University of Glasgow | James Watt School of Engineering

Degrees of MEng, MSc, BEng and BSc in Engineering

Digital Communication 4 (ENG4052)

Friday 14th May 2021
Release time: 0930 (BST) for 4 hours
Recommended time for completion: 120 minutes

Total 100 marks.

Answer ALL questions.

- 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 physical or software calculator may be used. Candidates should ensure their answers show all intermediate steps in calculations or otherwise risk a reduction in the awarded marks.
- This is an open book exam and you may consult your notes and any other available reference material. However, the answers you submit must be **entirely your own work** — the marker needs to be able to assess **your understanding** of the material. Do not copy from lecture slides, books, online sources or anywhere else.
- Although you can discuss how to approach the exam, and revise with other students, you must not discuss specific exam questions or answers with other students. This is collusion and will result in conduct action.

Selected Mathematical identities

$$\log_2 x = (\log_a x)/(\log_a 2)$$

Q1. Table Q1 shows the range of mobile (cellular) network technologies in current deployment.

2G	2.5G	3G	4G	5G
GSM	GSM+GPRS	UMTS	LTE	NR

Table Q1: range of mobile (cellular) network technologies in current deployment

(a) State which of these network technologies have circuit-switched elements. [3]

(b) State which of these network technologies have packet-switched elements. [3]

(c) Indicate what provisions there are for voice calls where a network technology consists of only packet-switched elements. [3]

(d) Two major network operators in the US have recently announced a deprecation of all circuit-switched elements. What are the motivations for the network operators in taking this action? [3]

(e) Indicate what detrimental consequences could affect some users, if any. [3]

Q2. Figure Q2 shows the carrier, the in-phase and in-quadrature components of a digitally modulated waveform.

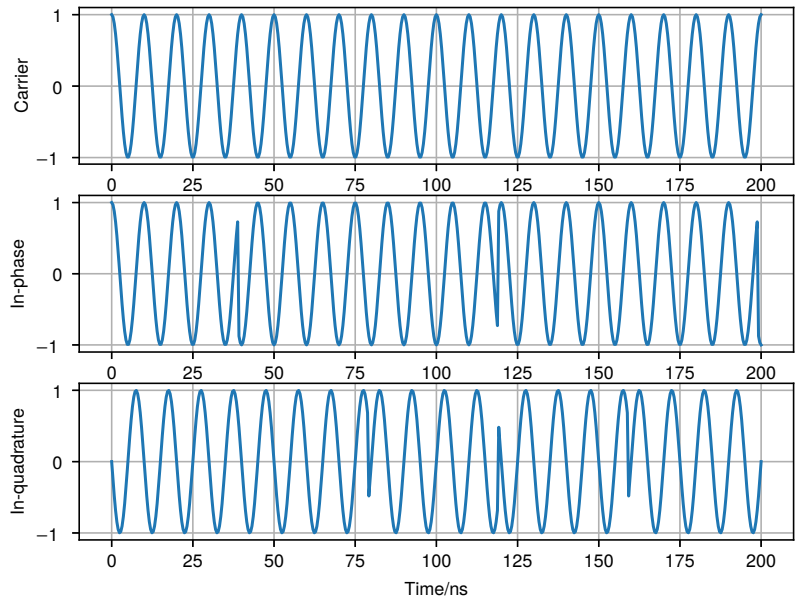

Figure Q2: The carrier, the in-phase and in-quadrature components of a digitally modulated waveform

(a) What is the carrier frequency? [2]

(b) What is the modulation scheme? [3]

(c) If there are no pairs of repeating symbols in Figure Q2, what is the symbol (baud) rate? [3]

(d) The modulation scheme uses Gray coding. Provide a valid digital data string that results in this modulated waveform? [4]

(e) Sketch a constellation diagram for the modulation with the Gray code labels corresponding to your answer to part (d). [3]

Q3. The distribution of the major blood group types in Scotland's population is given in Table Q3.

O+	A+	B+	AB+	O-	A-	B-	AB-
40.9%	28.8%	9.2%	2.7%	9.5%	6.3%	2.0%	0.6%

Table Q3: Major blood group distribution in Scotland's population

(a) Treating this as a symbol set with the given probabilities, calculate the entropy in bits of the complete symbol set. [5]

(b) A new database system is being devised. Determine an optimal Huffman prefix code for the symbol set that minimises the required storage space for the major blood group data. [7]

(c) Compare the storage space requirements for your Huffman code with a simple 3 bit code for the 8 major blood groups and the calculated entropy. [4]

(d) It is decided that, for simplicity, the database should use a simple 3 bit code for the 8 major blood groups, but there are concerns that the data could become corrupted due to single bit errors. Therefore additional parity bits must be included in the database. One of the block codes under consideration has a generator matrix in systematic form, [1]

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

What does the term **systematic** mean in this context?

(e) Determine the 8 valid codewords for this block code. [4]

(f) What is the minimum Hamming distance for this code? [2]

(g) How many single bit errors can be detected in a codeword? [1]

(h) How many single bit errors can be corrected in a codeword? [1]

(i) Determine the parity check matrix for this code? [2]

(j) The codeword 010011 is received. Is this a valid codeword? If not, what is the most likely correct codeword and corresponding input data? [4]

(k) If a requirement of the system is that there should be a probability of 10^{-9} or less of an error in the blood group data after error correction and decoding, what is the maximum single bit error ratio in the database which can be tolerated. [4]

Q4. A transmission channel of a digital communications system based on double sideband modulation has an available bandwidth of 12 MHz.

(a) If the signal to noise ratio corresponds to 8.45 dB, what does the Shannon-Hartley theorem give for the maximum rate at which information can be transmitted over this channel with an arbitrarily low error rate? [3]

(b) Pulse modulation is considered for the communications format in this channel. By using matched filtering, the pulse spectrum is a raised cosine pulse with a roll-off of $\beta = 0.5$. Explain what is meant by the term **matched filter**. [2]

(c) Sketch the pulse spectrum. [5]

(d) If the bandwidth of the pulse spectrum equals the available bandwidth, what is the minimum symbol separation time which suppresses inter-symbol interference? [3]

(e) For the quadrature phase shift keying (QPSK) modulation format, what is the corresponding data rate (bits per unit time) for this communication link? [2]

(f) Now Orthogonal Frequency Division Multiplexing (OFDM) with 4096 (complex coefficient) subcarriers is considered for the same digital communications system with QPSK constellation mapping. Why is it advantageous to have a power of 2, i.e. 2^N, for the total subcarriers, even if a number of them do not carry data? [3]

(g) What is the subcarrier spacing for this OFDM example? [3]

(h) Hence, or otherwise, what is the minimum useful symbol (time) length for this example? [3]

(i) What is the corresponding maximum data (bit) rate? [4]

(j) What practical considerations would result in a data rate somewhat reduced from the ideal case? [4]

(k) Determine an achievable data rate for a typical practical example configuration. [3]

 END OF QUESTION PAPER