



INTERNAL ASSESSMENT APPROVAL FORM (INCLUDING COLLABORATIVE PROVISION)

This form is used to ensure that assessment specifications have been through an internal review process prior to external examination/approval and release to students. It should be completed for each assessment for a particular module. The assessment tasks, criteria and marking scheme should accompany this form.

PARTNER (and taught location if relevant):	Coleg Sir Gar				
EXTERNAL EXAMINER NAME:	Dr Alison Griffiths				
ASSESSMENT AUTHOR :	Mike Hall				
MODULE TITLE:	Signals & Digital Comms				
MODULE CODE:	PSDE 5014 / SGEE5005		MODULE LEVEL:	5	
COMPONENT NO. (e.g. 1 of 2):	2 of 2		COMPONENT WEIGHTING (e.g. 50% of the module):	50%	
ASSESSMENT PERIOD	☐ Semester 1	☐ Semester 1 <i>Re-sit</i>	☒ Semester 2	☐ Semester 2 <i>Re-sit</i>	<i>Other, please state</i>
TYPE OF ASSESSMENT:	☐ Coursework		☒ Examination		☐ Practical
LANGUAGE OF ASSESSMENT:	English		TRANSLATION REQUIRED (Y/N):	N	
FOR EXAMINATIONS ONLY. SPECIFY BELOW ANY ADDITIONAL MATERIAL(S) TO BE USED IN THE EXAMINATION					
<i>This box will expand as you type</i>					

INTERNAL MODERATOR PLEASE TICK TO INDICATE THAT THE ASSESSMENT INCLUDES:		<i>Please</i> ✓		Comments
		YES	NO	
1	Tasks that are specified clearly, accurately and comprehensibly, with appropriate use of language and neat presentation	☒	☐	
2	Tasks which enable the module learning outcomes to be demonstrated (as per the module syllabus)	☒	☐	
3	Tasks which conform to the assessment described in the module syllabus	☒	☐	
4	Tasks which are written at the appropriate level of the Framework for Higher Education Qualifications (see http://www.qaa.ac.uk/docs/qaa/quality-code/qualifications-frameworks.pdf?sfvrsn=170af781_14).	☒	☐	
5	Clear criteria for assessment and guidance about how marking/grading will be applied	☒	☐	
6	Guidance about expected evidence for submission, e.g. essay or report, word count, bibliography and references	☒	☐	
7	Reference to good academic conduct, for example referencing, plagiarism and Turnitin	☒	☐	
8	Actions to complete <i>This box will expand as you type</i>			
SIGNATURE OF APPROVAL:		SIGNATURE		DATE
INTERNAL MODERATOR: I confirm that this version of the assessment specification is ready to be sent to the Partnership Team Leader		<i>R. Davies</i>		21-03-19

ONLY TO BE COMPLETED IF THE ASSESSMENT IS LINKED TO A COLLABORATIVE PARTNER

PARTNERSHIP TEAM LEADER PLEASE TICK TO INDICATE THAT THE ASSESSMENT INCLUDES:		Please ✓		Comments
		YES	NO	
1	Tasks that are specified clearly, accurately and comprehensibly, with appropriate use of language and neat presentation			
2	Tasks which enable the module learning outcomes to be demonstrated (as per the module syllabus)			
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8	Actions to complete <i>This box will expand as you type</i>			
SIGNATURE OF APPROVAL:		SIGNATURE		DATE
PTL: I confirm that this version of the assessment specification is ready to be sent to the External Examiner				

UWTSD PROVISION: please submit the completed document to the appropriate Programme Director.

COLLABORATIVE PROVISION: please submit the completed document (or make available electronically) to the Partnership Team Leader. This must be in accord with specific arrangements for sharing electronic documents (e.g. via SharePoint or similar).

The assessment tasks, criteria and marking scheme should accompany this form

LOCATION: COLEG SIR GAR

LLEOLIAD: COLEG SIR GAR

LEVEL 5

LEFEL 5

EXAMINATION PERIOD

MAY 2019

CYFNOD ARHOLIADAU

MAI 2019

MODULE CODE: PSDE 5014 / SGEE5005

Signals and Digital Communications

TIME: 2½ HOURS

THIS PAPER IS IN 2 PARTS:

