UCL DEPARTMENT OF ELECTRONIC &
ELECTRICAL ENGINEERING

Masters Programmes in Communications

Broadband Technologies and Components

16th November 2012

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 these questions
- **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, $k = 1.38 \times 10^{-23}$ JK^{-1}
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) Derive the maximum data rate for the following link.

Transmitter	Type: DFB laser, directly modulated.
Link Length	100 km
Fibre Dispersion	17 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 and modulation of 2.5 Gbit/s)
Operating system margin	2 dB

Define and justify any assumptions included in your calculations.

[70%]

b) What would you propose to do to increase the data rate for the 100 km link without the addition of optical amplifiers or forward error correction? Please argue your answer.

[30%]

Question 2

a) List the main factors that degrade the error performance of digital transmission systems? Give a simple definition for each (one or two lines only).

[30%]

b) A telecommunications operator is designing a microwave Line of Sight (LoS) link to transmit a 500 Mbit/s data stream using a 10 GHz carrier. The link spans a distance of 4km and employs two identical microwave transmit and receive antennas, each having a gain of 12 dB and each fed by a coaxial cable with coupling efficiency of 55%. The receiver and transmitter antennas are at the same height above sea level and the receiver front end equipment has a noise figure of 5 dB and is operating at room temperature (27 ^{o}C).

a. The transmission bandwidth allowed is limited to 250 MHz. Given this restriction, choose an appropriate modulation scheme that achieves the target data rate and minimises the required transmission power. You should fully justify your selection by appropriate calculations and clearly state any assumption you make.

[35%]

b. Using free-space power budget calculations and Figure 1 below, determine the transmit power required for your selected modulation scheme, for data transmission with a maximum error rate of 10^{-6}.

[35%]

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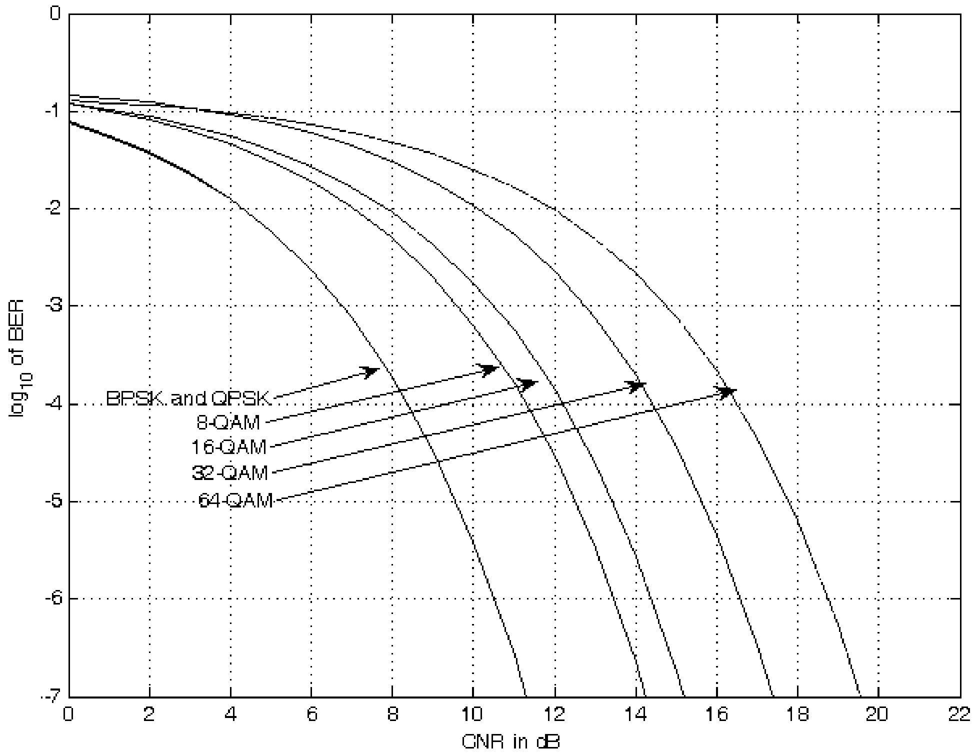

Figure 1: Bit Error Rate versus CNR for different modulation schemes

Section Two

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

Please answer each question in a separate answer book.

Question 3

a) Calculate the length in microns of a semiconductor Fabry Perot Laser having a wavelength in free space of 1.31 µm, made from a crystalline material with a refractive index of 3.3 if the strongest longitudinal mode has 1008 half wavelengths within the cavity. [15%]

b) Briefly list 4 benefits of optical fibre amplifiers as opposed to semiconductor optical amplifiers (SOAs). [15%]

c) Draw a graph showing the typical gain and bandwidth of an erbium doped optical fibre amplifier (EDFA). [10%]

d) List the names of the noise sources which exist in a receiver once an optically amplified signal with Amplified Spontaneous Emission (ASE) has been directly detected, and write a mathematical expression for each type of noise in units of photons squared per Hertz or in units of receiver current. Hence, or otherwise, deduce which noise sources are dependent on the level of the original signal entering the optical amplifier and which noise sources have a much wider bandwidth than the original signal. Briefly explain the reason for the differences in the spectral bandwidths of the different types of noise. [35%]

e) Discuss the benefits of wavelength division multiplexing compared to time division multiplexing, taking care to consider both the optical source and the optical fibre. [10%]

f) Draw a fully labelled schematic diagram, using recognised symbols, for an optical wavelength routing add-drop multiplexer. How is an original incoming signal affected by passage through an add drop multiplexer when an additional 10 Gb/s signal at a different wavelength is added? [15%]

Question 4

a) State the different sources of noises in a digital system transmission and explain how they affect the system.

[30%]

b) State the four key concepts that need to be considered when choosing a digital modulation format in a transmission system.

[20%]

c)

i) Sketch a typical NRZ eye diagram

[10%]

ii) Label the eye diagram detailing the significance of each of its parts

[20%]

iii) Show how the Q factor of the system can be derived from the eye diagram

[20%]

Question 5

a) Sketch the basic structure of a PIN photodiode and explain its principle of operation. [40%]

a) b) Define briefly the following terms:

i) The unit of dBΩ in the context of defining the gain of an optical receiver;
ii) Quantum efficiency of a photodiode and the range of values this quantity may take.

[20%]

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

[40%]

END OF PAPER