UNIVERSITY OF GLASGOW

Degrees of MEng, BEng, MSc and BSc in Engineering

DIGITAL COMMUNICATIONS 4 (ENG4052)

Tuesday 30 April 2019
14:00-16:00

Time 120 minutes. Total 100 marks

Answer ALL of Section A, and 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.

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

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

Continued overleaf

SECTION A: 40 MARKS

Answer ALL questions

Q1 (a) Define the terms *symbol rate* and *bit rate* applied to digital communications.[4]

(b) How many bits per symbol are transmitted via 4-QAM, and how would you assign bits to the constellation? [3]

(c) The constellation diagrams for 16 Amplitude and Phase Shift Keying (APSK) and 16-QAM are shown in Figure Q1. Under what conditions would APSK be preferable to QAM and vice versa? [3]

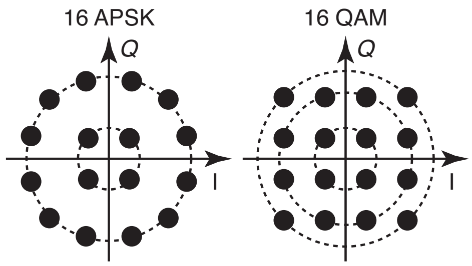

Figure Q1

Q2 (a) Figure Q2 shows a BPSK signal which is encoded with a cosine, and starts at phase zero with a binary '1'. The frequency of the signal is $f = 0.1$ and the symbol interval is $T = 20$ samples. Which bit values have been transmitted? [4]

(b) Sketch the block diagram of a Costas loop designed to recover the carrier from a BPSK system, and describe its operation [6]

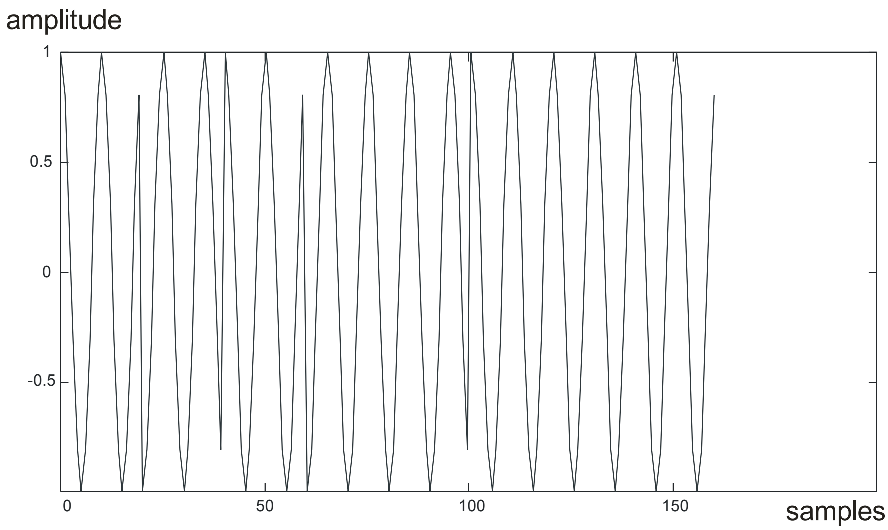

Figure Q2

Continued overleaf

Q3 Figure Q3 shows the principal licensed mobile phone spectral bands currently in use in Europe.

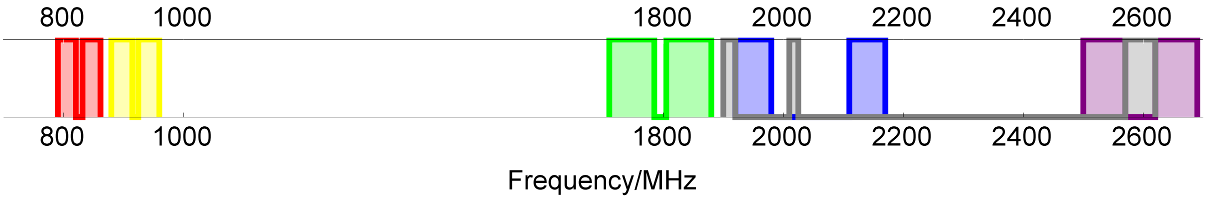

Figure Q3: Mobile phone bands currently in use in Europe

(a) Some of the frequency allocations are shown as pairs of coloured bands. Explain how such pairs of bands are deployed in mobile networks. [3]

(b) Identify the frequency bands used in LTE mobile networks. [3]

(c) Specify the types of channel coding schemes used for forward error correction in LTE mobile networks. [3]

Q4 A convolutional encoder is shown in Figure Q4, where the two outputs shown are bit inter- leaved into a single output stream.

