

ENGINEERING TRIPOS PART IIB
ELECTRICAL AND INFORMATION SCIENCES TRIPOS PART II

Friday 25 April 2003 9-10:30

Paper 4F5

DIGITAL COMMUNICATION

*You must answer at least **three** questions.*

All questions carry the same number of marks.

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

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

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1 (a) Derive an expression for the power spectral density (PSD) of a binary phase-shift keyed (BPSK) modulated signal with bit rate R_b bit sec^{-1} . Hence show that the bandwidth that would be needed for the modulated signal is approximately $1.62 R_b$, if frequency components with spectral densities down to 12dB below the peak PSD must be passed. [25%]

(b) Compare the relative merits of time division multiple access (TDMA) and direct sequence spread spectrum multiple access (DS SSMA) methods. Explain briefly the concept of coding gain as applied to DS SSMA systems. [25%]

(c) It is desired to transmit data signals over a satellite channel with a bandwidth of 300 MHz, using either TDMA or DS SSMA. The bit rate of each data source is 56 kbit sec^{-1} and error-correction coding (ECC) is employed with a coding rate of 2:3. At the receiver detector, the ratio of energy-per-bit to noise PSD (E_b/N_0) required to give an acceptable error rate into the ECC decoder is 4 dB. For both TDMA and DS SSMA options, estimate the maximum number of users that could be accommodated through the satellite, assuming that BPSK modulation is used in all cases and that all frequency components down to 12 dB below the peak must be passed by the channel. [30%]

(d) For the scenario in part (c), what would be the effect in each case if quadrature phase-shift keying (QPSK) modulation were used instead of BPSK? [20%]

2 (a) What is usually the main reason for choosing multi-level modulation schemes over binary methods? Explain any disadvantages of this choice and why quadrature amplitude modulation (QAM) is usually preferred to multilevel phase-shift keying (MPSK). [25%]

(b) Sketch the phasor constellation for 16-level QAM and show the decision boundaries that would be used by a detection circuit for equiprobable symbols. Label your constellation points with a binary coding method that will result in the lowest output bit error rate at the receiver. [25%]

(c) Given that the probability of noise causing the received phasor to cross one of its nearby decision boundaries is

$$Q \left(\sqrt{\frac{3E_s}{(M^2 - 1)N_0}} \right)$$

Where M^2 is the number of QAM constellation points, and E_s and N_0 are the mean energy per QAM symbol and the noise power spectral density at the receiver, calculate the bit error rate of the receiver in terms of the mean energy per bit (E_b) and N_0 . [25%]

(d) Compare the two schemes, 16-QAM and 256-QAM, in terms of their bandwidth requirements and signal-to-noise ratios to achieve a bit error rate of approximately 1 in 10^3 . [25%]

Note the Gaussian error integral function:

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

(TURN OVER)

3 You are required to design an ultrasonic indoor location system.

(a) Outline the design of a system which could provide three-dimensional accuracy of up to 3 centimetres in each dimension most of the time. [40%]

(b) Assuming a system based on active tags, comment on techniques for maximizing battery life. [20%]

(c) How could the location quality of service (LQoS) be improved for those situations where a human in the loop is performing a control function? [20%]

(d) How does the accuracy of an ultrasonic system compare to one based on ultrawideband radio? [20%]

- 4 (a) What is IPv4's most fundamental obstacle to transparent mobile networking? [10%]
- (b) Mobile IP has been developed to address this obstacle.
- (i) Give a brief overview of the Mobile IP approach, using the correct jargon ("mobile node", "home address", "home agent", "foreign network", etc) [20%]
- (ii) What are the functions of the foreign agent? [10%]
- (iii) The three principle mechanisms of Mobile IP are: discovering X , registering X and tunnelling to X . After stating what X stands for in these definitions, describe these three mechanisms in detail. [30%]
- (c) The base Mobile IP specification is affected by routing difficulties.
- (i) Explain the problem of triangle routing. [10%]
- (ii) Describe a solution to it. [10%]
- (iii) What are the drawbacks, if any, of this solution? [10%]

END OF PAPER