ANSWER ALL QUESTIONS IN PART A

ANSWER TWO QUESTIONS OUT OF THREE IN PART B

Equipment or materials required – Calculator

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Main

Formulae

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} = \frac{V_{modulation}}{V_{carrier}}$$

$$V_{min} = E_c - mE_c, \quad V_{max} = E_c + mE_c$$

$$E_c = \frac{V_{max} + V_{min}}{2}, \quad E_s = \frac{V_{max} - V_{min}}{2}$$

$$V = \frac{mE_c}{2}$$

$$v = [E_c + v_s] \cos(\omega_c t)$$

$$P_{sideband} = \frac{1}{2} m^2 P_{carrier}, \quad P = \sum \frac{E^2}{2R}$$

$$f_c = \frac{f_{max} + f_{min}}{2}$$

$$\Delta f_c = f_{max} - f_c$$

$$\beta = \frac{\Delta f_c}{f_s}$$

$$e = E_c \cos(\omega_c t + m_f \sin \omega_s t)$$

$$\overline{\rho_v} = \frac{\overline{v_r}}{\overline{v_i}}, \quad \overline{\rho_v} = \frac{\overline{Z_L} - Z_0}{\overline{Z_L} + Z_0}$$

$$VSWR = \frac{1 + |\overline{\rho_v}|}{1 - |\overline{\rho_v}|} = \frac{|\overline{V_I}| + |\overline{V_R}|}{|\overline{V_I}| - |\overline{V_R}|}$$

$$\overline{V_L} = \overline{V_I} + \overline{V_R}$$

$$\overline{Z_{in}} = \frac{Z_0^2}{\overline{Z_L}}$$

$$Z_0 = \frac{138}{\sqrt{k}} \log \frac{D}{d}$$

$$DR = 20 \log_{10}(N)$$

$$q = \text{Voltage Range} / N$$

$$V_{QN} = q / \sqrt{12}$$

$$SQNR = \text{rms Signal Voltage} / V_{QN}$$

PART A – Answer ALL 10 questions.

- A1. Calculate the wavelength for a carrier wave of frequency 210MHz. (3 marks)
- A2. A carrier of 40V and 25MHz is amplitude modulated by a 2V, 3kHz sine wave signal. Find the modulation factor. (3 marks)
- A3. A 5MHz carrier is amplitude modulated by an audio signal with frequency span of 300Hz – 3kHz. What are the frequencies of lower and upper sidebands? (4 marks)
- A4. A 60MHz carrier is frequency modulated by a 2kHz audio sine wave. If the carrier voltage is 6V and the maximum frequency deviation is 40kHz, write down the voltage equation of the FM wave in radians. (6 marks)
- A5. A 50Ω transmission line is connected to a load impedance of $170 + j58\Omega$. Calculate the reflection co-efficient ρ_v and express the answer in polar form. (8 marks)
- A6. Explain with the aid of diagrams the concept of a standing wave on a transmission line paying regard to the 4 “special” cases of load impedance. (8 marks)
- A7. Explain how a R/2R DAC works. (5 marks)
- A8. Explain what is meant by the terms ‘quantisation’ and ‘quantisation error’ in ADCs. (3 marks)

Total Marks for Part A = 40

PART B – Only answer 2 of the following 3 questions (B1, B2, B3)

If you answer all 3, only B1 and B2 will be marked

Question B1 – Modulation and Transmission Lines

- a. The final stage of a 500kHz AM transmitter feeds into a 50Ω load and the waveform shown in Figure B1.1 is observed on an oscilloscope:

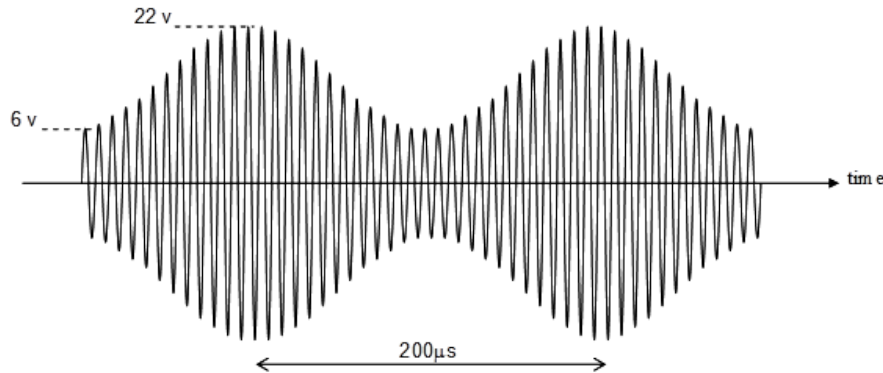


Figure B1.1

- i. Calculate the modulation index for this waveform
(2 marks)
 - ii. Sketch the amplitude spectrum of this AM wave, labelling the amplitude and frequency of each component and explaining how they were obtained.
(4 marks)
 - iii. Calculate the average power of this AM wave
(3 marks)
- b. 25 metres of loss-free, air-spaced, 75 ohm coaxial cable is terminated by a load of impedance $85 + j120$ ohms. A sinusoidal generator of internal resistance 75 ohms which, on open circuit, gives an output of $24V_{rms}$ is now connected to the input of this line.
- i. Calculate the voltage reflection coefficient (ρ_v) at the load expressed in polar form.
(4 marks)
 - ii. Calculate the voltage standing wave ratio (VSWR) on the line
(3 marks)

- c. A 200kHz carrier wave of peak amplitude 25 volts is frequency modulated by a sinusoidal message of peak amplitude 7.5 volts and frequency 10kHz using an FM modulator with the transfer characteristic shown in Figure B1.2. Using this transfer characteristic, determine:

i. The maximum frequency deviation (δF_C)

(2 marks)

ii. The modulation index (β)

(2 marks)

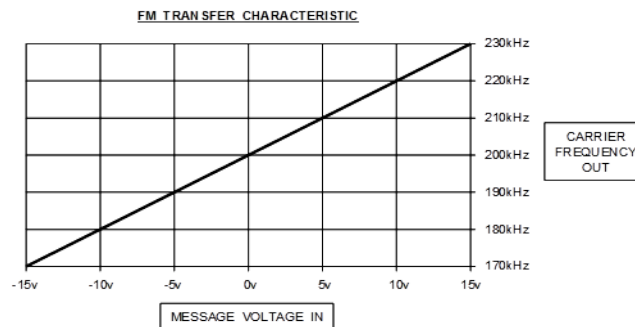


Figure B1.2

- iii. Use the Bessel Tables in Table B1.1 below to sketch the amplitude spectrum of this FM wave. Label the amplitude and frequency of each component and explain clearly how each value was obtained. Calculate and indicate the bandwidth of the waveform on this spectrum.

(6 marks)

x	Bessel-function order, n																
m_f	J_0	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}
0.00	1.00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0.25	0.98	0.12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0.5	0.94	0.24	0.03	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1.0	0.77	0.44	0.11	0.02	—	—	—	—	—	—	—	—	—	—	—	—	—
1.5	0.51	0.56	0.23	0.06	0.01	—	—	—	—	—	—	—	—	—	—	—	—
2.0	0.22	0.58	0.35	0.13	0.03	—	—	—	—	—	—	—	—	—	—	—	—
2.41	0	0.52	0.43	0.20	0.06	0.02	—	—	—	—	—	—	—	—	—	—	—
2.5	−0.05	0.50	0.45	0.22	0.07	0.02	0.01	—	—	—	—	—	—	—	—	—	—
3.0	−0.26	0.34	0.49	0.31	0.13	0.04	0.01	—	—	—	—	—	—	—	—	—	—
4.0	−0.40	−0.07	0.36	0.43	0.28	0.13	0.05	0.02	—	—	—	—	—	—	—	—	—
5.0	−0.18	−0.33	0.05	0.36	0.39	0.26	0.13	0.05	0.02	—	—	—	—	—	—	—	—

Table B1.1

- d. A coaxial cable has an inner conductor diameter of 0.2mm and uses a dielectric insulator of constant 2.1. Calculate the necessary outer diameter to achieve a characteristic impedance of 75Ω.

(4 marks)

Total Marks for Question B1 = 30

Question B2 – Digital Modulation

- a. Sketch a diagram showing the quantisation levels and corresponding codes of a 3 bit quantiser. Use this diagram to explain how an analogue signal is converted into a pulse code modulated (PCM) signal and what is meant by the term 'resolution'.
(6 marks)
- b. Briefly explain how a PCM signal achieves greater noise immunity than an analogue signal.
(4 marks)
- c. A speech signal with a value of $4.7V_{rms}$ and maximum frequency 3.4KHz is transmitted as a PCM signal using an 8-bit quantiser which covers the voltage range -16 to +16 volts.
- i. Calculate the dynamic range of this system in dB.
ii. Calculate the signal-to-quantisation noise ratio for this signal giving the answer in decibels.
(6 marks)
- d. With the aid of a constellation diagram explain the basic principle of carrier modulation by 16-QAM.
(8 marks)
- e. Explain with the aid of suitable diagrams the principles of ASK, FSK and PSK.
(6 marks)

Total Marks for Question B2 = 30

Question B3 – Ethernet and the ISO Model

- Explain the concept of CSMA as used in Ethernet networks.
(8 marks)
- Describe the composition and purpose of each layer of the OSI network model.
(10 marks)
- Using the diagram of the multiplexing structure shown in Figure B3.1, explain how a 2Mbit/s E1 service would be combined onto the STM trunk.

