University of Glasgow | School of Engineering

Degrees of MEng, BEng, MSc and BSc in Engineering

DIGITAL COMMUNICATIONS 4 (ENG4052)

Tuesday 12th May 2020
Release time: 1400 (BST) for 24 hours
Recommended time for completion: 2 hours

Answer ALL of section A, any ONE question from section B and any ONE question from section C.

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 calculator may be used. Candidates should ensure their answers show all intermediate steps in calculations or otherwise risk a reduction in the awarded marks.

Selected Mathematical identities

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

Section A : Attempt ALL Questions [40 marks]

Q1 (a) Define the term *symbol* as applied to digital communications [2]

(b) For a phase modulated communication signal, sketch the block diagrams and explain the operation of :

i) a quadrature demodulator and, [4]

ii) a typical system for carrier recovery. [4]

Q2 Consider figures Q2(a) and Q2(b) below, which represent the amplitude of a received phase modulated communication signal before and after demodulation respectively. The transmitter was nominally of constant output power.

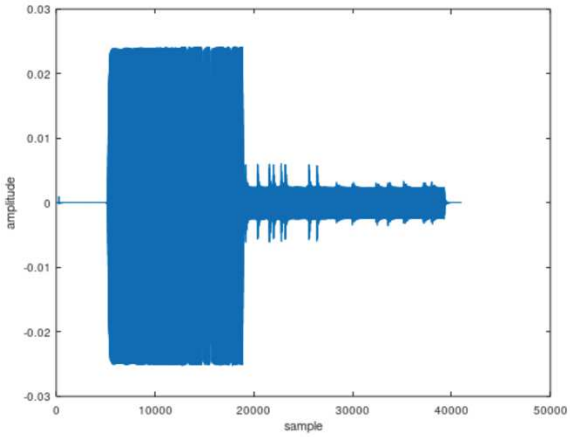

Figure Q2(a)

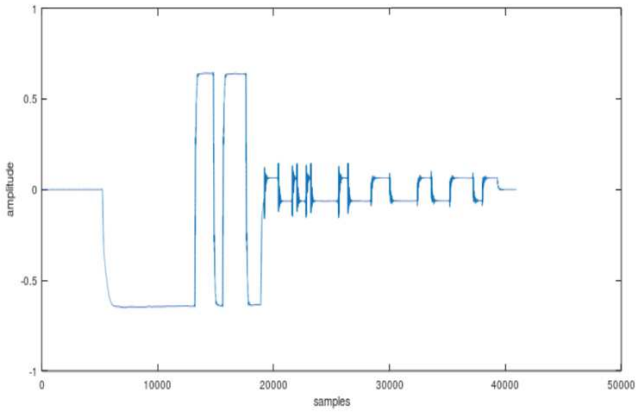

Figure Q2(b)

(a) What are the most important benefits and disadvantages of phase modulation compared with amplitude modulation in practical digital communications systems. [4]

(b) Describe the nature of the imperfection(s) in the received signal of Figure Q2, and indicate possible causes of such imperfection(s). [2]

(c) How could a practical receiver be made more robust to the imperfection(s) described in part (b)? [4]

Continued overleaf

Q3. 4 fair coins are tossed and the outcome is recorded as the number of "heads" visible.

(a) Determine the probability for each possible outcome. [2]

(b) If each outcome represents a symbol in a code, what is the entropy of the code? [2]

(c) Devise a Huffman prefix source code for this symbol set. [4]

(d) What is the average bits per symbol for your Huffman code? How does this compare to the entropy calculated in part (b)? [2]

Q4. For each of the following mobile network systems: GSM, UTMS, LTE and 5G eMBB

(a) Specify which of these network systems contain packet-switched elements and which systems contain circuit-switched elements [3]

(b) Specify which of these network systems employ a form of OFDM? [2]

(c) For the network systems which do not employ a form of OFDM, specify any other techniques used to enable several users to share a band of frequencies. [3]

(d) What are the options for carrying voice traffic where an LTE system is implemented? [2]

Section B: Attempt any ONE questions [30 marks]

Q5 (a) DVB-T uses a sampling rate of 9.1473 MHz for the complex coefficients. Out of the 8192 frequency samples of the (Inverse) Fast Fourier Transform it uses 6818 samples.

i) What is the bandwidth of the DVB-T signal ? [5]

ii) What is the duration of one symbol (without any cyclic prefix)? [5]

(b) One wants to encode 256 bytes / symbol with the help of OFDM. The bytes are coded as 4QAM. The system will be used as a communication system transmitting video and audio from a mobile news gathering vehicle to a central reception point in a major city.

