ES3350

THE UNIVERSITY OF WARWICK

Third Year Examinations: Summer 2012

COMMUNICATIONS SYSTEMS

SECTION A

SECTION B

Candidates should answer FOUR QUESTIONS.

Time Allowed: 3 hours.

Only calculators that conform to the list of models approved by the School of Engineering may be used in this examination. The Engineering Databook will be provided.

Read carefully the instructions on the answer book and make sure that the particulars required are entered on each answer book.

PLEASE USE A SEPARATE ANSWER BOOK FOR EACH SECTION

SECTION A

1. A signal which occupies a baseband spectrum from 300 Hertz to 3.5 kHz is used to modulate a carrier at a frequency of 10 MHz using:
   (a) Full amplitude modulation (AM) with carrier;
   (b) double sideband AM with suppressed carrier;
   (c) vestigial sideband AM with only 1 kHz of bandwidth for the lower sideband.

   If any modulating frequency may be used within the baseband spectrum and it is a sinewave, and its maximum, peak amplitude, is 10 volts (peak-to-peak = 20 volts), and the peak carrier amplitude is 15 volts, then draw the spectrum for each of the cases (a) to (c) above.

   (10 marks)

   Also determine the ratio X, where:

$$X = \frac{\text{(Power in sidebands)}}{\text{(Total transmitted power)}}$$

   for <u>each</u> of these three cases, for modulation frequencies of (i) 500 Hertz, and (ii) 3 kHz, assuming that all powers are calculated with respect to a standard 50 Ω load resistance.

   (6 marks)

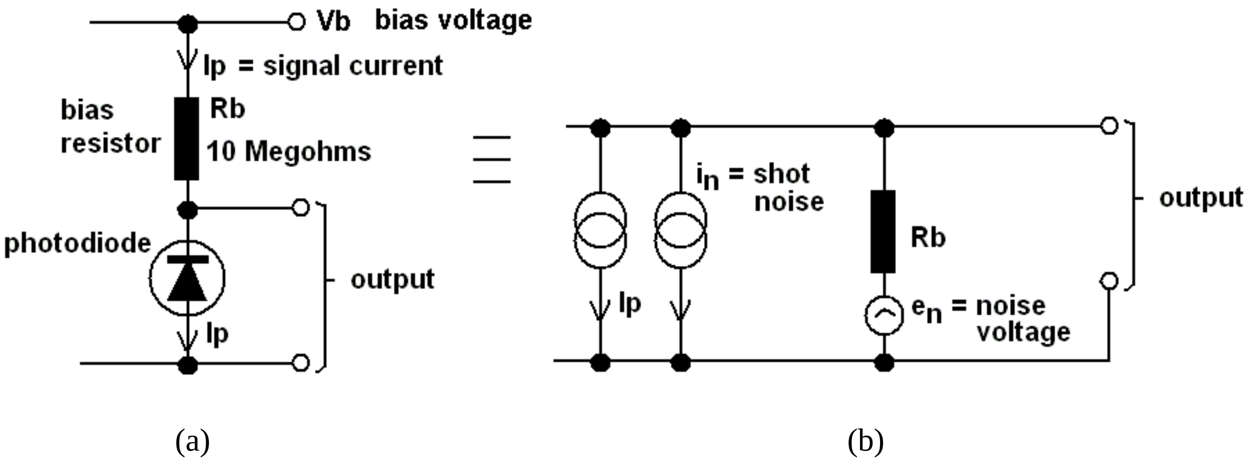
   State which modulation type you would choose and briefly say why, for the following applications:
   (d) Long distance communication around the world using radio equipment in the home powered by the mains electricity supply.
   (e) Mobile telephony with a range of around 3 km, where power consumption is very critical as battery life is limited due to space restrictions in the phone, and also cost is an important factor in the phone.
   (f) Domestic, consumer radios, for entertainment and news, where the cost of the equipment must be kept to a minimum, more than any other factors in the overall design.

   (9 marks)

2. (a) Three stages of a communication channel have three different power gains, being: (i) 40 dB, with a noise figure of 10 dB, (ii) 35 dB, with a noise figure of 7 dB, and (iii) 40 dB, with a noise figure of 11 dB. Determine the noise figure in dB for the sequence of stages which gives the best overall noise figure, and also determine the overall gain of the channel. (12 marks)

   (b) Next, determine the best sequence of stages if a fault occurs with configuration (ii) (i.e gain of 35 dB, noise figure of 7 dB) if this stage suddenly becomes noisier, and its noise figure increases to 10 dB but the gain remains the same at 35 dB. (3 marks)

   (c) A simple optical receiver front end is shown below in Figure 1(a) below, and simply consists of a reverse-biased photodiode. The photodiode can be regarded as a current source producing an electrical signal current, **Ip**, and also a shot noise current, $\mathbf{i_n}$, as shown in Figure 1(b). The bias resistor, **Rb**, also produces a thermal (Johnson) noise voltage $\mathbf{e_n}$. Determine which noise is the greater at the output of the front end, if the signal current, **Ip**, due to the photodiode, is 50 μA and the room temperature is 300K, in an overall channel bandwidth, Δf = 10 MHz. (Boltzmann's constant = 1.38×10^{-23} JK^{-1}, and q = 1.6×10^{-19} C).