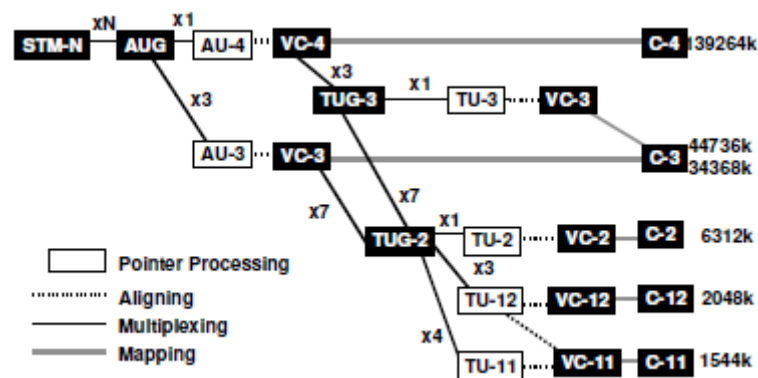


Figure B3.1

- Figure B3.1 below shows the path overhead for high and low order virtual containers. Explain what the following high order overheads are used for: J1, B3, C2, G1, F2 and H4.

Path Overhead			
J1	Virtual Container		
B3	VC-3	48.960 Mbit/s	85 Columns
C2	VC-4	150.336 Mbit/s	261 Columns
G1	Virtual Container		
F2	V5	Virtual Container	
H4	J2	VC-2	6.912 Mbit/s 12 Columns
F3	N2	VC-12	2.304 Mbit/s 4 Columns
K3	K4	VC-11	1.728 Mbit/s 3 Columns
N1			

Figure B3.1

(6 marks)

Total Marks for Question B3 = 30

Diwedd/End



EXAMINATION SOLUTIONS
(to accompany the examination paper sent to the external examiner
but NOT to be seen by students)

Programme:	HND in Electrical & Electronic Engineering	Level:	5
Module:	PSDE5014 / SGEE5005 Signals and Digital Communications		
Author:	M Hall	Page:	Page 1 of 12

Part A	Question	Marks
A1	$\lambda = \frac{3 \times 10^8}{210 \times 10^6} = 1.43m$	3
A2	$m = \frac{V_{modulation}}{V_{carrier}} = \frac{2}{40} = 0.05$	3
A3	The sideband frequencies produced range from $f_s \pm 300$ Hz to $f_s \pm 3$kHz. The upper sideband ranges from 5.0003MHz to 3.003MHz. The lower sideband ranges from 4.9997 MHz to 4.997MHz.	2 2
A4	$e = E_c \cos(\omega_c t + m_f \sin \omega_s t)$ $E_c = 6$ $\omega_c = 2\pi f_c = 2\pi \times 60 \times 10^6 = 377 \times 10^6 rad/s$ $\omega_s = 2\pi f_s = 2\pi \times 2000 = 12566 rad/s$ $m_f = \frac{\Delta f}{f_s} = \frac{40000}{2000} = 20$ $e = 6 \cos(377 \times 10^6 t + 20 \sin 12566 t)$	4 2

A5

$$Z_0 = 50\Omega, \bar{Z}_L = 170 + j58$$

$$\rho_v = \frac{\bar{Z}_L - Z_0}{\bar{Z}_L + Z_0} = \frac{170 + j58 - 50}{170 + j58 + 50} = \frac{120 + j58}{220 + j58}$$

In polar form:

$$120 + j58 = \sqrt{120^2 + 58^2} \angle \tan^{-1} \frac{58}{120} = 133.3 \angle 25.8^\circ$$

$$220 + j58 = \sqrt{220^2 + 58^2} \angle \tan^{-1} \frac{58}{220} = 227.5 \angle 14.8^\circ$$

$$\rho_v = \frac{133.3 \angle 25.8^\circ}{227.5 \angle 14.8^\circ} = 0.59 \angle 11^\circ$$