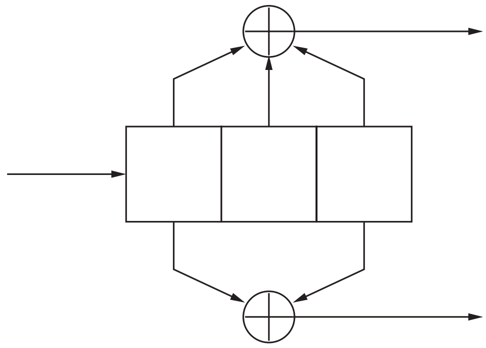

Figure Q4: A convolutional encoder

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

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

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

(d) What is the constraint length for the encoder? [1]

(e) Draw a state transition diagram for this convolutional encoder. [4]

(f) Using a Trellis diagram, or otherwise, find the convolutional code corresponding to the digital input 101. You can assume the shift register is initially in the default all-zero state. [3]

Continued overleaf

SECTION B: 30 MARKS

Answer ONE question

Q5 A Binary Phase Shift Keying (BPSK) phase demodulator with carrier recovery uses a Voltage Controlled Oscillator (VCO) to lock to a carrier signal. The VCO attempts to lock over a period of 2000 time steps before being fixed in frequency. Figure Q5 shows the VCO control voltage and demodulator output for two different demodulator configurations, where the traces A, result in correct image decoding, and the traces B, do not. Note that the time bases of the demodulator and VCO traces are not identical.

(a) Explain which system parameter or parameters are most likely to have been set incorrectly in the right hand trace B, giving reasons for your answer. [7]

(b) Discuss the best practical method of correcting this problem. [3]

(c) The demodulator output is labelled as ‘lowpass filtered’. What is the purpose of this low pass filtering and what is the typical level of filtering required? [6]

(d) In the demodulator outputs, small spikes have been added to indicate when bits are recovered. Discuss the best time to sample and recover bits within a symbol period, sketching the signal to illustrate your discussion. [6]

(e) In many scenarios it might be useful to track the carrier at all times, rather than freezing the VCO. List the challenges in doing this, and provide a possible solution. [8]

