UCL DEPARTMENT OF ELECTRONIC &
ELECTRICAL ENGINEERING

# Masters Programmes in Communications

# Broadband Technologies and Components

22nd January 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***
***MRes Photonic Systems Design***
***EngD in Telecommunications***

***Physical Constants***

Spontaneous emission lifetime: $\tau = 10$ ms

Emission cross section in Erbium: $\sigma_s = 0.35$ pm$^2$

Core diameter: $D = 7$ $\mu$m

Plank constant: $h = 6.626 \cdot 10^{-34}$ J$\cdot$s

Wavelength of operation: $\lambda = 1550$ nm

Pump power: $P_{pump} = 23$ dBm

Speed of light: $c = 2.998 \cdot 10^8$ m$\cdot$s$^{-1}$

Planck’s constant, h = 6.626 x 10-34 Js

Boltzmann's Constant, k = 1.38 x 10-23 Joule/Kelvin

Electron Charge, e = 1.602176 x 10-19 C

0°C = 273 K

***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***

a) You are requested to demonstrate the dispersion limited distance and the loss limited distance for an unamplified optical fibre link with the following parameters.

| | |
|---|---|
| Transmitter | Type: DBF laser, directly modulated. |
| Bit Rate | 2.5 Gbit/s |
| Fibre Dispersion | 18 ps/nm.km |
| Attenuation | 0.25 dB/km |
| Laser Wavelength | 1550 nm |
| Laser Linewidth | 1MHz |
| Peak Laser output | 1mW |
| 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 150 km 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) What are the main factors that degrade the error performance of digital transmission systems? What are the compromises facing designers of such systems so as to achieve optimum performance?

**[40%]**

b) A microwave Line of Sight (LoS) link is designed to transmit a 64 QAM modulated 1.5 Gbit/s data stream using a 10 GHz carrier, with the transmitter power being limited to 1 Watt. The link employs two identical microwave transmit and receive antennas each has a gain of 12 dB and each is fed by a coaxial cable with coupling efficiency of 35%. 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 $10^{-6}$, over a short distance of 2 km. Assume that the receiver and transmitter antennas are of the same height and that the receiver front end equipment has a noise figure of 8 dB and is operating at room temperature (27 $^{o}$C).

**[60%]**

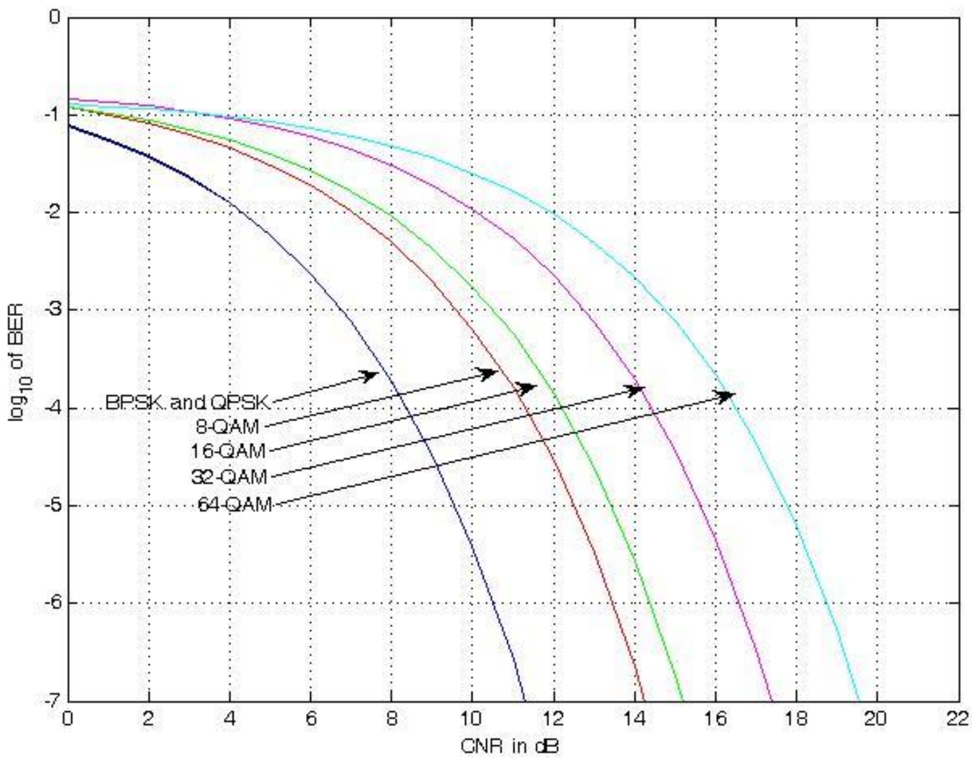


**Figure 1: Bit Error Rate versus CNR for different modulation schemes**

# *Section Two*

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

***Please answer each question in a separate answer book.***

***Question 3***

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

**[30%]**

b) Where does the noise come from that affects the signal to noise ratio on the photocurrent of a photodiode?

**[20%]**

c) Explain the structure and operation of the Mach-Zehnder Modulator.

**[30%]**

d) What is the difference between coarse and dense WDM?

**[20%]**

***Question 4***

a) Describe the essential features of an optically packet switched (OPS) network and discuss the benefits and technical challenges that such a network brings.

**[25%]**

b) Explain how optical burst switched (OBS) networks operate. State the advantages that these have over wavelength routed and optical packet switched network architectures.

**[25%]**

c) Define saturation for an amplifier and discuss why you would prefer to use an amplifier in the saturated regime in a transmission system.

**[25%]**

d) Considering a typical EDFA, describe how you would develop a simple model to describe its behaviour, then calculate its saturation power for the following parameters:

**[25%]**

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Core diameter: $D = 7\ \mu$m
Plank constant: $h = 6.626 \cdot 10^{-34}$ J$\cdot$s
Wavelength of operation: $\lambda = 1550$ nm
Pump power: $P_{pump} = 23$ dBm
Speed of light: $c = 2.998 \cdot 10^8$ m$\cdot$s$^{-1}$

***Question 5***

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 received

ii) Calculate the optimum decision threshold

iii) Determine the extinction ratio

iv) Determine the signal to noise ratio

**[60%]**

**END OF PAPER**