2017/2018 SEMESTER ONE EXAMINATION

Diploma in Electrical & Electronic Engineering
3rd Year FT

SATELLITE & OPTICAL COMMUNICATION

Time Allowed: 2 Hours

Instructions to Candidates

1. The examination rules set out on the last page of the answer booklet are to be complied with.
2. This paper consists of **THREE** sections :

   Section A - 20 Multiple Choice Questions, 2 marks each.

   Section B - 4 Short Questions, 10 marks each.

   Section C - 1 Long Questions, 20 marks each.
3. **ALL** questions are **COMPULSORY**.
4. All questions are to be answered in the answer booklet.
5. Start each question in Sections B and C on a new page.
6. Fill in the Sections B and C Question Numbers, in the order that they were answered, in the boxes found on the front cover of the answer booklet under the column "Question Answered".
7. This paper consists of 8 pages, inclusive of formula sheets.

SECTION A

MULTIPLE CHOICE QUESTIONS [2 marks each]

1. Please **tick** your answers in the **MCQ box** behind the front cover of the answer booklet.

2. No marks will be deducted for incorrect answers.

A1. Single mode fiber is used to:
- (a) Reduce modal dispersion.
- (b) Reduce material dispersion.
- (c) Eliminate modal dispersion.
- (d) Eliminate material dispersion.

A2. Which one of the following statements is correct?
- (a) In graded index multimode fiber, light travels down the fiber along a curved path.
- (b) In graded index multimode fiber, light travels down the fiber along a zigzag path.
- (c) In step index multimode fiber, light travels down the fiber along a circular path.
- (d) In step index multimode fiber, light travels down the fiber along a curved path.

A3. Rayleigh scattering is the type of fiber attenuation which is:
- (a) Directly proportional to the fourth power of the wavelength.
- (b) Directly proportional to the fifth power of the wavelength.
- (c) Inversely proportional to the fourth power of the wavelength.
- (d) Inversely proportional to the fifth power of the wavelength.

A4. In APD, the high carrier multiplication is caused by:
- (a) High forward biased voltage.
- (b) High reverse biased voltage.
- (c) High population inversion.
- (d) High threshold voltage.

A5. One of the advantages of ILD source is that:
- (a) It produces coherent light.
- (b) It can be used with any detector.
- (c) It produces less noise.
- (d) It is not temperature dependent.

A6. Which one of the following events is not a Fresnel Reflection (FR) event?
- (a) Dead zone.
- (b) Splice.
- (c) Ghost.
- (d) End of fiber.

A7. Identify the incorrect statement:
- (a) To attain total internal reflection in a fiber, the cladding refractive index must be smaller than the core refractive index.
- (b) In glass, the reflective index varies with wavelength.
- (c) A large acceptance angle implies a large numerical aperture.
- (d) The numerical aperture of a fiber depends on the line width of the source used.

A8. Photodiodes used as optical detectors are:
- (a) Unbiased.
- (b) Forward biased.
- (c) Reversed biased.
- (d) Thermoelectrically cooled.

A9. Responsivity of a photodetector is defined as:
- (a) The spectral response.
- (b) The amount of current produced per unit light power input.
- (c) The amount of time needed to respond to an input.
- (d) The amount of power output given the input current.

A10. Losses incurred as light rays travel through fiber are the result of:
- (a) Reflection and absorption.
- (b) Refraction and reflection.
- (c) Scattering and absorption.
- (d) Total Internal Reflection (TIR) and absorption.

A11. Which amplifier is used in the receive subsystem of the earth satellite station:
- (a) Travelling Wave Tube Amplifier.
- (b) Low Noise Amplifier.
- (c) Solid State Power Amplifier.
- (d) Channel Amplifier.

A12. Which one of the following is not a common IF frequency used in earth satellite station:
- (a) 770 MHz.
- (b) 140 MHz.
- (c) 70 MHz.
- (d) 90 MHz.

A13. The modulation normally used with digital data is:
- (a) AM.
- (b) FM.
- (c) SSB.
- (d) QPSK.

A14. The approximate time taken by GPS satellites to orbit around the earth is:
- (a) More than 24 hours.
- (b) Less than 24 hours.
- (c) 12 hours.
- (d) 24 hours.

A15. Geostationary satellites use their secondary power supplies:
- (a) During the hours of darkness.
- (b) During the solstice times in December and June each year.
- (c) During the equinox times in March and September each year.
- (d) Only if and when the solar cells fail.

