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

Main Examination – December 2019

Title of paper: Digital Communication Systems

Course Number: EEE543 / 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 processes of the following OSI layers in regard to how they affect the design of digital communication systems

i) Physical Layer [3]

ii) Data Link Layer [3]

iii) Network Layer [3]

b) Describe the following terms

i) Point-to-point communication [2]

ii) Point-to-multipoint communication [2]

iii) Broadcasting [2]

c) Consider the MISO system in **Figure 1** below, find the following

i) The SNR when MRC is employed with full CSI [6]

ii) The channel capacity [4]

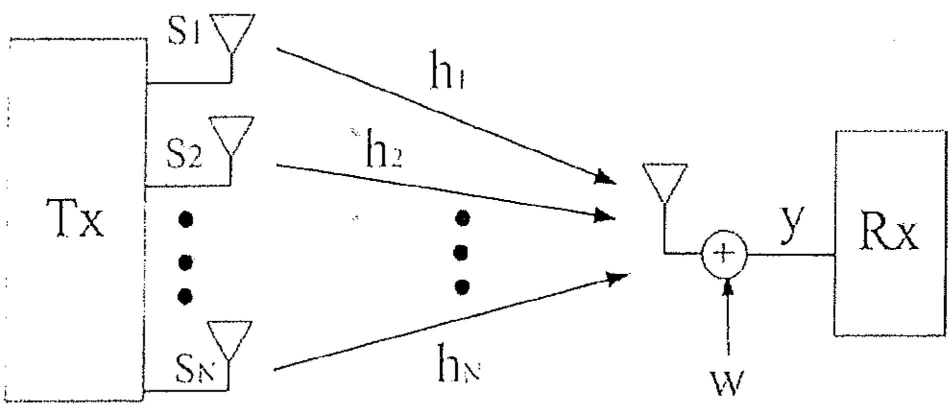

Figure 1

Question 2

(a) One method to counter the practical difficulties of the Nyquist condition for zero ISI is the using the *Raised Cosine* filter'

i) Write the equation of the raise cosine filter [4]

ii) Calculate the data rate(in b/s) that can be transmitted if we use 16-QAM signalling with the raised-cosine pulses and a roll-off factor α=0.40 [4]

(b) Describe three timing features of the eye pattern. [5]

(c) Consider a single input multiple output (SIMO) communication system

i) With an aid of a diagram describe the SIMO system [4]

ii) Give the equation of the received signal and the channel capacity. [4]

(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) An MPSK receiver can be reduced and be implemented by $N = 2$ correlators. With an aid of a diagram describe how this simplification be can achieved and how the estimate angle is obtained [8]

(b) 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]

(c) 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) Describe the minimum distance decision rule in detection of signals in Gaussian noise. Use diagrams and associated equations to support your answer. [6]

(b) 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]

(c) 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]

(d) Show that the channel capacity of an ideal AWGN channel with infinite bandwidth is given by

$$C_\infty = \frac{1}{\ln 2}\frac{S}{\eta} \approx 1.44\frac{S}{\eta}\ \text{b/s} \qquad [5]$$

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 the estimate of the transmitted vector can be obtained from the received signal y. [5]

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

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

(c) Consider OFDM

(i) State the property of the subcarriers that makes OFDM symbols not to interfere with each other and write the equation for the subcarrier [3]

(ii) Given that an 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]

(d) Given the convolutional encoder below

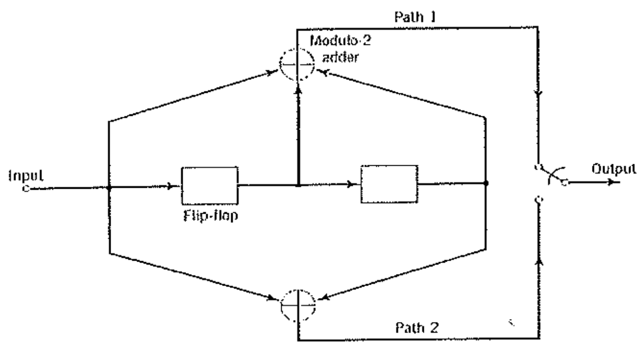

Figure 1

(i) Find the generator polynomials for *Path 1* and *Path 2* [4]

(ii) Given the input sequence $m = 11011$, find the encoder output sequence [5]

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}						