UCL DEPARTMENT OF ELECTRONIC &
ELECTRICAL ENGINEERING

Masters Programmes in Communications

Broadband Technologies and Components

18th November 2016

Closed Book Exam

10.00am - 12.30pm

Guidelines:

- This paper comprises 2 sections:
  Section 1 is **2 compulsory questions** each worth 30%. It is advised that you spend no longer than 1 hour and 30 minutes on this question
- **Section 2** contains 3 questions of which you must answer **2 questions only**
- Please **answer each question** in a **separate answer book**
- The distribution of marks among parts of questions is indicated for guidance

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Physical Constants

Velocity of light in a vacuum, $c = 3 \times 10^8$ ms^{-1}
Planck's constant, $h = 6.626 \times 10^{-34}$ Js
Boltzmann's Constant, $k = 1.38 \times 10^{-23}$ Joule/Kelvin
Electron Charge, $e = 1.602176 \times 10^{-19}$ C
0°C = 273 K

NEXT PAGE

Section 1 ***This section has* two *compulsory questions Each is worth 30% of the total mark.***

Please answer each question in a separate answer book.

Optical Design question

Question 1

For a link distance of 200 km, derive the details of a full link for 1 Gbit/s considering the following potential elements.

Transmitter	DFB laser
Laser Wavelength	1550 nm
Laser Linewidth	2 MHz
Peak transmitter output	2 mW
Fibre:	Standard single mode with
	Dispersion 16 ps/nm.km @ 1550 nm
	Attenuation 0.2 dB/km
	Dispersion compensated fibre
	Dispersion -38 ps/nm.km @ 1550 nm
	Attenuation 0.35 dB/km
EDFA:	Saturated power: 16 dBm
	Gain: 30 dB
	Noise Figure: 5 dB
Receiver Sensitivity	-27 dBm (BER=10^{-9} at 1550 nm and modulation of 10 Gbit/s)

State and justify any assumptions included in your calculations.

[100%]

Question 2

a) Explain the following aspects of multipath propagation with a brief description (two or three lines only) for each:

a. What is the mechanism in the communication channel that causes multipath propagation?

[10%]

b. What is the resulting effect of multipath propagation that causes signal degradation, and why?

[10%]

c. A multipath channel is described by the channel impulse response $h(\tau)$ shown in Figure 1 below. Write the mathematical expression that describes the channel impulse response.

[10%]

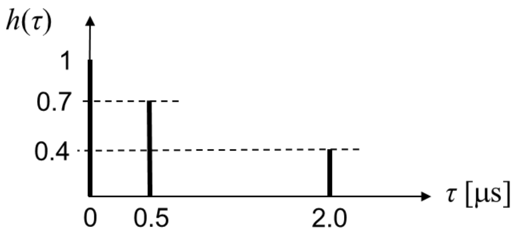

Figure 1: Channel impulse response

b) A 500 Mbit/s Line of Sight (LoS) link is being set up with a range of 2 km, a carrier at 10 GHz, and a transmission bandwidth limited to 250 MHz. The transmit and receive antennas are placed at the same height above sea level, and each of them has a gain of 10 dB and each is fed by a coaxial cable with coupling efficiency of 50%. The receiver is operating at room temperature (27 ^{o}C) and has a noise figure of 11 dB.

a. Which of the modulation schemes from the ones shown in Figure 2 below, achieves the target data rate and minimises the required transmit power? You should fully justify your selection by appropriate calculations and clearly state any assumption you make.

[35 %]

NEXT PAGE

b. Using free-space power budget calculations, determine the transmit power required for your selected modulation scheme, for data transmission with a maximum error rate of 10^{-6}, given the BER performances in Figure 2 below.

[35%]

