



DEPARTMENT of ELECTRICAL and ELECTRONIC ENGINEERING  
EXAMINATIONS 2002

M.Sc and EEE/ISE PART IV: M.Eng. and ACGI

## ADVANCED COMMUNICATION THEORY

- *There are FOUR questions (Q1 to Q4)*
- *Answer Question ONE plus TWO other questions.*
- *Distribution of marks*
  - Question-1: 40 marks*
  - Question-2: 30 marks*
  - Question-3: 30 marks*
  - Question-4: 30 marks*

### *Comments for Question Q1:*

- *Question Q1 has 20 multiple choice questions numbered 1 to 20.*
- *Circle the answers you think are correct on the answer sheet provided.*
- *There is only one correct answer per question.*

*The following are provided:*

- *A table of Fourier Transforms*
- *A "Gaussian Tail Function" graph*

**Information for candidates:**

The following are provided:

- a table of Fourier Transforms;
- a graph of the 'Gaussian Tail Function'.

Question 1 is in a separate coloured booklet which should be handed in at the end of the examination.

You should answer Question 1 on the separate sheet provided. At the end of the exam, please tie this sheet securely into your main answer book(s).

**Special instructions for invigilators:**

Please ensure that the five items mentioned below are available on each desk.

- the main examination paper;
- the coloured booklet containing Question 1;
- the separate answer sheet for Question 1;
- a table of Fourier Transforms;
- a graph of the Gaussian Tail Function.

Please remind candidates at the end of the exam that they should tie their Answer Sheet for Question 1 securely into their main answer book, together with supplementary answer books etc.

Please tell candidates they must **NOT** remove the coloured booklet containing Question 1. Collect this booklet in at the end of the exam, along with the standard answer books.

- 1.** *This question is bound separately and has 20 multiple choice questions numbered 1 to 20, all carrying equal marks .*

*You should answer Question 1 on the separate sheet provided.*

*Circle the answers you think are correct .*

*There is only one correct answer per question.*

- 2.** Consider an  $M$ -ary amplitude shift keyed signal set described as follows:

$$s_i(t) = A_i \cos(2\pi F_c t), \quad i = 1, 2, \dots, M, \quad 0 < t < T_{cs}.$$

$$\text{with } \begin{cases} M = 4 \\ A_i = (2i - 1 - M) \times 10^{-3} \text{ Volts} \\ T_{cs} = 2 \text{ second} \\ \text{the symbols are equally likely.} \end{cases}$$

- a) Draw a properly labelled block diagram of the MAP correlation receiver when the signals are corrupted by additive white Gaussian noise having a double-sided spectral density of  $10^{-6}$  Watts/Hz. [9]
- b) Plot the constellation diagram and properly label the decision regions. [6]
- c) Model the whole system as a discrete communication channel. [12]
- d) Find the bit error probability  $p_e$ . [3]

- 3.** Consider a binary message signal of rate 8 kbits/s at the input of a fully synchronized direct sequence spread spectrum system (DS/SSS) which employs a binary PSK modulator and a matched filter receiver. The system operates in the presence of both additive white noise,  $n(t)$ , and a broadband noise jammer,  $j(t)$ , of power 1 Watt. The double sided power spectral density of the noise is  $10^{-12}$  Watts/Hz and the processing gain of the system is  $10^5$ . The bit error probability at the output of the receiver is equal to  $4 \times 10^{-6}$  while the protection probability is equal to  $4 \times 10^{-2}$ .

- a) What is the amplitude  $A$  of the sinewaves which are used by the binary PSK modulator? [9]
- b) What is the bit error probability if the jammer switches to: [12]
  - a partial noise jammer mode with the same power but with this being uniformly distributed over 40% of the signal bandwidth
  - a pulse jammer mode, transmitting "broadband noise" which is "on" for 40% and "off" for 60% of the time?
- c) What is the Anti-jam Margin, in dBs, when the jammer switches to the above-mentioned different modes? [9]

4. For a binary pulse-code-modulation (binary-PCM) system, which employs an ideal sampler, a uniform Q-level quantizer, a Binary-Coded-Decimal (BCD) source encoder and a digital modulator, the average signal-to-noise power ratio ( $\text{SNR}_{out}$ ) at the output of the receiver is given by:

$$\text{SNR}_{out} = \frac{2^{2\gamma}}{1 + 4p_e 2^{2\gamma}}$$

where  $p_e$  depends on the modulation scheme being used and  $\gamma$  is the number of bits per codeword.

Suppose the modulation scheme being used is described as follows:

“The input to the digital modulator is a binary sequence of 1s and 0s with the number of 1s being twice the number of 0s. The binary sequence is transmitted as a pulse signal  $s(t)$  with a one being sent as  $6 \cdot \text{rect}(\frac{t}{T_{cs}})$  and a zero being sent as  $0 \cdot \text{rect}(\frac{t}{T_{cs}})$ .”

The channel noise is assumed to be additive Gaussian of zero mean and variance 1 i.e.  $N(0,1)$ .

- a) Plot the probability density function of  $s(t)$  [1.5]
- b) Plot the probability density function of  $r(t) = s(t) + n(t)$  [1.5]
- c) Identify the likelihood functions  $p_0(r)$  and  $p_1(r)$  [1.5]
- d) Design a Bayes Detector (i.e. decision rule) with the following costs

$$C_{00}=C_{11}=0; C_{10}=0.9; C_{01}=0.1. \quad [9]$$

- e) For the above Bayes detector, estimate the

- i) the false alarm probability [3]
- ii) the probability of a miss [3]
- iii) the bit error probability  $p_e$ . [4.5]

- f) If the above Bayes Detector is used in the receiving part of the PCM system, what is the number,  $\gamma$ , of bits per codeword at the output of the source encoder for which threshold occurs at the output of the receiver? [6]

N.B.: The threshold point is the value of the signal-to-noise ratio at the input of the receiver at which  $\text{SNR}_{out}$  falls 1dB below the value  $2^{2\gamma}$  ( $2^{2\gamma}$  is the maximum value of  $\text{SNR}_{out}$ ).