i) How many frequency coefficients are theoretically required to encode this data? [3]

ii) State how many frequency coefficients you would use in a practical system to encode this data, and why your result differs from that of the theoretical value. [7]

(c) The guard interval (also called cyclic prefix) in DVB-T transmission can be set between 1/4 down to 1/16 of the symbol length. Discuss the advantages and disadvantages of different guard intervals, and specifically how a guard interval might be chosen for a mobile news gathering vehicle in an urban versus a rural environment. [10]

Continued overleaf

Q6 Figure Q6 shows the results of two BPSK transmission with carrier recovery using a 2nd generation Costas loop. Transmission shown in Figure Q6(a/b) indicates correct data decoding, whilst transmission shown in Figure Q6(c/d) indicate incorrect decoding. The upper sub-figures show the results of carrier demodulation, and the lower figures show associated VCO control voltages. In each of the questions below, give detailed reasoning for your answers.

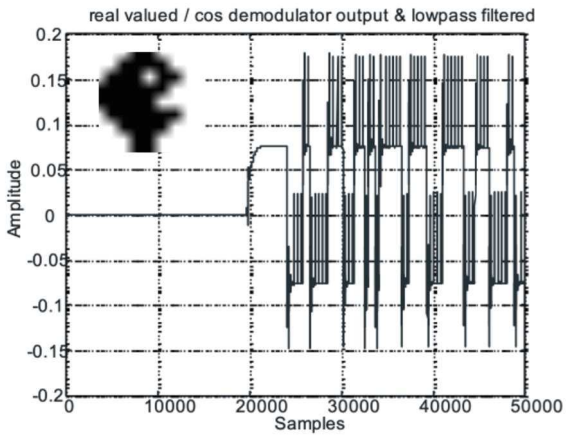

Figure Q6a

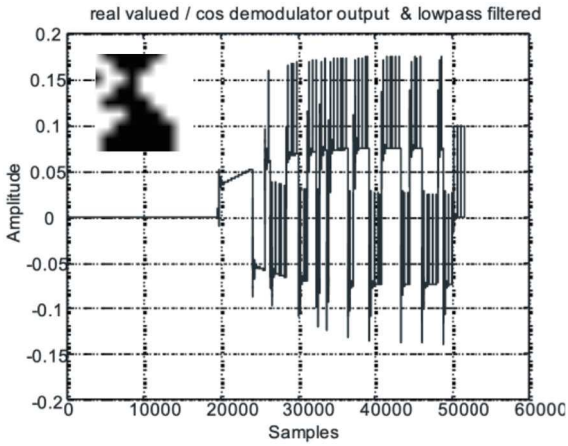

Figure Q6c

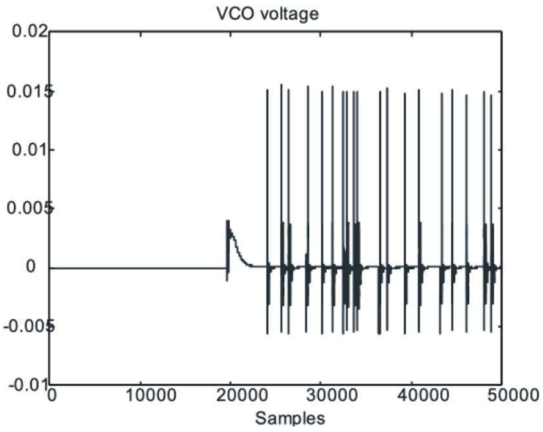

Figure Q6b

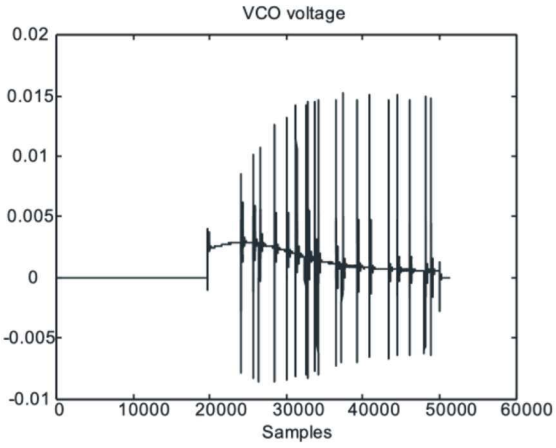

Figure Q6d

(a) Why does the trace, Figure Q6(c) lead to an incorrectly decoded Pacman? [6]

(b) Which parameter(s) is/are most likely to have been tuned incorrectly in the receiver to cause the problems associated with Figures Q6(c) and Q6(d), and how should this/these parameter(s) be altered to correct the problem? [10]

(c) What is the origin of the narrow spikes in the VCO control voltage traces? [8]

(d) If the system the sampling rate is fixed at 10 MHz, how long is required to transmit the complete Pacman when decoded correctly, and in your judgement, what is the shortest time possible for such a transmission? [6]

Continued overleaf

Section C

Answer ONE question

Q7. A $m = 4$ BCH code which can correct $t = 2$ bit errors per codeword, has a generator polynomial given in octal form as 721.