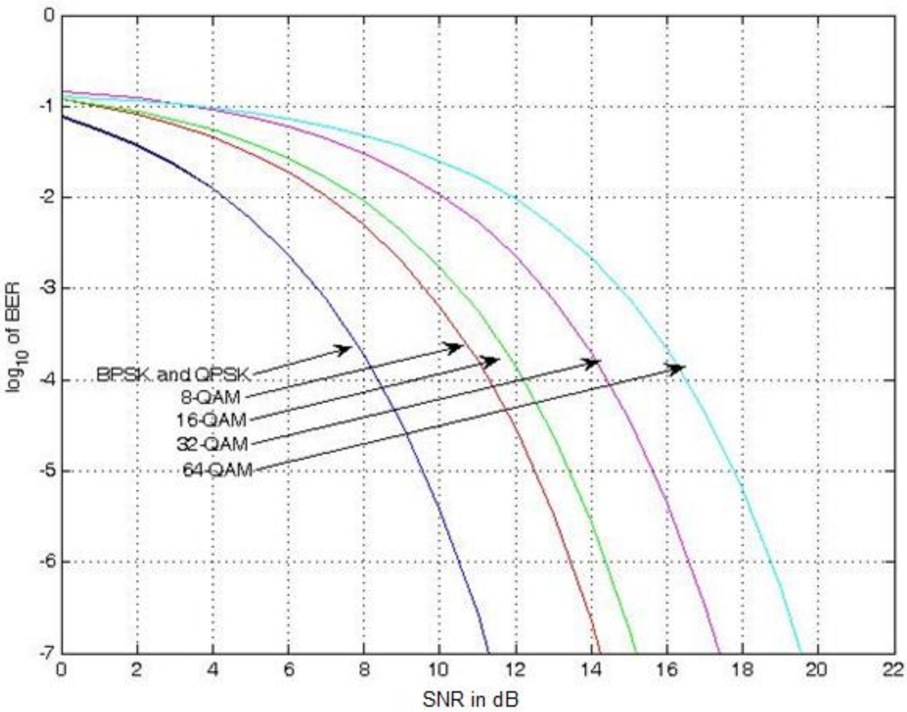

Figure 2: Bit Error Rate versus SNR for different modulation schemes

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Section Two

This section contains 3 questions. Answer ***2 questions only.***

Please answer each question in a separate answer book.

Question 3

a) For an optical source, derive, showing and explaining all your steps, the equation relating the spectral linewidth in wavelength units to the spectral linewidth in frequency units from the equation

$c = f\lambda$ Equation (1)

[10%]

b) Making use of the fact that the range of energies of the photons emitted from an optical source is related to its junction temperature, T, by

$\Delta E \propto kT$ Equation (2)

derive, showing and explaining all of your steps, two equations, one showing the dependence of the spectral linewidth in frequency units and the other in wavelength units. [28%]

c) Draw diagrams and use text to clearly the explain the difference, advantages and limitations between a Distributed Bragg Reflector, DBR and a Distributed Feedback, DFB laser. [34%]

d) In a long single mode optical transmission system operating at 1.55 micron wavelength incorporating an erbium doped optical amplifier with a spectral bandwidth of 5 THz, calculate how many wavelength channels can be transmitted using

i.) Coarse WDM

ii.) Dense WDM

In both cases make sure you clearly state your assumptions [28%]

Question 4

a) Explain the purpose of a raised cosine filter for NRZ optical signal transmission and its impact on the bandwidth.

[30%]

b) Explain what an eye-diagram is and its uses in assessing the performance of digital systems;

[20%]

c) For an unamplified optical system the received signal has rms noise values on zeros and ones of $\sigma_0 = 0.1\mu V$ and $\sigma_1 = 0.25\mu V$ respectively with the mean zero and one levels being $\langle V_0 \rangle = 0.01\mu V$ and $\langle V_1 \rangle = 1.01\ \mu V$ respectively.

i) Sketch the eye diagram and noise distribution at the received

[10%]

ii) Calculate the optimum decision threshold

[10%]

iii) Determine the extinction ratio

[10%]

iv) Determine the signal to noise ratio

[20%]

Question 5

a) Describe the three different topologies commonly used in the design of optical receiver circuitry. Compare the basic characteristics of these topologies.

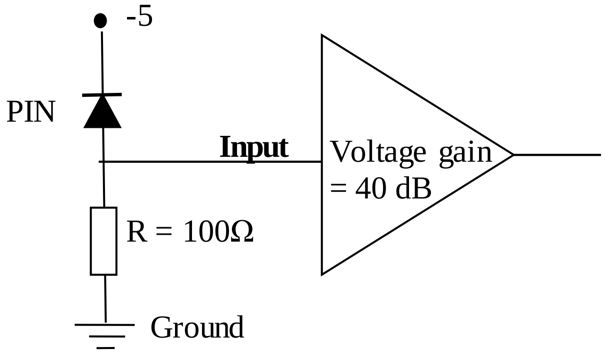
[20%]

b) Define briefly the following terms:

i) The long wavelength cut-off of a photodetector
ii) Optical receiver sensitivity

[20%]

c) An optical receiver, operating at room temperature of 27° C, is constructed from a pin photodiode with a responsivity of 0.7 A/W, and a 50Ω load resistor of 50Ω, followed by a 15 GHz amplifier as in the block diagram below:



The input to the receiver is an equi-probable 10 Gbit/s optical binary. Derive the receiver sensitivy for a BER of 10^{-9}.

[60%]

END OF PAPER