

City University of Hong Kong

Course code & title : EE3101 Communication Engineering

Session : Semester A 2010–2011

Time allowed : Two hours

This paper has **SIX** pages (including this cover page)

1. This paper consists of **FIVE** questions.
 2. Attempt **FOUR** questions.
 3. Start each question on a **NEW** page.
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Materials, aids & instruments permitted to be used during examination:

1. Approved calculator
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(a) $Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} \exp(-\frac{u^2}{2}) du.$

$$Q(x) \approx \frac{\exp(-x^2/2)}{x\sqrt{2\pi}} \quad \text{for } x > 3.3.$$

if $h(t) = 1$ for $-Y/2 \leq t < Y/2$ and

(b) $= 0$ for other t

$$H(\omega) = Y \frac{\sin(\omega Y/2)}{(\omega Y/2)}$$

(c) $\cos^2 A = \frac{1 + \cos(2A)}{2}, \sin^2 A = \frac{1 - \cos(2A)}{2}.$

(d) $\cos A \cos B = \frac{1}{2} [\cos(A - B) + \cos(A + B)], \sin 2A = 2 \sin A \cos A.$

(e) $\cos A + \cos B = 2 \cos[(A + B)/2] \cos[(A - B)/2],$
 $\cos A - \cos B = -2 \sin[(A + B)/2] \sin[(A - B)/2].$

(f) $\cos \theta = \frac{\exp(j\theta) + \exp(-j\theta)}{2}, \sin \theta = \frac{\exp(j\theta) - \exp(-j\theta)}{2j}.$

Question 1 [Total: 25 marks]

(a) Show that the power spectral density of the line coding in Fig.Q1 can be expressed as:

$$S(\omega) = a \frac{\sin^2(\omega T/8)}{(\omega T/8)^2} [b \cos^2(\omega T/8) - c \cos(\omega T/8) \cos(d\omega T) + 1]$$

where a , b , c and d are constants. Determine their values.

[16 marks]

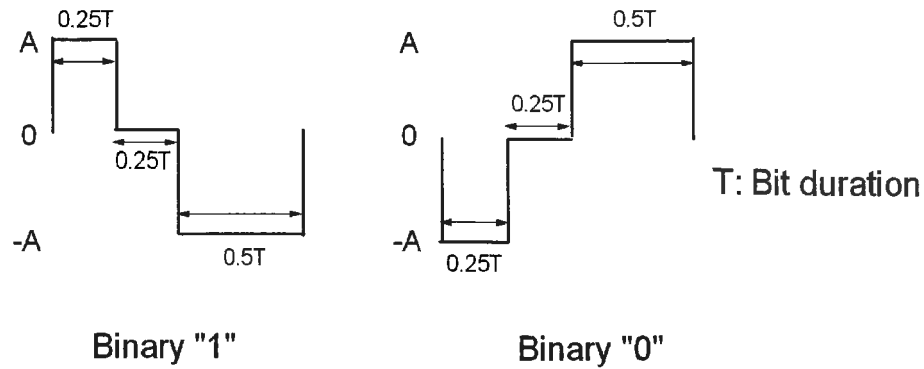


Fig.Q1 Line Coding for "1" and "0"

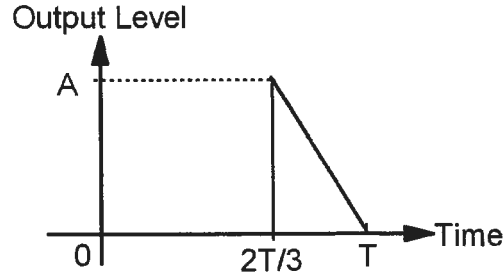
(b) Draw the block diagram of a duobinary transmission system with pre-coder. What is the purpose of adding a pre-coder? Find the output data sequence at the system output if the input data sequence is 110001. You can assume any initial condition at the pre-coder.

[9 marks]

Question 2 [Total: 25 marks]

Matched filter theory has been widely adopted in the receiver design of digital communication systems.

- (a) What is the main purpose of using a matched filter ? [3 marks]
 (b) Assume that a matched filter is used for the signal $s(t)$. Derive and sketch the correlation realization of a matched filter, i.e., a correlator in a practical receiver. [8 marks]
 (c) Sketch the impulse response of an ideal matched filter with sampling time T for the following signal at the matched filter input. [2 marks]



- (d) Consider a correlator is used for an antipodal binary system, i.e.
 “1”: $s(t) = s_1(t)$ $0 \leq t \leq T$, $s_1(t)$ is a real signal and T is the bit duration
 “0”: $s(t) = -s_1(t)$ $0 \leq t \leq T$

The waveforms for “1” and “0” are mirror images. Assume that $s_1(t)$ is used as the reference signal in the correlator all the time, and E_b is the average bit energy of $s(t)$. The system is operated in an Additive White Gaussian Noise channel with double-sided power spectral density of $\frac{N_0}{2}$.

- (i) Show that the average signals at correlator output at time T are E_b and $-E_b$ for “1” and “0” inputs respectively.
 (ii) Show that the error probability is: $P_e = Q\left[\sqrt{\frac{2E_b}{N_0}}\right]$.

[Assume that the decision threshold is set at the middle of the two adjacent signal levels (average value)].

- (iii) If $\frac{E_b}{N_0} = 9dB$, estimate the error probability P_e .

