

City University of Hong Kong

Module code & title: EE3101 Communication Engineering

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

$$Q(x) \approx \frac{\exp(-x^2/2)}{x\sqrt{2\pi}} \quad \text{for } x > 3.5, \quad \text{and } Q(5.61) \approx 1 \times 10^{-8}$$

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

(b) $= 0$ for other t

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

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

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

$$(e) \quad Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} \exp\left(-\frac{u^2}{2}\right) du, \quad \Rightarrow \quad \frac{dQ(x)}{dx} = -\frac{1}{\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right), \quad \Rightarrow \quad \frac{dQ(x)}{dy} = \frac{dQ(x)}{dx} \frac{dx}{dy}$$

Question 1

P. 2

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

[8 marks]

(b) Differential Manchester encoding is a modified version of Manchester encoding technique for binary data. It is specified in the IEEE 802.5 standard for token ring LANs, and has been used in many other applications, including magnetic and optical storage. The waveforms for binary "1" and binary "0" are shown in Fig.Q1a, and the waveform for data sequence of 10010110 is shown in Fig.Q1b. The coding rule is as follows:

A '1' bit is indicated by making the first half of the signal equal to the last half of the previous bit's signal i.e. no level transition at the start of the bit-time.

A '0' bit is indicated by making the first half of the signal opposite to the last half of the previous bit's signal i.e. a level transition at the beginning of the bit-time.

In the middle of the bit-time there is always a level transition, whether from high to low, or low to high.

(i) Show that the power spectral density of Differential Manchester encoding for random binary data with equal probability can be expressed as:

$$S(\omega) = A^2 T \frac{\sin^a(\omega T / 4)}{(\omega T / 4)^b} \quad \text{where } T \text{ is the bit duration, } a \text{ and } b \text{ are constants.}$$

Determine the values of a and b .

You need to show the detailed analysis of the autocorrelation function for R_0 , R_1 and R_2 .

(ii) State the disadvantage of having a level transition at the middle of the bit-time.

{Hint: The binary "1" and "0" can be represented by the impulses shown in Fig.Q1c with equal probability}

[17 marks]

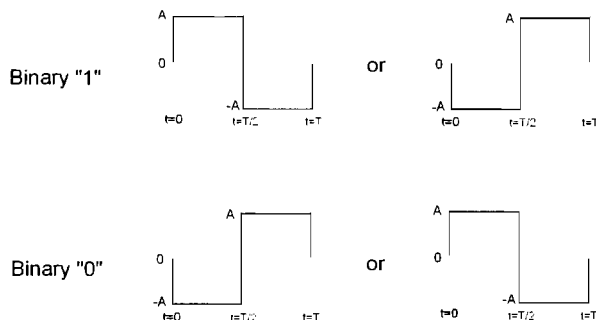


Fig.Q1a Waveform Representations for "1" and "0"

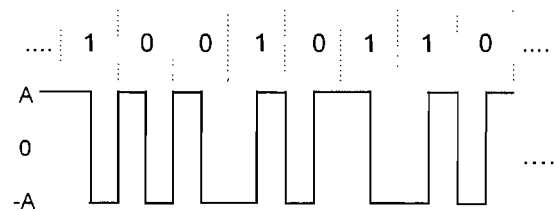


Fig.Q1b Output Waveform after Differential Manchester encoding.

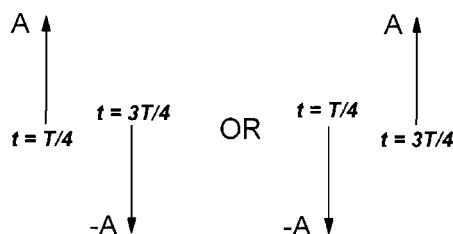


Fig.Q2c Possible impulse representations for "1" and "0"

Question 2

- (a) State the key advantages of using a raised cosine filter in digital communication systems. Comment on the use of a Butterworth filter (up to 6th order, which is quite common in analogue communication systems) to replace the raised cosine filter with 30% excess bandwidth (i.e. $\alpha = 0.3$) in digital communication systems. [7 marks]
- (b) A pre-coder is normally used in a duobinary system.
- What is the purpose of using a pre-coder? Briefly explain the operation principle of the pre-coder and how it solves the problem in a duobinary system.
 - Draw the block diagram of the pre-coder. Determine the output sequence at the pre-coder if the input sequence is 101100. You can assume any initial condition at the pre-coder. [10 marks]
- (c) Consider a bipolar non-return-to-zero (i.e. NRZ-L) system which operates under an Additive White Gaussian Noise (AWGN) channel. Assume that an optimum detection is used and the probability of error is $P_e = Q\left[\sqrt{\frac{2E_b}{N_0}}\right]$, where $\frac{E_b}{N_0}$ is the ratio of average-bit-energy to noise-spectral-density. Suppose that the current $P_e = 10^{-8}$. What is the value of P_e if the transmission power is reduced by 4dB? [4 marks]
- (d) Suggest a suitable modulation scheme; determine the number of bits per symbol and the symbol duration for a 135Mb/s system. The maximum permission bandwidth is 20MHz and an appropriate raised cosine filter with 35% excess bandwidth (i.e. $\alpha = 0.35$) is used at the transmitter. Assume that the modulation scheme should be as simple as possible. [4 marks]

