

City University of Hong Kong

Course code & title: EE3101 Communication Engineering

Session : Semester A 2009–2010

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
-

$$(a) \quad Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} \exp\left(-\frac{u^2}{2}\right) du$$

$$Q(x) \approx \frac{\exp(-x^2/2)}{x\sqrt{2\pi}} \quad \text{for } x > 4, \quad \text{and } Q(5.61) \approx 1 \times 10^{-8}$$

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

(b) $= 0$ for other t

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

$$(c) \quad \cos^2 A = \frac{1 + \cos(2A)}{2}, \quad \sin^2 A = \frac{1 - \cos(2A)}{2}, \quad \cos A \cos B = \frac{1}{2} [\cos(A - B) + \cos(A + B)]$$

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

Question 1

In a binary transmission system, the line coding scheme in Fig.Q1(a) is used to represent binary "1" and "0". A receiver in Fig.Q1(b) is used for signal detection.

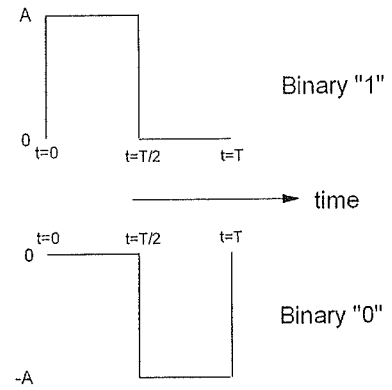


Fig.1(a) Waveforms for Binary "1" and "0"
(T is the bit duration)

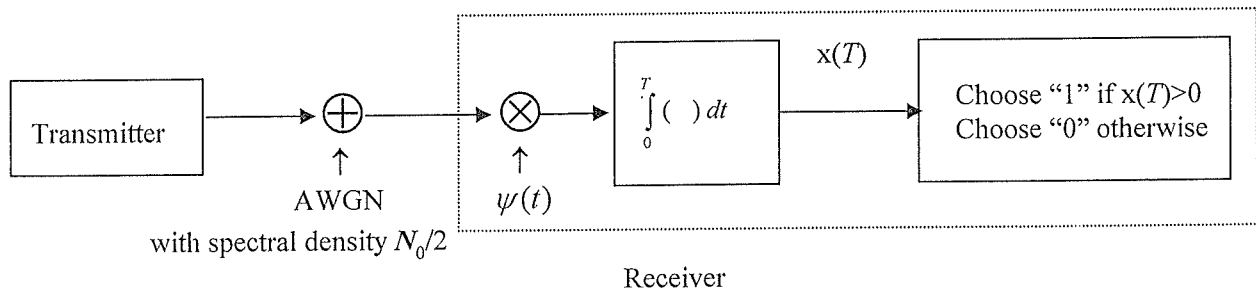


Fig.1(b) Binary transmission System

(a) If the reference signal $\psi(t) = B$, where B is a constant,

(i) derive the average bit energy E_b at the receiver input in terms of A and T , and

(ii) show that the bit error probability of the system is $P_e = Q\left[\sqrt{\frac{E_b}{N_0}}\right]$.

[12 marks]

(b) (i) Determine the optimum reference signal $\psi(t)$ for binary "1" and binary "0" such that the maximum signal-to-noise (power) ratio can be achieved at the integrator output.

(ii) State the difficulty of applying the above optimum reference signal $\psi(t)$ in a practical receiver design.

(iii) Suggest a simple change of the waveform for binary "0" to simplify the receiver implementation but remaining the same transmission power and same signal-to-noise ratio as in b(i). Justify your answer.

[13 marks]

Question 2

(a) Describe the basic criteria for selecting the line coding for baseband transmission.

[8 marks]

(b) Bi-Phase Mark (Bi- ϕ -M) is a coding scheme for binary data and has been used in digital audio (AES3 and SPDIF), where binary "1" and "0" are represented by the waveforms in Fig.Q2a. The coding rule is to have a level change at the beginning of each bit, as shown in Fig.Q2b, for a binary sequence of 10010110.

(i) What is the average DC voltage of Bi- ϕ -M?

(ii) Show that the power spectral density of Bi- ϕ -M can be expressed as:

$$S(\omega) = A^2 T \frac{\sin^4(\omega T / 4)}{(\omega T / 4)^2} \quad \text{where } T \text{ is the bit duration}$$

You need to show the detailed analysis of the autocorrelation function for at least from R_0 to R_2 .

