THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMMUNICATIONS ENGINEERING

FINAL EXAMINATION (2021)

EE321 COMMUNICATIONS SYSTEMS

THIRD YEAR ELECTRICAL ENGINEERING – BEEL3

TIME ALLOWED: 3 HOURS

27th October 2021

Name: ______________________ **ID Number:** ________________

Signature: ______________________ **Venue:** ______________

INFORMATION FOR STUDENTS

1. You have **TEN (10) MINUTES** to read the paper. **NO WRITING** during this time.
2. There are two parts in this paper. Answer all questions.
3. Part A, Multiple Choice is worth 20 marks. Part B, Short Answer and Problem, consists of 4 questions with equal marks (16 marks) worth 64 marks. Total available mark is 84.
4. All PART A Multiple Choice answers to must be written in this **BOOK.** All PART B Problems must be answered in the **ANSWER BOOK** supplied.
5. Only drawing instruments and calculators are permitted on your desk.
6. If you are found cheating in the Examination, the penalties specified by the University shall apply.
7. **TURN OFF** all mobile phone and place them on the floor under your seat or leave it in your bag in the holding area before the start of examination.

PART A: Multiple Choice Question [10 Marks]

Circle the correct option. If you which to change, put a cross over the wrong option.

1. Which of the following option is correct about the frequency range of 300 kHz to 3000 kHz?
   a) High frequency
   b) Medium frequency
   c) Low frequency
   d) None of These

2. In which reusing of components can be made possible?
   a) Analog communication
   b) Digital communication
   c) Analog & Digital communication
   d) None of the mentioned

3. What is the process of transmitting a baseband signal over long distances?
   a) Sampling
   b) Quantization
   c) Modulation
   d) Encoding

4. Entropy is defined as
   a) the amount of information per source symbol.
   b) the average amount of information per source symbol.
   c) the amount of information per receive symbol.
   d) the average amount of information per receive symbol.

5. Information is defined as
   a) is a continuous function of probability
   b) is a discrete function of probability
   c) is a continuous function of entropy
   d) is a discrete function of entropy

6. Channel capacity is defined as
   a) maximum of information that may be transmitted through the channel.
   b) maximum of mutual information that may be transmitted through the channel.
   c) minimum of mutual information that may be transmitted through the channel.
   d) minimum of information that may be transmitted through the channel.

7. Define information rate.
   a) Average number of bits of information per second.
   b) Number of bits of information per second.
   c) Average number of bits of information per minute.
   d) Number of bits of information per minute.

8. Calculate the entropy of source with a symbol set containing 64 symbols each with a probability $p_i = 1/64$.
   a) 4 bits / symbol
   b) 6 bits / symbol
   c) 8 bits / symbol
   d) 10 bits / symbol

9. TDM is used to
   a) Increase the information transmission rate
   b) Use only one carrier frequency to handle different signals
   c) To use different frequency bands for different signals
   d) To protect all small signals in PCM from quantizing noise

10. What type of multiplexing is shown in Figure 1?

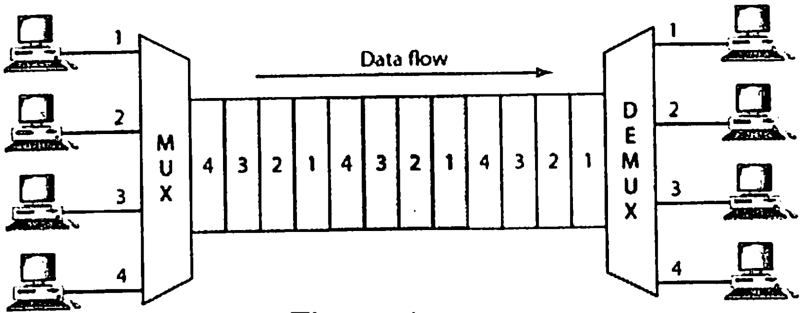

Figure 1

   a) FDM
   b) WDM
   c) AM
   d) TDM

11. What is a random process?
   a) A random function which is a variable of time
   b) A random variable which is a function of time
   c) A random function which is a variable of frequency
   d) A random frequency which is a function of time

12. If x(t), what is $F_x(x,t)$?
   a) Possibility density function of x(t) at time, t.
   b) Probability destiny function of x(t) at time, t.
   c) Possibility destiny function of x(t) at time, t.
   d) Probability density function of x(t) at time, t.