Question 3

For high bandwidth efficiency ($\geq 4\text{b/s/Hz}$) applications, M-QAM appears to be one of the suitable modulation schemes. Consider a 16QAM system with coherent detection and operates under an Additive White Gaussian Noise (AWGN) channel with double-sided power spectral density of $N_0/2$. The received signal at the demodulator input is:

$$s(t) = E_1(t)\sqrt{\frac{2}{T}}\cos(\omega_c t) - E_2(t)\sqrt{\frac{2}{T}}\sin(\omega_c t) + n(t)$$

where $E_1(t)$ and $E_2(t)$ are the amplitude information of I-channel and Q-channel respectively, $E_1(t) \in \{\pm A_1, \pm 3A_1\}$, $E_2(t) \in \{\pm A_2, \pm 3A_2\}$, ω_c is the angular frequency of the carrier, T is the symbol duration, $n(t)$ is the AWGN noise. Assume that the high frequency component can be ignored during the demodulation process and the decision thresholds are set at the middle of the two adjacent signal levels (average value).

- (a) Draw the block diagram of a 16QAM demodulator with coherent detection. [4 marks]
- (b) Show that the symbol error probability at I-channel is: $P_{S_I} = \frac{3}{2}Q\left[\sqrt{\frac{2A_1^2}{N_0}}\right]$ [6 marks]
- (c) Derive the average symbol energy E_S in terms of A_1 and A_2 . [2 marks]
- (d) Assume that Gray code is used and large values of A_1^2/N_0 and A_2^2/N_0 are applied; show that the overall bit error probability P_B can be approximated as:

$$P_B \cong \frac{3}{8}Q\left[\sqrt{\frac{2A_1^2}{N_0}}\right] + \frac{3}{8}Q\left[\sqrt{\frac{2(E_S - 5A_1^2)/5}{N_0}}\right] \quad [4 \text{ marks}]$$

- (e) For a given transmission power (i.e. E_S is fixed), derive the relationship between A_1 and A_2 mathematically such that a minimum P_B in (d) can be obtained. [9 marks]

{Note: for $\exp\left(\frac{E_S - 2x}{N_0}\right) - \left(\frac{E_S}{x} - 1\right)^{-1/2} = 0$

$E_S = 2x$ is a solution of the above equation and is independent of the N_0 value }

Question 4

Consider a communication system transmits N BPSK signals simultaneously and each BPSK signal has the same bit rate $1/T$ but with different carrier frequencies, i.e. $S(t) = \sum_{i=1}^N s_i(t)$, where

$$s_i(t) = E_i(t) \sqrt{\frac{2}{T}} \cos[(\omega_0 + i\omega_T)t], \quad E_i(t) \in \{-E, +E\}, \quad \omega_0 \gg \omega_T.$$

Assume that (i) the system operates under a noiseless channel; (ii) an individual ideal BPSK coherent detector is used for data detection for each BPSK signal $s_i(t)$; and (iii) all high frequency components involving $2\omega_0$ can be ignored in the demodulation process (however, the frequency components for $i\omega_T$ where $i = 1, 2, \dots, N$ cannot be ignored).

- (a) What is the total bit rate of the system? [2 marks]
- (b) Assume that an ideal reference signal of $\psi_i(t) = \sqrt{\frac{2}{T}} \cos[(\omega_0 + i\omega_T)t]$ is used in the i^{th} BPSK demodulator for $s_i(t)$. Find the relationship between T and ω_T such that there is no inter-channel-interference (ICI), i.e. the signal at the correlator output of the i^{th} BPSK demodulator depends only on $E_i(t)$ but not on $E_j(t)$ for $j \neq i$. [6 marks]
- (c) Assume that there exists a small amount of constant timing offset Δ_i at the reference signal in the i^{th} BPSK demodulator, i.e. $\psi_i(t) = \sqrt{\frac{2}{T}} \cos[(\omega_0 + i\omega_T)(t - \Delta_i)]$. Find the relationship between T and ω_T such that there is no inter-channel-interference (ICI). [8 marks]
- (d) Determine the minimum frequency separation $\omega_{T_{\min}}$ in (c). [2 marks]
- (e) If the minimum frequency separation $\omega_{T_{\min}}$ is used and an appropriated raised cosine filter of 30% excess bandwidth is used for each individual BPSK signal $s_i(t)$, express the overall bandwidth of the system in Hz in terms of N and T . Assume that the bandwidth is defined as the frequency band which covers 100% transmission power. [5 marks]
- (f) If a single carrier BPSK system is used to transmit the same information as in (a), express the overall bandwidth of the new system in Hz in terms of N and T . Assume that the same bandwidth definition as in (e) is applied. [2 marks]

Question 5

(a) Draw the block diagrams of any TWO open-loop symbol synchronizers. [6 marks]

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

$$p_1 = m_1 + m_2 + m_3$$

$$p_2 = m_2 + m_3 + m_4$$

$$p_3 = m_1 + m_2 + m_4$$

$$p_4 = m_1 + m_3 + m_4$$

where m_i are message bits and p_i are check bits.

(i) Find the generator matrix **G** and the parity-check matrix **H** for this code.

(ii) Explain whether the following received codes are valid codewords:

00110110, 11111001.

What is the Hamming distance between these two codewords?

(iii) Assume that the minimum distance $d_{\min}$ of the above (8, 4) systematic block code is 4, find the error-correcting capability e of the code.

(iv) Assume that BPSK is used to transmit the data and it cannot correct any error patterns with more than e as specified in (iii), estimate the probability of un-correctable message error if the channel symbol error probability is 2×10^{-3} .

[19 marks]

***** END *****