A16. Round trip propagation delay between two earth stations through a geostationary satellite is approximately equal to:
- (a) 0.5 sec.
- (b) 1.5 sec.
- (c) 2.0 sec.
- (d) 2.5 sec.

A17. A satellite in a circular orbit above the equator takes 5 to 12 hours to complete one orbit. The satellite is in:
- (a) A geostationary orbit.
- (b) A Helios-synchronous orbit.
- (c) A low earth orbit.
- (d) A medium earth orbit.

A18. Which one of the following statements is true for geostationary satellites?
- (a) Earth's polar regions are not covered by geostationary satellites.
- (b) About 60% of the Earth's surface is covered by a geostationary satellite.
- (c) The round trip propagation delay through a geostationary satellite is less than 50 ms.
- (d) The altitude of the geostationary satellite must be 33,786 km.

A19. The function of Solid State Power Amplifier (SSPA) in the earth satellite station is:
- (a) To translate the signal frequencies.
- (b) To reduce the system noise.
- (c) To boost the signal to a sufficient high power.
- (d) To modulate the baseband signals.

A20. In a full transponder TDMA satellite system how many carriers are present in the transponder at any instant in time?
- (a) 1
- (b) 24
- (c) 36
- (d) 900

Section B [10 Marks Each]

B1. An optical communication link consists of the following components:

- ILD with bandgap energy 0.950 eV
- Optical fiber with core refractive index 1.45, cladding refractive index 1.35
- PIN photodiode

(a) Determine the operating wavelength of the optical communication link. (2 marks)

(b) Determine the numerical aperture & acceptance cone angle of the fiber. (4 marks)

(c) If the laser light from ILD enters the fiber at an angle of 34^0 with the fiber core axis, can the laser light be detected by the PIN photodiode?
Give reasons to support your answer. (4 marks)

B2. An optical fiber link is set up using the following devices:

- ILD source
- 10 km length of single mode fiber
- PIN photodiode with a responsivity of 0.8 A/W

(a) Give TWO advantages of using the ILD source. (4 marks)

(b) Name the dominant dispersion that occurs in the fiber. (1 mark)

(c) 9×10^{10} photons/sec are incident onto the PIN photodiode.
Determine the operating wavelength in nm, if the current generated at the photodiode output terminal is found to be 9.23nA. (5 marks)

B3. You have the following components available for setting up an optical fiber link:

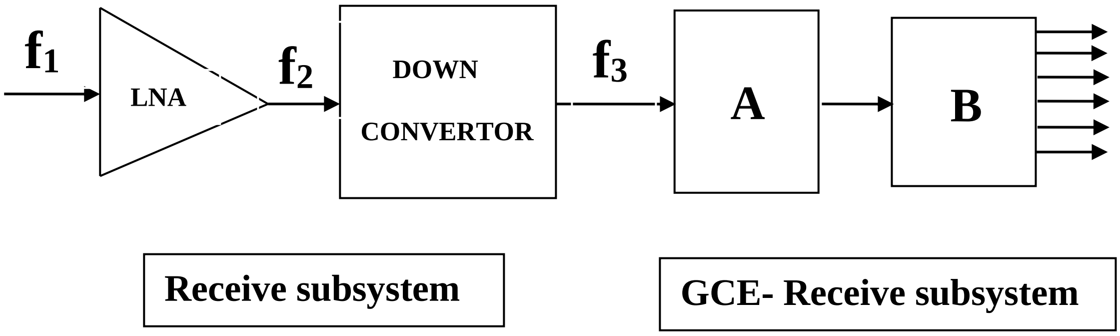
ILD source	:	Output power 5mW;	Risetime 1 ns
Step index fiber	:	Attenuation 2 dB/km;	Dispersion 243.2 ps/km.
Optical connectors	:	Loss 0.5 dB each	
Optical splices	:	Loss 0.2 dB each;	Total of 20 splices
APD detector	:	Sensitivity -53 dBm;	Risetime 2 ns
Safety margin	:	6 dB	

(a) Use **power budget** analysis to determine the maximum link length. (3 marks)

(b) Find the maximum Bit Rate (in Mb/s) of the above link using NRZ signal. (4 marks)

(c) State the THREE wavelengths commonly used in the optical fiber link. (3 marks)

B4. The block diagram shows Receive & GCE-Receive subsystems of the satellite earth station:



(a) Name Box A and B in the above block diagram. (2 marks)

(b) State the functions of LNA and Down Converter. (2 marks)

(c) Identify the frequency values of f_1, f_2 and f_3 for the following frequency bands:
(i) Ku-band.
(ii) C-band (6 marks)

