UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 8 Examination in Engineering: November 2016

Module Number: EE8210 **Module Name: Digital Communication**

[Three Hours]

[Answer **all questions**, each question carries **10 marks**]

Q1 a) A discrete Bernoulli Random Variable (RV) has the pmf (Probability Mass Function)

$$P_X(x) = \begin{cases} s & x=1 \\ 1-s & x=0 \\ 0 & \text{otherwise} \end{cases}$$

i) Determine the entropy $H[X]$ of the RV.

ii) "Entropy is a measure of the randomness of a RV." Sketch the entropy $H[X]$ as a function of s and verify the meaning of the aforesaid definition of the entropy.

[4.0 Marks]

b) Three variable length codes are shown in Table Q1.

Table Q1

Letter	$P[a_k]$	Code I	Code II	Code III
a_1	1/2	1	0	0
a_2	1/4	00	10	01
a_3	1/8	01	110	011
a_4	1/8	10	111	111

i) Define the uniquely decodable property of the variable length codes and check the unique decodability of each coding scheme.

ii) Which uniquely decodable code is a prefix-free code? How do you verify this?

iii) Design a Huffman code for the above alphabet.

[6.0 Marks]

Q2 a) Sketch the signal space diagram for the signals

$$s_0(t) = u(t) - u(t-1)$$
$$s_1(t) = u(t-1) - u(t-2)$$
$$s_2(t) = u(t) - u(t-2)$$

given the orthonormal basis functions

$$\phi_0(t) = u(t) - u(t-1)$$
$$\phi_1(t) = u(t-1) - u(t-2)$$

Here, $u(t)$ is the unit step function.

[6.0 Marks]

b) Two basis functions of an orthonormal set are shown in Figure Q2 b) I).

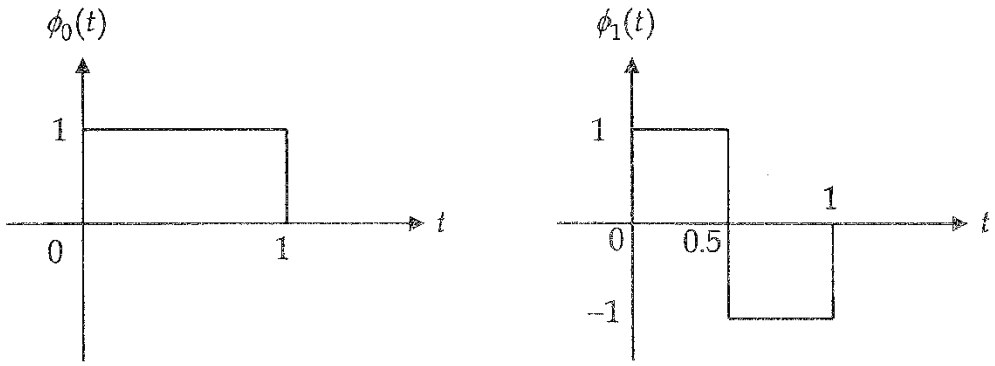

Figure Q2 b) I)

Using these basis functions, sketch the waveforms corresponding to the points in the signal constellation diagram in Figure Q2 b) II).

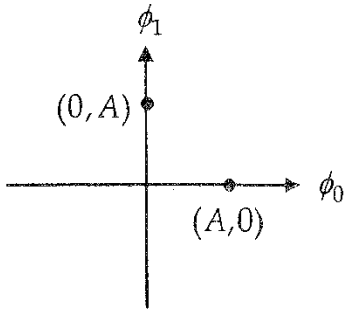

Figure Q2 b) II)

[4.0 Marks]

Q3 A typical M-ary PAM (Pulse Amplitude Modulated) system uses the following amplitudes for even M signal points.

$$-(M-1)A,\ -(M-3)A,\ \ldots\ldots,\ -A,\ A,\ \ldots\ldots,\ (M-3)A,\ (M-1)A$$

The average symbol energy of the M-ary PAM system is given by

$$E_s = \frac{(M^2-1)}{3}A^2.$$

a) Determine an expression for the average bit energy (E_b) for the M-ary PAM system.

[2.0 Marks]

b) Determine E_b and the probability of error for a

i) Bipolar binary PAM system

ii) Unipolar binary PAM system (On-Off Keying)

[5.0 Marks]

c) Figure Q3 shows the theoretical probability of error curves for Bipolar and Unipolar PAM systems. Explain why the Bipolar PAM system is better than the Unipolar PAM system by considering their signal point locations in signal constellation diagrams.

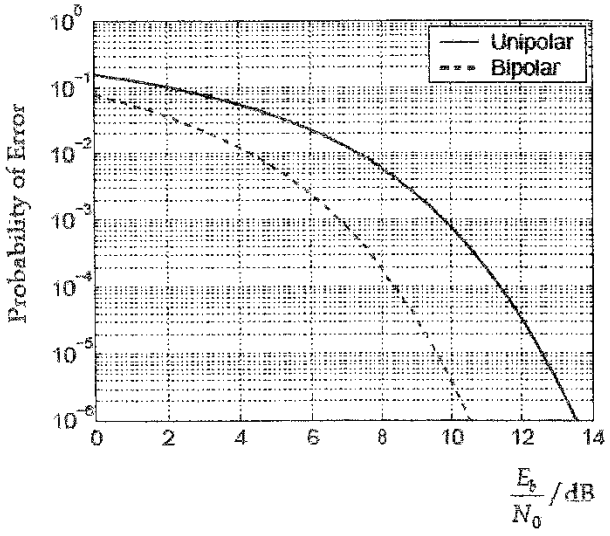

Figure Q3

[3.0 Marks]

Q4 a) Explain the difference between the correlation receiver and the matched-filter receiver in digital communication.

[3.0 Marks]

b) Explain the method that is used to define the decision boundaries for M-ary detection of an N-dimensional signal space.

[2.0 Marks]

c) Identify and draw the decision regions for the signal constellation diagram shown in Figure Q4 by stating the assumptions appropriately.

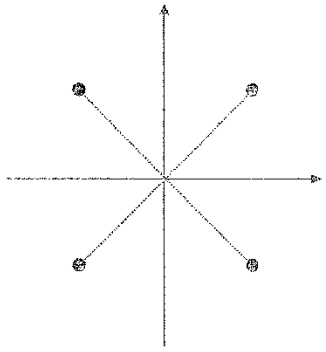

Figure Q4

[5.0 Marks]

Q5 a) Determining the exact probability of error analysis for *M*-ary PSK (Phase Shift Keying) and QAM (Quadrature Amplitude Modulation) constellations are not straightforward. Hence, some approximations are used such as union bound and nearest-neighbour approximation. Explain briefly how these methods are used for determining the probability of error.

[2.0 Marks]

b) Determine the probability of symbol error for the signal space diagram shown in Figure Q5 using the method of

i) Union bound

ii) Nearest-Neighbour approximation

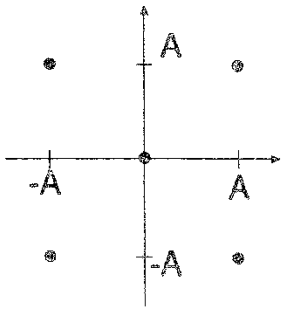

Figure Q5

[5.0 Marks]

c) Explain briefly the difference between coherent and non-coherent detection in Frequency Shift Keying (FSK).

[3.0 Marks]