University of Swaziland
Faculty of Science
Department of Electrical and Electronic Engineering
Main Examination 2016

Title of Paper	**:**	**Digital Communication Systems**
Course Number	**:**	**EE543**
Time Allowed	**:**	**3 hrs**
Instructions	**:**	

1. **Answer any four (4) questions**
2. **Each question carries 25 marks**
3. **Useful information is attached at the end of the question paper**

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The paper consists of six (6) pages

Question 1

(a) We know the usable bandwidth of the local loop is approximately 3000 hz, and we are given a higher signal-to-noise ratio (SNR) of 60 to 80 decibels. Calculate the channel capacity using Shannon's law. [5]

(b) Explain how the delta modulator works and how it overcomes slope overload and quantizing noise. [5]

(c) An analog signal is sampled at the Nyquist rate f_s and quantized into L levels. Find the duration τ of 1 b of the binary encoded signal. [3]

(d) Discuss the advantages and disadvantages of the following three signalling formats; Unipolar NRZ, Bipolar RZ and AMI RZ .[6]

(e) What do we mean about the code efficiency? [1]

(f) In a certain telemetry system, eight message signals having 2 kHz bandwidth each are time-division multiplexed using a binary PCM. The error in sampling amplitude cannot be greater than 1 percent of the peak amplitude. Determine the minimum transmission bandwidth required if raised-cosine pulses with roll-off factor $\alpha = 0.2$ are used. The sampling rate must be at least 25 percent about the Nyquist rate. [5]

Question 2

(a) We have the output SNR of a matched filter receiver as

$$\frac{S}{N} = \frac{2E_d}{\eta} = \frac{2}{\eta}\int_0^T [s_1(t) - s_2(t)]^2 dt$$

Now suppose that we want $s_1(t)$ and $s_2(t)$ to have the same signal energy. Show that The optimum choice of $s_2(t)$ is

$$s_2(t) = -s_1(t)$$

and the resultant output SNR is

$$\frac{S}{N} = \frac{8}{\eta}\int_0^T s_1^2(t)\, dt = \frac{8E}{\eta}$$

Where E is the signal energy. [8]

(b) An on-off binary system uses pulse waveforms

$$s_i(t) \begin{cases} s_1(t) = A\sin\frac{\pi t}{T} & 0 \le t \le T \\ s_2(t) = 0 & 0 \le t \le T \end{cases}$$

Let A =0.2 mV and T =2μs. Additive white noise with a power spectral density $\frac{\eta}{2} = \frac{10^{-15} W}{Hz}$ is added to the signal. Determine the probability of error when$P(s_1) = P(s_2) = 0.5$. [5]

(c) Explain the Nyquist no-ISI criteria for time and frequency. [8]

(d) Given the following random binary sequence 10011011001110. Perform partial response signalling, that is, show the signal formed assuming the initialization bit is 1. [2]

(e) Show that C = {0 0 0, 1 1 1} is a linear code. [2]

Question 3

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

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

Where S is the average signal power and $\eta/2$ is the power spectral density of white Gaussian noise. [6]

(b) A DMS has five symbols x_1, x_2, x_3, x_4 and x_5 with $P(x_1) = 0.4, P(x_2) = 0.19, P(x_3) = 0.16, P(x_4) = 0.15$, and $P(x_5) = 0.1$

(i) Construct a Shannon-Fano code for X, and calculate the efficiency of the code [8]

(ii) Repeat for the Huffman code and compare the results. [8]

(c) What is the maximum theoretical capacity in bits per second of a coaxial cable band with a frequency spectrum of 50 MHz to 100 MHz and a signal-to-noise ratio of 40 dB? [3]

Question 4

(a) We have a channel with a 1 MHz bandwidth. The ratio S/N is 63 dB. What is the appropriate bit rate and number of signal levels? [4]

(b) What is the purpose of the "physical layer" in digital systems? Draw a block diagram of a "single carrier" digital transmitter and corresponding receiver for the physical layer transmission of a bit-stream over a wired or wireless channel. As used in this block diagram, state the purpose of

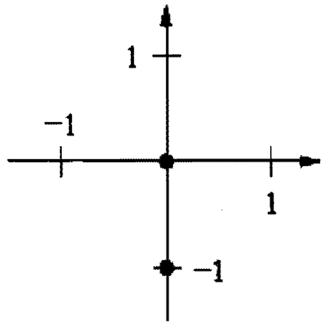
(i) A transmitter pulse shaping filter

(ii) A matched filter

(iii) An adaptive equalizer

Explain why a Nyquist frequency response is required between appropriate points in the block diagram and indicate where these points occur. [7]

(c) A binary modulation scheme uses the following two signal points



Determine the error probability if we communicate over an AWGN channel where the noise has power spectral density $N_0/2 = 0.15$. The receiver uses an ML detector. [2]

(d) What are the advantages of orthogonal frequency division multiplexing (OFDM) for digital transmission over channels subject to fading, and what is the main disadvantage of OFDM? [8]

(e) Explain the concept of eye patterns and how it describes how good the reception is. Make sure to include a sketch of an eye pattern. Explain how the choice of basis function affects the error decoding capability. [4]

Question 5

(a) Compared to analogue techniques, what do you consider to be the three main advantages of digital voice transmission in wired and wireless telephony? [3]

(b) Speech is digitised at 64 kb/s. How could this bit-stream be efficiently transmitted over a channel of 48 kHz bandwidth centred on 100 kHz? According to the Shannon-Hartley Law, what signal-to-noise ratio would be required to ensure that arbitrarily low bit-error rates are achievable for this transmission? [6]

(c) State what is meant by the 'bandwidth-efficiency' of a digital communication system. What is the maximum-bandwidth efficiency achievable, in theory, by a base-band binary transmission system? Why would this maximum be difficult to achieve in practice? [6]

(d) Explain the term asynchronous as applied to digital transmission. Describe one commonly used asynchronous technique and its main applications. [7]

(e) What are the main requirements for PCM wave-forms used for the synchronous transmission of digital signals over wired links in telephone networks? [2]

(f) What are the advantages of Manchester coding as compared to NRZ?

[1]

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 [illegible]						
4.75	10 [illegible]						
5.20	10 [illegible]						
5.60	10 [illegible]						

Table 2

Type	Minimum bandwidth	Error performance	
Baseband signalling			
Unipolar	$R/2$	$\text{erfc}\sqrt{\frac{E_b}{\eta}}$	
Polar	$R/2$	$\text{erfc}\sqrt{\frac{2E_b}{\eta}}$	
Bandpass signalling		Coherent	Noncoherent
OOK	R	$\text{erfc}\sqrt{\frac{E_b}{\eta}}$	$\frac{1}{2}e^{-(1/2)E_b/\eta}$
BPSK	R	$\text{erfc}\sqrt{\frac{2E_b}{\eta}}$	None
FSK	$2\,\Delta f + R$	$\text{erfc}\sqrt{\frac{E_b}{\eta}}$	$\frac{1}{2}e^{-(1/2)E_b/\eta}$
DPSK	$2\,R$	Not used	$\frac{1}{2}e^{-E_b/\eta}$
QPSK	$R/2$	$\text{erfc}\sqrt{\frac{2E_b}{\eta}}$	None
MSK	$2\,1.5R$	$\text{erfc}\sqrt{\frac{2E_b}{\eta}}$	$\frac{1}{2}e^{-(1/2)E_b/\eta}$