Section C [20 Marks]

C1. A satellite communications system employing Ku band has the following parameters:

Up link distance	:	38,000 km
Down link distance	:	42,000 km
Earth station transmitting power	:	2 kW
Earth station transmitting antenna gain	:	65 dB
Earth station receiving antenna gain	:	51 dB
Earth station G/T	:	27 dB/K
Satellite transponder output power	:	18 dBW
Satellite transmitting antenna gain	:	16 dB
Satellite G/T	:	-10 dB/K
Satellite transponder bandwidth	:	36 MHz

(a) State the RF frequency appeared at the input of the earth station terminal. (2 marks)
(b) Calculate the round trip echo delay in ms. (4 marks)
(c) Calculate the EIRP values in dBW at the satellite & earth station terminals. (4 marks)
(d) Determine the received signal level in pW at the earth station terminal. (4 marks)
(e) Calculate the C/N value at the input of the earth station terminal. (6 marks)

******* End of Paper *******

Constants & Formulas Sheet

Gravitational constant G = 6.673 x 10^{-11} Nm^2 Kg^{-2}

Mass of Earth M_e = 5.975 x 10^{24} Kg , Radius of Earth = 6378 km

Boltzmann's constant k = 1.38 x 10^{-23} J/K

Speed of light c = 3 x 10^8 m/s

Plank's constant h = 6.626 x 10^{-34} Js

Electron charge e = 1.602 x 10^{-19} C

$$v = \sqrt{\frac{Gm_e}{r}}$$

$$S(\Theta) = 52 - 10\log_{10}\left(\frac{D}{\lambda}\right) - 25\log(\Theta) \quad dBi$$

For D < 100λ

$$S(\Theta) = 29 - 25\log_{10}(\Theta) \quad dBi$$

For 2.0^0 spacing

$$S(\Theta) = 32 - 25\log_{10}(\Theta) \quad dBi$$

For 2.9^0 spacing

$$L_{dB} = 20\log\left(\frac{4\pi d}{\lambda}\right) = 32.44 + 20\log[d] + 20\log[f]$$

$$(C)_{dBW} = (P_T)_{dBW} + (G_T)_{dB} + (G_R)_{dB} - (L)_{dB}$$

$$\left(\frac{C}{N_0}\right)_{dBHz} = (P_T)_{dBW} + (G_T)_{dB} + \left(\frac{G_R}{T}\right)_{dB} - (L)_{dB} - (L_o)_{dB} - 10\log K$$

$$\left(\frac{C}{N}\right)_{dB} = \left(\frac{C}{N_0}\right)_{dBHz} - 10\log B$$

$$\left(\frac{C}{N}\right)_{Total}^{-1} = \left(\frac{C}{N}\right)_{Up}^{-1} + \left(\frac{C}{N}\right)_{Down}^{-1}$$

$$n_1 Sin\Theta_1 = n_2 Sin\Theta_2 \qquad NA = Sin\Theta_a = \sqrt{n_1^2 - n_2^2}$$

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2} \qquad \Delta\tau = \frac{Ln_1}{c}\left(\frac{n_1 - n_2}{n_2}\right) \qquad v = \frac{c}{n}$$

$$V = \frac{\pi d}{\lambda}(NA) \qquad n(r) = n_1\sqrt{1 - 2\Delta\left(\frac{r}{a}\right)^{\alpha}} \qquad a \le \frac{2.405\lambda}{2\pi\sqrt{n_1^2 - n_2^2}}$$

For step-index multimode fiber

$$M = \frac{V^2}{2} \qquad \sigma = \frac{n_1 L \Delta}{c\sqrt{12}}$$

For graded index multimode fiber

$$M = \frac{V^2}{4} \qquad \sigma = \frac{n_1 L \Delta^2}{c\sqrt{48}}$$

$$B = \frac{0.35}{\sigma} \qquad B = \frac{0.35}{t_{sys}} \qquad f = \frac{c}{\lambda}$$

$$\lambda = \frac{hc}{E_g} \qquad \lambda = \frac{1.24}{E_g} \qquad D = \frac{ct}{2n}$$

$I_p = (r_e)(e)$ $\qquad P_o = (r_p)(hc/\lambda)$ $\qquad R = \frac{\eta\lambda e}{hc}$

$$t_f = \sqrt{t_{modal}^2 + t_{material}^2} \qquad t_{sys} = 1.1\sqrt{t_f^2 + t_s^2 + t_d^2}$$