UCL DEPARTMENT OF ELECTRONIC &
ELECTRICAL ENGINEERING

Masters Programmes in Communications

Broadband Technologies and Components

15th November 2013

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

---

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

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

a) Determine the loss limited and dispersion limited distance for an un-amplified optical link at 2 Gbit/s formed of devices with the following parameters.

Transmitter	Type: DFB laser, directly modulated.
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	-30 dBm (BER=10^{-9} at 1550nm and modulation of 1 Gbit/s)

State and justify any assumptions included in your calculations.

[70%]

b) What would you propose to do to increase the data rate to 10 Gbit/s for a 100 km link without the addition of forward error correction? Please argue your answer.

[30%]

Question 2

a) What are 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 microwave systems engineer is designing a 3km microwave Line of Sight (LoS) link to transmit a 500 Mbit/s data stream using a 10 GHz carrier with the transmit power limited to 10 Watts. The link employs a receive antenna with a gain of 10 dB fed by a coaxial cable with coupling efficiency of 30% and a transmit antenna with a gain to be determined. 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).

i. If the transmission bandwidth available is limited to 500 MHz, choose an appropriate modulation scheme that achieves the target data rate and minimises the required transmit antenna gain. You should fully justify your selection by appropriate calculations and clearly state any assumption you make.

[35%]

ii. Based on Figure 1 below and using free-space power budget calculations, determine the transmit antenna gain required for your selected modulation scheme, for data transmission with a maximum error rate of 10^{-6}, assuming a coaxial cable at the transmitter with a coupling efficiency of 30%.

[35%]

NEXT PAGE

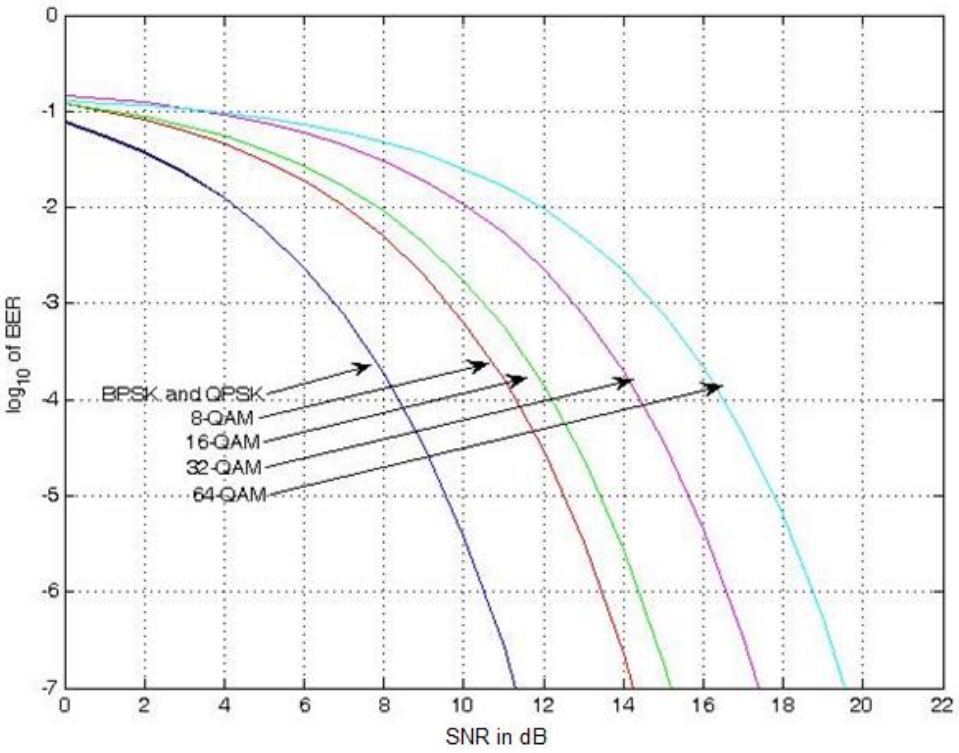

Figure 1: Bit Error Rate versus SNR for different modulation schemes

TURN OVER

Section Two

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

Please answer each question in a separate answer book.

Question 3

Design the structure of an optical repeater for undersea use in a non- WDM duplex communication system making use of optical amplifiers by considering each of the following points

a) How will you design the repeater to amplify communications through a pair of single mode optical fibres each for upstream and downstream respectively? [6%]

b) Justify which type of optical amplifier will you choose if:

- lasers are distributed feedback lasers (DFB)
- 10 Gb/s external electro-absorption modulator
- no thermoelectric control so thermal drift over time and from chirp

[6%]

c) How does a laser's performance change with its age and how will you deal with laser failure? [6%]

d) How will you design the system to deal with unpredictable fluctuations in the power of the original signals in the single mode optical fibre? [6%]

e) Sketch different pumping mechanism for EDFAs and explain why you would choose a particular one in a system. [14%]

f) What is the theoretical best noise figure achievable for an EDFA? [6%]

g) State the different kind of noises in a system and their effect? [10%]

h) What problems do back reflections through the optical amplifier cause and how can you avoid back reflections? [6%]

i) How will you minimise the noise to maximise the SNR? [6%]

j) How do you avoid wasting pump power which may remain after sufficient amplification has been achieved? [6%]

k) How will you connect the optical amplifiers to the fibres? [4%]

l) How will you deal with the polarisation of any lasers in the system and of any optical noise? [10%]

m) Finally draw the structure, in detail, of the optical repeater you have designed. [14%]

NEXT PAGE

Question 4

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

[20%]

b) Explain briefly line coding and its applications

[20%]

c) For an unamplified optical system the received signal has rms noise values on zeros and ones of $\sigma_0 = 0.12\ \mu V$ and $\sigma_1 = 0.3\ \mu V$ respectively with the mean zero and one levels being $\langle V_0 \rangle = 0.01 \mu V$ and $\langle V_1 \rangle = 1.2\ \mu V$ respectively.

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

[15%]

ii) Calculate the optimum decision threshold

[15%]

iii) Determine the extinction ratio

[15%]

iv) Determine the signal to noise ratio

[15%]

Question 5

a) Sketch the basic structure of a PIN photodiode and explain its principle of operation. [20%]

b) Define briefly the following terms:

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

[10%]

c) List the main sources of noise encountered in an optical receiver preamplifier and briefly describe the causes of each.

[20%]

d) Derive the SNR at the receiver considering that; the temperature in the room is 27 degree C, the signal power is 2 mW, the responsivity is 0.8 A/W, the link has one EDFA with a gain of 20dB and the ASE power of 10 μW, the signal is at 10 Gb/s, the amplifier at the receiver has a noise figure of 3dB.

State which source of noise dominates

Throughout state and justify any assumption you make.

[50%]

END OF PAPER