GLASGOW COLLEGE UESTC

Main Exam

Wireless & Optical Transmission Systems (UESTC 4024)

Date: Jan 4th, 2022
Time: 0930-1130

Attempt all PARTS. Total 100 marks

Use one answer sheet for each of the questions in this exam.
Show all work on the answer sheet.

Make sure that your University of Glasgow and UESTC Student Identification Numbers are on all answer sheets.

An electronic calculator may be used provided that it does not allow text storage or display, or graphical display.

All graphs should be clearly labelled and sufficiently large so that all elements are easy to read.

The numbers in square brackets in the right-hand margin indicate the marks allotted to the part of the question against which the mark is shown. These marks are for guidance only.

Continued overleaf

Q1

(a) An Earth Station has an antenna with a transmit gain of 57 dB. The output power of the transmitter is set to 90 W with a frequency of 6.2 GHz. The signal is received by an antenna with a gain of 24 dB on a satellite at a distance of 36,575 km. The signal is then routed to a transponder that has a bandwidth of 36.2 MHz, a gain of 108 dB, and a noise temperature of 512 K. (Boltzman's Constant = 1.38×10^{-23} J/k)

(i) Design the output port of the satellite antenna by determining its power, in dBW, given the wavelength is 0.05 m. [7]

(ii) Determine the transponder Carrier-to-Noise, C/N, ratio (CNR), in dB, operating under a bandwidth of 36.2 MHz. [7]

(iii) Calculate the transponder output carrier power, in dBW and in Watts. [3]

(b) A CubeSat communication link has a transponder that is operated at an output power level of 23 W. The transponder is operating under frequency division multiple access (FDMA) mode to transmit 475 binary phase shift keying (BPSK) voice channels with half rate forward error correction (FEC) coding. The carrier-to-noise (C/N) ratio in clear air for an Earth base-station (BS) receiving one BPSK voice signal is set at 5.676 dB. The gain of antennas within the earth station utilised to receive these voice signals is 41 dB.

(i) Determine the power transmitted by the CubeSat in a single voice channel. [2]

(ii) Evaluate the margin over a coded BPSK threshold of 5 dB? [2]

(c) An Earth base-station receiving system has an antenna with a noise temperature of 50 K, a low noise amplifier (LNA) with a noise temperature of 100 K and a gain of 40 dB, and a mixer with a noise temperature of 1,000 K. Based on the above, analyse the system noise temperature. [4]

Continued overleaf

Q2

(a) Orbital dynamics define the motion of bodies / nodes in space around a desired center. Being a complex and an inexpensive process, the design parameters are highly correlated. As such, considering Kepler's laws of planetary motion:

(i) With the help of a suitably-labelled diagram, describe the orbit of a satellite revolving around the planet Earth. [4]

(ii) Derive the relationship between semi-minor axis and semi-latus rectum of the satellite's orbit. [4]

(b) A satellite is to be launched to orbit the Earth in the same direction of Earth's rotation. The satellite's orbit will have a lowest altitude of 1,200 km and a highest altitude of 33,000 km.

(i) Comment on the orbital properties of such a satellite system with respect to the orbit type, apogee, and perigee. Also, demonstrate these properties diagrammatically with appropriate labels. [5]

(ii) Examine the orbital dynamics / mechanics in terms of the orbital time-period. [4]

(iii) Describe and explain the eccentricity of the orbit of the satellite. [3]

(c) A satellite is launched in an elliptical equatorial orbit **opposite** to the earth's rotation. The eccentricity of the orbit is 0.6 and its period is 10 hours. Calculate the semi-major and semi-minor axes of the orbit. Demonstrate your findings with the help of a labelled diagram. (Kepler's Constant = $3.986 * 10^5$ km^3/s^2). [5]

Continued overleaf

Q3

(a) A CubeSat receiver has an overall System Temperature of 97.45 K. It is experiencing temperatures: at the input of the radio-frequency (RF) antenna as 35 K, in the RF processing unit as 50 K, and in the mixer stage as 250 K. The RF processing unit exhibits a gain of 1000 whereas the gain being provided by the mixer is 0.125. If the bandwidth of the signal is 20 MHz, examine the noise power levels that are accompanying this signal at the output of the antenna, the RF processing unit, and the mixer stage. [6]

(b) A communication satellite in geostationary orbit (GEO) is at a distance of 37,000 km from an Earth base-station (BS). The required flux density at the satellite to saturate one transponder at a frequency of 15.7 GHz is -89.0 dBW/m^2. The Earth BS has a transmitting antenna with a gain of 50 dB. Calculate the minimum output power of the Earth BS transmitter. [9]

(c) A satellite communication system consists of 50 medium earth orbit (MEO) satellites. For any satellite system to be feasible, the communication capacity must be sold at a price that is attractive to clients. You are required to look at the overall cost of the system over its lifetime and propose a minimum cost per voice circuit.

