OLLSCOIL NA hÉIREANN, CORCAIGH
THE NATIONAL UNIVERSITY OF IRELAND, CORK

COLÁISTE NA hOLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

AUTUMN EXAMINATIONS, 2005

B.E. DEGREE (ELECTRICAL)
B.E. DEGREE (MICROELECTRONIC)
M.ENG.SC. DEGREE (MICROELECTRONIC)

TELECOMMUNICATIONS
EE4004

Professor Dr. U. Schwalke
Professor R. Yacamini
Professor P. J. Murphy
Dr. K. G. McCarthy
Mr. C. Murphy

Time allowed: *3 hours*

Answer *five* questions.
All questions carry equal marks.
The use of a Casio fx570w or fx570ms calculator is permitted.

1. (a) A receiver for geostationary satellite transmissions at 12 GHz consists of a pre-amplifier with a noise temperature 95 K and a gain of 11 dB followed by an amplifier with a gain of 25 dB and a noise figure of 4 dB. Compute the overall noise figure of the receiver in dB.

[8 marks]

(b) A PCM-TDM system is to handle four video signals each band limited to 5 MHz. The signals are sampled at the minimum rate and signal to quantisation noise level must be at least 53 dB. If one bit per word is used for synchronisation, and QPSK is used for transmission, what is the rate of phase change of the carrier?

[12 marks]

2. (a) Compare the capacities of BPSK, QPSK, and QAM systems.

[*10 marks*]

(b) (i) Illustrate the format of an ATM cell and briefly describe the function of each field in the cell.

[4 *marks*]

(ii) Describe how the cell boundaries are identified in an ATM system.

[*3 marks*]

(iii) Draw a state diagram to illustrate ATM cell synchronization.

[*3 marks*]

3. (a) Illustrate the operation of a store and forward packet data network considering source and destination nodes and two intermediate nodes (nodes 1 and 2). From this, determine formulas for the network delay (ND) and total message transmission time (TT). Ignore propagation delay.

[*12 marks*]

(b) A message of 1000 bits is to be sent over a data network from source to destination via two intermediate nodes. Each link along the route has a data-rate of 1Mbps and is totally dedicated to this transmission. When the message is broken into packets, a header size of 100 bits is used in all cases. Calculate the network delay and the total transmission time if the message is sent using the following arrangements:

(i) As a single packet

[*2 marks*]

(ii) As 5 equally-sized packets

[*2 marks*]

(iii) As 10 equally-sized packets

[*2 marks*]

(iv) Comment on the trend indicated by these results.

[*2 marks*]

4. The channel matrix for the "binary erasure channel" is given by: -

$$\left[P(Y|X)\right] = \begin{bmatrix} 1-p & 0 & p \\ 0 & 1-p & p \end{bmatrix}$$

where p denotes the probability that a transmitted symbol will be in doubt and should, therefore, be erased. Show that: -

(a) $H(Y) = (1-p)\left((\alpha-1)\log_2[1-\alpha] - \alpha\log_2[\alpha] - \log_2[1-p]\right) - p\log_2[p]$.

[7 *marks*]

(b) $H(Y|X) = -p\log_2[p] - (1-p)\log_2[1-p]$.

[7 *marks*]

(c) The channel capacity $C_s = 1 - p$.

[6 *marks*]

5. A binary modulation scheme is described by: -

$$s_i(t) = \begin{cases} s_1(t) = A_1\cos(\omega_c t) & 0 \le t \le T \\ s_2(t) = A_2\cos(\omega_c t) & 0 \le t \le T \end{cases}$$

where T is an integer times $1/f_c$. For this modulation scheme, given that (under the usual assumptions) $P_e = Q\left[\sqrt{\frac{E_d}{2\eta}}\right]$, show that: -

(a) $P_e = Q\left[\sqrt{\frac{(A_1 - A_2)^2 T}{4\eta}}\right]$.

[8 *marks*]

(b) If the average signal energy per bit (denoted E_b) is a fixed constant, prove that P_e in part (a) above is minimized if $A_2 = -A_1$. Hint: - the minimum value of $Q\left[\sqrt{x}\right]$ occurs when x takes on its maximum possible value.

[12 *marks*]

6. Given the following table of field elements of $GF\left(2^4\right)$: -

$$
\begin{aligned}
&0\\
&1\\
&\alpha\\
&\alpha^2\\
&\alpha^3\\
&\alpha^4 = \alpha + 1\\
&\alpha^5 = \alpha^2 + \alpha\\
&\alpha^6 = \alpha^3 + \alpha^2\\
&\alpha^7 = \alpha^3 + \alpha + 1\\
&\alpha^8 = \alpha^2 + 1\\
&\alpha^9 = \alpha^3 + \alpha\\
&\alpha^{10} = \alpha^2 + \alpha + 1\\
&\alpha^{11} = \alpha^3 + \alpha^2 + \alpha\\
&\alpha^{12} = \alpha^3 + \alpha^2 + \alpha + 1\\
&\alpha^{13} = \alpha^3 + \alpha^2 + 1\\
&\alpha^{14} = \alpha^3 + 1
\end{aligned}
$$

(a) Show that the generator polynomial for the $(15,7)$ double error correcting primitive BCH code based upon this field, denoted $g(x)$, is given by: -

$$g(x) = x^8 + x^7 + x^6 + x^4 + 1\,.$$

[7 *marks*]

(b) If an error free non-systematic code word, denoted $c(x)$, is given by: -

$$c(x) = x^{11} + x^8 + x^7 + x^6 + x^3 + x^2,$$

deduce the user data corresponding to this code word.

[2 *marks*]

(c) If the error polynomial affecting the code word polynomial $c(x)$ in part (b) above, denoted $e(x)$, is given by: -

$$e(x) = x^8 + x^3,$$

show how the syndrome decoding method can correct these errors.

[11 *marks*]

7. (a) An analogue signal having a bandwidth of B_A Hz is sampled at 1.5 times the Nyquist rate and each sample is quantised into one of L equally likely levels. Assuming that successive samples are statistically independent, the signal power at the receiver is S watts and the communication is affected by additive white Gaussian noise with power spectral density $\eta/2\ W/Hz$, show that the minimum channel bandwidth, denoted B_C, required for error-free transmission of the information produced by this source must satisfy the following non-linear equation: -

$$L^{3B_A} = \left(1 + \frac{S}{\eta B_C}\right)^{B_C}.$$

[5 *marks*]

(b) For the system described in (a) above estimate, using a graph or otherwise, the required value of B_C if $B_A = 4\ kHz$, $L = 256$, $S = 0.2\ mW$ and $\eta = 2\times10^{-10}\ W/Hz$. Hint: - taking the logarithm of both sides of the non-linear equation in part (a) above helps to avoid very large numbers….

[5 *marks*]

(c) Summarise the principle characteristics of spread spectrum communications.

[10 *marks*]