Professional Engineers of Ontario

Annual Examinations – May 2016

07-Elec-B3
Digital Communication 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. A PEO-approved non-programmable calculator is permitted.
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 source coding.

(10 marks) a. You are given a source with six letters: A, B, C, D, E, F. The probabilities of these letters are: Pr(A) = 0.05; Pr(B) = 0.11; Pr(C) = 0.17; Pr(D) = 0.28; Pr(E) = 0.23; Pr(F) = 0.16. Find a Huffman code for this source.

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

(5 marks) c. Explain how you might modify the code in part a to get closer to the entropy.

(5 marks) d. A salesman offers you compression software, and promises that it will compress the source to half the rate you found in part a. Do you purchase this product? Explain.

(25 marks) **Question 2.** This question concerns link budgeting.

(10 marks) a. Consider a wireless system with transmitter power of 10 W, antenna gains of 4 dB, receiver losses of 6 dB, receiver noise figure of -174 dBm/Hz, a bandwidth of 10 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 6 dB, what is the maximum allowed path loss (in dB)?

(10 marks) b. Using a free-space 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, is the signal-to-noise criterion satisfied when d = 200 m? Show all work.

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

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

(5 marks) a. Suppose a convolutional encoder has generator polynomials

$$g_1(D) = 1 + D^2$$
$$g_2(D) = 1 + D + D^2$$

For each input, the outputs are read out as g_1 first, then g_2. If the input to the convolutional encoder is 11010, the initial state is all-zero, and the encoder uses zero padding, give the encoded output.

(20 marks) b. For the same convolutional encoder, suppose the receiver observes 00111110000111. Assuming the encoder starts and ends in the all-zero state, use the Viterbi algorithm to determine the most likely input to the encoder, correcting any errors.

(25 marks) **Question 4.** This question concerns sampling and D/A conversion.

(6 marks) a. An NTSC video signal has a bandwidth of 6 MHz. Using the Nyquist sampling criterion, what is the minimum sampling frequency that is needed to represent this signal exactly?

(7 marks) b. Briefly explain pulse code modulation (PCM). If PCM is used to encode the signal from part a with 24 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.)

(6 marks) c. Suppose 24-bit PCM is used to sample a signal restricted between -3 V and +3 V. What is the maximum quantization error?

(6 marks) d. To obtain a signal of the same quality, modern video recording standards would use a much lower data rate than your answer from part b. Briefly explain why.

(25 marks) **Question 5.** This question concerns the use of spread spectrum modulation.

(10 marks) 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"?

(5 marks) c. Give an example of a system in which spread spectrum is more appropriate than e.g. TDMA/FDMA. Also give an example of a system where TDMA/FDMA is more appropriate than spread spectrum. Explain your choices.

Marking Scheme

1. 25 marks
    a. 10 marks
    b. 5 marks
    c. 5 marks
    d. 5 marks
2. 25 marks
    a. 10 marks
    b. 10 marks
    c. 5 marks
3. 25 marks
    a. 5 marks
    b. 20 marks
4. 25 marks
    a. 6 marks
    b. 7 marks
    c. 6 marks
    d. 6 marks
5. 25 marks
    a. 10 marks
    b. 10 marks
    c. 5 marks