GLASGOW COLLEGE UESTC

Exam

Wireless & Optical Transmission Systems (UESTC 4024)

Date: 30th Dec. 2019
Time: 14:30 – 16:30

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.

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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. (***<u>Assume:</u>*** Boltzman's Constant = 1.38×10^{-23} J/k)

(i) Determine the path loss at 6.2 GHz given that the wavelength is 0.05 m. [3]

(ii) Calculate the output port power of the satellite antenna, in dBW. [3]

(iii) Analyse the transponder input noise power, in dBW, operating under a bandwidth of 36.2 MHz. [3]

(iv) Solve the transponder Carrier-to-Noise, C/N, ratio (CNR), in dB. [3]

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

(b) A 11 GHz satellite communication link has a transponder that is operated at an output power level of 23 W with a bandwidth of 52 MHz. At 11 GHz, the satellite transmit antenna gain is 28 dB towards a particular earth station. The path loss to this particular earth station is given as 210 dB inclusive of the clear air atmospheric loss. 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. Each coded BPSK signal has a symbol rate of 50 kbps and requires a receiver with a noise bandwidth of 52 kHz per channel. The gain of antennas within the earth station utilised to receive these voice signals is 41 dB (1m diameter). The earth station also has a receiver with temperature, T_{system} = 145 K in clear air and an intermediate frequency (IF) noise bandwidth of 52 kHz.

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

(ii) Determine the C/N in clear air for an earth station receiving one BPSK voice signal. [6]

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

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Q2

(a) A satellite in GEO orbit is at a distance of 37,000 km from an earth station. 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 station has a transmitting antenna with a gain of 50 dB at 15.7 GHz.

(i) Analyse the equivalent isotropic radiated power (EIRP) of the earth station. [6]

(ii) Calculate the output power of the earth station transmitter. [3]

(b) A satellite in earth orbit has a semi-major axis of 6,700 km and an eccentricity of 0.01. Calculate the satellite's altitude at both perigee and apogee. [6]

(c) A satellite communication system consists of 50 LEO satellites. For any satellite system to be feasible, the communication capacity must be sold at a price that is attractive to customers. This question looks at the cost of the system over its lifetime and calculates a minimum cost per voice circuit.

(i) Each LEO 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 are needed given that it takes two channels to make a telephone circuit? [3]

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

Continued overleaf

Q3

(a) A satellite orbits Earth in an elliptic orbit in the same direction of Earth's rotation. The Perigee of this satellite's orbit has an altitude of 1,200 km and its Apogee has an altitude of 33,000 km.

(i) Calculate the orbital period 'T' of this satellite in seconds format and also in Hours + Minutes + Seconds format. [5]

(ii) Describe and explain the eccentricity of the orbit of the satellite. [5]

(b) A satellite receiver has an overall System Temperature, T_{System} = 97.45 K and the following other specifications:

T_{In} = 35 K

T_{RF} = 50 K $\quad$ G_{RF} = 1000

T_{Mixer} = 250 K $\quad$ G_{Mixer} = 0.125

If the bandwidth of the signal that we are interested in is 20 MHz, critically examine the noise power that would be accompanying this signal at:

(i) the output of the antenna, [2]

(ii) the output of the RF stage, and [2]

(iii) the output of the mixer. [2]

(c) A satellite is launched in an elliptic equatorial orbit **opposite** to the earth's rotation. The eccentricity of the orbit is 0.6 and its period is 10 hours. (***Assume:*** Kepler's Constant = $3.986 * 10^5$ km^3/s^2).

(i) Design the semi-major axis distance. [4]

(ii) Design the semi-minor axis distance. [5]

Continued overleaf

Q4

(a) Explain with the aid of suitable diagrams, the concept of effective length with respect to nonlinear propagation effects. [6]

(b) Derive an expression for the nonlinear effective length involving the fibre loss and the physical length of the fibre. [8]

(c) Calculate the effective length of a 100km and 1000km length of fibre with loss equal to 0.1/km. Explain your answers. [5]

(d) Discuss the design of modern transmission fibres with respect to effective area and chromatic dispersion in the context of WDM transmission. [6]

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FORMULA SHEET

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

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

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

$$R_P = a(1-e)$$

$$R_A = a(1+e)$$

$$R_E = 6375\ km$$

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

$$\mu = 3.986004418 \times 10^5$$

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

$$P_N = kTB$$

$$N_0 = P_N / B_N$$

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

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

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

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

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

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

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

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

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

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

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

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

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

$$M = \eta(t - t_p)$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

End of question paper