MACQUARIE
UNIVERSITY ~ SYDNEY

END-OF-YEAR EXAMINATIONS 2004

Unit:	**ELEC321 Communication Systems (D2)**
Day and Time:	Friday, 19 November 2004, 9:20 a.m.
Time Allowed:	Three hours plus 10 minutes reading time.
Total Number of Questions:	SIX (6)
Instructions:	Answer any **FIVE** (5) questions only.
	Total marks for this paper: 100. The questions are of equal value. Use one or more examination booklets. Non-programmable electronic calculators may be used. No dictionaries permitted.

1. Miscellaneous

Write concise but informative notes explaining the significance, in the context of communication systems, of the following terms.

(a) **(3 marks)** 'convolution'

(b) **(3 marks)** 'synchronous demodulation'

(c) **(3 marks)** 'Nyquist sampling criterion'

(d) **(3 marks)** 'companding'

(e) **(3 marks)** 'predictor' for 'differential PCM'

(f) **(2 marks)** 'limiter'

(g) **(3 marks)** 'eye pattern'

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2. Fourier Analysis; Intersymbol Interference

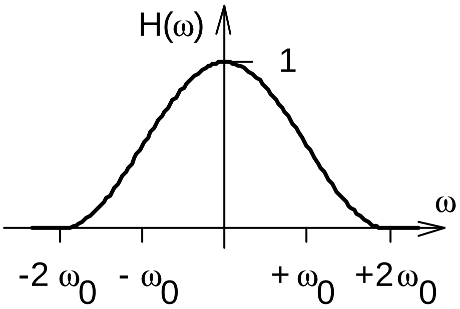


Fig. 2 Raised-cosine Filter

(a) (15 marks)

The raised-cosine filter of Fig. 2 has the frequency response

$$H(w) = ½ + ½ \cos\left(\frac{w}{w_0} \times \frac{\pi}{2}\right) .$$

Prove that the impulse response is given by

$$h(t) = \frac{\sin(2w_0 t)}{2\pi} \times \frac{-\left(\frac{\pi}{2w_0}\right)^2}{t \times \left[t^2 - \left(\frac{\pi}{2w_0}\right)^2\right]}$$

$$= \frac{w_0}{\pi} \times \frac{\sin w_0 t}{w_0 t} \times \frac{\cos w_0 t}{1 - \left(\frac{2w_0}{\pi} t\right)^2}$$

(Hints: At an early stage in your proof, use the identity

$$\cos q = ½\, e^{jq} + ½\, e^{-jq}$$

and, at a later stage, make use of

$$\sin(x + \pi) = \sin(x - \pi) = -\sin x$$.)

(b) (5 marks)

What feature of this response does this filter share with a brick-wall filter response, and why is this feature important in dealing with intersymbol interference?

3. Modulation Systems

(a) (14 marks)

Figures 3A - 3G show block diagrams of a variety of modulation systems.
Explain what form of modulation each illustrates, briefly giving reasons for your answers.

