UCL DEPARTMENT OF ELECTRONIC &
ELECTRICAL ENGINEERING

Masters Programmes in Communications

Broadband Technologies and Components

25th November 2011

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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IGDP Communications for Industry
MSc in Communications Research
MSc in Telecommunications
MSc in Telecommunications with Business
MSc in Internet Engineering
MSc in Wireless and Optical Communications
MRes Photonic Systems Development
EngD in Communications

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

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<u>Section 1</u> 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

a) Determine the loss limited and dispersion limited distance for an un-amplified optical link formed of devices with the following parameters.

Transmitter	Type: DFB laser, directly modulated.
Bit Rate	2.5 Gbit/s
Fibre Dispersion	16 ps/nm.km @ 1550nm
Attenuation	0.2 dB/km
Laser Wavelength	1550 nm
Laser Linewidth	<1MHz
Peak transmitter output	2mW
Receiver Sensitivity	-25dBm (BER=10^{-9} at 1550nm)

Define and justify any assumptions included in your calculations.

[60%]

b) Outline what additions would need to be made to the link so that a span of 175km is possible. Give an indication of the requirements (including any calculations required) of any components you add.

[20%]

c) Comment on any implications for future upgrades to a 10Gbit/s system including any calculation required to demonstrate the issues.

[20%]

Question 2

a) A microwave system designer is required to setup a line of Sight (LoS) link to transfer digital data from the 11^{th} floor of UCL Engineering building (100 m above sea level) to the top of the barbican building in London (200m above sea level). The two buildings are separated by 3 km distance. The requirement is to transmit a 16 QAM modulated 1 Gbit/s data stream using an 8 GHz carrier, with the transmitter power being limited to 10 Watt. The link employs two identical microwave transmit and receive antennas each has a gain of 15 dB and each is fed by a coaxial cable with coupling efficiency of 40%. Using power budget calculations and Figure 1 below, comment on the suitability of this link for the purpose of high quality data transmission with bit error rate better than 10^{-4}. Assume that the receiver front end equipment has a noise figure of 3 dB and is operating at room temperature (27 ^{o}C) and that given London weather attenuation due to rain and pollution could be as high as 3.3 dB/km.

[100%]

