

City University of Hong Kong

Module code & title: EE3101 Communication Engineering

Session : Semester A 2003-2004

Time allowed : Two hours

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

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

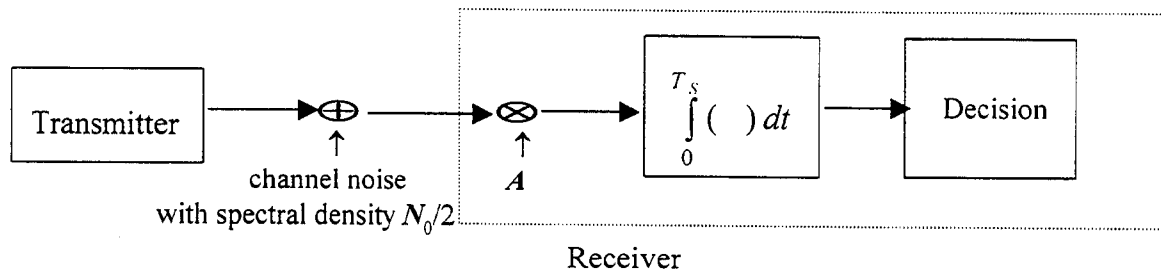
- (a) Approved calculator
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Question 1

A 8Mb/s pseudo random binary signal is translated into a 4-level signaling. The four NRZ output levels are: -3 , -1 , 1 and 3 . The corresponding probability of occurrence is 0.23 , 0.27 , 0.27 , and 0.23 . Determine:

- the symbol duration T_s and the minimum baseband transmission bandwidth without inter-symbol interference; [3 marks]
- the power spectral density of the transmitted signal in terms of T_s . [8 marks]

Consider an ideal receiver as shown below is used. Assuming that apart from the Additive White Gaussian noise (with double-sided power spectral density of $N_0/2$), there is no channel loss, i.e. the signal levels at the receiver input are: -3 , -1 , 1 and 3 . **The decision levels are set at the middle of the two adjacent signal levels.**



- What are the four mean output signal levels at the integrator output? [4 marks]
- Show that the average bit energy, E_b , is $2.34T_s$. [4 marks]
- Express the probability of symbol error in terms of E_b and N_0 . [6 marks]

Question 2

- State the major characteristics of a partial response signaling system like duobinary system, and briefly explain why pre-coding is necessary. [9 marks]
- What is the main purpose of using a matched filter? Derive and sketch the correlation realization of a matched filter in a practical receiver. [10 marks]
- With ideal optimum detection, the bit error performance of a 1Mb/s uni-polar NRZ system is 3×10^{-6} . Determine the bit error performance if the uni-polar NRZ system is replaced by a bi-polar NRZ (i.e. NRZ-L) system with the same transmission power.

{ Note: $Q(x) \approx \frac{\exp(-x^2/2)}{x\sqrt{2\pi}}$ for $x > 3$, and $Q(4.526) \cong 3 \times 10^{-6}$ }

[6 marks]

Question 3

The signal constellation of an M equally spaced M-ASK signal is shown in Fig.Q3. The received signal is:

$$r(t) = E_i \sqrt{\frac{2}{T}} \cos(\omega_c t) + n(t)$$

where E_i is the signal level of the signal point i , T is the symbol duration, ω_c is the carrier frequency, and $n(t)$ is the Additive White Gaussian Noise (AWGN) with double-sided power spectral density of $N_0/2$. Random data with equal probability is used. Assuming that Gray coding is used and with optimum detection, shown that:

(a) the average probability of bit error can be expressed as:

$$P_B = \frac{2(M-1)}{M \log_2 M} Q \left[\sqrt{\frac{E^2}{2N_0}} \right] \quad [9 \text{ marks}]$$

(b) the average bit energy can be expressed as:

$$E_b = \frac{1}{\log_2 M} \left[E_1^2 + E_1 E(M-1) + \frac{(M-1)(2M-1)}{6} E^2 \right] \quad [7 \text{ marks}]$$

If E is a constant, to minimize the bit error probability with a given transmission power, show that

(c) $E_1 = -E \frac{(M-1)}{2}$; and [4 marks]

(d) the corresponding average bit error can be expressed as:

$$P_B = \frac{2(M-1)}{M \log_2 M} Q \left[\sqrt{\frac{6E_b \log_2 M}{N_0(M^2-1)}} \right] \quad [5 \text{ marks}]$$

{ Note: $\sum_{i=1}^M i = \frac{M(M+1)}{2}$ $\sum_{i=1}^M i^2 = \frac{M(M+1)(2M+1)}{6}$ }

