UCL DEPARTMENT OF ELECTRONIC &
ELECTRICAL ENGINEERING

Masters Programmes in Communications

Broadband Technologies and Components

17th December 2010

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

---

IGDP Communications for Industry
MSc in Communications Research
MSc in Telecommunications
MSc in Internet Engineering
MSc in Technologies for Broadband Communications
MSc in Telecommunications with Business
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

TURN OVER

<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) The following devices have been proposed for a 10Gbit/s link to span 40km of dispersion shifted fibre. Determine if the system will give acceptable performance (BER=10^{-10}) by calculating the power and dispersion budgets.

Transmitter	Type: DFB laser, externally modulated.
Bit Rate	10 Gbit/s
Fibre Dispersion	4 ps/nm.km @ 1550nm
Attenuation	0.28 dB/km
Laser Wavelength	1550 nm
Laser Linewidth	<5MHz
Peak transmitter output	0.5mW
Receiver Sensitivity	-20dBm (BER=10^{-10} at 1550nm)

Define and justify any assumptions included in your calculations.

[60%]

b) It has been suggested that amplifiers could be used to extend the system to a reach of 140km. Give an indication of the number of amplifiers required and suggest any other components (including any calculations required) needed to make the system functional. Discuss any issues concerning the location of any amplifiers in the link.

Amplifier Type: C-Band EDFA

Small Signal Gain: 20dB

Saturated Output Power: 6dBm

Noise Figure: 5dB

[40%]

Question 2

a) What are the main factors that limit signal transmission in line of sight (LoS) radio channels?

[20%]

b) A telecommunications operator is considering using a microwave link to carry 280 MBit/s data stream from the centre of Manchester (100 meters above sea level) to the top of the "Kinder Scout" mountain (700 m above sea level). A land survey was carried out and showed that a "Line of Sight" path exists between Manchester and Kinder Scout and that the horizontal distance between the two is 30 km. Knowing that the allocated carrier frequency for the link is 6 GHz and that the operator is provided with state of the art microwave transmitter and receiver equipment having equal coupling efficiencies of 65%. The microwave receiver provided has a noise figure of 4 dB and is located in an air-conditioned room where the ambient temperature never rises above 15 °C.

The operator is limited, by planning permission, to using 1 meter parabolic dish in Manchester and a parabolic dish of 2 meters in Kinder Scout. The operator is required to minimise the output power of the Manchester transmitter and to operate the receiver with a maximum bit error rate of 10^{-6}.

Using the BER curves given below, suggest an appropriate modulation scheme and the corresponding transmitter output power that will achieve the required error rate and offer an acceptable operating margin in an environment where fading and environmental factors can result in signal strength variation as high as 40 dB. You are required to back up your design decisions by appropriate calculations and to state clearly any assumptions you make.

Note: Boltzmann's Constant = $1.38 * 10^{-23}$ Joule/Kelvin

speed of electromagnetic propagation = $3 * 10^{8}$ m/s

0 C° = 273 K

[80%]

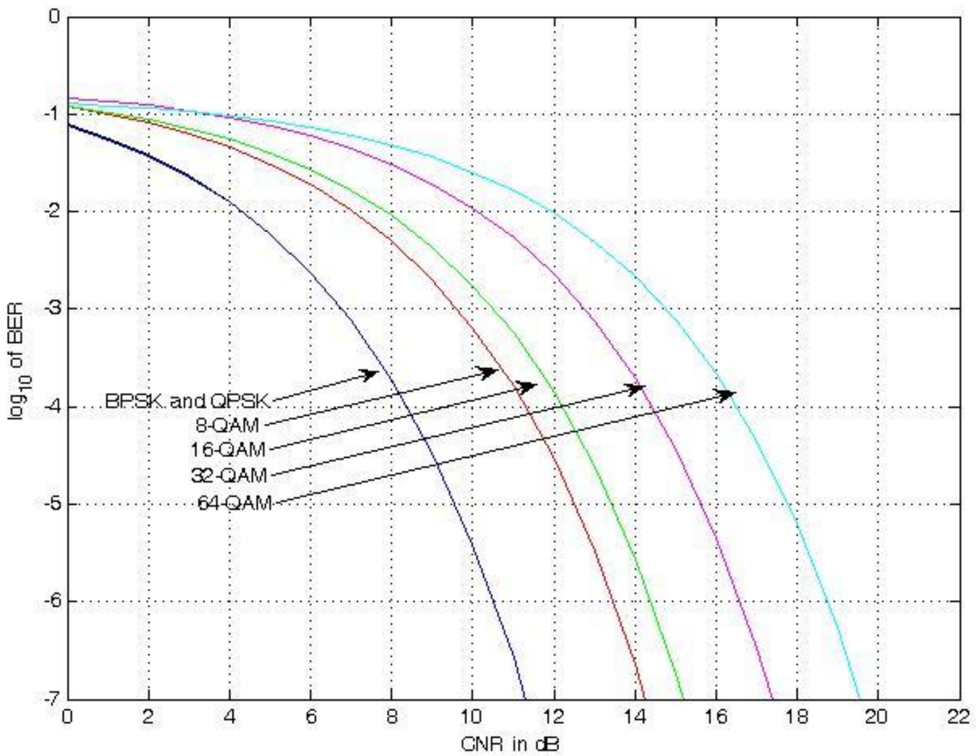

Figure 1: Bit Error Rate versus CNR for different modulation schemes

TURN OVER

Section Two

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

Please answer each question in a separate answer book.

Question 3

a) Describe the type of optical fibre communications system in which you would choose to use a multi-longitudinal mode Fabry-Perot Laser, giving your reasons in relation to the laser's performance characteristics.

[30%]

b) In a long distance submarine optical fibre communications system a designer chooses to form a cascade or chain of many optical fibre amplifiers. What precautions must the designer take to overcome any negative properties of the optical fibre amplifiers?

[30%]

c) Is it better to use wavelength division multiplexing or time division multiplexing with binary signalling to achieve a high 40 Gb/s aggregate bit rate through a single mode optical fibre, giving the reasons for your decision? State the components and system designs you consider in order to make your decision. Briefly state how your designs would deal with the laser's resonance frequency.

[40%]

Question 4

a) Sketch the basic structure of a PIN photodiode and explain its principle of operation.

[30%]

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

[40%]

c) Define briefly the following terms:

i) Dark current in a photodiode

ii) Responsivity of a photodiode

[30%]

Question 5

a) Detail the requirement for line coding in a digital transmission system making specific reference to the following:

- Uni-polar and Bi-polar Codes
- Ease of clock recovery
- Suitability for ac coupled links
- Return to zero and non return to zero coding
- Run length limiting codes

[30 %]

b) With the aid of a diagram, describe the effects that can be witnessed from the eye diagram including a description of the noise sources that contribute to the signal in an amplified optical system.

[30%]

c) Demonstrate how a Q based analysis of the noise incurred in an optically amplified link can be calculated

[40%]

END OF PAPER