UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: October 2019

Module Number: EE7211 **Module Name: Optical Fibre Communication**

[Three Hours]

[Answer **all questions**, each question carries **12.5 marks**]

Notes:

- **All notations have their usual meaning**
- **Clearly mention any assumption you make.**
- **Use following standard values for your calculations.**

Planck's constant (h) = 6.63×10^{-34} Js **Velocity of light in vacuum (c) = 3×10^{8} m/s**

Charge of an electron (e) = 1.602×10^{-19} C **Boltzmann constant (k_B) = 1.38×10^{-23} J/K**

Q1 a) Write the equations for "photo current" and "responsivity" of an avalanche photodiode (APD) receiver.

[1.0 Mark]

b) Consider a receiver with an InGaAs APD which has a wavelength of 0.8 μm. Assume 65% quantum efficiency, 1 nA dark current, 8 pF junction capacitance and 50 Ω load resistance. The APD operates with a multiplication factor of 30 and an excess noise factor of 2.5. The receiver is illuminated with 5 μW optical power and operated at 27^{0}C.

i) Determine the following.

I. Responsivity (R_{APD}) of the photodiode
II. Photo current of the APD
III. Shot noise currents for bit 1 and bit 0
IV. Thermal noise current
V. Signal to noise ratio (SNR)

ii) Identify the main noise contribution factor of the receiver and comment on the receiver limitations.

[11.5 Marks]

Q2 a) Mention two different types of optical amplifiers.

[1.0 Mark]

b) An optical link is shown in Figure Q2. The transmitter emits a signal with an average optical power of 10 dBm. Then the signal is launched to a 100 km fibre segment contains two splices. Each splice has a loss of 0.5 dB. The attenuation of the fibre is 0.2 dB/km. At the end of the fibre segment 1, the signal is amplified using an optical amplifier with a gain of 20 dB.

The total noise power measured at 0.1 nm bandwidth for the input and the output of the optical amplifier is 0.316 μW and 100 μW respectively.

Then, the amplified signal is launched in to the fibre segment 2 with a length of 100 km and an attenuation of 0.3 dB/km. This fibre segment also contains two splices each with 0.4 dB loss. At the end of the fibre segment 2, the signal is detected using an optical receiver.

Hint:

Amplified Spontaneous Emission (ASE) Noise Power;

$$P_n = 2n_{sp}(G-1)hfB_{opt}$$

OSNR of chain amplifier link;

$$\text{OSNR (dB)} = P_{out} + 58 - 10\log(n) - 10\log(N+1) - L_{sp}$$

Determine the following.

i) Received power at the input of the optical amplifier
ii) Optical-signal-to-noise ratio (OSNR) at the input of the optical amplifier
iii) OSNR at the output of the optical amplifier
iv) Noise figure (NF) of the optical amplifier
v) Received power at the input of the receiver

[11.5 Marks]

Q3 a) Name three different types of fibre according to the refractive index profile.

[1.5 Marks]

b) Using diagrams, indicate the difference between meridional and skew ray paths in step index fibres.

[2.0 Marks]

c) A step index fibre has a core radius of 62.5 μm and a cladding radius of 125 μm. The core and cladding refractive indices are 1.51 and 1.49 respectively. Determine the number of modes that supports at a wavelength of 1550 nm.

[3.0 Marks]

d) A perfectly cylindrical rod of glass has a refractive index n_c. It is immersed in a liquid with a refractive index of n_w. Show all the light incident on the rod facet is guided through the rod, when $n_c^2 \geq 2n_w^2$.

[2.0 Marks]

e) An optical fiber has a numerical aperture (NA) of 0.20 in air and a cladding refractive index of 1.59. Determine the following.

i) Acceptance angle for the fiber in water which has a refractive index of 1.33
ii) Critical angle at the core-cladding interface

[4.0 Marks]

Q4 a) Mention two types of light scattering mechanism in optical fibres.

[2.5 Marks]

b) Assume an optical link with 1 Gb/s data rate and non-return to zero (NRZ) modulation. The dispersion and the attenuation at the wavelength of 1.55 μm are 17 ps/nm.km and is 0.25 dB/km respectively. The attenuation at the wavelength of 1.3 μm is 0.5 dB/km. Consider the following specifications of the transmitter and the receiver of optical fiber links. Neglect all losses except the attenuation loss in the fiber.

- A transmitter that operates at a wavelength of 1.55 μm, has a spectral width of 1 nm and an output power of 0.5 mW. The receiver requires (−30) dBm of input power to achieve the desired bit error rate.
- A transmitter that operates at a wavelength of 1.3 μm, has a spectral width of 2 nm and an output power of 1 mW. Assume the same receiver as before.

i) Calculate the maximum link length with respect to the attenuation and dispersion for both links.

ii) Decide on the possible longest link length with a proper justification.

[10.0 Marks]

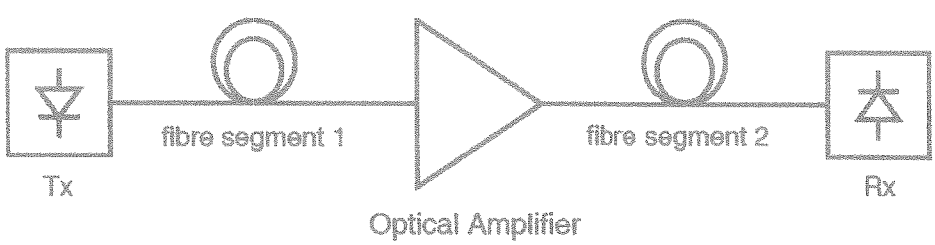

Figure Q2