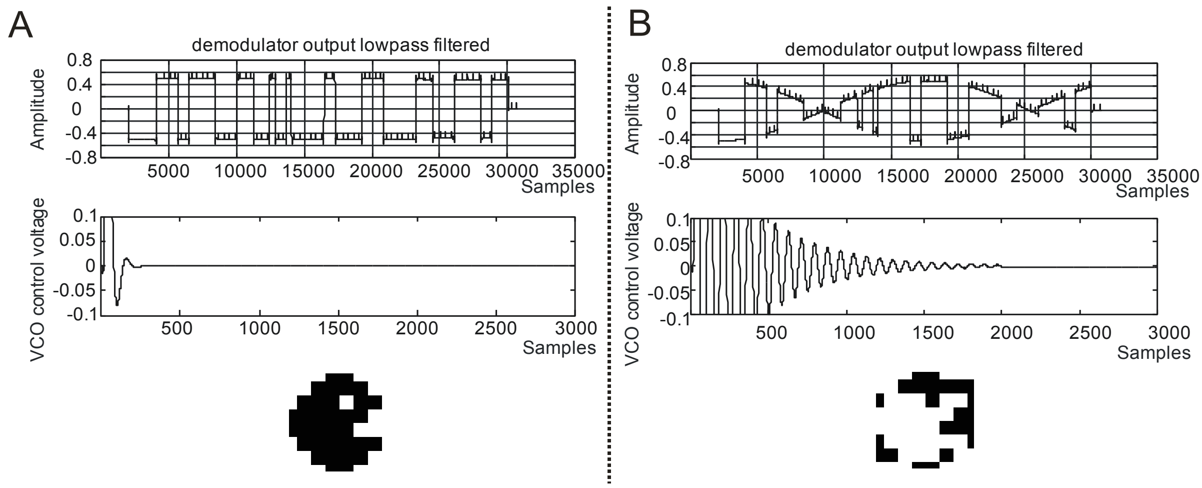

Figure Q5

Continued overleaf

Q6 An image of 120 lines, each comprising 100 pixels coded into single bytes, is transmitted using Orthogonal Frequency Division Multiplexing (OFDM). Each line of the image is to be transmitted as one symbol.

(a) If the number of complex coefficients is to be a power of two, how many coefficients are required, assuming Quadrature Phase Shift Keying? [10]

(b) Describe how a receiver obtains both a coarse estimate and more exact prediction of the start of a symbol in OFDM, and how a signal is modified in the transmitter to allow detection of symbol start. [8]

(c) Are the number of coefficients calculated in part (a) sufficient for a practical OFDM based transmission system? Explain your answer. [6]

(d) If a completely white image was to be transmitted, where might problems occur in this system, and how might those problems be prevented? [6]

Continued overleaf

SECTION C: 30 MARKS

Answer ONE question

Q7 An (n, k) linear cyclic code with $k = 3$ is defined by the generator polynomial $x^6 + x^3 + 1$.

(a) What is the length of the codeword, corresponding to the value of n? [1]

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

(c) Determine all the valid codewords for this code. [5]

(d) What is the minimum Hamming distance for this code? [3]

(e) What is the maximum number of bit errors in a codeword this code would be able to detect? [2]

(f) What is the maximum number of bit errors in a codeword this code would be able to correct? [2]

(g) If the system has a bit error ratio of p, what is the probability of a codeword being wrongly corrected? Assume all possible bit errors are uncorrelated single bit errors only, and $p \ll 1$. [6]

(h) Calculate the syndrome by determining the remainder under modulo 2 division for,

i) a single bit error occurring in position 2,

ii) a single bit error occurring in position 8,

iii) two bit errors occurring in positions 2 and 8 [5]

(i) Carrier Aggregation has been used since deployment of HSPA+ to increase data transmission rates for typical “bursty” applications such as Web browsing or Video streaming. Explain what is meant by the term *Carrier Aggregation* and explain how it provides for increased data rates. [5]

Continued overleaf

Q8. DNA is a molecule which contains the genetic information for life. The information is stored as a sequence of 4 possible nucleotides (bases): Adenine (A), Cytosine (C), Thynine (T) and Guanine (G), all with overall equal probability.

(a) What is the entropy for this base code? [3]

(b) The complete genome for a human being has approximately 3.2×10^9 of these bases. What is the total information content in bits? [1]

(c) A DNA base sequence has been compressed using the Lempel-Ziv-Welch (LZW) coding scheme, with an initial dictionary A:0, C:1, T:2, G:3. The numerical values in decimal for the symbols of the compressed sequence are

1 0 2 3 3 5 4 1 6 2 6 9 8

What is the minimum number of bits corresponding to this compressed sequence? [3]

(d) Decode the compressed sequence to obtain the original base sequence. [8]

(e) What is the information in bits for the decoded sequence? Hence write down the compression ratio for this example. [3]

(f) Is this a useful source coding scheme for extended lengths of random base sequences, where each base occurs with equal probability? Explain your reasoning. [4]

(g) LZW is an example of a lossless source coding. What is the difference between *lossless* and *lossy* source coding schemes? [2]

(h) Give an example of lossy source coding is used in Digital Broadcasting. [2]

(i) What is the main benefit and the main disadvantage by moving to higher order modulation, e.g. 64-QAM (for example, as used in SD digital television broadcasts) to 256-QAM (for example, as used in HD digital television broadcasts)? [4]

End of question paper