UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS AND ELECTRONIC ENGINEERING

SUPPLEMENTARY EXAMINATION 2007

TITLE OF PAPER : DIGITAL COMMUNICATIONS

COURSE NUMBER : E530

TIME ALLOWED : THREE HOURS

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

THIS PAPER HAS 5 PAGES INCLUDING THIS PAGE.

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USEFUL INFORMATION

$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$
$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B.$$

$$\sin A \sin B = \tfrac{1}{2}[\cos(A - B) - \cos(A + B)]$$
$$\cos A \cos B = \tfrac{1}{2}[\cos(A + B) + \cos(A - B)]$$
$$\sin A \cos B = \tfrac{1}{2}[\sin(A + B) + \sin(A - B)]$$

Table 1 Values for Q(x)

x	10log x	Q(x)	x	10log x	Q(x)	x	10log x	Q(x)
3.00	4.77	1.35 E-03	4.00	6.02	3.17 E-05	5.00	6.99	2.87 E-07
3.05	4.84	1.14 E-03	4.05	6.07	2.56 E-05	5.05	7.03	2.21 E-07
3.10	4.91	9.68 E-04	4.10	6.13	2.07 E-05	5.10	7.08	1.70 E-07
3.15	4.98	8.16 E-04	4.15	6.18	1.66 E-05	5.15	7.12	1.30 E-07
3.20	5.50	6.87 E-04	4.20	6.23	1.30 E-05	5.20	7.16	9.96 E-08
3.25	5.12	5.77 E-04	4.25	6.28	1.07 E-05	5.25	7.20	7.61 E-08
3.30	5.19	4.83 E-04	4.30	6.33	8.54 E-06	5.30	7.24	5.79 E-08
3.35	5.25	4.04 E-04	4.35	6.38	6.81 E-06	5.35	7.28	4.40 E-08
3.40	5.31	3.37 E-04	4.40	6.43	5.41 E-06	5.40	7.32	3.33 E-08
3.45	5.38	2.80 E-04	4.45	6.48	4.29 E-06	5.45	7.36	2.52 E-08
3.50	5.44	2.33 E-04	4.50	6.53	3.40 E-06	5.50	7.40	1.90 E-08
3.55	5.50	1.93 E-04	4.55	6.58	2.68 E-06	5.55	7.44	1.43 E-08
3.60	5.56	1.59 E-04	4.60	6.63	2.11 E-06	5.60	7.48	1.07 E-08
3.65	5.62	1.31 E-04	4.65	6.67	1.66 E-06	5.65	7.52	8.03 E-09
3.70	5.68	1.08 E-04	4.70	6.72	1.30 E-06	5.70	7.56	6.00 E-09
3.75	5.74	8.84 E-05	4.75	6.77	1.02 E-06	5.75	7.60	4.47 E-09
3.80	5.80	7.23 E-05	4.80	6.81	7.93 E-07	5.80	7.63	3.32 E-09
3.85	5.85	5.91 E-05	4.85	6.86	6.17 E-07	5.85	7.67	2.46 E-09
3.90	5.91	4.81 E-05	4.90	6.90	4.79 E-07	5.90	7.71	1.82 E-09
3.95	5.97	3.91 E-05	4.95	6.95	3.71 E-07	5.95	7.75	1.34 E-09

QUESTION 1

(a) You are required to transmit information in an analog waveform whose maximum frequency $f_m = 4000Hz$. The quantization distortion should not exceed $\pm$ 1% of the peak-to-peak analog signal, when an 8 - bit PCM scheme is used.

(i) Which line code will you select between the NRZ unipolar, NRZ polar and NRZ bipolar to represent the binary digits so they can be transmitted through the available baseband channel? Explain. (8 marks)

(ii) What is coding gain? (2 marks)

(b) For the input sequence a_k = [01101110101], determine the transmitted data stream when precoded modified duobinary signalling is used. (4 marks)

(c) The codeword of an (*n, k*) linear block code is defined by

$$U = m_1 + m_2 + m_4 + m_5, m_1 + m_3 + m_4 + m_5, m_1 + m_2 + m_3 + m_5,$$
$$m_1 + m_2 + m_3 + m_4, m_1, m_2, m_3, m_4, m_5$$

Find

(i) the parity check matrix, **H.** (3 marks)

(ii) *n* and *k* (2 marks)

(iii) Design a simple logic circuit which will generate any codeword U, given an input message **M** of *k* bits. Use the information in section (c) above. (6 marks)

QUESTION 2

(a) Consider a rate $-\frac{1}{2}$ convolutional encoder described by the following generator functions:

$$g_1 = [111]$$
$$g_2 = [101]$$

Generated messages are sent over a binary symmetric channel.

