Durham University

Examination Paper

Examination Session:	Year:	Exam Code:
May/June	2022	ENGI4507-WE01/ ENGI44G10-WE01

Title: (MEng/MSc)
Radio and Digital Communications 4

Time Allowed:	2 hours
Additional Material provided:	Yes, table included as part of exam paper
Reporting problems during the exam:	Queries about the instructions for this exam (rubric) should be directed to: eng.boe@durham.ac.uk If you experience any difficulties uploading your exam answers to Gradescope report these immediately to: eng.boe@durham.ac.uk.

Instructions to Candidates:	Answer ALL questions. Please answer each question on a new page. All workings must be shown. This is an online open-book exam, submission is time-limited to 4 hours within a 24 hrs window. • *The examination attempt must be all your own work. You must not interact with another person (either one-to-one, by telephone, on the internet, in chat rooms, on social media, via smart watches, etc.), or use cheat sites, etc. whilst completing the exam. You must not discuss any examination papers with friends, relatives, current or past students of this or any other University before the end of the relevant 24-hour window.* • *Candidates are expected to answer all questions in their own words. Should close paraphrasing, direct quotation be necessary candidates must acknowledge the source of any material used in their answers (this includes text, images, diagrams, charts, tables and/or graphs). Full referencing is not expected, but a brief indication of the source of the material (e.g. name of author) must be given.*

Revision:	

Q.1

(a) An amplitude shift keying signal (ASK) is represented by

$$f_m(t) = \cos\omega_1 t \qquad 0 \le t \le T$$
$$f_s(t) = 0 \qquad 0 \le t \le T$$

where m and s denote the mark and space signals, respectively, and $\omega_1 = \frac{4\pi}{T}$

(i) Give a block diagram for a suitable matched filter and a correlation detector for the ASK signal and show their equivalence at t = T.

[30%]

(ii) Give an alternative non-coherent receiver for its detection and discuss the difference in requirements and performance between the non-coherent detector and the detectors used in part (i).

[15%]

(iii) Identify a suitable threshold for the detection of the mark and space signals for the detectors in parts (i) and (ii).

[10%]

(b) Binary coded information is transmitted at 10 kb/s using phase shift keying of a 10 MHz carrier. The received carrier amplitude is 10^{-2} V. The additive single sided noise power density spectrum is 5×10^{-9} W/Hz. Design a coherent detector for decoding the signal and find the bit error rate using the values of the complementary error function provided on page 4. Use can be made of

$$P_e = \frac{1}{2} erfc \sqrt{\frac{E(1-\rho)}{2N_o}}$$

where P_e is the probability of error, E is the energy per bit, N_o is the noise power spectral density, ρ is the correlation coefficient between the mark and space signals and $erfc$ is the complementary error function.

[25%]

(c) Assume that the bandlimited signal,

$$x(t) = \sin(20\pi t)$$

is sampled at 19 samples /sec. The sampled function then forms the input to a lowpass filter with cut-off frequency of 10 Hz. Find the output of the lowpass filter and compare it with x(t).

[20%]

Q.2

Suppose that a satellite in geosynchronous orbit (36,000 km above the earth's surface) radiates 100 W of power at a carrier frequency of 4 GHz and has a transmit antenna with 17 dBi gain. The earth station employs a parabolic antenna with a 3 m diameter and efficiency factor η=0.5.

(a) Given that for a parabolic antenna, the gain G is related to its diameter D and efficiency by

$$G=\eta(\pi D/\lambda)^2$$

where λ is the wavelength

Determine the following:

(i) The effective radiated power in dBm [10%]

(ii) The earth station antenna gain in dBi [10%]

(iii) The free space path loss in dB for unit gain transmit and receive antennas [20%]

(iv) The received power in dBm [10%]

(b) Suppose the receiver has noise temperature T_o which is equal to 300° K. Given that the noise power density $N_o = k_B T_o$ W/Hz where k_B is Boltzman's constant (1.38×10^{-23} W.s/K)

(i) Determine the noise power density in dBW/Hz [8%]

(ii) Determine the ratio of the received power to the noise power in dB [7%]

(iii) If the required energy per bit, E_b, to noise ratio is 10 dB, determine the data rate, *R*, that can be transmitted over the link. Use can be made of the following relationship

$$E_b/N_o=P_R/(N_oR)$$

[25%]

(c) Discuss the concept of space division multiple access.

[10%]

Continued

Error function and the complementary error function

$$\operatorname{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-u^2}\, du \qquad \operatorname{erfc}(x) = \frac{2}{\sqrt{\pi}} \int_x^\infty e^{-u^2}\, du$$

Table of Error function and complementary error function

x	erf(x)	erfc(x)	x	erf(x)	erfc(x)
0.00	0.0000000	1.0000000	1.30	0.9340079	0.0659921
0.05	0.0563720	0.9436280	1.40	0.9522851	0.0477149
0.10	0.1124629	0.8875371	1.50	0.9661051	0.0338949
0.15	0.1679960	0.8320040	1.60	0.9763484	0.0236516
0.20	0.2227026	0.7772974	1.70	0.9837905	0.0162095
0.25	0.2763264	0.7236736	1.80	0.9890905	0.0109095
0.30	0.3286268	0.6713732	1.90	0.9927904	0.0072096
0.35	0.3793821	0.6206179	2.00	0.9953223	0.0046777
0.40	0.4283924	0.5716076	2.10	0.9970205	0.0029795
0.45	0.4754817	0.5245183	2.20	0.9981372	0.0018628
0.50	0.5204999	0.4795001	2.30	0.9988568	0.0011432
0.55	0.5633234	0.4366766	2.40	0.9993115	0.0006885
0.60	0.6038561	0.3961439	2.50	0.9995930	0.0004070
0.65	0.6420293	0.3579707	2.60	0.9997640	0.0002360
0.70	0.6778012	0.3221988	2.70	0.9998657	0.0001343
0.75	0.7111556	0.2888444	2.80	0.9999250	0.0000750
0.80	0.7421010	0.2578990	2.90	0.9999589	0.0000411
0.85	0.7706681	0.2293319	3.00	0.9999779	0.0000221
0.90	0.7969082	0.2030918	3.10	0.9999884	0.0000116
0.95	0.8208908	0.1791092	3.20	0.9999940	0.0000060
1.00	0.8427008	0.1572992	3.30	0.9999969	0.0000031
1.10	0.8802051	0.1197949	3.40	0.9999985	0.0000015
1.20	0.9103140	0.0896860	3.50	0.9999993	0.0000007

END