UCL DEPARTMENT OF ELECTRONIC &
ELECTRICAL ENGINEERING

Masters Programmes in Communications

Broadband Technologies and Components

14th November 2014

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 Telecommunications
MSc in Telecommunications with Business
MSc in Internet Engineering
MSc in Wireless and Optical Communications
MRes Photonic Systems Development

Physical Constants

Velocity of light in a vacuum, c = 3 x 10^8 ms^{-1}
Planck's constant, h = 6.626 x 10^{-34} Js
Boltzmann's Constant, k = 1.38 x 10^{-23} JK^{-1}
Electron Charge, e = 1.602176 x 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 maximum link distance for an un-amplified optical link at 1 Gbit/s formed of devices with the following parameters.

Transmitter	Type: DFB laser, directly modulated.
Fibre Dispersion	16 ps/nm.km @ 1550 nm
Attenuation	0.2 dB/km
Laser Wavelength	1550 nm
Laser Linewidth	<1 MHz
Peak transmitter output	2 mW
Receiver Sensitivity	-27 dBm (BER=10^{-9} at 1550 nm and modulation of 1 Gbit/s)

State 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 175 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 10 Gbit/s system including any calculation required to demonstrate the issues.

[20%]

Question 2

a) Consider a car moving across a cellular base station with velocity *v*. If the base station is emitting signal of carrier frequency f_c, using a diagram of the scenario and appropriate mathematical expressions prove that the Doppler shift $\Delta f = f_o - f_c$ between the carrier frequency f_c and the observed frequency f_o follows

$$-f_c \frac{v}{c} \leq \Delta f \leq f_c \frac{v}{c}$$

as the car moves towards and away from the base station, where *c* is the speed of light.

[30%]

b) You are asked to evaluate a Line of Sight (LoS) link designed to transfer digital data between two buildings that 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 2 Watt. The link employs two identical microwave transmit and receive antennas, each with a gain of 15 dB and each fed by a coaxial cable with coupling efficiency of 30%. Using free space power budget calculations and Figure 2.1 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).

[70%]

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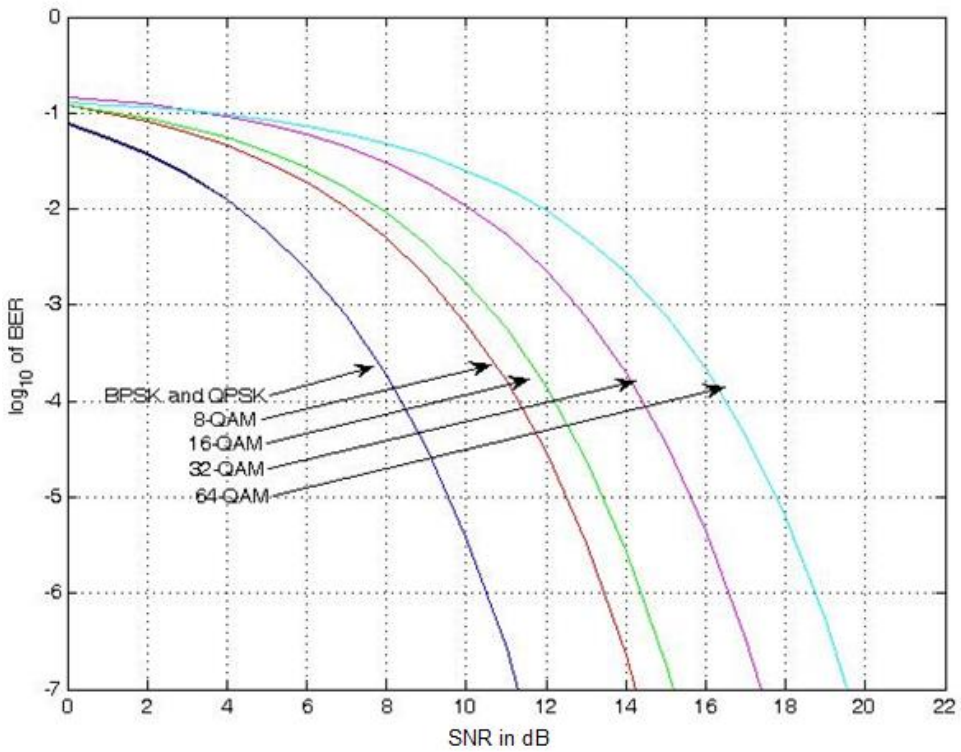

Figure 2.1: Bit Error Rate versus SNR for different modulation schemes

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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 Dense Wavelength Division Multiplexed, DWDM, optical communication system uses single mode silica core/silica cladding fibre along most of the transmission path apart from one erbium doped fibre amplifier, EDFA to overcome the loss of the fibre. The transmitting laser has a wavelength of 1.55 microns. The EDFA has a spectral bandwidth of 5 THz. The DWDM channels are spaced 25 GHz apart. Each channel carries data modulated at a rate of 10 Gbit/s. Please justify your answer clearly through the use of the relevant figure or equation.

a) Calculate how many DWDM channels can be transmitted through the communications link. Calculate the total aggregate data rate through the link.

[20%]

b) Estimate the amount of crosstalk between adjacent channels. Please justify your estimation with your chosen assumption.

[40%]

c) Explain what you must consider in making your choice of laser and associated components for this application. State your choice of laser and associated components for this application.

[40%]

Question 4

a) Explain, briefly, the following:

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

[10%]

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

[10%]

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

[10%]

iv) Line coding and its applications.

[10%]

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 $\langle V_1 \rangle = 1\ \mu V$ respectively.

i) Calculate the optimum decision threshold;

[15%]

ii) Determine Q;

[15%]

iii) Calculate the expected BER assuming no ISI and Gaussian noise.

[30%]

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 Figure 5.1:

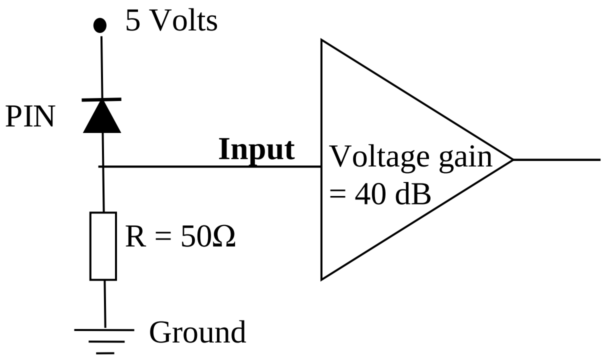

Figure 5.1: Schematic of the receiver circuit

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