National Examinations

May 2019

16-Elec-B3
Digital Communications Systems

3 Hours Duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made.
2. This is a closed book exam. One of two calculators is permitted – any Casio or Sharp approved model.
3. There are **5 questions** on this exam. **Any 4 questions constitute a complete paper.** Only the first 4 questions as they appear in your answer book will be marked.
4. Marks allocated to each question are noted in the left margin. A complete paper is worth 100 marks.

(25 marks) **Question 1.** This question concerns link budgeting.

(10 marks) a. Consider a wireless system with transmitter power of 4 W, antenna gains of 6 dB, receiver losses of 3 dB, receiver noise figure of -174 dBm/Hz, a bandwidth of 1 MHz, and a fading margin requirement of 6 dB. Aside from free-space losses, no other gains or losses are present other than path loss. If the receiver requires a signal-to-noise ratio of at least 10 dB, what is the maximum allowed path loss (in dB)?

(5 marks) b. Using a path loss of $30 \log_{10}(4 \pi df/c)$, where d represents the distance from transmitter to receiver, f represents the carrier frequency, and c represents the speed of light ($c = 3.0 \times 10^8$ m/s), and assuming a carrier frequency of 2.4 GHz, find the maximum distance so that the path loss criterion in part a is satisfied.

(5 marks) c. From the path loss expression in part b, what is the path loss exponent?

(5 marks) d. Suppose you receive a signal with power -30 dBm. Express this power level in watts.

(25 marks) **Question 2.** This question concerns source coding.

(10 marks) a. You are given a source with eight letters: A, B, C, D, E, F, G, H. The probabilities of these letters are: Pr(A) = 0.02; Pr(B) = 0.13; Pr(C) = 0.24; Pr(D) = 0.21; Pr(E) = 0.07; Pr(F) = 0.18; Pr(G) = 0.10; Pr(H) = 0.05. Find a Huffman code for this source.

(5 marks) b. What is the entropy of the source in part a?

(5 marks) c. What is the average length of the code in part a?

(5 marks) d. In general, should your answer from part c be the same as, less than, or greater than, the result from part b? Briefly explain.

(25 marks) **Question 3.** This question concerns error-control coding.

(5 marks) a. Consider a binary code with the following parity check matrix. Find the corresponding generator matrix.

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

(5 marks) b. Using the result from part a, give the codeword for the information sequence: 1 1 0 1

(10 marks) c. Using an example, illustrate how the code from part a can correct a single bit error.

d. What is the minimum Hamming distance of this code? What does this imply about its ability to **detect and correct** errors?

(5 marks)

(25 marks)

Question 4. This question concerns the use of spread spectrum modulation.

a. Explain the operation of direct sequence spread spectrum, including signal modulation and detection. In what sense is this technique "spread spectrum"? (10 marks)

b. Explain the operation of frequency hopping spread spectrum, including signal modulation and detection. In what sense is this technique "spread spectrum"? (10 marks)

c. For a system with bursty (highly irregular) traffic, is spread spectrum more appropriate than TDMA/FDMA? Briefly explain. (5 marks)

(25 marks)

Question 5. This question concerns sampling and D/A conversion.

a. NTSC-quality video has a bandwidth of 5 MHz. Using the Nyquist sampling criterion, what is the minimum sampling frequency in order to reconstruct the signal exactly? (5 marks)

b. Briefly explain pulse code modulation (PCM). If PCM is used to encode the signal from part a with 16 bits per sample, what is the required data rate to represent the signal? (If you didn't get an answer for part a, assume a value.) (5 marks)

c. Give an example of "aliasing" (2-3 sentences). (5 marks)

d. Suppose 24-bit PCM is used to sample a signal restricted between -5 V and +5 V. What is the maximum quantization error? (5 marks)

e. The data rate of MPEG-quality video is much less than your answer from part b. Give one reason why. (5 marks)