University of Eswatini
Faculty of Science and Engineering
Department of Electrical and Electronic Engineering

Main Examination – 2019

Title of paper: **Digital Communication Systems**

Course Number: **EE543**

Time allowed: 3 hours

Instructions:

1. Answer any FOUR (4) questions
2. Each question carries 25 marks
3. Marks for each question are shown at the right hand margin
4. Useful information is attached at the end of the paper.

This paper contains 5 pages including this one.

This paper should not be opened until permission has been granted by the invigilator.

Question 1

(a) Describe the following terms
  (i) Point-to-point communication [2]
  (ii) Point-to-multipoint communication [2]
  (iii)Broadcasting [2]

(b) Assuming a 4-bit ADC channel accepts analogue input ranging from 0 to 5 volts, determine the following: [4]

  (i) Number of quantization levels
  (ii) Step size of the quantizer or resolution
  (iii) Quantization level when the analogue voltage is 3.2 volts
  (iv) Binary code produced

(c) Consider the binary sequence 1001011. Draw the waveforms for the following signalling formats. [6]
  (i) Bipolar RZ signalling format
  (ii) AMI (alternate mark inversion) RZ signalling format

(d) State four advantages of digital communications [4]

(e) Describe a satellite channel [2]

(f) Define the term space division multiple access (SDMA) [3]

Question 2

(a) Consider a single input multiple output (SIMO) communication system
  (i) With an aid of a diagram describe the SIMO system [5]
  (ii) Give the equation of the received signal and the channel capacity. [4]
  (iii) Give two ways in which diversity can be attained in a SIMO system [2]

(b) Consider an AWGN channel with 4 kHz bandwidth and the noise power spectral density $\frac{\eta}{2} = 10^{-12}\ W/Hz$. The signal power required at the receiver is 0.1mW. Calculate the capacity of this channel. [4]

(c) Given the following random binary sequence 10011011001110.
  (i) Perform partial response signalling, that is, show the signal formed assuming the initialization bit is 1. [4]
  (ii) Draw a transmitted Delta Modulation waveform [2]

(d) A DMS X has four symbols x_1, x_2, x_3, x_4 with probabilities $P(x_1) = 0.4, P(x_2) = 0.3, P(x_3) = 0.2, P(x_4) = 0.1$
Find the amount of information contained in the messages $x_1\ x_2 x_1\ x_3$ and $x_4 x_3\ x_3\ x_2$. [4]

Question 3

(a) A DMS X has four symbols x_1, x_2, x_3 and x_4 with $(x_1) = \frac{1}{2}, P(x_2) = \frac{1}{4}$, and $P(x_3) = P(x_4) = \frac{1}{8}$. Construct a Shannon-Fano code for X, Show that this code has the optimum property that $n_i = I(x_i)$ and that the code efficiency is 100 percent. [8]

(b) Given that a transmitter transmit a signal at 18mW to a receiver at line of sight, and the received signal is 16.5mW, calculate the free space path loss in dB [3]

(c) Simplify the following QPSK equation into its orthogonal basis function and message points [5]

$$s_i(t) = \sqrt{\frac{2E}{T}} \cos\left[(2i-1)\frac{\pi}{4}\right] \cos(2\pi f_c t) - \sqrt{\frac{2E}{T}} \sin\left[(2i-1)\frac{\pi}{4}\right] \sin(2\pi f_c t), i = 1, \dots, 4$$

(d) Consider a cooperative system where two users share information via a relay

(i) Describe the *basic* decode and forward (DF) scheme, use a diagram to support your answer [5]

(ii) Write the equation of the received signals at the **relay** and the **destination** during phase I [4]

Question 4

(a) Consider a MIMO communication system,

(i) Give four benefits of a MIMO system [4]

(ii) Given the channel matrix $\boldsymbol{H}$ and the covariance matrix $\boldsymbol{R}$ determine the channel capacity [4]

(iii) Assuming a 6 by 8 MIMO system, what is the rank of the matrix $\boldsymbol{H}$ [1]

