2015/2016 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. Graded index fibre is used to :
- (a) Reduce modal dispersion.
- (b) Reduce material dispersion.
- (c) Reduce fibre loss.
- (d) Reduce coupling loss.

A2. Which one of the following statements is incorrect ?
- (a) A laser diode has a longer life than an LED.
- (b) A laser diode has a higher output power than an LED.
- (c) A laser diode is more expensive than an LED.
- (d) A laser diode is more temperature sensitive than an LED.

A3. 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.

A4. Identify the incorrect statement :
- (a) To attain total internal reflection in a fibre, the cladding refractive index must be smaller than the core refractive index.
- (b) In glass, the reflective index varies with wavelength.
- (c) The numerical aperture of a fibre depends on the line width of the source used.
- (d) A large acceptance angle implies a large numerical aperture.

A5. One of the advantages that an APD has over PIN is that :
- (a) It costs less.
- (b) The circuitry is simpler.
- (c) It produces less noise.
- (d) It is more sensitive.

A6. The maximum link length of an optical fibre link is limited by which one of the following mechanisms :
- (a) Reflection.
- (b) Refraction.
- (c) Dispersion.
- (d) Radiation.

A7. Material dispersion in Silica glass fibre can be minimized by using a laser source with centre operating wavelength of :
(a) 850 nm.
(b) 950 nm.
(c) 1310 nm.
(d) 1550 nm.

A8. 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.

A9. Absorption losses in fibre result from :
(a) The fracture in the fiber.
(b) The microbending in the fiber.
(c) The water bands (OH^- ions) in the fiber.
(d) The modal dispersion in the fiber.

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A10. Light is guided down a graded index multimode fibre because of :
(a) Total Internal Reflection.
(b) Refraction.
(c) Dispersion.
(d) Total Internal Reflection & Refraction.

A11. What is the altitude, in km, of a geostationary satellite orbit :
(a) 6,378.
(b) 35,786.
(c) 42,164.
(d) 24.

A12. A geostationary satellite has 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 vernal equinox.
- (d) The night hours.

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. Which one of the following elements are used to make corrections to the attitude of satellite :
- (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 Ku band frequencies used by communication satellite are :
- (a) 6/8 GHz.
- (b) 4/6 GHz.
- (c) 12/14 GHz.
- (d) 14/16 GHz.

A19. Which 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 Ku band has over C band in satellite communication is that :
- (a) It has less propagation delay.
- (b) Free Space Path Loss (FSPL) is lower.
- (c) It suffers less atmospheric losses.
- (d) It will not cause interference to terrestrial microwave links.

Section B [10 Marks Each]

B1. An optical communication link consists of an ILD with bandgap energy 0.950 eV, an optical fibre with core refractive index of 1.45 and cladding refractive index of 1.35, and a PIN photodiode.

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

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

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

B2. (a) Name the TWO types of optical source used in optical communication. (2 marks)

(b) An optical light beam with 9 x 10^{10} photons/sec at 1550 nm is incident onto the PIN photodiode which has a responsivity of 0.8 A/W. Calculate :

(i) The maximum possible bandgap energy of the PIN photodiode in eV. (2 marks)

(ii) The quantum efficiency of the PIN photodiode. (3 marks)

(iii) Find the current generated at the PIN photodiode output terminal. (3 marks)

B3. An optical fiber link operating at 1550 nm wavelength, NRZ signal with bitrate of 1.0 Gbps and BER of 10^{-9}, safety margin of 6 dB, is set up between Singapore & Malaysia at 500 km apart. The following optical components will be used :

ILD Source
Output power = 30 mw
Rise time = 0.1 ns
Connector loss = 0.6 dB

APD Detector
Sensitivity at 10^{-9} BER = -48 dBm
Rise time = 0.2 ns
Connector loss = 0.6 dB

Single-mode Fiber
Material dispersion = 15 ps/km
Attenuation = 0.5 dB/km
60 Splices with 0.2 dB loss each

(a) Calculate the maximum link distance between repeaters. (8 marks)

(b) Determine the total number of repeaters required for this optical link. (2 marks)

B4. The C-band broadcasting satellite is equipped with a transmitting antenna of 25 dB gain, has a transmitted output power of 150W.
If a TVRO system is installed to receive the broadcast TV programs from the satellite, the TVRO system has a receiving antenna gain of 50 dB and receiver equivalent noise temperature of 1000K. Determine :

(a) The EIRP of the satellite in dBW. (2 marks)

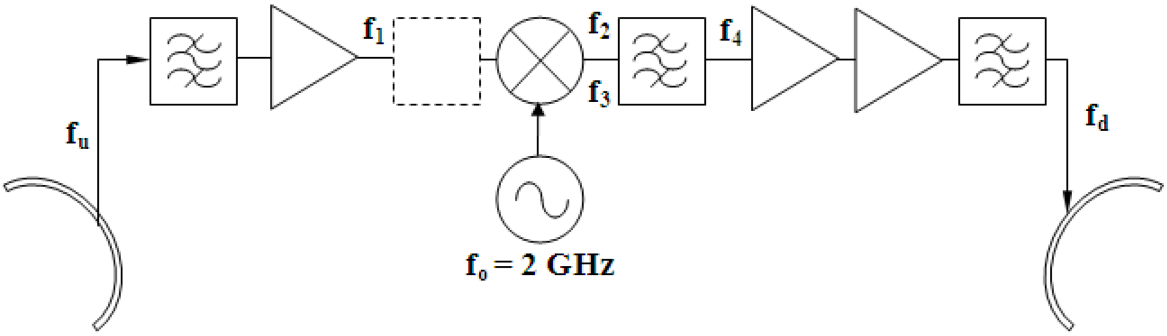
(b) The figure of merit (G/T) of the TVRO system. (2 marks)

(c) The downlink Free Space Path Loss, if the downlink distance is 36,000 km. (2 marks)

(d) The C/N ratio at the TVRO system for an 18 MHz TV channel. (4 marks)

Section C [20 Marks]

C1. The following block diagram shows the transponder subsystem of a communication satellite:



(a) If the transponder subsystem operates at Ku-band, identify the frequency values : f_u , f_1 , f_2 , f_3 , f_4 and f_d . (6 marks)

(b) Name the blocks that are responsible for the amplification function. (3 marks)

(c) Name the blocks that are responsible for the frequency translation function. (3 marks)

(d) State the two types of POLARIZATION used in the transponder subsystem and hence explain the advantage of using these polarizations. (4 marks)

(e) Briefly explain why the satellite transponder needs to change the incoming uplink frequency (f_u) to another downlink frequency (f_d). (4 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

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

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

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

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

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

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

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

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

For step-index multimode

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

For graded index

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

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

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

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

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