UNIVERSITY OF GLASGOW

Degrees of MEng, BEng, MSc and BSc in Engineering

DIGITAL COMMUNICATIONS 4 (ENG4052)

Tuesday 2nd May 2017
09:30–11:30

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) State the most important benefits and disadvantages of phase modulation compared with amplitude modulation in digital communications. [4]

(b) Figure Q1 shows a BPSK signal with a symbol duration of 80 samples.

i) define the term BPSK. [2]

ii) What bit sequence is being coded by this signal? Describe how you arrive at your answer and any assumptions made. [4]

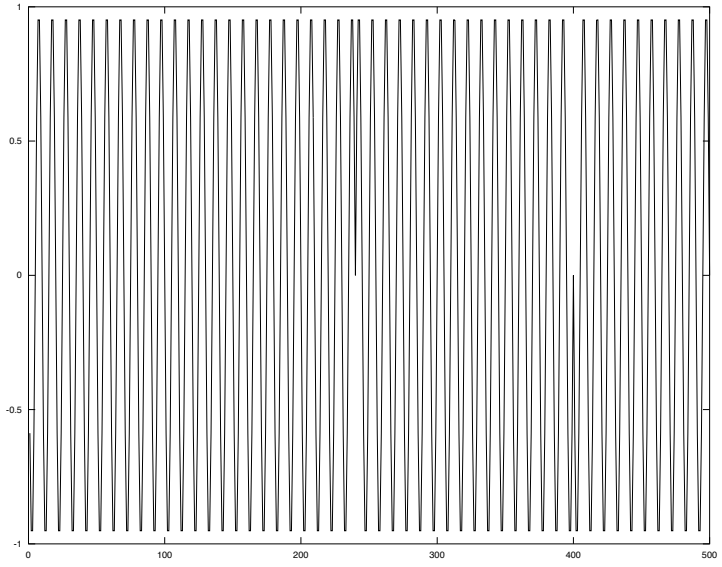

Figure Q1

ANS: (a) key points are lack of carrier transmission in phase modulation. Advantages are no energy to the carrier and constant amplitude (and less complex demodulation than some schemes), whereas the carrier needs to be recovered or generated correctly at the receiver, and despite phase demodulation being simple, nothing is as simple as amplitude demodulation. [4]

(b) i) Binary Phase Shift Keying, two possible phases separated by 180°, one bit per symbol, equivalent to 2-QAM [2]

(b) ii) need to know the encoding of each phase! {1 mark} Student can make choice, but assuming normal sin = 1 and –sin = 0 then the figure encodes 000110 up to 480 samples (and another 0 in the next sample) {3 marks}. [4]

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Q2 (a) How many bits per symbol can be transmitted using 512 point OFDM with QPSK at its inputs if its output is allowed to be complex valued (i.e. fed into a quadrature modulator)? [6]

(b) How many bits per symbol could be transmitted if the outputs are constrained to be real-valued? [4]

ANS: (a) In the case of complex values at the output no mirroring is required {2} so all 512 points can be used {2}. Every input point can have 2 bits because they can be complex {2} so 1024 bits can be transmitted.

(b) In case of real valued output we have 512 bits / symbol because we need to mirror the input.{4}

Section B : 30 marks

Answer ONE question

Q6 The PAL colour encoding system for (now obsolete) analogue television used quadrature encoding with an preliminary transmitted reference carrier.

(a) Sketch a block diagram of a quadrature demodulator, including the building blocks for carrier recovery of a PAL style signal. [10]

(b) Describe in detail the operation of a quadrature demodulator on an input signal $y(t) = s(t)\cos(\omega_c t)$. [8]

More modern digital communications systems employ a Costas loop for carrier recovery.

(c) Resketch your answer to part (a) to include ether a classical or 2nd generation Costas loop. [4]

(d) Figure Q6 shows the output of the voltage controlled oscillator of the Costas loop in a quadrature encoding system. The transmitted symbols are 400 samples long, and two start bits are used in the encoding of each transmitted word.

i) Will the system reliably transmit data? Justify your answer. [5]

ii) How might the characteristic time of the VCO voltage be altered? [1]

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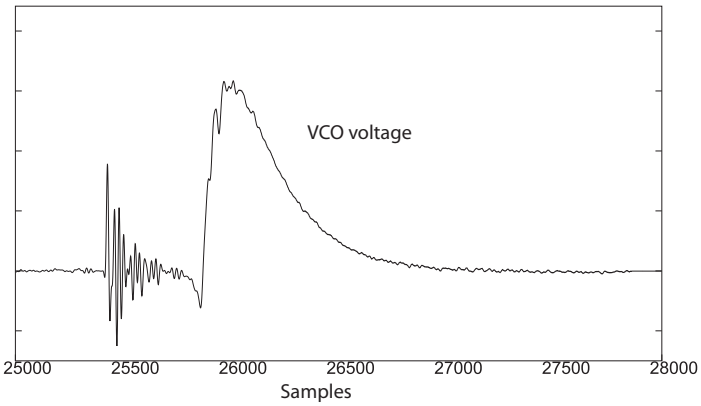
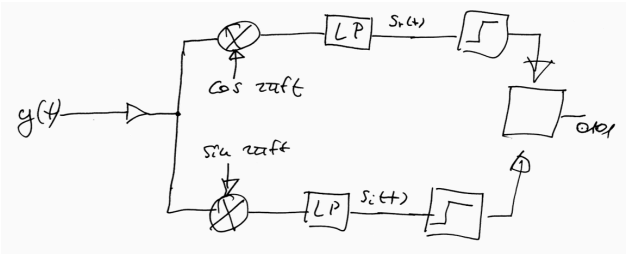
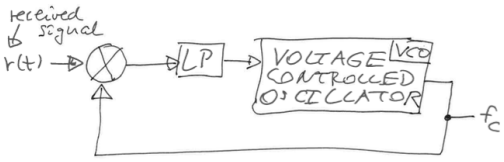


Figure Q6

ANS: (a) because the reference carrier is transmitted first, can use a PLL to recover the carrier and then lock it, separating the creation and use of f_c.

