2018/2019 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. Light is confined within the core of an optical fibre by:
- (a) Total Internal Reflection at the core-cladding boundary
- (b) Refraction at the outer edge of the cladding
- (c) Dispersion.
- (d) Total Internal Reflection & Refraction.

A2. Optical fibres are immune to:
- (a) High frequency transmission losses.
- (b) Signal losses.
- (c) Electromagnetic interference.
- (d) Signal distortion.

A3. Which one of the following statements is correct?
- (a) An LED has a longer life than a laser diode
- (b) An LED has a higher output power than a laser diode.
- (c) An LED is more expensive than a laser diode.
- (d) An LED is more temperature sensitive than a laser diode.

A4. Dark current in a PIN photodetector is :
- (a) The amount of output current measured in the absence of light in a photodetector.
- (b) The number of dark electrons produced in a photodetector.
- (c) The leakage current for a given light input in a photodetector.
- (d) The current flow of a special type of a photodetector.

A5. Dispersion in single mode optical fibre can be further minimized by using a laser source with operating wavelength of:
- (a) 850 nm.
- (b) 950 nm.
- (c) 1310 nm.
- (d) 1550 nm.

A6. The main advantage of an APD over PIN is that:
- (a) It costs less.
- (b) The circuitry is simpler.
- (c) It produces less noise.
- (d) It is more sensitive.

A7. The maximum transmission distance of an optical fibre link is limited by which one of the following mechanisms:
- (a) Reflection.
- (b) Refraction.
- (c) Dispersion.
- (d) Radiation.

A8. The narrow spectral width of ILD source in an optical fibre link will:
- (a) Reduce fibre modal dispersion.
- (b) Reduce fibre material dispersion.
- (c) Increase fibre modal dispersion.
- (d) Increase fibre material dispersion.

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A9. One of the disadvantages an APD receiver has over PIN receiver is that :
- (a) It produces more heat.
- (b) The circuitry is reversed biased.
- (c) It produces less current.
- (d) It produces more noise.

A10. 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.

A11. Which one of the following is not an international satellite organization?
- (a) INTELSAT
- (b) PALAPA
- (c) INMARSAT
- (d) INTERSPUTNIK

A12. A geostationary satellite permits coverage of a zone equal to about _______ of the Earth's surface:
- (a) 10%.
- (b) 20%.
- (c) 30%.
- (d) 40%.

A13. The use of frequency reuse technique in satellite communication is to:
- (a) Increase the transmitting power of the satellite.
- (b) Increase the coverage area of the satellite.
- (c) Increase the information carrying capacity of the satellite.
- (d) Increase the line of sight (LOS) of the satellite.

A14. Geostationary communication satellites need to use battery power during:
- (a) The summer solstice.
- (b) The winter solstice.
- (c) The autumnal equinox.
- (d) The night hours on earth.

A15. Which one of the following is not the function of the thruster subsystem?
- (a) To keep satellite in the correct orbit.
- (b) To assist in attitude control.
- (c) To maintain station keeping.
- (d) To provide gyroscopic stiffness for stabilizing the satellite.

A16. 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) Reaction wheels inside the satellite body.
- (d) Both momentum wheels and reaction wheels inside the satellite body.

A17. The satellite subsystem that converts uplink to downlink frequencies is the :
- (a) Transponder subsystem.
- (b) Power supply subsystem.
- (c) Command, telemetry and control subsystem.
- (d) Antenna subsystem.

A18. The C band frequencies used by communication satellite are :
- (a) 14/12 GHz.
- (b) 4/6 GHz.
- (c) 12/14 GHz.
- (d) 6/4 GHz.

A19. Which one of the following requirement is crucially important for a TDMA system?
- (a) System output power.
- (b) System bandwidth.
- (c) System timing.
- (d) System beamwidth.

A20. One of the advantages that C band has over Ku band in satellite communication is that:
- (a) It has less propagation delay.
- (b) Free Space Path Loss (FSPL) is higher.
- (c) It suffers less atmospheric losses.
- (d) It will not cause interference to terrestrial microwave links.

Section B [10 Marks Each]

B1. A step index multimode fibre has core refractive index of 1.475, cladding refractive index of 1.455 and an operating wavelength of 1550 nm.

(a) State THREE types of dispersion found in step index multimode fibre. (3 marks)

(b) Find the largest core diameter for which the fibre will become single mode. (4 marks)

(c) Recommend the operating wavelength for the single mode fibre to achieve maximum bandwidth. Explain your answer. (3 marks)

B2. 3×10^{10} photons/sec are incident onto a PIN photodiode with a bandgap of 1.30 eV and responsivity of 0.55 A/W. Determine:

(a) The wavelength of optical light (in nm) that can be detected by the photodiode. (3 marks)

(b) The current (in nA) generated at the PIN photodiode output. (4 Marks)

(c) If PIN photodiode is replaced by a APD photodiode, would the current generated at photodiode output increase or decrease? Give a reason to support your answer. (3 marks)

B3. An optical fiber system using NRZ signaling has a bandwidth of 50 MHz and a safety margin of 7 dB. If the following optical components are used:

ILD Source
Output power = 3dBm
Rise time = 0.2 ns
Connector loss = 0.5 dB

APD Detector
Sensitivity at 10^{-9} BER = -40 dBm
Rise time = 0.3 ns
Connector loss = 0.5 dB

Fiber
Dispersion = 1.12 ps/km Attenuation = 0.5 dB/km Splice loss = negligible

(a) Determine the maximum transmission distance for the optical fibre system (8 marks)

(b) State if the system is power limited or rise time limited (2 marks)

B4. A satellite having a mass 100 kg is in circular equatorial orbit at an altitude of 13312 km.

(a) Find the velocity and period of rotation of the satellite above the equator. (7 marks)

(b) Determine how many transmissions per day an earth satellite station will receive from this satellite. (3 marks)

Section C [20 Marks]

C1. A Ku-band communication satellite in geostationary orbit has the following parameters:

Earth satellite station
Antenna gain: 60.0 dB (Receive)
64.0 dB (Transmit)
System equivalent noise temperature: 100K

Uplink path distance: 35,860 Km
Downlink path distance: 42,000 Km

Satellite transponder:
Antenna gain : 14 dB (Receive)
12 dB (Transmit)
Transmitter output power: 10 dBw
Receiving electronics noise temperature: 30K

(a) State the downlink and uplink frequency for both C-band and Ku-band geostationary satellite. (4 marks)

(b) Calculate figure of merit of the earth satellite receiver. (3 marks)

(c) Calculate the down-link free space path loss. (3 marks)

(d) Calculate the power received by the earth satellite station. (3 marks)

(e) Calculate the C/N ratio at the earth satellite station for a 30 MHz TV channel. (4 marks)

(f) Will the C/N ratio be improved if the communication satellite uses C-band instead of Ku-band and assuming all other parameters remain the same? Explain your answer. (3 marks)

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

Constants & Formulas Sheet

Gravitational constant $G = 6.673 \times 10^{-11}\ Nm^2 Kg^{-2}$

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

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

Speed of light $c = 3 \times 10^8$ m/s

Plank's constant $h = 6.626 \times 10^{-34}$ Js

Electron charge $e = 1.602 \times 10^{-19}$ 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

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

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

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

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

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

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

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

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

For step-index multimode

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

For graded index

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

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

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

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

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