Fig. 3A

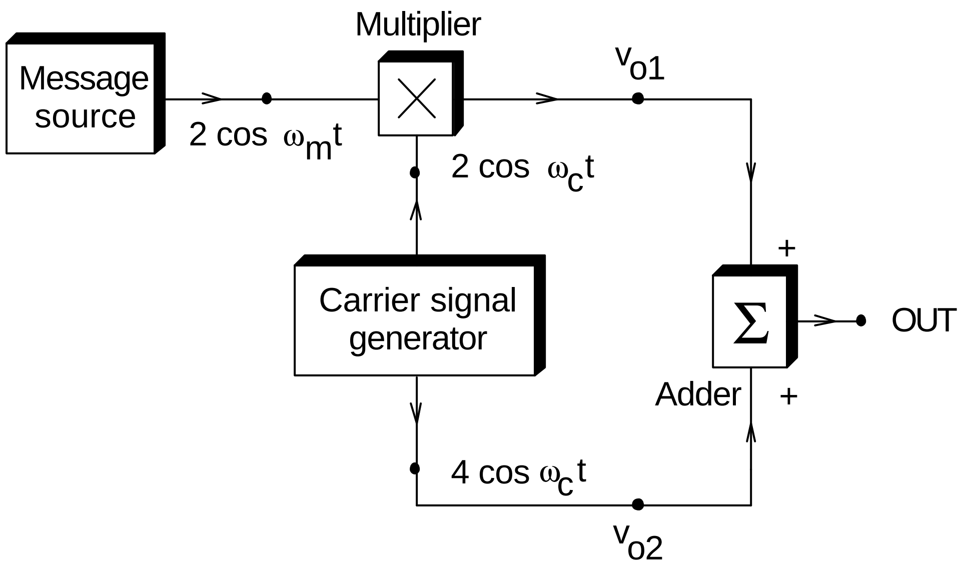


Fig. 3B

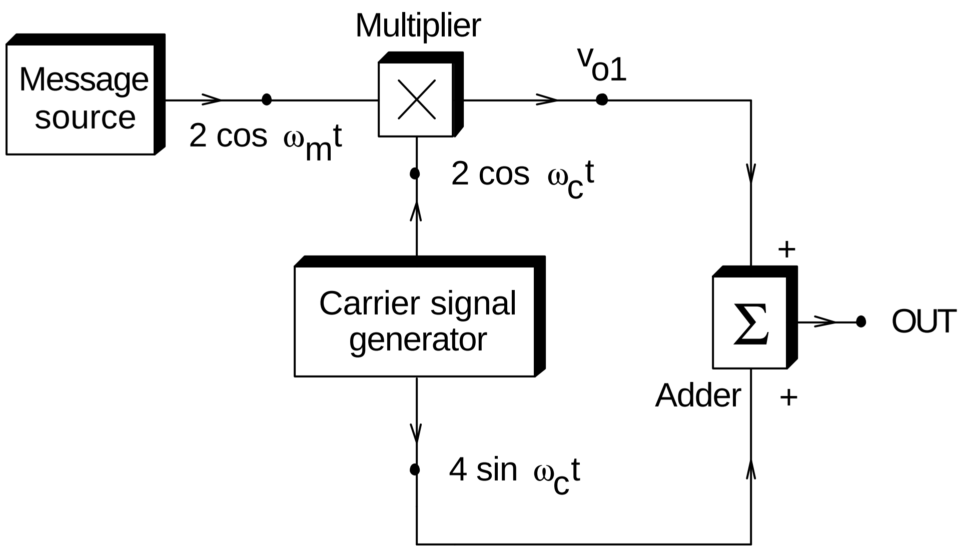


Fig. 3C

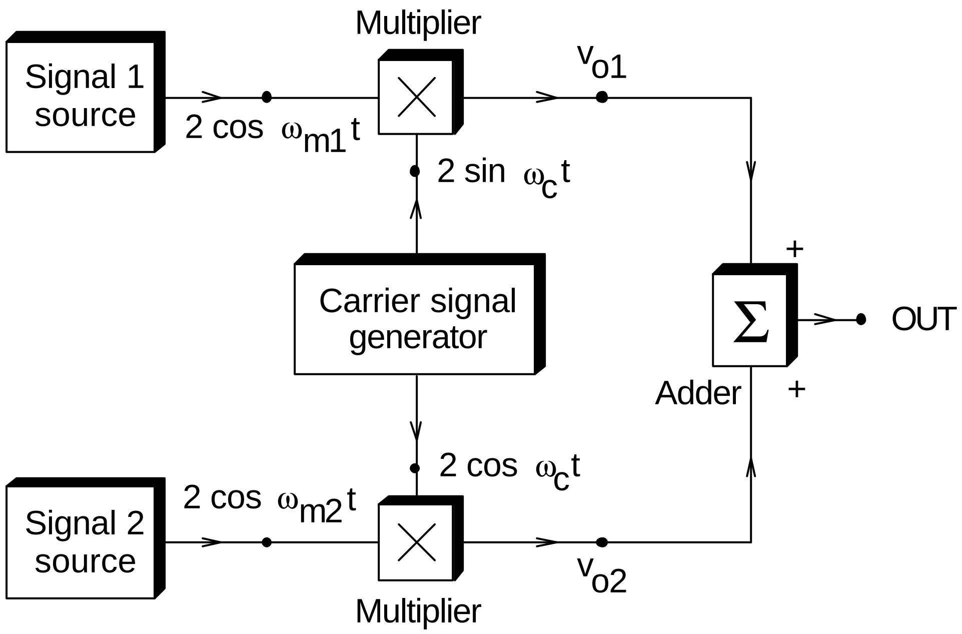


Fig. 3D

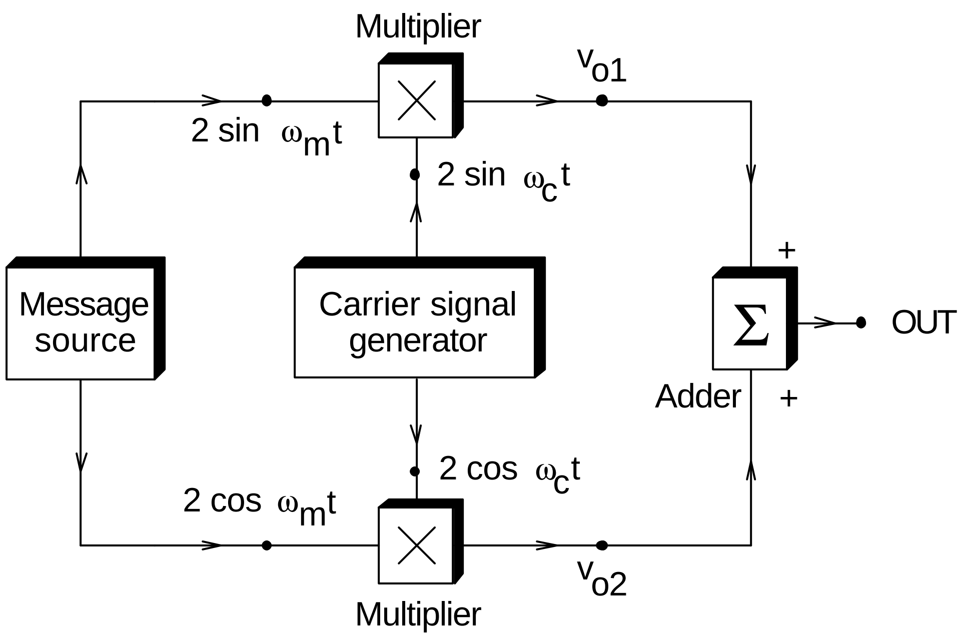