13. What is the auto- or self-correlation of a function x(t)?
   a) $R_{xx}(t_1, f_2) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x_1 x_2\, F(x_1, x_2, t_1, f_2)\, dx_1 dx_2$
   b) $R_{xx}(f_1, t_2) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x_1 x_2\, F(x_1, x_2, f_1, t_2)\, dx_1 dx_2$
   c) $R_{xx}(t_1, t_2) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x_1 x_2\, F(x_1, x_2, t_1, t_2)\, dx_1 dx_2$
   d) $R_{xx}(f_1, f_2) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x_1 x_2\, F(x_1, x_2, f_1, f_2)\, dx_1 dx_2$

14. For a wide sense stationary, the mean is
   a) independent of time and is average
   b) dependent on time and is constant
   c) independent of time and is constant
   d) dependent on time and is average

15. The power spectrum density of x(t) is
   a) real and less than zero.
   b) complex and greater than zero.
   c) real and greater than zero.
   d) complex and greater than zero.

16. In a binary communication system, the threshold detector at the receiver end is needed to
   a) shape the received signal against a threshold voltage.
   b) filter the received signal against a threshold voltage.
   c) compare the received signal against a threshold voltage.
   d) decode the received signal against a threshold voltage.

17. A requirement for the selected detection technique is that the detection technique must have
   a) maximum probability of error.
   b) minimum probability of error
   c) zero probability of error
   d) constant probability of error

18. If the output of an optimum receiver is $Z = a_i + n_0$, with white Gaussian noise; what would be the output if no signal is detected?
   a) $Z = n_0$
   b) $Z = a_i$
   c) $Z = 1$
   d) $Z = 0$

19. A white Gaussian noise with the classification of n(0,1) implies that:
   a) It's distribution is normal with expected amplitude of 1
   b) It's distribution is random with expected amplitude of 1
   c) It's distribution is normal with expected amplitude of 0
   d) It's distribution is random with expected amplitude of 0

20. What is the effective of the variance, σ^2, in the noise signal characterized by $n_0(t) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\mu^2/2\sigma^2}$?
   a) Decreasing variance, improves system performance
   b) Increasing variance, improves system performance
   c) Decreasing variance, degrades system performance
   d) Increasing variance, degrades system performance

PART B: WORKING PROBLEMS [16 + 16 + 16 + 16 = 64 Marks]

QUESTION ONE – COMMUNICATION SYSTEMS [6 + 4 + 6 = 16 Marks]

a) Compare and contrast two major difference between analog and digital communications systems that makes digital systems the preferred communication for the future. [6 Marks]

b) If you were to measure the interference of wireless networks available on campus:

i) What frequencies are allocated for Wireless LAN and 4G/LTE mobile networks? [2 Marks]

ii) Give wavelength of interest for each networks. [2 Marks]

c) In the wireless solution proposed for your group, discuss the two main propagation impairments present in the selected project site. Also offer a solution to combat the effect of the impairment. [6 Marks]

QUESTION TWO – INFORMATION THEORY [5 + 5 + 6 = 16 Marks]

a) A single-digit, seven-segment liquid crystal display (LCD) emits a 0 with a probability of 0.25; a 1 and a 2 with a probability of 0.15 each; 3, 4, 5, 6, 7, and 8 with a probability of 0.07 each; and a 9 with a probability of 0.03. Find the average information for this source. [5 Marks]

b) A standard television picture is composed of approximately 300,000 basic picture elements (about 600 picture elements in a horizontal line and 500 horizontal lines per frame). Each of these elements can assume 10 distinguishable brightness levels (such as black and shades of gray) with equal probability. Find the information content of a television picture frame. [5 Marks]

c) Assume that a computer terminal has 110 characters (on its keyboard) and that each character is sent by using binary words.

i) What are the number of bits needed to represent each character? [2 Marks]

ii) How fast can the characters be sent (characters/s) over a telephone line channel having a bandwidth of 3.2 kHz and an SNR of 20 dB? [2 Marks]

iii) What is the information content of each character if each is equally likely to be sent? [2 Marks]

QUESTION THREE – PCM, LINE CODING (CONVOLUTION CODING) AND TDM MULTIPLEXING [6 + 4 + 6 = 16 Marks]

a) In a PCM system, the bit error rate due to channel noise is 10^{-4}. Assume that the peak signal-to-noise ratio on the recovered analog signal needs to be at least 30 dB.

i) Find the minimum number of quantizing steps that can be used to encode the analog signal into a PCM signal. [3 Marks]

ii) If the original analog signal had an absolute bandwidth of 2.7 kHz, what is the null bandwidth of the PCM signal for the polar NRZ signaling case?