{Hint: The binary "1" and "0" can be represented by the impulses shown in Fig.Q2c with equal probability}

[17 marks]

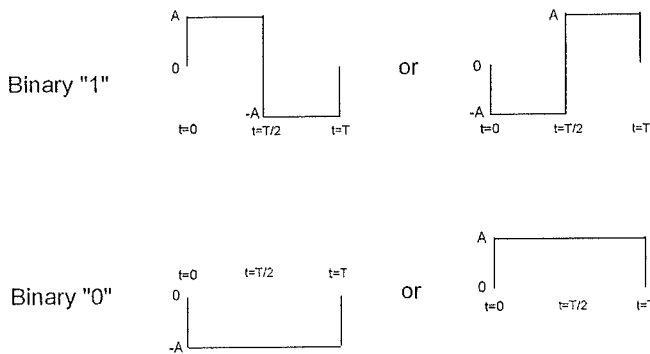


Fig.Q2a. Waveform Representations for "1" and "0"

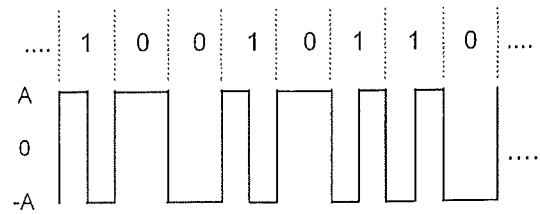


Fig.Q2b. Output Waveform for ..10010110..

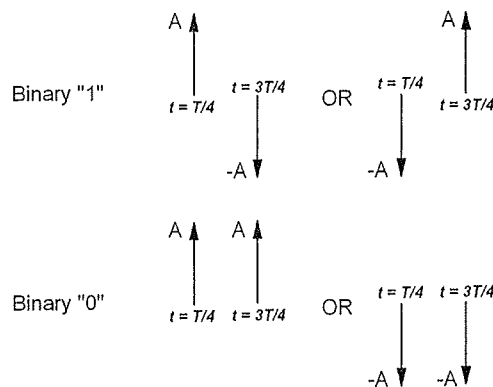


Fig.Q2c Possible impulse representations for "1" and "0"

Question 3

In wireless communications, 16QAM appears to be one of the suitable modulation schemes for systems that require high bandwidth efficiency, like Digital Video Broadcasting (DVB). Consider a 16QAM system that operates under an Additive White Gaussian Noise (AWGN) channel with double-sided power spectral density of $N_0/2$.

- (a) How many bits per symbol are there for a 16QAM system? [2 marks]
(b) What is the maximum achievable bit rate (in Mbit/s) without ISI within a 8MHz (RF) bandwidth if a raised cosine filter of 30% excess bandwidth (i.e. $\alpha = 0.3$) is used? [3 marks]
(c) Assume that the transmitted 16QAM signal is represented as:

$$s(t) = E_1(t)\sqrt{\frac{2}{T}} \cos(\omega_c t) - E_2(t)\sqrt{\frac{2}{T}} \sin(\omega_c t) \quad E_1(t), E_2(t) \in \{\pm E, \pm 3E\}$$

- (i) Draw the block diagram of a 16QAM demodulator with coherent detection.
(ii) Show that the average bit energy $E_b = \frac{5}{2}E^2$, and whereby to further show that the symbol error probability at I-channel is:

$$P_{s_I} = \frac{3}{2}Q\left[\sqrt{\frac{4E_b}{5N_0}}\right]$$

- (iii) Assume that a complete set of Gray codes is used, show that the overall bit error probability of the demodulator for large value of E_b/N_0 can be approximated as:

$$P_b \cong \frac{3}{4}Q\left[\sqrt{\frac{4E_b}{5N_0}}\right].$$

[20 marks]

Question 4

Consider a communication system transmits N BPSK signals with the same bit rate $1/T$ but different carrier frequencies simultaneously, i.e. $S(t) = \sum_{i=1}^N s_i(t)$, where $s_i(t) = E_i(t) \sqrt{\frac{2}{T}} \cos(i\omega_0 t)$,

$$E_i(t) \in \{-E, +E\}, \quad \omega_0 = \frac{2\pi}{T}.$$

Assume that the system operates on an Additive White Gaussian Noise (AWGN) channel with double-sided noise power spectral density of $N_0/2$ and individual ideal BPSK coherent detectors are used for data detection. Fig.Q4 shows the coherent detector for the i^{th} BPSK signal.