(b) Show that the error probability of equal-energy signal for a BPSK receiver

$$P_B = \int_{\gamma_0 = \frac{(a_1 - a_2)}{2}}^{\infty} \frac{1}{\sqrt{2\pi}\sigma_0} \exp\left(-\frac{1}{2}\left(\frac{z - a_1}{\sigma_0}\right)^2\right) dz$$

... results in $Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$ in AWGN [6]

(c) Find the BER for a BPSK system with a bit rate of 1 $Mbits/s$ the received waveforms $s_1(t) = A\cos(\omega_0 t)$ and $s_2(t) = -A\cos(\omega_0 t)$are coherently detected with a matched filter. The value of A = 10mV. Assume that $N_0 = 10^{-11} W/Hz$ and the signal power and energy is normalized relative to a 1 Ω resistor [4]

(d) Show that the code C = { 0 0 0 0, 0 1 0 1, 1 0 1 0, 1 1 1 1} is a linear cyclic code. [6]

Question 5

(a) Digital receivers include Zero Forcing (ZF) receiver and a Minimum Mean Square Error (MMSE) receiver. Given the channel matrix $\boldsymbol{H}$, in both cases show how can the estimate of the transmitted vector be obtained from the received signal $\mathbf{y}$. [5]

(b) Given the generator sequences of a convolutional encoder $g_1 = 1\ 1\ 1$ and $g_2 = 1\ 0\ 1$,
  (i) Draw the convolutional encoder [3]
  (ii) Find the impulse response of the encoder [3]

(c) Show that the matched filter of signal $s(t)$ is given by

$$h(t) = \begin{cases} s(t-T), & for\ 0 \leq t \leq T \\ 0, & otherise \end{cases}$$ [5]

(d) Consider OFDM
  (i) State the property of the subcarriers that make OFDM symbols not to interfere with each other and write the equation for the subcarrier [3]
  (ii) Draw the OFDM symbol and state the reason for using a cyclic prefix [3]
  (iii) Given that the OFDM symbol is $10\mu s$ long with a cyclic prefix of $2\mu s$, calculate the SNR loss due to the insertion of the cyclic prefix [3]

Table 1

z	$Q(z)$	z	$Q(z)$	z	$Q(z)$	z	$Q(z)$
0.00	0.5000	1.00	0.1587	2.00	0.0228	3.00	0.00135
0.05	0.4801	1.05	0.1469	2.05	0.0202	3.05	0.00114
0.10	0.4602	1.10	0.1357	2.10	0.0179	3.10	0.00097
0.15	0.4404	1.15	0.1251	2.15	0.0158	3.15	0.00082
0.20	0.4207	1.20	0.1151	2.20	0.0139	3.20	0.00069
0.25	0.4013	1.25	0.1056	2.25	0.0122	3.25	0.00058
0.30	0.3821	1.30	0.0968	2.30	0.0107	3.30	0.00048
0.35	0.3632	1.35	0.0885	2.35	0.0094	3.35	0.00040
0.40	0.3446	1.40	0.0808	2.40	0.0082	3.40	0.00034
0.45	0.3264	1.45	0.0735	2.45	0.0071	3.45	0.00028
0.50	0.3085	1.50	0.0668	2.50	0.0062	3.50	0.00023
0.55	0.2912	1.55	0.0606	2.55	0.0054	3.55	0.00019
0.60	0.2743	1.60	0.0548	2.60	0.0047	3.60	0.00016
0.65	0.2578	1.65	0.0495	2.65	0.0040	3.65	0.00013
0.70	0.2420	1.70	0.0446	2.70	0.0035	3.70	0.00011
0.75	0.2266	1.75	0.0401	2.75	0.0030	3.75	0.00009
0.80	0.2169	1.80	0.0359	2.80	0.0026	3.80	0.00007
0.85	0.1977	1.85	0.0322	2.85	0.0022	3.85	0.00006
0.90	0.1841	1.90	0.0287	2.90	0.0019	3.90	0.00005
0.95	0.1711	1.95	0.0256	2.95	0.0016	3.95	0.00004
4.00	0.00003						
4.25	10^{-5}						
4.75	10^{-6}						
5.20	10^{-7}						
5.60	10^{-8}						