Fig. 3E

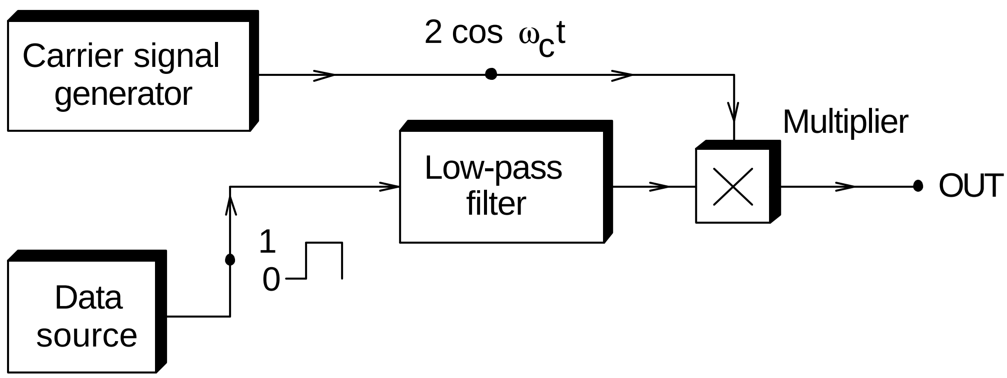


Fig. 3F

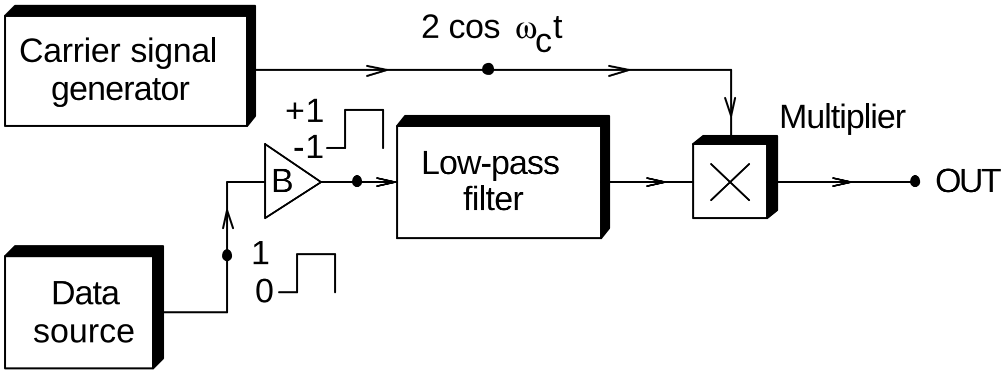
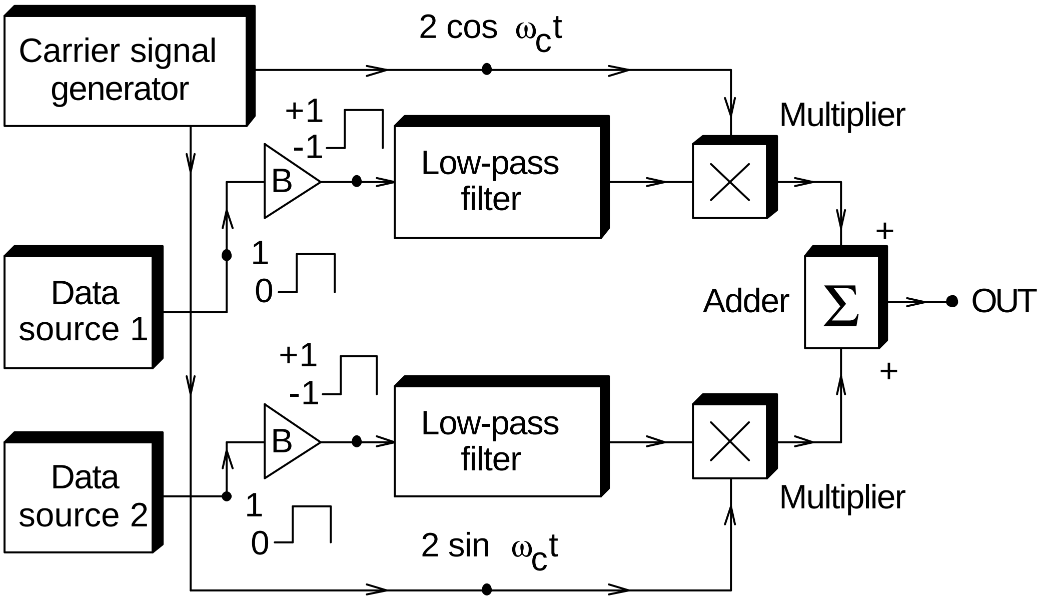


Fig. 3G



(b) (3 marks)

Give a mathematical justification of your answer for Fig. 3A, and calculate the modulation index.

(c) (3 marks)

Use a phasor (vector) diagram to justify your answer for Fig. 3B, and estimate the modulation index.