- (a) Show that there is an overlap of the power spectral density of neighboring BPSK signals if a raised cosine filter with excess bandwidth greater than zero (i.e. $\alpha > 0$) is used for each BPSK signal. Express the overlapped region between the i^{th} BPSK ($i < N$) signal and the $(i+1)^{\text{th}}$ BPSK signal in terms of i, ω_0, T and α . Assume that the unfiltered power spectral density of BPSK signal extends from $-\infty$ to $+\infty$ Hz. [8 marks]

- (b) Assume that there exists a small amount of timing offset Δ at the reference signal for the i^{th} BPSK demodulator, i.e. $\psi_i(t) = \sqrt{\frac{2}{T}} \cos[i\omega_0(t - \Delta)]$.

- (i) Show that signal $x_i(T)$ at the integrator output can be expressed as:

$$E_i \cos(i\omega_0 \Delta) + \sum_{\substack{j=1 \\ i \neq j}}^N E_j \left\{ \frac{\sin[(i-j)\omega_0 T - i\omega_0 \Delta] + \sin(i\omega_0 \Delta)}{T(i-j)\omega_0} \right\} + \sum_{j=1}^N E_j \left\{ \frac{\sin[(i+j)\omega_0 T - i\omega_0 \Delta] + \sin(i\omega_0 \Delta)}{T(i+j)\omega_0} \right\} + \text{noise}$$

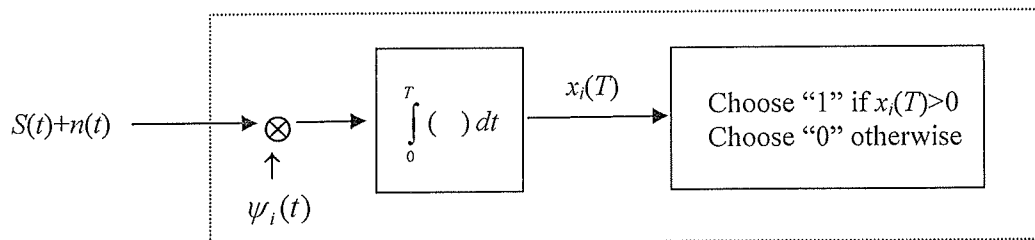
$$\text{where noise} = \sqrt{\frac{2}{T}} \int_0^T n(t) \cos[i\omega_0(t - \Delta)] dt$$

{Note: You need to consider ALL frequency components, i.e. both low and high frequency components}

- (ii) Show that the probability of error P_e at the i^{th} BPSK demodulator is:

$$P_e = Q\left[\sqrt{\frac{2}{N_0}} E \cos(i\omega_0 \Delta)\right]$$

- (iii) If the P_e without timing offset (i.e. $\Delta=0$) is 10^{-8} , estimate the P_e when $i=5$ and $\omega_0 \Delta = 0.1 \text{ rad}$. [17 marks]



$n(t)$: AWGN with double-sided power spectral density of $N_0/2$

Coherent BPSK Demodulation

$$\psi_i(t) = \sqrt{\frac{2}{T}} \cos(i\omega_0 t)$$

Fig.Q4 Coherent Detector for the i^{th} BPSK Signal

Question 5

- (a) Phase Locked Loops (PLLs) have been widely used in communication systems.
- Draw the block diagram of a PLL.
 - A second order PLL with Lag-Lead loop filter is used to track the phase of a sinusoidal signal $\cos[\omega_0 t + \theta(t)]$. Assume that the gain of the VCO is K_0 ($K_0 \neq 0$) and the transfer function of the Lag-Lead loop filter is:

$$F(\omega) = \frac{j\omega\tau_2 + 1}{j\omega\tau_1 + 1} \quad \text{where } \tau_1 \text{ and } \tau_2 \text{ are non-zero constants, and } \tau_1 > \tau_2$$

Determine the phase error at equilibrium state if the phase angle $\theta(t)$ of the incoming signal has the following frequency characteristic:

$$\Theta(\omega) = \frac{j\omega A + B}{(j\omega)^2} \quad \text{where } A \text{ and } B \text{ are constants}$$

[9 marks]

- (b) Consider a (8,4) systematic block code whose parity-check equations are:

$$p_1 = m_1 + m_2 + m_3$$

$$p_2 = m_2 + m_3 + m_4$$

$$p_3 = m_1 + m_3 + m_4$$

$$p_4 = m_1 + m_2 + m_4$$

where m_i are message bits and p_i are check bits.

- Find the generator matrix $\mathbf{G}$ and the parity-check matrix $\mathbf{H}$ for this code.
- What are the codewords for the message signals 0100 and 1001? Determine their Hamming distance.
- Assume that the minimum distance $d_{\min}$ of the above linear code is 4, find the error-correction capability of the code.
- Explain whether the following received sequences are valid codewords.
01111100, 01110001

[16 marks]

***** END *****