b) Using the definitions for terms associated with convolutional coding, draw a block diagram for a convolutional coder that has rate and constraint length R = K= 3. [4 Marks]

c) Design a TDM PCM system that will accommodate four 200-bit/s (synchronous) digital inputs and one analog input that has a bandwidth of 400 Hz. Assume that the analog samples will be encoded into 4-bit PCM words.

i) Draw a block diagram for your design, [2 Marks]

ii) Indicating the data rates at the various points on the diagram [2 Marks]

iii) Explain how your design works [2 Marks]

QUESTION FOUR – **PERFORMANCE ANALYSIS [6 + 8 + 2 = 16 Marks]**

a) Digital data are to be transmitted over a toll telephone system. Regenerative repeaters are spaced 50 km apart along the system. The total length of the system is 900 km. The telephone lines between the repeater sites are equalized over a 300- to 2,700-Hz band and provide an E_b/N_0 (Gaussian noise) of 15 dB to the repeater input.

i) Using FSK system, find the largest bit rate R that can be accommodated with no ISI. [2 Marks]

ii) Using BPSK signaling, find the largest bit rate R that can be accommodated with no ISI. [2 Marks]

iii) Find the overall P_e for the system. (Be sure to include the receiver at the end of the system.) [2 Marks]

b) An analog baseband signal has a uniform PDF and a bandwidth of 3500 Hz. This signal is sampled at an 8 samples/s rate, uniformly quantized, and encoded into a PCM signal having 8-bit words. This PCM signal is transmitted over a DPSK communication system that contains additive white Gaussian channel noise. The signal-to-noise ratio at the receiver input is 8 dB.

i) Find the P_e of the recovered PCM signal.[2 Marks]

ii) Find the peak signal/average noise ratio (decibels) out of the PCM system. [2 Marks]

iii) What is the impact on the PCM system if the PCM word-size is halved or doubled? [4 Marks]

c) Examine the performance of an AM communication system where the receiver uses a product detector. For the case of a sine-wave modulating signal, plot the ratio of [(S/N)out /(S/N)in] as a function of the percent modulation. [2 Marks]

Formula Sheet

Information in message:

$$I_j = \log_2\left(\frac{1}{P_j}\right) \text{bits} \quad (1\text{–}7a)$$

Average Information:

$$H = \sum_{j=1}^{m} P_j I_j = \sum_{j=1}^{m} P_j \log_2\left(\frac{1}{P_j}\right) \text{bits} \quad (1\text{–}8)$$

Source Rate:

$$R = \frac{H}{T} \text{ bits/s} \quad (1\text{–}9)$$

Channel Capacity:

$$C = B \log_2\left(1 + \frac{S}{N}\right) \quad (1\text{–}10)$$

Total Average Noise Power:

$$\left(\frac{S}{N}\right)_{\text{pk out}} = \frac{3M^2}{1 + 4(M^2 - 1)P_e} \quad (3\text{–}16a)$$

Ratio of the Average Signal Power to Average Noise Power:

$$\left(\frac{S}{N}\right)_{\text{out}} = \frac{M^2}{1 + 4(M^2 - 1)P_e} \quad (3\text{–}16b)$$

SNR at the Receiver Input:

$$\left(\frac{S}{N}\right)_{\text{in}} = \frac{P_s}{N_0 B_T} = \left(\frac{S}{N}\right)_{\text{baseband}} \left(\frac{B}{B_T}\right) \quad (7\text{–}85)$$

Output SNR for analog systems:

$$\left(\frac{S}{N}\right)_{\text{out}} = \frac{A_c^2 \overline{m^2(t)}}{\overline{x_n^2(t)}} = \frac{A_c^2 \overline{m^2(t)}}{2N_0 B} \quad (7\text{–}87)$$

Input SNR for analog systems:

$$\left(\frac{S}{N}\right)_{\text{in}} = \frac{(A_c^2/2)(1 + \overline{m^2})}{2N_0 B} \quad (7\text{–}88)$$

Ratio of Output to Input SNR for analog systems:

$$\frac{(S/N)_{\text{out}}}{(S/N)_{\text{in}}} = \frac{2\overline{m^2}}{1 + \overline{m^2}} \quad (7\text{–}89)$$