2

2

2

2

A6

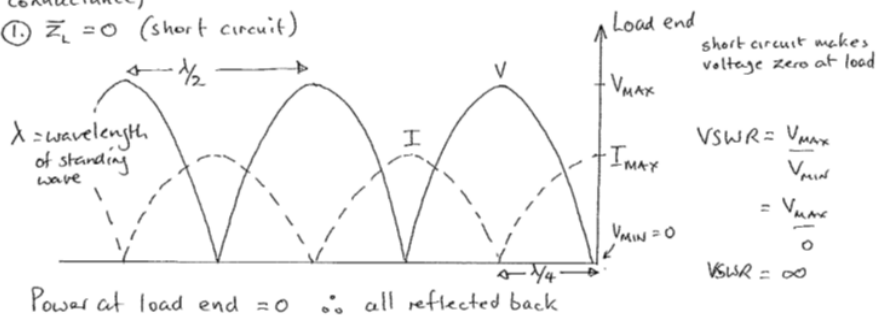
STANDING WAVES & VSWR

There are 4 special cases to consider regarding the load impedance

1. $\bar{Z}_L = 0$ (short circuit)
2. $\bar{Z}_L = \infty$ (open circuit)
3. $\bar{Z}_L = Z_0$ (characteristic impedance)
4. $\bar{Z}_L \neq Z_0$ (mismatched load)

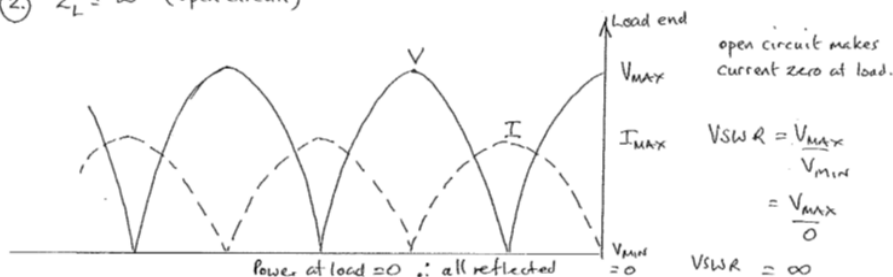
Assuming the line itself is loss-less (i.e. ignoring its resistance and leakage conductance)

- ① $\bar{Z}_L = 0$ (short circuit)



2

- ② $\bar{Z}_L = \infty$ (open circuit)



2

- ③ $\bar{Z}_L = Z_0$ (characteristic impedance)

All energy is absorbed in the load i.e. no reflections ∴ no standing wave caused by interference between incident and reflected waves

using equation $VSWR = \frac{1 + |\bar{\rho}_v|}{1 - |\bar{\rho}_v|}$ when $\bar{\rho}_v = 0$

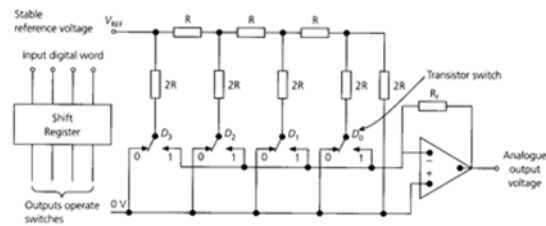
$$\therefore VSWR = \frac{1 + 0}{1 - 0} = 1$$

2

2

- ④ $\bar{Z}_L \neq Z_0$ (unmatched) - some power absorbed, some power reflected back

A7



The circuit uses resistors of only two different values, one of which is twice the other. The principle of operation relies on the fact that the total resistance of 2 equal resistors in parallel is equal to half their individual value. i.e. the total resistance of $2R$ in parallel with $2R$ is R .

In the above diagram, half the input current flows through each resistor. In fig (b), half flows through the left hand resistor while only a quarter flows in the other 2 . In fig(c), half flows in the left resistor, quarter in the next and one eighth in the last 2 .

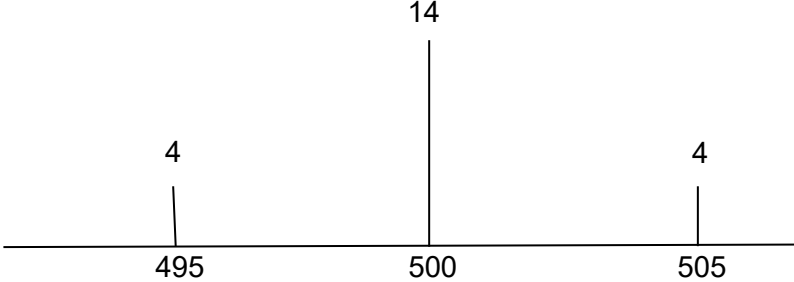
It follows that for each additional $R/2R$ resistor pair added the current flowing in the final 2 resistors is halved.