  (i) Each MEO satellite carries 20 transponders. When fully loaded, what is the total number of speech channels that the satellite can support? Formulate how many telephone circuits will be needed given that it takes two channels to make a valid telephone circuit? [3]

  (ii) Each MEO satellite costs CNY 20 M in-orbit and the MEO system costs CNY 50 M per year to run. The expected lifetime of the satellites is 15 years and the system requires a total of 10 spare satellites to be launched over the 15-year period. Determine the cost of operating the system for a 15-year period. Add a 23% factor to cover interest payments and dividends. Comment on the 15-year cost of the entire system. [7]

Continued overleaf

Q4

(a) We have a 1000 km roll a single mode optical fibre of unknown attenuation. In this question, we are interested in determining the effective non-linear length for this fibre.

(i) First, we should estimate the attenuation coefficient of the fibre. We cut a 100 m of the fibre and measured the transmitted power. The launch power into the fibre is 10 mW and the detected power is 8.2 mW. Calculate the attenuation coefficient of the fibre. [4]

(ii) We now consider 500 km of this fibre. Calculate the effective length? [3]

(b) In this question, we are tasked with deciding a suitable optical fibre for a low data rate, short distance communication network. The targeted length of the optical link is 3 km and the data rate is lower than 10 Mb/s.

(i) Discuss the dispersion mechanism involved in single mode fibre and multimode fibre (make sure to explain what these mechanisms are) and compare the level of distortion in both types of fibre. [4]

(ii) Give the advantages of multimode fibres compared to single mode fibres. [3]

(iii) Decide which fibre is best suited from a performance and maintenance point of view to implement the short distance optical link. Justify your answer. [3]

(c) Explain what SONET is and give its frame format and data rate for STS-1. [4]

(d) With suitable diagrams, describe the operation of an Erbium fibre laser. [4]

Continued overleaf

FORMULA SHEET

$[EIRP] = [Ps] + [G]$

$\Pr = \frac{GP}{4\pi^2} = GPs$

Flux Density $= F$

$= 10\ \log(\frac{EIRP}{4\pi R^2})$

$R_P = a(1-e)$

$R_A = a(1+e)$

$R_E = 6375\ km$

$T = \sqrt{\frac{4\pi^2 a^3}{\mu}}$

$\mu = 3.986004418 \times 10^5$

$R_0 = \frac{a(1-e^2)}{1+e\ \cos\emptyset}$

$P_N = kTB$

$N_0 = P_N / B_N$

$N_{0,ant} = k * T_{ant}$

$k = 1.3806 \times\ 10^{-23}$

$T = 2\pi\sqrt{\frac{Rs^3}{\mu}}$

$d = Rs\sqrt{1 + \left(\frac{R_E}{R_S}\right)^2 - 2\left(\frac{R_E}{R_S}\right)}$

$G_A = \frac{4\pi}{\lambda^2} A_e$

$A_E = \frac{\pi d^2}{4}$

$\lambda = \frac{c}{f} = \frac{3\times 10^8}{f}$

$[FSPL] = 20\log\left(\frac{4\pi df}{c}\right)$

$r \times \frac{dr}{dt} = const$

$\frac{T^2}{a^3} = const$

$a = \frac{p}{1-e^2} = \frac{h^2/\mu}{1-e^2}$

$b = \frac{p}{\sqrt{1-e^2}}$

$\eta = \mu^{1/2} / a^{3/2}$

$M = \eta(t - t_p)$

$M = E - e\sin(E)$

$r_0 = a[1 - e\cos(E)]$

$\phi_0 = \cos^{-1}[\frac{a(1-e^2) - r_0}{er_0}]$

$A = G\lambda^2 / 4\pi$

$\frac{C}{N} = [EIRP] - [LOSSES] - [k]$

$[P_{HPA,sat}] = [P_{HPA}] + [BO]_{HPA}$

$P_{out} = GP_{in} = \frac{P_{in}}{L}$

$\frac{E_b}{N_0} = \frac{S}{N}(\frac{W}{R})$

$F = \frac{(SNR)_{in}}{(SNR)_{out}} = 1 + \frac{N_{ai}}{N_i}$

$kT_R W = (F-1)kT_0 W$

$T_R = (F-1)290^0 K$

$N_{out} = GkT_g W + GkT_R W$

$F_{comp} = F_1 + \frac{F_2 - 1}{G_1} + \ldots + \frac{F_n - 1}{G_1 \ldots G_{n-1}}$

$T_{comp} = \mathrm{T}_1 + \ldots + \frac{T_{\mathrm{n}}}{\mathrm{G}_1 \ldots G_n}$

$v_e \approx \sqrt{\frac{2GM}{r}}$

End of question paper