ENGINEERING TRIPOS PART IIA

Thursday 1 May 2008 9 to 10.30

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.*

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 In a baseband digital transmission system the receive pulse shape $p_R(t)$, satisfies the Nyquist pulse shaping criterion and

$$H_T(\omega)H_C(\omega)H_R(\omega) = kP_R(\omega)$$

where k is an arbitrary positive gain factor.

(a) Explain with the aid of a block diagram the terms $H_T(\omega)$, $H_C(\omega)$ and $H_R(\omega)$. Indicate how the effects of channel noise may be included and state the usual assumptions made about the noise. [30%]

(b) Show that

$$\frac{\sigma_v^2}{k^2} \geq \frac{1}{(2\pi)^2 E_T}\left|\int_{-\infty}^{\infty} \sqrt{N(\omega)}\frac{|P_R(\omega)|}{|H_C(\omega)|}d\omega\right|^2$$

where σ_v^2 is the noise power at the output of the receive filter, E_T is the energy of the transmitted pulse and $N(\omega)$ is the noise power spectral density at the input to the receive filter. [40%]

(c) Binary unipolar line coding is employed with transmit symbols of duration T that can take values of $+1$ V and 0 V . For the case where $N(\omega) = N_0$, $|H_C(\omega)| = 1$, $p_R(0) = 1$, determine an expression for the probability of bit error in terms of E_T and N_0 if

$$P_R(\omega) = \begin{cases} T\cos^2\left(\dfrac{\omega T}{4}\right) & \dfrac{-2\pi}{T} \leq \omega \leq \dfrac{2\pi}{T} \\ 0 & \text{elsewhere} \end{cases}$$

assuming an optimally designed receiver. [30%]

Note: The Schwartz inequality is

$$\int_{-\infty}^{\infty} |F(\omega)|^2 d\omega \int_{-\infty}^{\infty} |G(\omega)|^2 d\omega \geq \left|\int_{-\infty}^{\infty} F(\omega)G(\omega)d\omega\right|^2$$

2 (a) Give reasons for the use of line coding in a baseband digital communication system. [25%]

(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 bipolar line coding scheme is used to generate the symbols a_n . A fault in the line coding circuit yields symbol values of 1.2 V, 0 V and -0.8 V . Determine and sketch the power spectrum of $x(t)$ assuming that the input data bits are random with equal probability of binary ones and zeros. [50%]

(c) Prior to transmission the weighted impulses are passed through a filter with the following impulse response

$$h(t) = \begin{cases} 1 & -T/2 \le t \le T/2 \\ 0 & \text{elsewhere} \end{cases}$$

Determine the power spectrum of the transmitted signal and sketch the result. [25%]

3 (a) A modulated wave is given by $s(t) = a(t)\cos(\omega_C t + \phi(t))$. Explain the meaning of a , ω_C and ϕ in this expression, and show how $s(t)$ may be expressed in terms of a complex modulation phasor waveform $p(t)$ instead of $a(t)$ and $\phi(t)$. [25%]

(b) Sketch the phasor diagram of 64-level Quadrature Amplitude Modulation (64-QAM). Describe how to assign binary codewords to the 64 states so that the bit error rate at the output of a demodulator for this signal is minimized for a given signal-to-noise ratio at the demodulator input. [25%]

(c) Explain why 64-QAM is usually a better constellation to use than 64-level Phase Shift Keying (64-PSK). What potentially useful property of 64-PSK is sacrificed in the case of 64-QAM? [25%]

(d) Briefly describe Quadrature Phase Shift Keying (QPSK) and discuss the relative merits of the 3 modulation schemes: 64-QAM, 64-PSK and QPSK. [25%]

4 (a) Why are digital transmission methods generally preferred over analogue methods for modern communication systems and what difficulties have had to be overcome to enable this? [25%]

(b) Coded Orthogonal Frequency Division Multiplexing (COFDM) is a popular method for digital audio and video transmissions. Explain why both coding and multiple carriers are useful in overcoming the problems caused by multiple transmission paths. In the case of digital audio broadcasting in the UK, what additional significant advantage has been achieved by allowing proper operation with path differences of up to approximately 0.25 ms? [25%]

(c) In a digital audio broadcast system, it is desired to transmit a block of audio channels with a combined audio bit rate of 1.5 Mbit/s and to accommodate path differences of up to 0.25 ms. Assuming that rate 1:2 error correction coding and Quadrature Phase Shift Keying (QPSK) modulation are employed, and that a Fourier transform based receiver is used with an analysis period of 1.00 ms, calculate the number of orthogonal frequency division multiplexing (OFDM) carriers that would be needed. Hence estimate the bandwidth for transmission of this audio block. [25%]

(d) If there are 15 national radio channels, each of which can be coded at a rate between 144 kbit/s and 192 kbit/s, estimate the amount of radio bandwidth that would be needed to transmit these to the whole of the UK using the above digital system. Compare this to the bandwidth needed for an equivalent analogue FM system in which each FM signal occupies 250 kHz of bandwidth, and a 7:1 frequency reuse pattern is needed to overcome interference problems from adjacent transmitters. [25%]

END OF PAPER