TABLE 7-1 COMPARISON OF DIGITAL SIGNALING METHODS

Type of Digital Signaling	Minimum Transmission Bandwidth Required[a] (Where R Is the Bit Rate)		Error Performance			
Baseband signaling						
Unipolar	$\frac{1}{2}R$	(5-105)	$Q\left[\sqrt{\left(\frac{E_b}{N_0}\right)}\right]$	(7-24b)		
Polar	$\frac{1}{2}R$	(5-105)	$Q\left[\sqrt{2\left(\frac{E_b}{N_0}\right)}\right]$	(7-26b)		
Bipolar	$\frac{1}{2}R$	(5-105)	$\frac{3}{2}Q\left[\sqrt{\left(\frac{E_b}{N_0}\right)}\right]$	(7-28b)		
Bandpass signaling			*Coherent detection*		*Noncoherent detection*	
OOK	R	(5-106)	$Q\left[\sqrt{\left(\frac{E_b}{N_0}\right)}\right]$	(7-33)	$\frac{1}{2}e^{-(1/2)(E_b/N_0)}, \left(\frac{E_b}{N_0}\right) > \frac{1}{4}$	(7-58)
BPSK	R	(5-106)	$Q\left[\sqrt{2\left(\frac{E_b}{N_0}\right)}\right]$	(7-38)	Requires coherent detection	
FSK	$2\Delta F + R$ where $2\Delta F = f_2 - f_1$ is the frequency shift	(5-89)	$Q\left[\sqrt{\left(\frac{E_b}{N_0}\right)}\right]$	(7-47)	$\frac{1}{2}e^{-(1/2)(E_b/N_0)}$	(7-65)
DPSK	R	(5-106)	Not used in practice		$\frac{1}{2}e^{-(E_b/N_0)}$	(7-67)
QPSK	$\frac{1}{2}R$	(5-106)	$Q\left[\sqrt{2\left(\frac{E_b}{N_0}\right)}\right]$	(7-69)	Requires coherent detection	
MSK	$1.5R$ (null bandwidth)	(5-115)	$Q\left[\sqrt{2\left(\frac{E_b}{N_0}\right)}\right]$	(7-69)	$\frac{1}{2}e^{-(1/2)(E_b/N_0)}$	(7-65)

[a] Typical bandwidth specifications by ITU are larger than these minima [Jordan, 1985].

A-10 TABULATION OF $Q(z)$

$$Q(z) \triangleq \frac{1}{\sqrt{2\pi}} \int_z^{\infty} e^{-\lambda^2/2} d\lambda$$

For $z \geq 3$, $\quad Q(z) \approx \frac{1}{\sqrt{2\pi}\, z} e^{-z^2/2}$ (See Fig. B-7.)

Also,

$$Q(-z) = 1 - Q(z)$$

$$Q(z) = \frac{1}{2}\operatorname{erfc}\left(\frac{z}{\sqrt{2}}\right) = \frac{1}{2}\left[1 - \operatorname{erf}\left(\frac{z}{\sqrt{2}}\right)\right]$$

where $\quad \operatorname{erfc}(x) \triangleq \frac{2}{\sqrt{\pi}} \int_x^{\infty} e^{-\lambda^2} d\lambda \quad$ and $\quad \operatorname{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^{x} e^{-\lambda^2} d\lambda$