5

A8

Quantising approximates a continuous range of values and replaces it with a binary number. Error is introduced between input voltage and output binary representation which depends on the resolution of the ADC.

3

Q. B1	Question	Marks
a.	$f = 500\text{kHz}$, therefore $\omega_c = 2\pi f = 2\pi \times 500 \times 10^3 = 314159 \text{ rad/s}$ $R_L = 50\Omega$ $V_{\max} = 22\text{V}$ $V_{\min} = 6\text{V}$ $f_s = 1/200\mu = 5\text{kHz}$ $m = \frac{V_{\max} - V_{\min}}{V_{\max} + V_{\min}} = \frac{22 - 6}{22 + 6} = 0.57$ $E_c = \frac{V_{\max} + V_{\min}}{2} = \frac{22 + 6}{2} = 14\text{V}$ $E_s = \frac{V_{\max} - V_{\min}}{2} = \frac{22 - 6}{2} = 8\text{V}$ Each sideband has amplitude = $E_s/2 = 4\text{V}$ and spaced by the modulating frequency f_s of 5kHz.  $P = \sum \frac{E^2}{2R} = \frac{14^2}{100} + \frac{4^2}{100} + \frac{4^2}{100} = 2.28\text{W}$	2 1 1 2 3
b. i	$\rho_v = \frac{(Z_L - Z_0)}{(Z_L + Z_0)}$ $\rho_v = \frac{(85 + j120 - 75)}{(85 + j120 + 75)}$ $\rho_v = \frac{(10 + j120)}{(160 + j120)}$ Converting to polar form: $\rho_v = \frac{120 \angle 85}{200 \angle 37}$ $\rho_v = 0.6 \angle 48$	1 1 1 1
ii.	$VSWR = \frac{1 + \rho_v }{1 - \rho_v }$ $= \frac{1.6}{0.4} = 4$	3

c.i

$$\text{Frequency deviation } (\delta f_c) = f_{\max} - f_c = 215 - 200 = \mathbf{15\text{kHz}}$$

2

ii.

$$\text{Modulation Index } (\beta) = \delta f_c / f_m = 15 / 10 = \mathbf{1.5}$$

2

iii.

Component amplitudes are calculated from the Bessel table for $\beta = 1.5$:

$$J_0 = 25 \times 0.51 = 12.75\text{V}$$

$$J_1 = 25 \times 0.56 = 14\text{V}$$

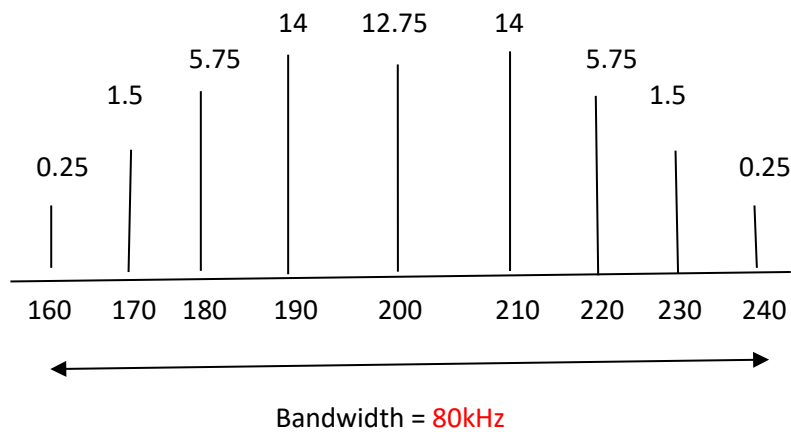
$$J_2 = 25 \times 0.23 = 5.75\text{V}$$

$$J_3 = 25 \times 0.06 = 1.5\text{V}$$

$$J_4 = 25 \times 0.01 = 0.25\text{V}$$

2

Component spacing is calculated as the modulating frequency i.e. 20KHz



3

d.