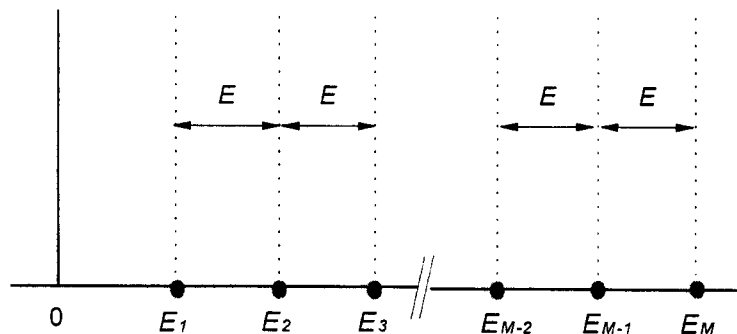


Fig.Q3 Signal Constellation for M equally spaced M-ASK Signals

Question 4

- (a) Suggest a suitable modulation scheme and determine the symbol duration for the following digital communication systems. Assuming that the transmission bandwidth equals 130% of the minimum Nyquist bandwidth.
- (i) 135Mb/s, maximum permissible channel bandwidth = 30MHz;
 - (ii) 64kb/s, maximum permissible channel bandwidth = 40kHz. [6 marks]
- (b) Draw the block diagram of a FSK modulator with two independent tones for binary data transmission. Derive the minimum frequency separation in term of the bit duration T_b for orthogonal transmission. [11 marks]
- (c) Sketch the block diagrams of on-off keying (i.e. 2 level ASK) demodulators with (i) coherent detection, and (ii) non-coherent detection. [8 marks]

Question 5

Consider a 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.

- (a) Find the generator matrix and the parity-check matrix $\mathbf{H}$ for this code. [6 marks]
- (b) Explain why no column of the $\mathbf{H}^T$ can be all zeros. [2 marks]
- (c) Explain why all columns of $\mathbf{H}^T$ must be unique. [2 marks]
- (d) Find all the codewords of the code. [8 marks]
- (e) Find the minimum distance, i.e. $d_{\min}$, of the code. [3 marks]
- (f) What is the error-detecting capability of the code? [2 marks]
- (g) What is the error-correcting capability of the code? [2 marks]

Question 6

- (a) AMI line coding technique has been widely used in the metallic cable systems like *T1*. However the power spectral density of AMI has a null at its bit frequency, and it may cause difficulties for bit time recovery by using traditional bandpass filtering technique. One of the possible solutions is to rectify the signal before entering the bandpass filter, as shown in Fig.Q6. Assuming that the amplitude of the AMI is normalized to +1 and -1 at the receiver input, show that the power spectral density after the absolute device can be expressed as:

$$S(\omega) = B \left[1 + C \sum_{r=-\infty}^{\infty} \delta(\omega - r\omega_T) \right] \frac{\sin^2(D\omega T)}{(D\omega T)^2} \quad \omega_T = \frac{2\pi}{T}$$

where T is the bit duration of the AMI signal. Determine B , C , and D values and hence shows that $S(\omega)$ has a peak value at $\omega = \omega_T$.

[16 marks]

{ Note: $\sum_{r=-\infty}^{\infty} \exp(-jr\omega T) = \frac{2\pi}{T} \sum_{m=-\infty}^{\infty} \delta(\omega - m\omega_T)$

if $h(t) = 1$ for $-Y/2 \leq t < Y/2$ and
 $= 0$ for other t

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

Hint: the signal becomes unipolar RZ format after the absolute device }

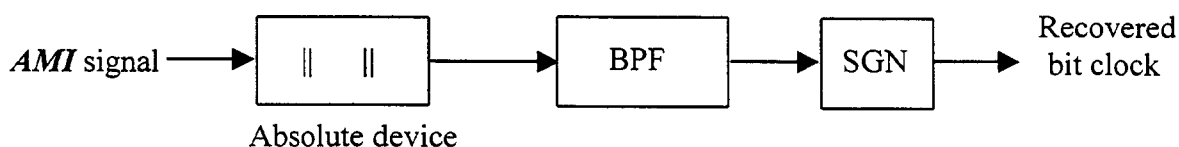


Fig.Q6 Bit timing recovery for AMI

- (b) Draw the block diagram of a traditional Costas loop. [4 marks]
- (c) Show that a traditional PLL can track out any phase step at the input if the loop filter has a non-zero DC response.

{ Note: $\theta(t) = \Delta\theta, \Delta\theta t, \Delta\theta t^2 \implies \Theta(\omega) = \frac{\Delta\theta}{j\omega}, \frac{\Delta\theta}{(j\omega)^2}, \frac{\Delta\theta}{(j\omega)^3}$ respectively }

[5 marks]

***** END *****