2018/2019 SEMESTER TWO 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.
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. The condition where the high energy level contains more electrons than the lower energy level is known as:
- (a) stimulated emission.
- (b) spontaneous emission.
- (c) light amplification.
- (d) population inversion.

A2. An optical fiber with an acceptance angle of 20 degree will have a numerical aperture of:
- (a) 0.34.
- (b) 0.94.
- (c) 11.53.
- (d) 0.64.

A3. Which one of the following statements is correct?
- (a) Intermodal dispersion is highest in single mode fiber
- (b) Material and intermodal dispersion cancel each other out at 1310 nm wavelength
- (c) Waveguide dispersion is negligible in multimode fibres
- (d) Intermodal dispersion is reduced if the light source is ILD instead of LED

A4. The conversion efficiency of a photodetector is often measured by its:
- (a) quantum of efficiency.
- (b) responsivity.
- (c) carrier multiplication.
- (d) sensitivity.

A5. The three major misalignments between joining fibres are:
- (a) end separation, angular misalignment and lateral displacement.
- (b) lateral displacement, longitudinal misalignment and end separation.
- (c) offset alignment, lateral displacement and longitudinal misalignment.
- (d) micro bending, macro bending and offset alignment.

A6. The OTDR’s ability to characterize a fibre is dependent on two types of optical phenomena:
- (a) rayleigh backscattering and fresnel reflection.
- (b) fresnel reflection and dead zone.
- (c) dead zone and rayleigh back scattering.
- (d) absorption and rayleigh back scattering.

A7. The wavelength of an ILD material with a band gap of 1.3 eV is:
- (a) 954μm.
- (b) 954 nm.
- (c) 0.954nm.
- (d) 0.954m.

A8. The responsivity of a PIN diode operating at a wavelength of 900nm with a quantum efficiency of 35% is:
- (a) 0.254 A/W.
- (b) 254 A/W.
- (c) 2.54 A/W.
- (d) 25.4 A/W.

A9. Propagation of light in optical fibres is based on the principle of:
- (a) core and cladding diameter.
- (b) numerical aperture.
- (c) total internal refraction.
- (d) total internal reflection.

A10. Attenuation in an optical fiber is:
- (a) lower at an operating wavelength of 850nm than 1310nm.
- (b) lower at an operating wavelength of 850nm than 1550nm.
- (c) lower at an operating wavelength of 1310nm than 1550nm.
- (d) lower at an operating wavelength of 1310nm than 850nm.

A11. In a satellite communication link, the uplink frequency is:
- (a) higher than the downlink frequency.
- (b) lower than the downlink frequency.
- (c) the same as the downlink frequency.
- (d) half of the downlink frequency.

A12. A satellite will remain in orbit if the centrifugal force caused by the satellite rotation is counterbalanced by the:
- (a) velocity of the satellite rotation.
- (b) earth's gravitational force acting on the satellite.
- (c) gyroscopic stiffness achieved by spinning the satellite body.
- (d) momentum wheels or three reaction wheels inside the satellite body.

A13. A telephone call is made by John at earth station 1 to Justin at earth station 2 via a satellite located 38000Km from both earth stations. The time taken for John to hear Justin reply assuming no other delays is:
- (a) 0.507 sec.
- (b) 0.127 sec.
- (c) 0.253 sec.
- (d) cannot be calculated.

A14. The purpose of the up converter is to:
- (a) translate the signal RF frequency to the IF frequency.
- (b) amplify the weak signal by providing a gain of 120 dB.
- (c) convert the IF signal to the final up-link frequencies.
- (d) change the uplink frequency to the downlink frequency.

A15. The altitude for a satellite whose period of rotation is to be equal to earth's rotation is:
- (a) 35876Km.
- (b) 35786Km.
- (c) 35687Km.
- (d) 35768Km.

A16. The most suitable multiple access technique for digital transmission is:
- (a) Frequency Division Multiple Access.
- (b) Frequency Division Multiplexing.
- (c) Time Division Multiple Access.
- (d) Bandwidth Division Multiple Access.