$$Z_o = \frac{138}{\sqrt{k}} \log\left(\frac{D}{d}\right)$$

1

$$75 = \frac{138}{\sqrt{2.1}} \log\left(\frac{D}{0.2}\right)$$

1

$$75 = 95.2 \log\left(\frac{D}{0.2}\right)$$

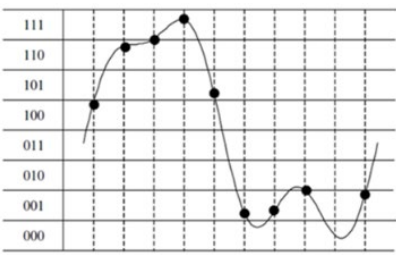
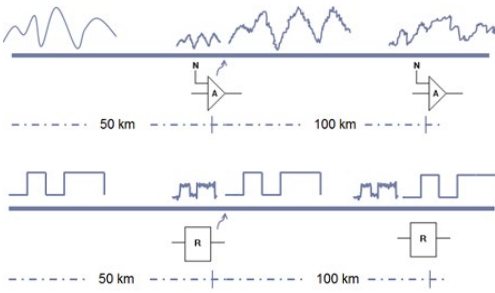
1

$$\text{antilog } \frac{75}{95.2} = \frac{D}{0.2}$$

1

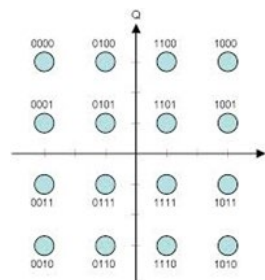
$$D = \mathbf{1.23\text{mm}}$$

1

Q.B2	Question	Marks
a.	 The range of the ADC is divided into discrete “quantisation” levels. When a voltage is sampled and converted to a binary code it is assigned the nearest quantisation level. Resolution determines the number of quantisation levels, the more bits that are used, the higher the resolution and the smaller the quantisation interval.	2 2 2
b.	 Noise is accumulative and increases with the length of the transmission path. With analogue signals, noise is very difficult to remove and once added results in a degraded signal. With a PCM digital signal, the system only has to differentiate between a 0 and 1, so as long as the noise isn’t sufficient to blur this distinction the signal can be regenerated effectively noise free.	4
c.	$DR = 20\log_{10}(N)$ If $n = 8$ then $N = 2^n = 256$ In dB = $20\log 256 = 48.2\text{dB}$ $q = \frac{\text{Voltage Range}}{N} = \frac{32}{256} = 0.125$$V_{QN} = \frac{q}{\sqrt{12}} = 0.036$$SQNR = \frac{4.7}{0.036} = 130.6$ In dB = $20\log 130.6 = 42.3\text{dB}$	2 1 1 1 1

d.

In the 16-QAM scheme, 4 'I' values and 4 'Q' values are used which gives 16 possible symbols from 0000 to 1111. In addition to the 3 phases per quadrant, there are 3 amplitude levels. Therefore QAM modulates both amplitude and phase at the same time. For example:



1101 is phase shifted 45° and the amplitude is reduced to 0.33 of $V_{\max}$

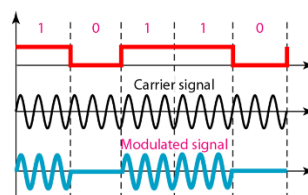
1001 is phase shifted 15° and the amplitude is reduced to 0.75 of $V_{\max}$

1100 is phase shifted 75° and the amplitude is reduced to 0.75 of $V_{\max}$

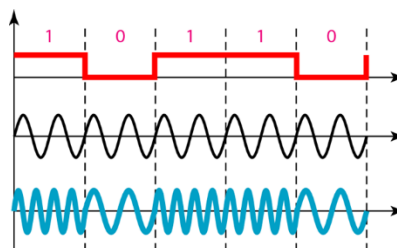
1000 is phase shifted 45° and the amplitude is $V_{\max}$

e.

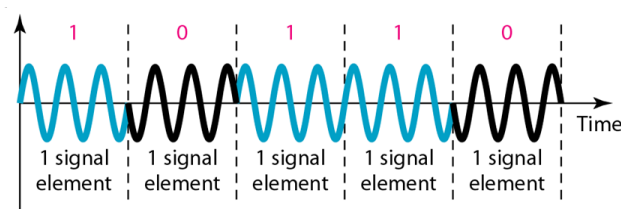
ASK is implemented by changing the amplitude of a carrier signal to reflect amplitude levels in the digital signal.