(a) (b)

Figure 1

Hint: consider the Thévenin-Norton transformation, as both noise sources are expressed differently.

(10 marks)

3. (a) Demonstrate the principle of coherent detection (i.e demodulation) of a Double Sideband Suppressed Carrier AM wave using a diagram and analysis, if the carrier signal is Ect = 100 cos (ω_1t), and $\omega_1 = 2\pi \times 145 \times 10^6$, which is modulated using a waveform Em = 50 cos (ω_2t), where $\omega_2 = 2\pi \times 3 \times 10^3$. Determine the output signal components if a local carrier is available at the receiver defined by: Ecr = 0.1 cos (ω_1t). (10 marks)

   (b) Suppose an unmodulated carrier signal i.e. E_{ct} = 100 cos (ω_1t) is now transmitted without any modulation by ω_2 and is accompanied by a noise voltage $v_n(t)$ by the time it is received by the coherent detector/demodulator mentioned above. Show that the process of demodulation of this carrier signal using coherent detection has the benefit of actually improving the SNR at the output relative to that at the input of the demodulator, and show how much, assuming that any filter at the final output of the demodulator has just sufficient bandwidth to allow the required signal components through it.

   (11 marks)

   (c) Briefly explain which types of noise are ignored by an AM detector, and which types of noise are ignored by an FM detector. (4 marks)

SECTION B

---

4. (a) Explain, the main processes necessary to produce a uniform pulse code modulation (PCM) signal, namely *sampling, quantisation and encoding*. (3 marks)

(b) Explain what is meant by quantisation noise, q, and show that its mean power, σ_Q^2, using a uniform quantisation step of Δv, is given by:

$$\sigma_Q^2 = \frac{(\Delta v)^2}{12}$$

(10 marks)

(c) An analogue signal v(t) is applied to a uniform PCM device that employs M quantisation levels. Show that the signal to quantisation error ratio (sqer), given by the ratio of the mean squared signal level to the mean squared quantisation noise, is given by:

$$sqer = \frac{3M^2}{\alpha}$$

where N is the number of quantisation levels and α is the peak power to mean power ratio of v(t).

(6 marks)

(d) A signal with a mean power of 5 mW is applied to a PCM device, which encodes it using 8-bit quantisation. Find the peak amplitude of the signal when the sqer is 40 dB.

(6 marks)

---

5. (a) Explain what is meant by the terms amplitude response and group delay in the context of transmission systems. (5 marks)

(b) Show that an idealised communication system should exhibit a constant amplitude response and group delay over the bandwidth of the signal being transmitted. (5 marks)

(c) A time domain function, $x(t) = \delta(t)$, is applied to a communication channel with a transfer function given by:

$$H(f) = \begin{cases} 0 & f < -B/2 \\ 1 & -B/2 \le f \le B/2 \\ 0 & f > B/2 \end{cases}$$

where B is a constant with the units of Hertz.

Determine:

(i) The spectrum at the output of the channel.

(2 marks)

(ii) The mean noise power at the channel output when white Gaussian double-sided noise with power spectral density (PSD) $N_0/2$ WHz^{-1} is present at the input.

(4 marks)

(iii) The signal to noise ratio at the channel output when a matched filter is used at the receiver.

(5 marks)

(d) Find the mean noise power at the output using the matched filter arrangement above when $B = 4$ kHz and $N_0/2 = 10^{-8}$ WHz^{-1}.

(4 marks)

6. (a) Compression and encryption are two common operations performed on data streams. When it is desired to implement both of these processes, justify the order in which they should be performed. (3 marks)

(b) A mod 7 source, Y, emits a sequence of symbols that are logged to form Table 1 below

Table 1

Symbol	0	1	2	3	4	5	6
Occurrences	8	45	15	8	8	8	8

Estimate the entropy of Y by assuming that it may be modelled by a discrete memoryless source (DMS) model. (8 marks)

(c) The source Y above is encrypted to form the Z by mod 7 addition (with no carry) so that the symbols are observed distributed as in Table 2.

Table 2

Symbol	0	1	2	3	4	5	6
Occurrences	15	14	14	13	15	14	15

Again estimate the entropy of Z by assuming it is a DMS. (7 marks)

(d) Determine the maximum compression ratios theoretically possible for Y and Z using the models above and comment on how successful the encryption has been in terms of its intended effect on the entropy. (7 marks)
