University of Glasgow | James Watt School of Engineering

Degrees of MEng, MSc, BEng and BSc in Engineering

Digital Communication 4 (ENG4052)

Friday 13th May 2022
0930–1130 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.
- This is an open book exam and you may consult your notes and any other available reference material. However, you are advised against directly copying from lecture slides or published materials.
- Marks will be awarded on the basis of understanding and application of the subject. Therefore candidates should ensure their answers show all intermediate steps and assumptions in calculations. Answers given without relevant working or justification will receive partial marks only.
- An electronic calculator may be used provided that it does not have a facility for either textual storage or display, or for graphical display.

Selected Mathematical identities

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

Q1. Figure Q1 shows the carrier, the in-phase and the in-quadrature components of a digitally modulated waveform.

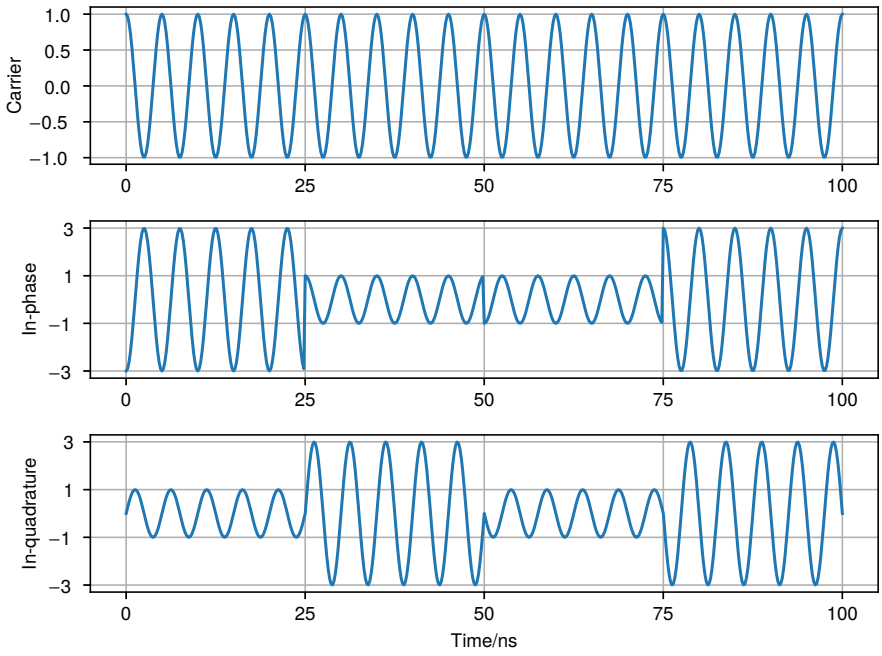

Figure Q1: The carrier, the in-phase and the in-quadrature components of a digitally modulated waveform

(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 Q1, 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]

Q2. Two fair, regular six-sided dice are rolled. The magnitude of the difference between the numbers on the top face is used to provide a set of symbols 0–5.

(a) Determine the probability for each of the symbols in the set. [4]

(b) What is the entropy of this symbol set? [3]

(c) Determine a Huffman binary prefix code for this symbol set. [7]

(d) What is the average number of bits per symbol for this source code? [3]

(e) How does your answer for part (d) compare with the entropy of the symbol set. Is this what you expect? [2]

Q3. A $(n = 15, k = 7)$ BCH code is provided in an octal representation as 721.

(a) How many bit errors in a codeword can be corrected? [3]

(b) Write down the generator polynomial for this code. [2]

(c) Obtain a seven bit binary code by taking modulo 2 of your student number digit by digit. For example, student number 3141592 would provide the binary code 1101110. Find the codeword corresponding to your seven bit code for the BCH code. [6]

(d) Calculate the syndrome corresponding to 2 bit errors in the third and thirteenth position. [7]

Q4.

(a) The acronyms FDD and TDD are used to describe the duplex mode of a mobile network. Specify what each of these acronyms stand for, and provide a brief description on their implementation. [5]

(b) In August 2021, the UK's second 5G spectrum auction (covering spectrum in the 700 MHz and 3.6–3.8 GHz bands) has concluded, and the four main commercial networks have each secured spectrum from it. Describe the relative advantages and disadvantages of these each of these 5G spectral bands. [5]

(c) Provide an example of a useful deployment environment for each of these 5G spectral bands. [4]

Q5. In the following question, you will provide additional specifications for a digital communications channel. The occupied bandwidth (OBW) is limited to 5 MHz. and the channel is required to achieve a communication data bit rate of at least 9 Mbit s^{-1}.

(a) Using the Shannon-Hartley theorem, what is the minimum signal-to-noise ratio required to achieve error-free transmission in this communications channel? [4]

(b) Pulse modulation is considered for the communications format in this channel using a raised cosine pulse with a roll-off. Choose a value for the roll-off β that in your judgement provides a suitable compromise between limiting the occupied bandwidth and damping the wings of the pulse in the time domain and sketch the appropriate pulse spectrum. [5]

(c) Hence, what is the minimum value for the symbol period that allows the inter-symbol interference to be suppressed? [4]

(d) Hence, identify a form of modulation keying that allows the required communication bit rate to be met. [3]

(e) Sketch a constellation diagram corresponding to this modulation format. [3]

(f) Now, Orthogonal Frequency Division Multiplexing (OFDM) is considered for the same digital communications system using an IFFT with 1024 (complex) sub-carriers. Identify a constellation mapping that meets the minimum communication data bit rate requirement. [6]

(g) In addition for symbol start detection, a guard interval (cyclic prefix) of $\frac{1}{4}$ and 64 pilot tones are to be incorporated in each OFDM symbol. Does the identified constellation mapping need to be changed to facilitate the symbol start detection functionality whilst meeting the required data rate? [5]

(h) Should the signal-to-noise ratio prove to be sufficient, higher data communication rates can be used within the same OBW. Identify two methods where the specifications referred to in this question for the OFDM channel can be modified to increase the data rate within the same OBW. [4]

 END OF QUESTION PAPER