FSK - The digital data stream changes the frequency of the carrier signal, f_c . For example, a "1" could be represented by $f_1 = f_c + \delta f$, and a "0" could be represented by $f_2 = f_c - \delta f$.



PSK - We vary the phase shift of the carrier signal to represent digital data.



Q. B3	Question	Marks
a.	Collision Detection means that a sending device can “detect” simultaneous transmission attempts. When two or more devices try to send data at the same time, the signals collide. When this happens, each device then transmits a jam signal, called a carrier, to alert all other devices that a collision has occurred. All devices then go into back off mode and wait a random amount of time before attempting to retransmit data. The random time provision prevents simultaneous retransmissions. When a collision occurs it affects all the devices on the same collision domain. It does not affect devices on any other collision domains within the same network. You can think of two collision domains as two roads that are on different sides of a bridge. You can travel up to the bridge on either side, but must get permission to cross the bridge. On an Ethernet collision domain, frames of data travel within their own domain unless they need to talk to a device on the other side of the bridge. If it is necessary to talk to a device on the other side of a bridge, the bridge must give permission for the frame to cross the bridge to reach the other collision domain. Bridges are capable of this because they are store and forward devices: they store the frame from the source domain until permission is granted to forward it. Data transmitted from one device to another on the same collision domain will not affect any other collision domains. This allows each collision domain to continue to transmit with no effect on each other except when a device needs to talk to a device on another collision domain. In summary, a computer device checks to see if the transmission media is busy, recognizes that multiple devices access the network, and detects when a collision has taken place and goes into back off mode.	8
	b. The <u>physical layer</u> defines connector and interface specifications, as well as the medium (cable) requirements. Electrical, mechanical, functional, and procedural specifications are provided for sending a bit stream on a computer network.	2
	<u>The data link layer</u> provides the following functions: • Allows a device to access the network to send and receive messages • Offers a physical address so a device’s data can be sent on the network • Provides error-detection capability	2
	<u>The network layer</u> of the OSI model, provides an end-to-end logical addressing system so that a packet of data can be routed across several layer 2 networks (Ethernet, Token Ring, Frame Relay, etc.).	1
	<u>The transport layer</u> of the OSI model, offers end-to-end communication between end devices through a network. Depending on the application, the transport layer either offers reliable, connection-oriented or connectionless, best-effort communications. <u>The session layer</u>, provides various services, including tracking the number of bytes that each end of the session has acknowledged receiving from the other end of the	1

session. This session layer allows applications functioning on devices to establish, manage, and terminate a dialog through a network.

1

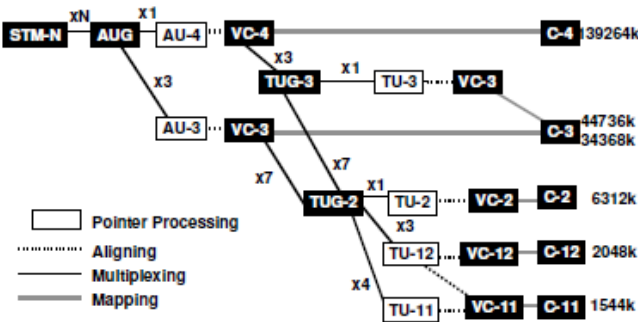
The presentation layer, is responsible for how an application formats the data to be sent out onto the network. The presentation layer basically allows an application to read (or understand) the message.

1

The application layer, provides an interface for the end user operating a device connected to a network. This layer is what the user sees, in terms of loading an application (such as Web browser or e-mail); that is, this application layer is the data the user views while using these applications.

2

c.



- The E1 frame is placed into a C-12 Container
- A Path Overhead (POH) is added and it becomes a VC-12 Virtual Container.
- A pointer is added to the VC-12 and it becomes a tributary unit TU-12. The pointers indicate the location of the first byte of each of the Virtual Containers.
- 3 TU-12s become a TUG-2 Tributary Unit Group.
- Seven of these TUGs can be mapped into a VC-3 Virtual Container
- Multiple VC-3 Virtual Containers will be assigned Pointers and placed into an Administration User Group (AUG) and the AUG will be placed in the STM Frame.

6

d.

- J1 – data string that allows the receiving device to check it is still connected to the transmitting device.
- B3 – Parity checking bits
- C2 – Specifies whether low order VCs or ATM cells are contained within the high order VC
- G1 – Conveys performance data for the path
- F2 – Communications between path elements
- H4 – Multiframe indicator

6