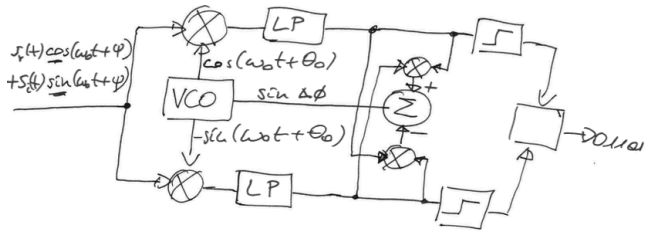


{6}



{4}

(b) signal $s(t)\cos(\omega_c t)$ multiplied by $\cos(\omega_c t)$ to give $\frac{1}{2}s(t)+\frac{1}{2}\cos(2\omega_c t)$ {2} and then LP filtered to recover *s(t)* at baseband {2}. Quadrature does this for the real and imaginary parts of the signal {2} and then decision maker can sample at symbol frequency {1} and translate into data at double the bits per symbol than without quadrature {1}. [8]



(c) second gen version. [4]

(d) i) ignoring the initial noise {1} critically it will take 800 samples for the start bits to be transmitted, at which point the VCO will be within 10% of its final full lock {3}. Under these conditions, reliable transmission is probable, although with less reliability than if the system were completely locked. {1} [5] ii) increase the gain of the VCO. [1]

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Q7 (a) Summarise the main features of FDMA, TDMA and CDMA communication techniques, and list the advantages of each in practical communication systems. [10]

(b) You wish to transmit an 8 bit image of 256×320 pixels with the help of OFDM, where every line of the image will be one symbol. The sampling rate of the system is 4.096 MHz

i) How many complex frequency coefficients *X(k)* (including the mirror) are needed if the number of coefficients should be a power of two, the modulation for every coefficient *X(k)* is QPSK and there are coefficients left free for the insertion of pilot tones? [6]

ii) Sketch the form of the coefficients of part i) in an *X(k)* plot. [4]

iii) What is the minimum carrier frequency spacing in this system? [3]

(c) In OFDM reception, finding the start of the symbol is a challenge. Describe how the transmitted signal is altered to aid the process of finding the start off the symbol. [7]

ANS: (a) Frequency division of the spectrum either by fixed frequencies or hopping {2} and time division multiplexing of data into chunks {1} compared with code division multiplexing where the symbol stream is modulated by a pseudorandom sequence with a spread spectrum and may users overlapped, but separated by the pseudorandom codes {2}. Theoretically they are identical {2} but in practice CDMA advantages include {up to 3 marks} less intersymbol interference, no need for complex TDMA temporal ordering, continuous power stages in transmitters, better resistance to multipath fading, more graceful degradation, less bandwidth expansion due to forward error correction and Doppler spreading, usefulness in military/encryption situations, no built in limit to the number of users.

(b) i) 256 pixels of eight bits each {2}, with QPSK allowing 2 bits per coefficient {2} = 1024x2 coefficients including mirroring {1}. So 4096 needed if additional pilot tones to be included {1} [6]

(b) ii) either the following, or with spikes in the spectrum including the pilot tones[4]

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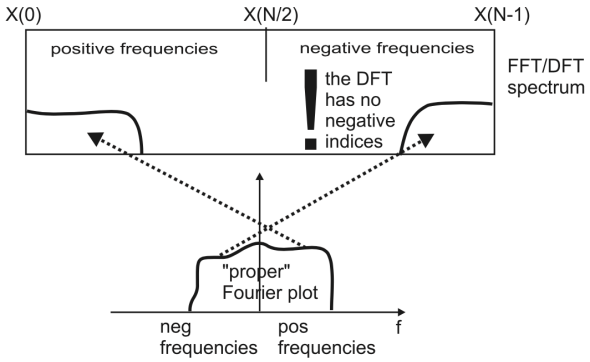
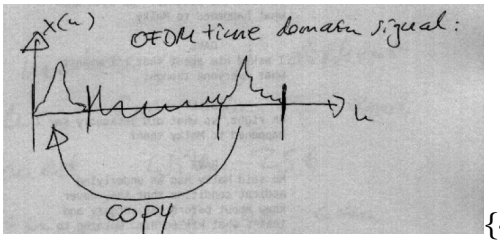


(b) iii) 4096 is the symbol length in samples, so a whole symbol is 1 ms and the carrier frequencies should be spaced 1 kHz apart [3]

(c) Cyclic prefix {2}. To find the beginning minimise {1} e(n) = $(X(n)-X(n-k))^2$



{4} [7]

End of question paper