Professional Engineers of Ontario

Annual Examinations – **December 2015**

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 link budgeting.

(10 marks) a. Consider a wireless system with transmitter power of 20 W, antenna gains of 6 dB, receiver losses of 9 dB, receiver noise figure of -174 dBm/Hz, a bandwidth of 20 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 1.5 GHz, is the signal-to-noise criterion satisfied when d = 200 m? Show all work.

(5 marks) c. If a radio transmits at a power level of 20 dBm, what is the radio's power output in W?

(25 marks) **Question 2.** 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) = 0.11; Pr(B) = 0.05; Pr(C) = 0.28; Pr(D) = 0.17; Pr(E) = 0.25; Pr(F) = 0.14. Find a Huffman code for this source.

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

(10 marks) c. Give a Shannon-Fano-Elias code for the source in part a.

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

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

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

(5 marks) b. Find the minimum Hamming distance of the code from part a.

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

(5 marks) d. If a given code has minimum Hamming distance of 9, how many errors can the code correct? How many errors can the code detect?

(25 marks) **Question 4.** This question concerns the use of spread spectrum modulation.

(5 marks) a. In traditional spectrum sharing, users are allocated a fraction of the resources in either time or frequency. However, in spread spectrum modulation, every user may use the entire bandwidth all the time. What features do spread spectrum systems use to make this feasible?

(5 marks) b. Explain the operation of direct sequence spread spectrum, including signal modulation and detection. Give an example of a system that uses direct sequence spread spectrum.

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

(5 marks) d. As the number of users increases, how does the performance of a spread spectrum system change? Compare this to the performance of a TDMA system with a fixed number of slots.

(5 marks) e. What are the disadvantages of spread spectrum compared with TDMA or FDMA?

(25 marks) **Question 5.** This question concerns sampling and D/A conversion.

(5 marks) a. State the Nyquist sampling criterion for reconstructing signals from periodic samples. Give a brief mathematical justification, referring specifically to the Fourier transform of the sampled signal.

(5 marks) b. CD-quality audio has a bandwidth of 20 kHz. Using the Nyquist sampling criterion, what is the minimum sampling frequency that is needed to represent this signal exactly?

(5 marks) c. 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) d. Suppose 16-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 MP3-quality audio is much less than your answer from part c. Give one reason why.