(a) What is the codeword length n for this code? [2]

(b) What is the maximum input data length k for this code? What value do you expect for the corresponding minimum Hamming distance for this code? [4]

(c) Write out the generator polynomial in polynomial form. [1]

(d) Generate seven bit binary data from your student number by calculating (student number) modulo 128. (This can be done by converting decimal to binary and taking the last seven bits, or by dividing in decimal by 128, multiplying the fractional part by 128 and converting to binary.) Hence generate the BCH codeword for this seven bit input data. [6]

(e) Two codewords received after transmission through a noisy channel (taking out the leading zeros) are: [100000111001] and [100000011101]. Calculate the syndrome in each case and identify if either of these correspond to a valid codeword. [9]

(f) In the UK, LTE networks were deployed on new licensed frequency bands EU-DD 791 MHz to 862 MHz and IMT-E 2500 MHz to 2690 MHz. What are the relative advantages and disadvantages of using each of these frequency bands and in what circumstances are each likely to be deployed? [4]

(g) The IMT-E 2500 MHz to 2690 MHz frequency band for LTE is subdivided into FDD 2500 MHz to 2570 MHz and 2620 MHz to 2690 MHz and TDD 2570 MHz to 2620 MHz. Explain the acronyms FDD and TDD and explain how each is utilised in a communications channel. [4]

Q8. A convolutional encoder is shown in Figure Q8, where the two outputs shown are bit interleaved (1 2 1 2. . .) into a single output stream.

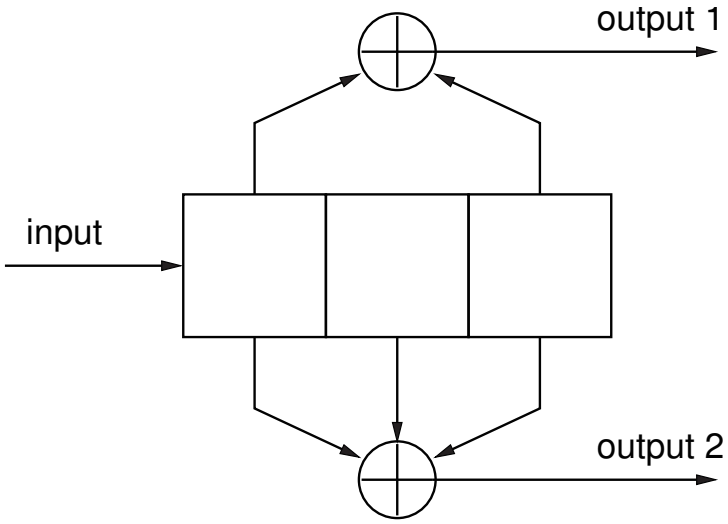

Figure Q8: A convolutional encoder

(a) What is the constraint length of this convolutional code? [1]

(b) What is the rate of this convolutional code? [1]

(c) Is this code recursive or non-recursive? [1]

(d) Is this code systematic or non-systematic? [1]

(e) Draw a state transition diagram for this convolutional encoder. [5]

(f) Generate six bit binary data from your student number by calculating (student number) modulo 64. (This can be done by converting decimal to binary and taking the last six bits, or by dividing in decimal by 64, multiplying the fractional part by 64 and converting to binary.) Using a Trellis diagram, or otherwise, find the convolutional code corresponding to the six bit binary input. You can assume the shift register is initially in the default all-zero state. [6]

(g) A received code, which may contain an error, is 11001000. Using the Viterbi algorithm and a Trellis diagram, determine the most likely binary data sequence that generated this code. [8]

(h) What is the rate 2/3 punctured code corresponding to part (f) using the puncturing matrix $\left(\begin{smallmatrix} 1 & 0 \\ 1 & 1 \end{smallmatrix}\right)$ [2]

(i) Sketch a diagram of an LTE access network; briefly describe the function of each of the component elements. [5]

 END OF QUESTION PAPER