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UNIVERSITY OF SWAZILAND
FACULTY OF SCIENCE
DEPARTMENT OF ELECTRONIC ENGINEERING
SUPPLEMENTARY EXAMINATION 2004/2005

TITLE OF PAPER: DIGITAL COMMUNICATIONS

COURSE NUMBER: E530

TIME ALLOWED : THREE HOURS

INSTRUCTIONS : READ EACH QUESTION CAREFULLY
ANSWER ANY **FOUR** OUT OF **FIVE** QUESTIONS.
EACH QUESTION CARRIES **25 MARKS**.
MARKS FOR EACH SECTION ARE SHOWN
IN THE RIGHT-HAND MARGIN.

THIS PAPER HAS 5 PAGES INCLUDING THIS PAGE.

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QUESTION 1

(a) Determine the power spectral density (PSD) for the following types of signaling formats as a function of *Tb*, the time needed to send 1 bit of data. Consider a random data pattern consisting of binary 1s and 0s, where the probability of obtaining either a binary 1 or a binary 0 is ½.

(i) NRZ bipolar format. [7 marks]
(ii) RZ polar format. [7 marks]

What is the first-null bandwidth of these signals? What is the spectral efficiency for each of these signaling cases?

(b) (i) A multilevel digital communication system is to operate at a data rate of 9600 bits/s. If 4- bit words are encoded into each level for transmission over the channel, what is the minimum required bandwidth for the channel? [4 marks]

(ii) Construct the return-to-zero (RZ) unipolar and bipolar formats for the binary sequence (0 0 0 1 0 1 0 1 1 0 1) based on a rectangular pulse. [2 marks]

(iii) Give one advantage offered by the unipolar format over the bipolar one and [1 mark]
(iv) two advantages offered by the use of the bipolar format over the unipolar one. [2 marks]

(v) What will the duobinary coder output of the binary sequence in (ii) be? [2 marks]

QUESTION 2

(a) Given the input sequence x_k = 0 1 0 0 1 1 1 0 1 0 , determine the transmitted data stream when

(i) precoded duobinary signaling is used. Also verify that the receiver decoding rule yields the input sequence x_k. [7 marks]

(ii) modified - duobinary signaling is used. [4 marks]

(b) Derive an expression of the net probability of error *(Pe)* for matched filter reception of a given NRZ bipolar binary format. Let the general decision thresholds be set at $\pm A/2$, where A is the peak amplitude of the pulse representing a symbol. Assume the channel noise is a zero - mean Gaussian process. Express *Pe* in terms of the average energy per bit, *Eb*.

[14 marks]

QUESTION 3

A source produces one of three possible independent symbols a, b, or c with probabilities 0.7, 0.2 and 0.1 respectively during successive signaling intervals.

(i) How much information does one gain by being told that w_i was emitted, w_i = a, b, c. [6 marks]

(ii) What is the average information of the source output ? [3 marks]

(iii) The source emits 1000 symbols per second. Compute

(a) the average information rate and [3 marks]

(b) the maximum possible information rate. [3 marks]

(iv) Design an efficient code which can be used for the discrete source in question. Consider any two binary source coding methods. [10 marks]

QUESTION 4

(a) Briefly explain the following:

(i) a binary symmetric channel [1 mark]

(ii) channel capacity [1 mark]

(iii) channel coding [1 mark]

(iv) redundancy [1 mark]

(v) automatic repeat request [1 mark]

(b) A discrete memoryless source with alphabet {so, s1, s2, s3} has statistics {0.7, 0.15, 0.10, 0.05} for its output.

(i) Compute the Huffman codewords, the average code-word length, the entropy of the source and efficiency of the code. **Hint:** move the combined symbol as high as possible. [10 marks]

(ii) If the source is extended to order two, compute the average code-word length and the efficiency of the code. [8 marks]

(iii) Comment on the performance of (i) as compared to (ii). [2 marks]

QUESTION 5

(a) A communicator needs to transmit a single message, 3 bits long. The message is convolutionally encoded using the code defined by the rate ½ convolutional encoder shown in Figure 5.0.

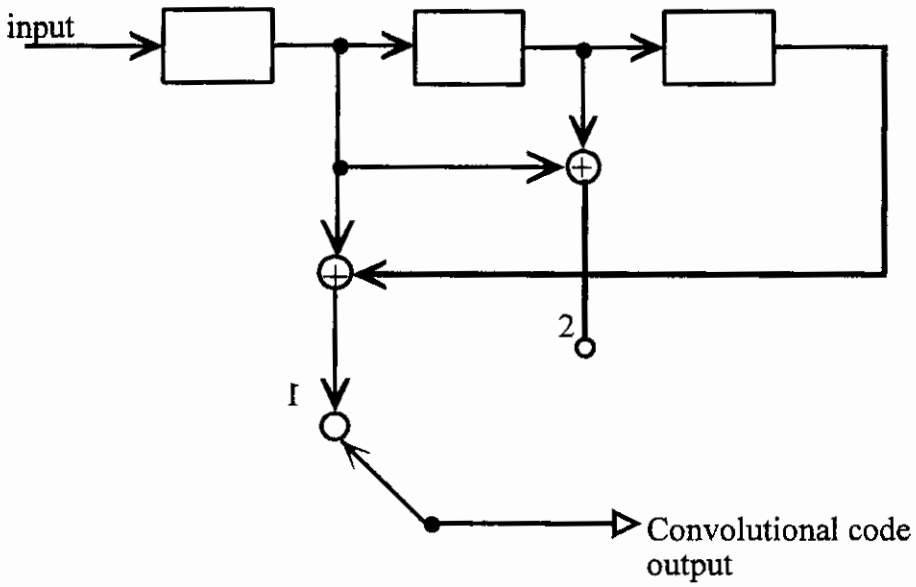

Figure 5.0

Two zeros are appended to the message to clear the encoder of message bits.

(i) If the code symbols are transmitted over a BSC with crossover probability $p = 0.2$ and the received sequence is (11, 01, 10, 10, 00), what is the corresponding decoder output? [7 marks]

(ii) Compute the decoder output using the maximum-likelihood decoding rule and compare the results with (i). [5 marks]

(b) Given the following generator matrix,

(i) determine all code vectors of a (6,3) block code.

$$G = \begin{bmatrix} 100011 \\ 010101 \\ 001110 \end{bmatrix}$$

[7 marks]

(ii) If the received noise corrupted vector, $R = [101111]$, find the actual transmitted vector, M . [6 marks]

USEFUL INFORMATION

The Q - function is defined as

$$Q(\mathrm{v}) = \frac{1}{\sqrt{2\pi}} \int_{v}^{\infty} e^{\frac{x^2}{2}} dx$$

The Gaussian probability density function, $P(y) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(y-m)^2/2\sigma^2}$