pre-detection signal to noise ratio of 12 dB. How far is the FM system above threshold (in decibels)? (In other words, how much more path loss would be necessary to place the system at the threshold point?) \( \text{(3 marks)} \)

Question 2 follows on page 3
Question 2

a) A 16QAM system uses the constellation shown below and transmits 2400 symbols/sec (i.e. 9600 bits/sec) at a carrier frequency of 1 MHz. The receiver impedance is 50 ohm.

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

(ii) Calculate the average energy per bit for the constellation in terms of the separation distance $d$. (Note that the energy of each symbol in the constellation is given by the square of its distance from the origin). (4 marks)

(iii) If the average received power $P = 1.200 \times 10^{-6}$ W, determine the symbol spacing $d$. (2 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)

![16QAM Constellation](image)

Figure 1: 16QAM Constellation

b) 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. (6 marks)

Question 3 follows on page 4
Question 3

a) A binary source generates symbols at 1000 per second with probabilities $P(0) = 0.8$ and $P(1) = 0.2$. These are transmitted along a channel which has an asymmetric error behaviour such that the probability of error is 0.2 for a transmitted 0 and 0.1 for a transmitted 1.

(i) What are the probabilities of the symbols received? (2 marks)
(ii) What is the information rate being transmitted? (6 marks)
(iii) Explain how you would compute the capacity of the channel (details not required). (2 marks)

b) A source generates binary symbol pairs $(i, j)$ with joint probabilities given in the table below.

<table>
<thead>
<tr>
<th>$P(i,j)$</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.20</td>
<td>0.10</td>
</tr>
<tr>
<td>$i$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.10</td>
<td>0.60</td>
</tr>
</tbody>
</table>

(i) Calculate the probabilities of the symbols $i$ and $j$. (2 marks)
(ii) Calculate the joint entropy of the symbol pairs. (2 marks)
(iii) Construct a Huffman code which codes the symbol pairs, and calculate the coding efficiency. (6 marks)

End of Questions