A17. The disadvantage of Ku-band over C-band is:
- (a) Ku-band interfere with terrestrial microwave transmission.
- (b) Ku-band frequency will interfere with mobile phone frequency range.
- (c) Ku-band suffer more free space path loss.
- (d) Ku-band is exclusively used by satellite communication.

A18. The main advantage of Time Division Multiple Access (TDMA) system is:
- (a) no guard bands are required.
- (b) precise timing is required.
- (c) only one carrier frequency is required.
- (d) only one data rate is required.

A19. Frequency translation process in the transponder is achieved by using:
- (a) input filter, mixer and local oscillator.
- (b) low noise amplifier, mixer and post mixer filter.
- (c) input filter, mixer and post mixer filter
- (d) mixer, local oscillator and post mixer filter.

A20. The two IF frequencies for dual conversion Down Converters in earth satellite stations are:
- (a) 12/14 GHz.
- (b) 12/14 MHz.
- (c) 70/770 GHz.
- (d) 70/770 MHz.

Section B [10 Marks Each]

B1. Arthur C Clarke in 1945 illustrated how geostationary satellites powered by solar energy could provide world-wide communications.

(a) Define the term geostationary satellite and the conditions required for a satellite to be geostationary. (5 marks)

(b) Explain how worldwide communications can be achieved using geostationary satellite. (2 marks)

(c) Can fibre optics cables provide worldwide communications? Give two reasons to support your answer. (3 marks)

B2. An Intelsat standard antenna with a diameter of 90λ is available for communicating with geostationary satellites at spacing of 2^0.

(a) State the three important performance characteristics for antenna. (3 marks)

(b) The measured sidelobe radiation pattern at 5^0 from the antenna boresight is 16.5 dBi. Evaluate and state clearly if the antenna should be allowed for communicating with the geostationary satellites. Give a reason to support your answer. (7 marks)

B3. A C-band (4/6 GHz) earth station sent a signal to a satellite located at a distance of 38000km using a transmitting antenna with a gain of 48 dB and an output power set to 100W. The signal is received by an antenna with a gain of 30 dB and routed to a transponder with a noise temperature of 770 K.

(a) Explain why the C-band uplink and downlink frequency are different. (2 marks)

(b) Calculate the free space path loss between the earth station and satellite. (3 marks)

(c) Determine the Carrier to Noise (C/N) ratio in the transponder of bandwidth 36 MHz**.** (5 marks)

B4. An optical link using a multimode step index fiber with core refractive index of 1.35 has a relative refractive index difference between the axial index n_1 and cladding index n_2 of 2%. The link length of the optical fibre is 5km.

(a) Determine the time difference between the fastest and slowest modes at the fibre output. (4 marks)

(b) Find the RMS pulse broadening or bandwidth of the optical fibre. (2 marks)

(c) Show by calculation that a graded index multimode fibre will improve the bandwidth of the 5 Km optical fiber by approximately 100 times. (You may use the same core refractive index of 1.35 and relative refractive index difference of 2%). (4 marks)

Section C [20 Marks]

C1. An optical fibre system with a bandwidth of 10 MHz has the following system parameters:

ILD source	Output power 4μw	Risetime 1.5ns
PIN detector	Sensitivity -58 dBm	Risetime 2.5ns
Step index multimode fibre core refractive index n1 = 1.5 cladding refractive index n2=1.47	Attenuation 3 dB/km	Dispersion 5ns/km
Optical splices	Loss 0.6 dB per splice	Total of 30 splices
Optical connecters	Loss 1 dB per connector	
Safety margin	7 dB	

(a) Determine the maximum link distance in Km for the optical fibre system. (8 marks)

(b) The ILD source output power is increased to 100μw. Calculate and state clearly the maximum link distance without degrading the system performance. Explain your answers.
(5 marks)

(c) Suggest TWO ways of improving the bandwidth of the optical fibre system.
(4 marks)

(d) An optical pulse from the Optical time-domain reflectometer (OTDR) was launched into the step index multimode fibre to locate a fracture. Determine the fracture point from the OTDR if the pulse echo took 3 μsec to return.
(3 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

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

For graded index

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

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

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

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

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