2017/2018 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 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. In satellite communication, round trip propagation delay between two earth stations is due to:
(a) The spinning of the satellite.
(b) The reflection of the electromagnetic wave at the antennae reflector.
(c) The high altitude of satellite.
(d) The rotation of the earth.

A2. 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

A3. Which one of the following is not an international satellite organization?
(a) INTELSAT.
(b) INMARSAT.
(c) ST2.
(d) INTERSPUTNIK

A4. A satellite in a circular orbit above the equator takes 12 hours to complete one orbit. The satellite is in:
(a) A geostationary orbit.
(b) A Helios-synchronous orbit.
(c) A low orbit.
(d) A medium orbit.

A5. In a full transponder TDMA satellite system, the number(s) of carrier in the transponder at any instant in time is:
(a) 1.
(b) 24.
(c) 36.
(d) 900.

A6. The function of TWTA in the satellites earth stations 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.

A7. Geostationary satellite permits coverage of a zone equal to _______ of the Earth's surface:
(a) 10%.
(b) 20%.
(c) 30%.
(d) 40%.

A8. Three-axis stabilized satellites are kept in a stable position by:
(a) Spinning the body of the satellite.
(b) Momentum wheels inside the satellite body.
(c) Thrusters mounted on the satellite body.
(d) Sensors mounted on the satellite body.

A9. Which one of the following amplifier is not part of Transmitter subsystem in the satellites earth station?
(a) SSPA.
(b) LNA.
(c) TWTA.
(d) Reflex Klystron.

A10. The satellite subsystem that produces shaped & contoured beam is the:
(a) Power subsystem.
(b) Transponder subsystem.
(c) Command, telemetry and control subsystem.
(d) Antenna subsystem.

A11. Light is guided in the core of multimode step index fibre by:
(a) Total internal reflection.
(b) Refraction.
(c) Reflection.
(d) Scattering.

A12. The high dispersion in multimode fibre is mainly caused by:
(a) Waveguide dispersion.
(b) Infrared absorption.
(c) Modal dispersion.
(d) Rayleigh scattering.

A13. For a long distance optical communication link, it is better to use an APD rather than a PIN photodiode because:
(a) The APD has a faster rise time than the PIN photodiode.
(b) PIN photodiodes diodes are not suitable for use with single mode fibre.
(c) PIN photodiodes only work at wavelengths below 1000 nm.
(d) The APD is more sensitive than the PIN photodiodes.

A14. Light Emitting Diode (LED) produces light by:
- (a) Spontaneous emission of electrons.
- (b) Spontaneous emission of photons.
- (c) Stimulated emission of electrons.
- (d) Stimulated emission of photons.

A15. The responsivity of a photodetector is:
- (a) The rise time of the photodetector.
- (b) The bandwidth of the photodetector.
- (c) The gain of the photodetector.
- (d) The ratio of output current to input optical power of the photodetector.

A16. Which one of the following statement is CORRECT for ILD source?
- (a) ILD is less temperature dependent than LED.
- (b) ILD has broader spectral width than LED.
- (c) ILD has a more directional radiation pattern than LED.
- (d) ILD has a lower radiant power than LED.

A17. Which one of the following statements is CORRECT for singlemode fibre?
- (a) Singlemode fibre has smaller bandwidth than multimode fibre.
- (b) Singlemode fibre has bigger core diameter than multimode fibre.
- (c) Singlemode fibre has smaller core diameter than multimode fibre.
- (d) Singlemode fibre has higher dispersion than multimode fibre.

A18. For wavelengths below 850 mm, loss in a silicon fibre is dominated by:
- (a) Waveguide dispersion.
- (b) Infrared absorption.
- (c) Modal dispersion.
- (d) Rayleigh scattering.

A19. What makes dispersion zero at about 1310 nm in single mode fibre?
- (a) Waveguide and material dispersions cancel each other out.
- (b) Waveguide dispersion equals the sum of material and modal dispersions.
- (c) Modal and material dispersions cancel each other out.
- (d) Waveguide and modal dispersions cancel each other out.

A20. An underground fibre link is experiencing high loss. It is thought that the fibre has been cut somewhere along the link. You need to find where the link has been cut.
What is the best measuring instrument to use for this task?
- (a) An optical spectrum analyser.
- (b) An optical power meter.
- (c) An Optical Time Domain Reflectometer.
- (d) A calibrated light source.