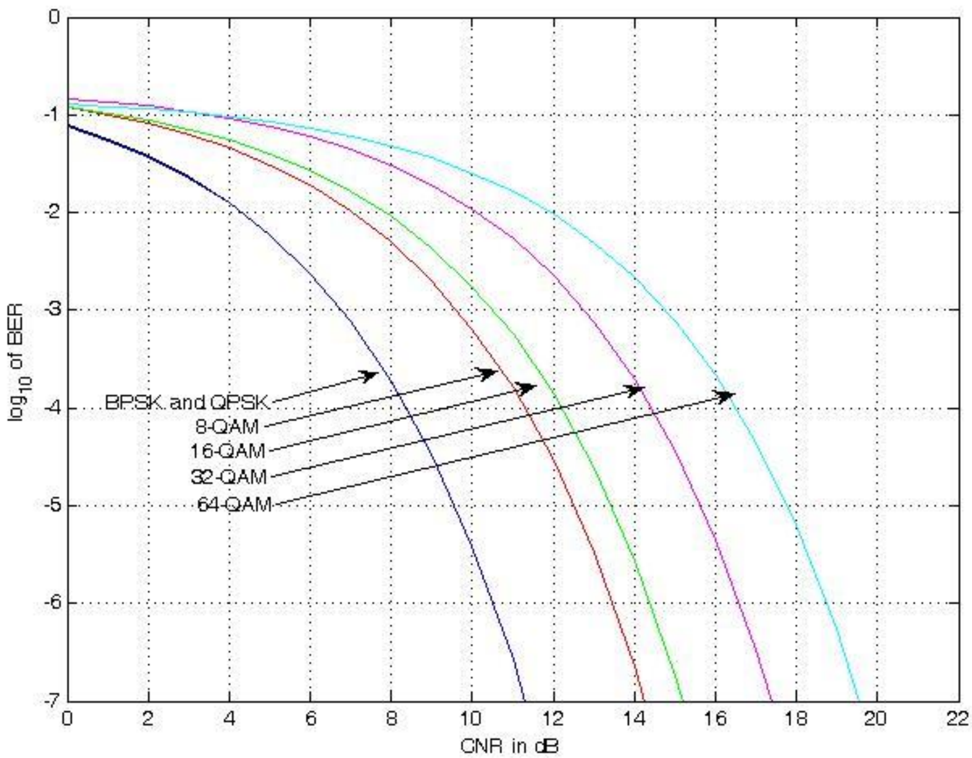

Figure 1: Bit Error Rate versus CNR for different modulation schemes

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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) Draw a fully labelled graph of optical loss in a silica single mode fibre versus optical transmission wavelength and superimpose on it at the correct positions firstly, the gain curve of an optical erbium doped fibre amplifier (EDFA) using the usual appropriate pump power for C-band operation and secondly, the gain curve of an EDFA using the appropriate pump power to cover L band operation? Explain what is the difference between the pump powers required in these two cases.

[10%]

b) What limits the maximum number of wavelengths that can be used in a single mode optical fibre communication link today and in the future? In your answer, make reference to relevant standards, quote relevant numerical values, draw relevant graphs, use the correct technical key words and perform relevant simple calculations.

[40%]

c) As part of the design of a single mode fibre, 10 Gb/s, 10^{-12} BER communication point to point 70 km link, choose and specify the performance characteristics of the most appropriate light source and transmitter explaining your reasons for your choice. In your answer, you will need to consider several performance characteristics for each of at least 4 light sources.

[50%]

Question 4

a) Explain, briefly, the following:

i) Intersymbol interference (ISI) and zero ISI signals;

ii) The key sources of noise encountered in optical communication systems;

iii) The eye diagram and its uses in assessing the performance of digital systems;

iv) Line coding and its applications.

[40%]

b) 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 receiver

ii) Calculate the optimum decision threshold

iii) Determine the extinction ratio

iv) Determine the signal to noise ratio

[60%]

Question 5

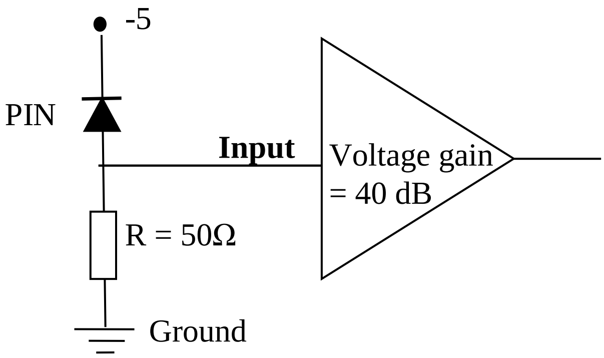
a) Explain the principle of direct optical detection and generation of a photocurrent in a PIN photodiode.

[30%]

b) List four key design parameters for optical receivers and briefly define these parameters.

[30%]

c) An optical receiver, operating at room temperature of 27^{o} C, is constructed from a pin photodiode with a responsivity of 0.9 A/W, and a 50Ω load resistor R, followed by a 1.5 GHz amplifier as in the block diagram below:



The input to the receiver is an equi-probable 1 Gbit/s optical binary signal with an average power of -20 dBm. You are required to find:

i) The receiver transimpedance gain expressed in dBΩ;

ii) The peak output voltage;

iii) The rms input noise current at the input of the receiver and the corresponding receiver sensitivity (in dBm) for operating at a BER of 10^{-12}, knowing that the required Q factor for BER of 10^{-12} is equal to 7. Comment on the expected signal quality at the receiver output.

[40%]

END OF PAPER