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4. Line Coding and Waveform Shaping

(a) (13 marks)

Line coding is a technique to convert a sequence of binary digits into a sequence of suitable waveforms for transmission. Describe the difference between a return-to-zero (RZ) and a non-return-to-zero (NRZ) waveform format. Given a binary sequence 1 1 0 0 0 1 0 1 1 1, describe and explain with diagrams what the polar NRZ signal, the bipolar NRZ signal and the Manchester-coded signal are, and indicate their respective advantages and disadvantages.

(b) (7 marks)

A telephone channel allows signal transmission in the range 600 Hz to 3300 Hz. 9600 bits per second of data are to be transmitted over this channel. If 20% sinusoidal roll-off shaping is used, prove that, with 16-point QAM, the desired transmission bit rate cannot be achieved.

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5. ASK Link Error Probability

(a) (12 marks)

An M-ary amplitude-shift-keying (M-ASK) signal symbol can be defined by

$$s(t) = \begin{cases} A_i \cos(2\pi f_c t), & 0 \le t \le T \\ 0, & elsewhere \end{cases}$$

where

$$A_i = A[2i - (M - 1)]$$

for $i = 0, 1, ..., M-1$. Here A is a constant, f_c is the carrier frequency, and T is the signalling interval.

The signal constellation for M-ASK signal symbols is shown in Fig. 5.

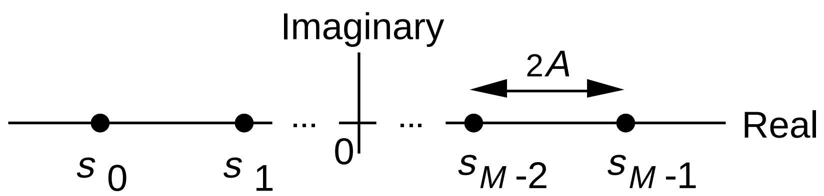

Fig. 5 Signal constellation for M-ASK signals

Use the signal constellation diagram to derive an expression for the probability of symbol error in the presence of additive white Gaussian noise as a function of A and the mean square noise power, N. It is to be assumed that the signal symbols are equally likely to be transmitted.

(b) (8 marks)

A 4-ASK communication system has a bit rate of 20 Mbit/s. If A = 80 mV, and the symbol error probability is 1.95×10^{-10}, calculate the noise power spectral density, N_0, in W/Hz.

Assume that power and energy per symbol are normalised to a 1-ohm load.

[Hint: use the approximation $erfc(\sqrt{20}) \approx 2.60 \times 10^{-10}$.]

6. Information Capacity and Coding

(a) (6 marks)

The channel capacity of a continuous channel of bandwidth W Hz, perturbed by bandlimited Gaussian noise of power spectral density $n_0/2$, is given by

$$C_c = W \log_2(1 + \frac{S}{N})$$

where S is the average transmitted signal power and N is the average noise power. Show that the channel capacity of an ideal additive white Gaussian channel with infinite bandwidth is given by

$$C_c = \frac{S}{n_0} \log_2 e = 1.44 \frac{S}{n_0}.$$

(b) (4 marks)

Write down the Huffman and Shannon-Fano encoding procedures for a discrete memoryless source with symbols x_i and corresponding probabilities p_i, $i = 1, 2, ..., m$.

(c) (10 marks)

In a binary single-parity-check code, the parity-check symbol v_k may be written as

$$v_k = u_0 + u_1 + ... + u_{k-1}$$

where k is the number of information symbols, u_i is the information symbol for $0 \leq i \leq k - 1$ and + implies modulo-2 addition.

(i) For $k = 3$, write down all the codewords in the code.

(ii) Which error patterns can the code detect?

(iii) Compute the probability of an undetected symbol error using this code on a binary symmetric channel, assuming that all symbol errors are independent and that the probability of symbol error is $p = 0.01$.
