University of Glasgow

James Watt School of Engineering

Degrees of MEng, BEng, MSc and BSc in Engineering

ENG3014 COMMUNICATION SYSTEMS 3

Friday, 13 December 2024, 13:30 – 15:30

Exam duration: 2 hours to complete exam

Attempt ALL questions

TOTAL MARKS AVAILABLE
50

The numbers in square brackets in the right-hand margin indicate the marks allotted to the part of the question against which the mark is shown. These marks are for guidance only.

A calculator may be used. Show intermediate steps in calculations. Equation sheet available at end of exam paper.

Equation sheet available at end of exam paper

OVER

Q1 Modulation is critically important optimising the spectral efficiency of communication systems.

(a) Explain what spectral efficiency refers to and how it relates to noise in communication systems. In your explanation, refer to both the fundamental theory and equations used to calculate the spectral efficiency. [5]

(b) Outline three common modulation schemes. For each provide details on their spectral efficiency and channel requirements to support their use. [6]

(c) Explain any difference between modulation of a sine wave as compared to square wave in relation to required spectrum for the same modulation frequency. [2]

(d) Explain how spectral efficiency is related to achievable digital data rate for wireless communication system. [4]

(e) A system has a measured electrical AGWN RMS power of -15dBm and received signal strength of -4dBm. Based on the three modulation schemes outlined in part b), specify the scheme that best suits this challenge and estimate the data rate available when 200MHz of licensed flat spectrum is available. [3]

Continued overleaf

Q2 Error correction in communication systems is important for system resiliency.

(a) Explain how convolutional codes are used to correct information in communication systems and how these affect the total amount of data transmitted over a communication link. You can use appropriate diagrams to explain your answer. [4]

(b) What is the difference between convolutional codes and Reed-Solomon codes? Please provide examples of area where each is used. [4]

(c) A system using Reed-Solomon codes is required to correct 6 errors, in a message comprising at least 32 English characters. Determine the total bit length of the stored information. [4]

(d) Draw a flow diagram for the components required to encode and decode binary data that implements Reed-Solomon error correcting codes. [6]

Continued overleaf

Q3 Cabled communication is widely used for distribution of information.

(a) Note three different types of cables used in networks for distribution of digital information, explaining for each the fundamental properties that limits the achievable data rate over that cable. [6]

(b) In relation to energy per bit, specify which is most efficient in term of Joules per bit and highlight where it is commonly used in urban communication networks. [3]

(c) State the common protocol used in transmission of information over networks and why this is effective for users in urban networks. [3]

End of question paper

ENG3014
Formula Sheet

$$C = B\log_2\left(1+\frac{S}{N}\right)$$

$$ENOB = \frac{SNR - 1.76}{6.02}$$

$$\cos x = \text{Re}\left(e^{ix}\right)] = \frac{e^{ix}+e^{-ix}}{2}$$
$$\sin x = \text{Im}\left(e^{ix}\right)] = \frac{e^{ix}-e^{-ix}}{2}$$

$$f(k) = \int_{-\infty}^{\infty} f(x)e^{-2\pi ixk}$$

$\text{IFFT}(\text{FFT}(f(t)) * \text{FFT}(g(t)))$

$$c = \nu\lambda = 3\times10^8 \text{ms}^{-1}$$

1 Km $= 0.62$ miles

$$\nu = \frac{V}{\lambda}\cos(\theta)$$

$$y(t) = [\text{DC} + m\sin(2\pi\nu_m t)]A\sin(2\pi\nu_c t)$$

$$y(t) = A_c\cos\left(2\pi\nu_c t + \frac{\nu_\Delta}{\nu_m}\sin(2\pi\nu_m t)\right)$$

$$y(t) = \sin(2\pi\nu_c t)I(t) + \sin\left(2\pi\nu_c t + \frac{\pi}{2}\right)Q(t) = \sin(2\pi\nu_c t)I(t) + \cos\left(2\pi\nu_c t\right)Q(t)$$

$$\text{FSPL} = \left(\frac{4\pi d}{\lambda}\right)^2 = \left(\frac{4\pi d\nu}{c}\right)^2$$

$$L_U = 69.55 + 26.16\log_{10}(\nu) - 13.82\log_{10}(h_b) - C_H + (44.9 - 6.55\log_{10}(h_b))\log_{10}(d)$$

$$C_H = 0.8 + (1.1\log_{10}(\nu) - 0.7)h_M - 1.56\log_{10}(\nu)$$

$$C_H = 3.2(\log_{10}(11.75h_M))^2 - 4.97$$

$$\frac{P_r}{P_t} = \Phi_t\Phi_r\left(\frac{\lambda}{4\pi d}\right)^2$$

$$v = \frac{c}{\sqrt{\epsilon_r\mu_r}}$$

$$f_c \approx \frac{c}{\pi\left(\frac{D+d}{2}\right)\sqrt{\mu_r\epsilon_r}}$$

$$\left(\frac{C}{h}\right) = \frac{2\pi\epsilon_0\epsilon_r}{\ln(D/d)}$$

$$\left(\frac{L}{h}\right) = \frac{\mu_0\mu_r}{2\pi}\ln(D/d)$$

$$Z = \sqrt{\frac{R+sL}{G+sC}} \quad \text{where} \quad s = j\omega$$

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

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

$$P = \begin{pmatrix} 1 & 1 & 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 & 1 \end{pmatrix}$$

$$P = \begin{pmatrix} 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

$$p = n_{\text{block}} - N_{\text{message}}$$

$$G = \begin{bmatrix} p_c(a_0) \\ p_c(a_1) \\ \vdots \\ p_c(a_{n-1}) \end{bmatrix}$$