Table 1: Values of $Q(x)$ for $0 \le x \le 9$

x	$Q(x)$	x	$Q(x)$	x	$Q(x)$	x	$Q(x)$
0.00	0.5	2.30	0.010724	4.55	2.6823×10^{-6}	6.80	5.231×10^{-12}
0.05	0.48006	2.35	0.0093867	4.60	2.1125×10^{-6}	6.85	3.6925×10^{-12}
0.10	0.46017	2.40	0.0081975	4.65	1.6597×10^{-6}	6.90	2.6001×10^{-12}
0.15	0.44038	2.45	0.0071428	4.70	1.3008×10^{-6}	6.95	1.8264×10^{-12}
0.20	0.42074	2.50	0.0062097	4.75	1.0171×10^{-6}	7.00	1.2798×10^{-12}
0.25	0.40129	2.55	0.0053861	4.80	7.9333×10^{-7}	7.05	8.9459×10^{-13}
0.30	0.38209	2.60	0.0046612	4.85	6.1731×10^{-7}	7.10	6.2378×10^{-13}
0.35	0.36317	2.65	0.0040246	4.90	4.7918×10^{-7}	7.15	4.3389×10^{-13}
0.40	0.34458	2.70	0.003467	4.95	3.7107×10^{-7}	7.20	3.0106×10^{-13}
0.45	0.32636	2.75	0.0029798	5.00	2.8665×10^{-7}	7.25	2.0839×10^{-13}
0.50	0.30854	2.80	0.0025551	5.05	2.2091×10^{-7}	7.30	1.4388×10^{-13}
0.55	0.29116	2.85	0.002186	5.10	1.6983×10^{-7}	7.35	9.9103×10^{-14}
0.60	0.27425	2.90	0.0018658	5.15	1.3024×10^{-7}	7.40	6.8092×10^{-14}
0.65	0.25785	2.95	0.0015889	5.20	9.9644×10^{-8}	7.45	4.667×10^{-14}
0.70	0.24196	3.00	0.0013499	5.25	7.605×10^{-8}	7.50	3.1909×10^{-14}
0.75	0.22663	3.05	0.0011442	5.30	5.7901×10^{-8}	7.55	2.1763×10^{-14}
0.80	0.21186	3.10	0.0009676	5.35	4.3977×10^{-8}	7.60	1.4807×10^{-14}
0.85	0.19766	3.15	0.00081635	5.40	3.332×10^{-8}	7.65	1.0049×10^{-14}
0.90	0.18406	3.20	0.00068714	5.45	2.5185×10^{-8}	7.70	6.8033×10^{-15}
0.95	0.17106	3.25	0.00057703	5.50	1.899×10^{-8}	7.75	4.5946×10^{-15}
1.00	0.15866	3.30	0.00048342	5.55	1.4283×10^{-8}	7.80	3.0954×10^{-15}
1.05	0.14686	3.35	0.00040406	5.60	1.0718×10^{-8}	7.85	2.0802×10^{-15}
1.10	0.13567	3.40	0.00033693	5.65	8.0224×10^{-9}	7.90	1.3945×10^{-15}
1.15	0.12507	3.45	0.00028029	5.70	5.9904×10^{-9}	7.95	9.3256×10^{-16}
1.20	0.11507	3.50	0.00023263	5.75	4.4622×10^{-9}	8.00	6.221×10^{-16}
1.25	0.10565	3.55	0.00019262	5.80	3.3157×10^{-9}	8.05	4.1397×10^{-16}
1.30	0.0968	3.60	0.00015911	5.85	2.4579×10^{-9}	8.10	2.748×10^{-16}
1.35	0.088508	3.65	0.00013112	5.90	1.8175×10^{-9}	8.15	1.8196×10^{-16}
1.40	0.080757	3.70	0.0001078	5.95	1.3407×10^{-9}	8.20	1.2019×10^{-16}
1.45	0.073529	3.75	8.8417×10^{-5}	6.00	9.8659×10^{-10}	8.25	7.9197×10^{-17}
1.50	0.066807	3.80	7.2348×10^{-5}	6.05	7.2423×10^{-10}	8.30	5.2056×10^{-17}
1.55	0.060571	3.85	5.9059×10^{-5}	6.10	5.3034×10^{-10}	8.35	3.4131×10^{-17}
1.60	0.054799	3.90	4.8096×10^{-5}	6.15	3.8741×10^{-10}	8.40	2.2324×10^{-17}
1.65	0.049471	3.95	3.9076×10^{-5}	6.20	2.8232×10^{-10}	8.45	1.4565×10^{-17}
1.70	0.044565	4.00	3.1671×10^{-5}	6.25	2.0523×10^{-10}	8.50	9.4795×10^{-18}
1.75	0.040059	4.05	2.5609×10^{-5}	6.30	1.4882×10^{-10}	8.55	6.1544×10^{-18}
1.80	0.03593	4.10	2.0658×10^{-5}	6.35	1.0766×10^{-10}	8.60	3.9858×10^{-18}
1.85	0.032157	4.15	1.6624×10^{-5}	6.40	7.7688×10^{-11}	8.65	2.575×10^{-18}
1.90	0.028717	4.20	1.3346×10^{-5}	6.45	5.5925×10^{-11}	8.70	1.6594×10^{-18}
1.95	0.025588	4.25	1.0689×10^{-5}	6.50	4.016×10^{-11}	8.75	1.0668×10^{-18}
2.00	0.02275	4.30	8.5399×10^{-6}	6.55	2.8769×10^{-11}	8.80	6.8408×10^{-19}
2.05	0.020182	4.35	6.8069×10^{-6}	6.60	2.0558×10^{-11}	8.85	4.376×10^{-19}
2.10	0.017864	4.40	5.4125×10^{-6}	6.65	1.4655×10^{-11}	8.90	2.7923×10^{-19}
2.15	0.015778	4.45	4.2935×10^{-6}	6.70	1.0421×10^{-11}	8.95	1.7774×10^{-19}
2.20	0.013903	4.50	3.3977×10^{-6}	6.75	7.3923×10^{-12}	9.00	1.1286×10^{-19}
2.25	0.012224						