UNIVERSITY OF LONDON [MSc-SC2, E4.01, ISE4.11]
IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE

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***

Examiners responsible: Dr. A. Manikas

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:

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

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

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 4×10^{-6} while the protection probability is equal to 4×10^{-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 (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 γ 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 $6.\text{rect}(\frac{t}{T_{cs}})$ and a zero being sent as $0.\text{rect}(\frac{t}{T_{cs}})$."

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

$C_{00}=C_{11}=0$; $C_{10}=0.9$; $C_{01}=0.1$. **[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, γ, 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 SNR_{out} falls 1dB below the value $2^{2\gamma}$ ($2^{2\gamma}$ is the maximum value of SNR_{out}).