EGT2
ENGINEERING TRIPOS PART IIA

Friday 1 May 2015 2 to 3.30

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) What are the objectives of equalisation in baseband transmission systems? Explain the principles of operation of the following:

(i) a *zero forcing* (ZF) equaliser;

(ii) a *minimum mean squared error* (MMSE) equaliser;

(iii) a *decision feedback equaliser* (DFE).

[30%]

(b) In a unipolar binary baseband transmission system, an optimally sampled average received pulse corresponding to the transmission of a '1' in the midst of a long run of '0's is

$$p_n = 1,\ 0.9,\ 0,\ 0,\ \ldots$$

Show the form of the filter and its coefficient values to implement an ideal ZF equaliser. [10%]

(c) The actual equaliser for the above channel is to be implemented using a 4-coefficient *finite impulse response* (FIR) filter. Determine the coefficient values for this equaliser and compute the ratio of the eye-opening to the rms noise at the slicer input both with and without this equaliser. Assume the effects of noise in the channel are modelled as the addition of independent zero mean Gaussian noise samples of rms value σ at the receiver input. [40%]

(d) The equaliser of part (c) is modified to be an MMSE design with filter coefficients

$$[1,\ -0.8,\ 0.5,\ -0.3]$$

Calculate the ratio of the eye opening to the rms noise at the slicer for this equaliser and compare it with that calculated for the ZF equaliser in part (c). Why, despite this result, does the MMSE have a performance advantage over the ZF equaliser? [20%]

2 (a) The encoder for a rate $1/2$ binary convolutional code is shown in Fig. 1.

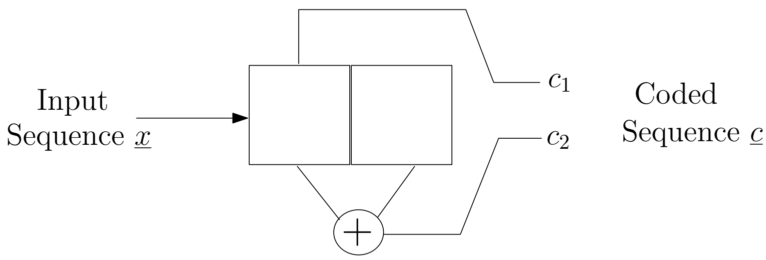

Fig. 1

(i) Draw the state diagram of the code. [15%]

(ii) Suppose the code is used on a binary symmetric channel and the received sequence is 11011011. Determine the decoded sequence $\underline{\hat{c}}$, and the corresponding input sequence $\underline{\hat{x}}$. [40%]

(b) A binary linear block code uses the following syndrome decoding table:

Syndrome	Error pattern
000	00000
001	00001
010	00010
011	00011
100	10000
101	01000
110	10010
111	00100

(i) Find the rate of the code. [5%]

(ii) Find the parity check matrix that corresponds to this table. [25%]

(iii) Find the error detecting and error correcting capability of the code. [15%]

3 A digital modulation scheme is to be designed, which employs either multi-level phase-shift keying (M-PSK) or multi-level quadrature amplitude modulation (M-QAM) for data at a rate of R bit s^{-1}.

(a) Sketch phasor constellations for 16-level versions of these two approaches (16-PSK and 16-QAM). [20%]

(b) Explain why M-QAM is likely to result in lower bit error rates for a given signal-to-noise ratio than M-PSK as M is increased from 16 in integer powers of 4. [20%]

(c) Derive an expression which relates $S(\omega)$, the spectrum of a modulated signal $s(t)$, to $P(\omega)$, the spectrum of the equivalent phasor waveform $p(t)$, when the carrier frequency is ω_c rad s^{-1}. [25%]

(d) Hence calculate the radio frequency bandwidth required by M-PSK and M-QAM signals as a function of $M = 2^m$, if the bandwidth is determined by the width of the main lobe of $S(\omega)$ to the first zeros on either side of the carrier frequency. You should assume that a full-width rectangular shaping pulse $g(t)$ is used to define each modulated symbol. [35%]

4 In recent years, radio and television broadcasts have largely shifted from analogue to digital formats.

(a) Briefly discuss why this shift has occurred, listing key technical developments and user benefits which have driven this move. [15%]

(b) In the UK, digital audio broadcasting (DAB) employs quadrature phase shift keying (QPSK) as the underlying modulation method, whereas digital TV employs 64-level quadrature amplitude modulation (64-QAM). Give likely reasons for these choices, explaining the tradeoffs in each case. [20%]

(c) Draw the block diagram of the modulator and demodulator for a coded orthogonal frequency division multiplexing (COFDM) system, based on the discrete Fourier transform (DFT) and its inverse. What key feature of the DFT allows OFDM to achieve high spectral efficiency with minimal inter-symbol interference, and how is this implemented efficiently? [20%]

(d) Explain why error-correction coding is needed and how guard periods are used in the time intervals between transmitted DFT blocks, in order to help combat the effects of multipath delays. [20%]

(e) Estimate the user data rate available and the bandwidth required for a COFDM DAB system, which employs 1200 subcarriers, QPSK modulation and rate $1/2$ error-correction coding, where the subcarrier spacing is 1.5 kHz and the guard periods are 100 μs wide. [25%]

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3F4 2015 Answers:

1 (a) –

(b) First-order IIR filter with feedback coef = -0.9 .

(c) $H_E(z) = 1 - 0.9z^{-1} + 0.81z^{-2} - 0.729z^{-3}$; $\frac{0.2}{\sigma}$; $\frac{0.1}{\sigma}$

(d) $\frac{0.185}{\sigma}$

2 (a) (i) –

(ii) $\underline{\hat{c}} = 11010011$; $\underline{\hat{x}} = 1001$

(b) (i) $2/5$

(ii) $H = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 & 1 \end{bmatrix}$

(iii) Correct 1 error; detect 2 errors

3 (a) –

(b) –

(c) $S(\omega) = \frac{1}{2}[P(\omega - \omega_c) + P^*(-(\omega + \omega_c))]$

(d) $\frac{2R}{m}$ Hz

4 (a) –

(b) –

(c) Orthogonality

(d) –

(e) 1.565 . 10^6 bit s^{-1}; $\sim$ 1.8 to 2.0 MHz.