ENGINEERING TRIPOS PART IIA

Thursday 6 May 2010 2.30 to 4

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.*

There are no attachments.

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

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

1 (a) Explain the purpose of line coding in a baseband digital communication system. [20%]

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

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

where a_n are the line coded symbols and T is the symbol period. A binary polar line coding scheme with levels of $+1\,\mathrm{V}$ and $-1\,\mathrm{V}$ is used to generate the symbols a_n . Determine the power spectrum of $x(t)$ assuming that the input data bits are random with equal probability of binary ones and zeros. [30%]

(c) To improve the performance of a polar binary transmission system, the source data are coded so that after every three source data bits a fourth bit is inserted that is alternately zero and one, i.e., transmitted as $-1\,\mathrm{V}$ and $+1\,\mathrm{V}$, respectively.

(i) Determine the power spectrum of $x(t)$ assuming that the input data bits are random with equal probability of binary ones and zeros. [40%]

(ii) What are the advantages and disadvantages of this proposed modification? [10%]

Note that in this question you may assume the following result that is obtained from the Fourier series representation of a periodic impulse train:

$$\sum_{m=-\infty}^{\infty} e^{jm\omega T} = \frac{2\pi}{T} \sum_{m=-\infty}^{\infty} \delta\left(\omega - \frac{m2\pi}{T}\right)$$

2 (a) Explain the term *inter-symbol interference* for a baseband digital transmission system. Describe the function of equalisers, stating the principle of operation and the relative merits of *zero-forcing*, *minimum mean-squared error* and *decision feedback* equalisers. [40%]

(b) A certain channel has a sampled response to a unit pulse given by

$$p(n) = 1,\ -0.5,\ 0.2$$

Calculate the coefficients of a 3-tap finite impulse response (FIR) digital filter such that the equalised output in response to $p(n)$ is constrained to be a single unity value pulse followed by two zero values, i.e., 1 , 0 , 0 , … . [20%]

(c) For a binary unipolar transmission scheme having the pulse response in (b) , determine the worst-case Bit Error Rate (BER) performance with and without the FIR equaliser if the channel noise is white, Gaussian, zero mean, with a standard deviation of 0.2 V . [30%]

(d) Calculate the worst-case BER performance for the transmission scheme in (c), this time assuming the use of an appropriate *decision feedback* equaliser. [10%]

Note the Gaussian error integral approximation is

$$Q(x) \approx \frac{e^{-x^2/2}}{1.64x + \sqrt{0.76x^2 + 4}}$$

3 (a) Explain how a complex phasor waveform $p(t)$ is able to represent both amplitude and phase modulation of a radio frequency signal $s(t)$, whose carrier frequency is ω_C rad/s. [15%]

(b) Consider the following three types of suppressed-carrier modulation:

(i) 16-level amplitude shift keying (16-ASK);

(ii) 16-level phase shift keying (16-PSK);

(iii) 16-level quadrature amplitude modulation (16-QAM).

Sketch the phasor constellation $p(t)$ for each type of modulation and hence estimate the minimum noise-phasor amplitude that would just cause a symbol error in each case. You should assume that each constellation is scaled such that the mean-squared amplitude of $p(t)$, with equiprobable random data, is unity. [40%]

(c) Obtain an expression for the power spectral density of 16-ASK, assuming that the transmitted data stream is equiprobable and random, that the bit period is T_b seconds and that the shaping pulse $g(t)$ is rectangular and of duration T_b seconds. Hence calculate the bandwidth of the main lobe (to its first zeros) of the spectrum of the transmitted signal $s(t)$. [25%]

(d) Estimate, giving reasons, the bandwidths of the main lobe of the spectrum of $s(t)$ for 16-PSK and 16-QAM. [10%]

(e) Hence discuss the relative merits of 16-ASK, 16-PSK and 16-QAM. [10%]

4 (a) Coded orthogonal frequency-division multiplexing (COFDM) is a popular choice for modern digital broadcast systems. What are the main features of COFDM, and what practical problems, encountered in such systems, is it designed to overcome? [30%]

(b) In a COFDM-based digital television (TV) broadcast system, a number of TV channels are multiplexed together to give a combined bit-rate of 30 Mbit/s. Forward error correction coding with a rate of 3:5 is applied to this data prior to transmission. Explain why coding is particularly important in OFDM systems. [20%]

(c) In the TV broadcast system in part (b), the carriers of the OFDM signal are spaced 5kHz apart, and the system is designed to tolerate differences of up to 6 km in the path length from transmitter to receiver. Each carrier uses 64-level quadrature amplitude modulation (64-QAM) and 200 carriers are used as pilot tones, which do not carry user data. Calculate the total number of carriers required and hence the total radio-frequency bandwidth needed to transmit the 30 Mbit/s data stream. [30%]

(d) Key design parameters of this system are the forward error correction coding rate of 3:5, the inter-carrier frequency spacing of 5 kHz, and the choice of 64-QAM as the modulation method. Briefly suggest tradeoffs that could well have led to the chosen values for these parameters. [20%]

END OF PAPER

Engineering Triops Part 2A

Module 3F4. Data Transmission, May 2010 - Answers

1.
a)
b)
c)

2.
a)
b) $b_0=1$, $b_1=0.5$, $b_2=0.05$
c) BER (no equaliser) = 0.224, BER (equaliser) = 0.02
d) BER = $6.23*10^{-3}$

3.
a)
b) (i) 0.1085 (ii) 0.1951 (iii) 0.3162
c)
d)
e)

4.
a)
b) 2034, 10.17MHz min so approx 11MHz practical
c)
d)

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