

# **Professional Engineers of Ontario**

Annual Examinations - 2002 (Spring)

98-Elec-B4

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 assumption made.
- 2) "Open-Book" - non-programmable calculator.
- 3) Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
- 4) All questions are of equal value.

- 1) A digital communication system is to be designed based on a QAM modulation scheme. The system is required to support a bit rate of 8 Mbps. Pulse shaping filters with excess bandwidth of 30% are to be used. The system utilizes an RF channel in the 2 GHz band.
  - a) Determine an appropriate signal constellation scheme for the system and plot the constellation diagram giving suitable values for the signal amplitudes.
  - b) What is the bandwidth of the transmitted signal?
  - c) Give an expression for the transmitted signal in the time domain.
  - d) What is the average power of the transmitted signal in terms of the above amplitudes?
  - e) If we now use a 1/2 rate convolutional error correction code and the transmission is organized into frames of 2 ms, determine the information bit rate for the system if the decoding is done on a block by block basis (with the state of the convolutional code returning to zero) and where the convolutional code has a memory of  $m = 8$ .
  - f) Draw the block diagram for a receiver.
- 2) Consider the Hamming (15, 11) code (i.e. the codewords are 15 bits long).
  - a) Give a parity check matrix for this code.
  - b) What is the rate of the code?
  - c) This code corrects all error patterns of how many errors?
  - d) This code detects all error patterns of how many errors?
  - e) Decode the following received codeword: 0 1 0 0 0 0 0 0 1 0 1 1 0 0 using the parity check matrix above.
  - f) If this code is generated as a cyclic code with generator polynomial  $g(x) = x^4 + x + 1$ , what is the codeword for the information block 0 1 1 0 0 0 0 0 0 1?

- 3) A cellular system utilizes two frequency bands with 10 MHz bandwidth each. One of these is for transmissions from base stations to mobile terminals and the other is for transmissions from mobile terminals to base stations. In the following give plausible values if you don't know the exact parameters.
- a) For the GSM system what is the bandwidth of the transmitted signal? (i.e. a basic RF channel). How many users share a basic RF channel?
  - b) If the above GSM system uses a frequency re-use cluster size of 7 what is the capacity of the system in terms of the number of calls per cell.
  - c) In the IS-95 CDMA system what is the bandwidth of the transmitted signal?
  - d) If the above system is IS-95 (CDMA), what is the frequency re-use cluster size?
  - e) Compare the typical speech coder rates for a second generation cellular system and the standard telephone system (PSTN).
- 4) A satellite access network utilizes the pure ALOHA protocol in the uplink. With continuous transmission from a terminal the system supports a packet rate of 500 packets per second. The system consists of a population of 10,000 users with each user transmitting packets at random with an average of 1 packet per minute. These packets include new packets plus packets that have collided previously and are retransmitted.
- a) What is the probability of packet collision in the above ALOHA scheme?
  - b) What is the throughput of the system in terms of packets per packet transmission time?
  - c) What is the average number of transmissions required to successfully send a packet in the system?
  - d) Describe the CSMA protocol as an improvement to the ALOHA protocol. Is CSMA suitable for this system? Explain.

5)

- a) A run-length code uses codewords of length 4. Give the encoded bit sequence for the following sequence of bits (the number of zeros are indicated below the corresponding sequence of zeros):

$$\begin{array}{cccc} 000\dots0001000\dots0001000\dots0001000\dots000111 \\ \hline \text{-----} \quad \text{-----} \quad \text{-----} \quad \text{-----} \\ 26 \qquad \qquad 55 \qquad \qquad 44 \qquad \qquad 15 \end{array}$$

- b) An image consists of  $100 \times 100$  pixels and each pixel is described by a luminance component of 512 possible values and two chrominance components of 64 possible values each. If all the possible colours and luminance levels are equally likely determine the number of bits required to encode the image.
- c) Describe the MPEG encoding process (discuss, qualitatively, the characteristics of the encoding algorithm that result in reduction of bit rate). What is the approximate bit rate of an MPEG signal with quality similar to that of an NTSC signal?
- d) A speech signal is to be digitized using a PCM coding scheme with uniform quantization. What is the bit rate of the coded signal if the bandwidth of the signal is 5 KHz and an SNR of at least 40 dB is required for the reconstructed signal?
- 6) A telephone modem is used to connect a personal computer to a host computer. The speed of the modem is 56 Kbps and the one-way propagation delay is 100 ms. The channel has a bit error rate of  $10^{-4}$  and a Stop-and-Wait ARQ protocol is used with frame size equal to 256 bytes.
- a) Find the effective throughput of the system (in terms of Kbps).
- b) The above ARQ scheme uses a CRC based on the polynomial  $g(x) = x^5 + x^4 + x^3 + 1$ . Draw the diagram of a logic circuit to compute the CRC.