Version IJW/5

EGT2
ENGINEERING TRIPOS PART IIA

Thursday 27 April 2017   9.30 to 11

Module 3F4

DATA TRANSMISSION

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

*Write your candidate number **not** your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book

10 minutes reading time is allowed for this paper.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

1 (a) Give reasons for the use of line coding in a baseband digital communication system. [20%]

(b) What is the advantage of high density bipolar 3 (HDB3) line coding over that of conventional alternate mark invert (AMI) encoding? Describe how this is achieved in HDB3. [20%]

(c) A pulse amplitude modulated (PAM) baseband communication system transmits data in the form of a weighted impulse train

$$x(t) = \sum_{n=-\infty}^{\infty} a_n \, \delta(t - nT_s)$$

where the a_n are the line coded symbols and T_s is the symbol period. A faulty AMI line encoder yields levels of $+1.2$ V, 0 V and -0.8 V for the symbols a_n. Assuming equiprobable random binary data, determine an expression for and sketch the power spectrum of $x(t)$. [40%]

(d) Prior to transmission, the line coded signal $x(t)$ of part (c) is passed through a filter with the following impulse response

$$h(t) = \begin{cases} 1 & \text{for } \frac{-T_s}{2} \leq t \leq \frac{T_s}{2} \\ 0 & \text{elsewhere} \end{cases}$$

Determine the power spectrum of the transmitted signal and sketch the result. What is the advantage of this scheme compared with polar line coding? [20%]

2 (a) An (n,k) error-correcting block code has a generator matrix given by:

$$G = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

Determine n and k for this code. [10%]

(b) Calculate the parity check matrix H and determine the minimum distance d_{min} for this code. [20%]

(c) Discuss the error correcting and detecting performance of this code. [15%]

(d) In an alternative error correcting code, a convolutional encoder generates code bits $c_{1,m}$ and $c_{2,m}$ for each new input bit x_m at time m, according to

$$\begin{aligned} c_{1,m} &= x_m + x_{m-1} + x_{m-2} + x_{m-3} \\ c_{2,m} &= x_m + x_{m-1} + x_{m-3} \end{aligned}$$

where addition is over the binary field $\{0,1\}$. Determine the coded bit streams c_1 and c_2 if $x_1 = 1$ and $x_m = 0$ for all $m \neq 1$, and hence estimate d_{min} for this code. [30%]

(e) Compare the error correction capabilities of the block and convolutional codes in parts (a) and (d) respectively, and briefly discuss the relative merits of each for a system designer. [25%]

3 (a) Many common modulation schemes employ multi-level symbols s_k instead of binary symbols b_k, where the number of levels M is > 2. Briefly explain why this is often a good design choice, and why values for the symbols are usually $(2i+1-M)$ where i is an integer from 0 to $M-1$. [20%]

(b) Three types of multi-level digital modulation are described by the following formulae for phasor waveforms $p(t)$ in terms of an input symbol stream s_k, where $k = 0, 1, 2, \ldots$:

$$(i) \quad p(t) = e^{j\phi_0} \sum_k e^{j(s_k \omega_D (t-kT_s) + \phi_k)} g(t-kT_s)$$

$$(ii) \quad p(t) = e^{j\phi_0} \sum_k [s_{2k} + js_{2k+1}] g(t-kT_s)$$

$$(iii) \quad p(t) = e^{j\phi_0} \sum_k e^{js_k\pi/M} g(t-kT_s)$$

Determine the type of modulation that each formula describes, giving reasons in each case and explaining any undefined symbols, including the pulse $g(t)$. [30%]

(c) If the bit rate of the binary data feeding into a multi-level modulator is R_b bit s^{-1}, estimate the bandwidth required for a radio-frequency signal $s(t)$ when the following three types of modulation are employed: 64-level phase-shift keying (64-PSK); 64-level quadrature amplitude modulation (64-QAM); and 64-level frequency-shift keying (64-FSK). You should assume that just the main lobe of the signal spectrum to its first zeros needs to be transmitted in each case. [30%]

(d) Discuss the relative merits of these three types of modulation, explaining why 64-PSK is rarely used, and what different tradeoffs are available with 64-FSK compared with 64-QAM. [20%]

4 In recent years there has been a switch from analogue to digital methods for broadcasting television and audio channels.

(a) Suggest reasons for this switch and why it has happened mainly in the last decade. [15%]

(b) What are typical bit rates associated with compressed audio and video data channels, and why do these rates present difficulties for conventional serial modulation methods over terrestrial wireless links? [15%]

(c) Describe coded orthogonal frequency division multiplexing (COFDM) and explain how it largely overcomes the problems of transmitting digital audio and video data over terrestrial links. [25%]

(d) A COFDM modulation scheme is required to transmit a 30 Mbit s^{-1} composite video bit stream over a wireless channel with a path delay variation of up to 10 μs. Error correction coding with rate 2/3 is applied to the video bit stream and 64-QAM modulation is employed. If the frequency spacing of the OFDM carriers is chosen to be 1.25 kHz, calculate the number of carriers required to carry the coded video data. Allowing an extra 10% of carriers to be pilot carriers that provide amplitude and phase references and carry system information, estimate the bandwith needed for the modulated radio-frequency signal and calculate the spectral efficiency (in bit s^{-1} per Hz) of the complete COFDM modulation system. [25%]

(e) Digital video is normally broadcast to fixed directional antennas, whereas digital audio needs to be compatible with reception in moving vehicles with small omnidirectional antennas. Briefly describe how this affects the choice of key modulation parameters for digital audio when compared with video. [20%]

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