(i) If the received sequence is (11, 10, 00, 00, 11), compute the possible original message using the corresponding trellis diagram. (13 marks)

(ii) What is the effective code rate of the encoder? (2 marks)

(b) Draw a practical block diagram for a differential encoding and decoding system. Explain how it works by showing the encoding and decoding for the bit stream, [100111101]. Assume a binary 1 as the reference digit. Show how a single error in the transmitted bit affects the output. (10 marks)

QUESTION 3

(a)
Consider transmission of binary information at 100 kbps using On-off Keying (OOK). If the additive noise power is $10^{-12} W / Hz$, the carrier frequency is 20 MHz and the received carrier amplitude is $10^{-3} V$,

(i) design a coherent detector and find the bit error rate. (15 marks)

(ii) Design an incoherent detector and find the bit error rate. (6 marks)

(b)
Discuss the generation of QPSK. (4 marks)

QUESTION 4

(a) A Hamming Code has the matrix

$$\overline{P} = \begin{bmatrix} 110 \\ 011 \\ 111 \\ 101 \end{bmatrix}$$

used in the parity check matrix $\overline{H}$.

(i) Compute the code-word for the message block **M** = (1 0 1)? (6 marks)

(ii) The received codeword **R** is (1 1 1 0 1 1 0). Is this the correct codeword? If not, determine it. (8 marks)

(b) Consider a discrete source emitting symbols from a fixed finite alphabet M = { s_1, s_2, s_3} with probabilities $P_1 = 0.1$, $P_2 = 0.2$, $P_3 = 0.7$, respectively. The emitted symbols are assumed statistically independent.
Compute

(i) the average information rate if 1000 symbols per second are emitted. (6 marks)

(ii) the number of binary digits which can be used to represent each symbol. (2 marks)

(iii) the maximum possible information rate. (3 marks)

QUESTION 5

(a)

Binary information is transmitted using baseband signals of the form shown in Figure 2.

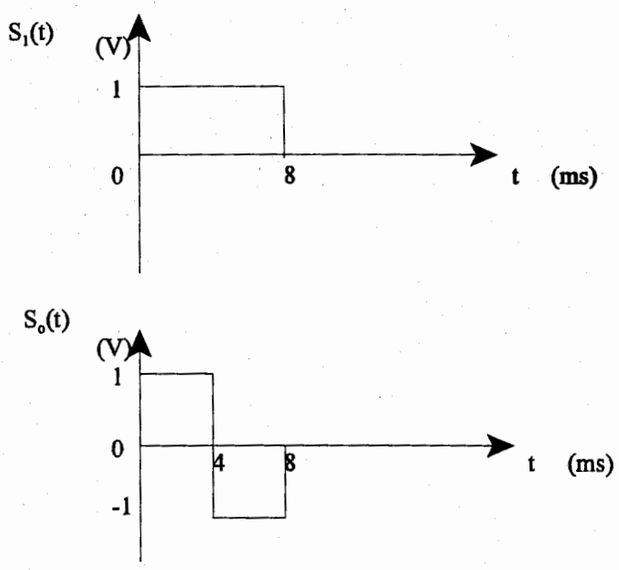

Figure 2: Baseband waveforms

(i) Design a matched filter detector for signals in Figure 2. Assume equal signal energies (8 marks)

(ii) Explain how the detector of (i) can be simplified to an integrate and dump detector. (5 marks)

(b)

Compare the average power requirements, expressed in decibels for binary PSK, coherent FSK and non-coherent FSK for non-return-to zero (NRZ) signalling at 300bps. Take the values of $No = 2x10^{-14} WHz^{-1}$ and the probability of error $P_e = 10^{-5}$. (12 marks)