[12 marks]

Question 3 [Total: 25 marks]

Consider a BFSK (2-FSK) system operates in an Additive White Gaussian Noise (AWGN) channel. The double-sided power spectral density of the noise is $\frac{N_0}{2}$. Fig.Q3 shows the block diagram of

the demodulator with coherent detection. Assume that (i) $\omega_1, \omega_2 \gg \frac{1}{T}$ such that all high frequency components at the integrator output are insignificant, (ii) $s_1(t)$ and $s_2(t)$ are not orthogonal, i.e. $\int_0^T s_1(t)s_2(t)dt \neq 0$, (iii) random data with equal probability are used, (iv) there is no correlation between the noise at the upper branch and the noise at the lower branch of the detector in Fig.Q3 (please note that actually there exists correlation between these two noises), and (v) the normalized correlation coefficient between $s_1(t)$ and $s_2(t)$ is defined as $\rho = \frac{\sin(\omega_1 - \omega_2)T}{(\omega_1 - \omega_2)T}$

(a) Show that the error probability P_e is: $Q[\sqrt{\frac{E_b}{N_0}}(1 - \rho)]$ where E_b is the average bit energy. [14 marks]

(b) Let $x = \omega_1 - \omega_2$, show that when $x = \frac{4.493}{T}$, then minimum ρ or in other words, minimum P_e can be achieved. [Note: the 1st solution for $y = \tan y$ is $y = 4.493$] [6 marks]

(c) Let P_{orth} be the transmission power of the BFSK system with orthogonal transmission and the same bit rate, i.e. $\int_0^T s_1(t)s_2(t)dt = 0$, and P_{opt} is the transmission power of the optimum BFSK system as described in (b), i.e. with minimum P_e . What is the ratio of $\frac{P_{orth}}{P_{opt}}$ in dB with the same error probability? [5 marks]

"1": $s_1(t) = E\sqrt{\frac{2}{T}}\cos(\omega_1 t)$

T : bit duration

"0": $s_2(t) = E\sqrt{\frac{2}{T}}\cos(\omega_2 t)$

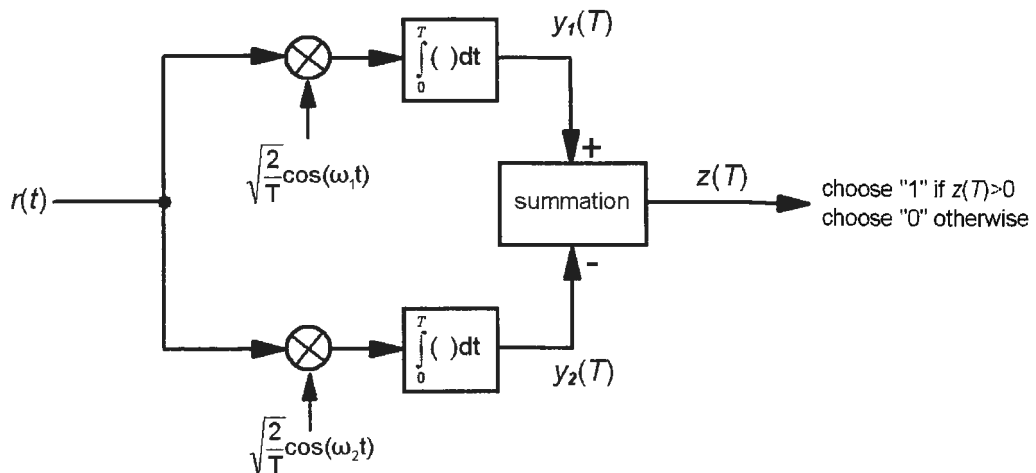


Fig.Q3 Block Diagram of a BFSK Demodulator with Coherent Detection

Question 4 [Total: 25 marks]

(a) In wireless communications, M -QAM appears to be one of the high bandwidth efficient modulation schemes. Consider a M -QAM 90Mb/s system operates in an Additive White Gaussian Noise (AWGN) channel with double-sided power spectral density of $N_0/2$. Assume that the maximum permissible bandwidth is 20MHz and the excess bandwidth in the transmission filter is 30% of the minimum Nyquist bandwidth.

- (i) What is the minimum M value? How many bits per symbol? What is the symbol duration?
- (ii) Draw the block diagram of the M -QAM modulator of (i) and specify the number of levels in both I and Q channels.
- (iii) Let the error probability at I channel be P_I , derive the exact symbol error probability P_S of the overall system in term of P_I .
- (iv) If P_I is given as: $P_I = 2(1 - \frac{1}{\sqrt{M}})Q[\sqrt{\frac{3E_b \log_2 M}{(M-1)N_0}}]$ where E_b is the average bit energy, estimate the bit error probability of the system when $E_b/N_0 = 18dB$. Assume that a complete set of Gray code is used.
- (v) If we want to increase the bit rate by ~30% and transmit the signal within the same bandwidth and with the same error performance, what system parameters need to be changed?

[19 marks]

(b) Draw the block diagram of a squaring loop carrier recovery for BPSK systems. State the reason of using squaring process.

[6 marks]

Question 5 [Total: 25 marks]

(a) Draw the block diagram of a Phase-locked loop (PLL) and briefly describe the three key components in it. [9 marks]

(b) Consider a system operates with a (8,4) systematic block code.

(i) What are the meanings of “8” and “4” in the above coding scheme?

(ii) What is the code rate of the system?

(iii) What is the Hamming distance between 00011101 and 11100010?

(iv) Assume that the minimum distance $d_{\min}$ of the above code is 4, find the error-correction capability e of the code.

(v) Assume that an ideal BPSK system is used to transmit the data and it cannot correct any error patterns with more than e as specified in (iv). The probability of the channel bit error is given by $Q[\sqrt{\frac{2E_b}{N_0}}]$, where E_b is the average bit energy and $N_0/2$ is the double-sided power spectral density of the Additive White Gaussian Noise (AWGN). Estimate the probability of un-correctable message error if $\frac{E_b}{N_0} = 8dB$.

[16 marks]

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