Section B [10 Marks Each]

B1. A Ku Band satellite communication system with TV signal occupying bandwidth of 36 MHz has the following specifications:

Transmitting Earth Station		Satellite	
Transmitter output power	: 1KW	Receiving Antenna Gain	: 20 dB
Antenna Gain	: 60 dB	G/T ratio	: 5 dB/K

Up-link

Atmospheric loss	: 2.0 dB
Distance	: 40,000 km

Calculate:

(a) EIRP of the earth station. (2 marks)

(b) Up-link Free Space Path Loss (FSPL). (2 marks)

(c) Up-link C/N ratio for the TV signal. (6 marks)

B2. (a) State the FOUR conditions for a satellite to become a geostationary satellite. (4 marks)

(b) Identify the type (GEO, MEO or LEO) and application of the following satellites:

(i) ASIASAT.

(ii) NOAA.

(iii) GPS (6 marks)

B3. The earth satellite station deploys the following two dish antennas to communicate with several satellites spaced at 2.0^0 apart in geostationary orbit:

- An 13m INTELSAT antenna with diameter of 400λ.
- A small 5m dish antenna with diameter of 40λ.

(a) Find the maximum permitted sidelobe levels at 5^0 from the boresight of the satellite dish for the 13m INTELSAT antenna & the small 5m dish antenna. (6 marks)

(b) If the same measured sidelobe radiation level of 12.5 dBi is obtained at 5^0 from the antenna boresight of the two antennas, which earth station antenna is **not suitable** to be used for the communication with the geostationary satellites?
Give reasons to support your answer. (4 marks)

B4. An optical communication link consists of the following components:

- ILD source with bandgap energy 0.950 eV.
- Optical fibre with Bandwidth Length Product (BWL) of 900 MHz.km, and core/cladding refractive index of 1.45/1.35.
- PIN photodiode.

Determine:

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

(b) The numerical aperture and acceptance cone angle of the fibre. (4 marks)

(c) The largest core diameter for the fibre to operate as a single mode fibre. (2 marks)

(d) The maximum length at which the fibre can support signal with 750 MHz bandwidth. (2 marks)

Section C [20 Marks]

C1. An optical fiber system using NRZ signaling is operating at 100Mbps with a BER of 10^{-9} and a safety margin of 5dB. If components with the following specifications are used :

Transmitter
Output Power = 2mW
Source Rise Time = 0.2ns
Connector Loss = 0.5dB

Receiver
Sensitivity at 10^{-9} BER = -40dBm
Detector Rise Time = 0.3ns
Connector Loss = 0.5dB

Fiber
Modal Dispersion = 1ns/km, Material Dispersion = 0.5ns/km
Attenuation = 0.4 dB/km, Splice Loss = negligible

Calculate :

(a) Transmitter output power expressed in dBm. (2 marks)

(b) Maximum length of the optical fiber system based on power budget. (5 marks)

(c) Maximum length of the optical fiber system based on risetime budget. (7 marks)

(d) Actual maximum length that the optical fiber system can be operated. (2 marks)

(e) Will the maximum length of the optical fiber system be increased if both the source and detector rise times are reduced ? Give reasons to support your answer. (4 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

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

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

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

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

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

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

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2} \qquad \Delta\tau = \frac{Ln_1}{c}\left(\frac{n_1 - n_2}{n_2}\right) \qquad n(r) = n_1\sqrt{1 - 2\Delta\left(\frac{r}{a}\right)^{\alpha}}$$

$$V = \frac{\pi d}{\lambda}(NA) \qquad a \leq \frac{2.405\lambda}{2\pi\sqrt{n_1^2 - n_2^2}}$$

For step-index multimode	For graded index
$M = \frac{V^2}{2}$ $\quad \sigma = \frac{n_1 L\Delta}{c\sqrt{12}}$	$M = \frac{V^2}{4}$ $\quad \sigma = \frac{n_1 L\Delta^2}{c\sqrt{48}}$

$$B = \frac{0.35}{\sigma} \qquad B = \frac{0.35}{t_{sys}} \qquad f = \frac{c}{\lambda} \qquad D = \frac{ct}{2n}$$

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

$$\lambda = \frac{1.24}{E_g} \qquad \lambda = \frac{hc}{E_g} \qquad R = \frac{\eta\lambda e}{hc}$$

$$I_p = (r_e)(e) \qquad P_o = (r_p)(hc/\lambda)$$