Beijing-Dublin International College

SEMESTER 1 FINAL EXAMINATION - (2017/2018)

School of Electrical and Electronic Engineering

EEEN3008J Wireless Communications

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Time Allowed: 120 minutes

Instructions for Candidates:

All questions carry equal marks. The distribution of marks in the right margin shown as a percentage gives an approximate indication of the relative importance of each part of the question.
Show **all details** in answer book, **not** on exam paper

BJUT Student ID:_____ **UCD Student ID:**_____

I have read and clearly understand the Examination Rules of both Beijing University of Technology and University College Dublin. I am aware of the Punishment for Violating the Rules of Beijing University of Technology and/or University College Dublin. I hereby promise to abide by the relevant rules and regulations by not giving or receiving any help during the exam. If caught violating the rules, I accept the punishment thereof.

Honesty Pledge:_____ **(Signature)**

Instructions for Invigilators

Non-programmable calculators are permitted.
No rough-work paper is to be provided for candidates.

Question 1:

a. Name the 4 main logical elements of the LTE Evolved Packet Core. **(4%)**

b. Explain the differences between TDMA, FDMA, and CDMA. **(6%)**

c. Briefly explain the essential difference between a Bluetooth piconet and a Bluetooth scatternet. **(5%)**

d. Explain why SC-FDMA is used in LTE uplink instead of OFDMA. **(5%)**

e. State any 5 desirable features of a Cognitive Radio System. **(5%)**

(Total 25%)

Question 2:

You are hired as consultant to design a cellular system for a major service provider in China. The total bandwidth allocated for the deployment is 19 MHz. You are asked to evaluate the feasibility of the two following systems:

System A: Uses 40 KHz per channel and operates at S/I of 18 dB and above.

System B: Uses 237.5 KHz per channel and operates at a S/I of 0 dB and above.

In the area where the cellular system is to be deployed, users make 1 phone call per hour and each call lasts 6 minutes on average. The service provider wants to keep the call blocking probability of 0.2% to protect the customers and the path loss exponent is 6.

a. What would be the cluster size N for 'System A' to reach target S/I of 18 dB and above? You can assume omnidirectional antenna and use the formula $S/I = (\sqrt{3N})^{(n/2)}/i_0$, where i_0 is the number of first tier interferers. **(5%)**

b. How many users can be serviced by each cell of 'System A' with the given traffic intensity per user and blocking probability? Use the Erlang-B chart at the end of this exam paper at your convenience. **(5%)**

c. What would be the cluster size of 'system B' to reach the target S/I of 0 dB? **(5%)**

d. How many users can be serviced by each cell of 'system B' with given traffic intensity per user and the blocking probability requirement? **(5%)**

e. The user population is uniformly distributed and there are 100 users per square km. Let the total area be 400 square km. How many base stations need to be installed for 'System A' and 'System B' and which one is more cost effective if the base stations cost the same in both cases? **(5%)**

(Total 25%)

Question 3:

A CDMA system has 4 users, U_1, U_2, U_3, U_4 with the following binary chip sequences.

U_1 : 10000111 U_2 : 00011110

U_3 : 00110011 U_4 : 00101101

A bipolar notation is used, with binary 0 being -1 and binary 1 being +1. In which case, during each bit time, a user can transmit a 1 by sending its chip sequence, it can transmit a 0 by sending the negative of its chip sequence, or it can be silent and transmit nothing. We assume that all stations are synchronised in time, so all chip sequences begin at the same instant. When two or more users transmit simultaneously, their bipolar signals add linearly.

a. Suppose that at a given transmit time slot, the bits transmitted by the users U_1, U_2, U_3 are: {1, 0, 0} whereas, user U_4 chooses to remain silent. What is the resulting (combined) bipolar chip sequence? **(15%)**

b. Suppose now the receiver receives the bipolar sequence = [+2 0 −2 −2 0 +2 0 0]. Which stations transmitted, and which bits did each one send? **(10%)**

(Total 25%)

Question 4:

Consider a 2×2 MIMO system with channel gain matrix given by:

$$\mathbf{H} = \begin{bmatrix} 3.1618 & 1.3925 \\ 0.4877 & 2.7344 \end{bmatrix}$$

The singular value decomposition of the above channel matrix is given as:

$$\mathbf{H} = \begin{bmatrix} 3.1618 & 1.3925 \\ 0.4877 & 2.7344 \end{bmatrix} = \begin{bmatrix} -0.8267 & x \\ -0.5626 & 0.8267 \end{bmatrix} \times \begin{bmatrix} \sqrt{\lambda_1} & 0 \\ 0 & \sqrt{\lambda_2} \end{bmatrix} \times \begin{bmatrix} -0.7318 & -0.6815 \\ -0.6815 & y \end{bmatrix}$$

a. Determine the values of x, y, λ_1, and λ_2. **(15%)**

b. If the above MIMO system is used with $\mathbf{H}$ known to both transmitter and receiver, calculate the channel capacity of the equivalent MIMO system. Assume total transmit power $P = 20$ mW across the two antennas, AWGN with $N_0 = 10^{-9}$ W/Hz at each receive antenna and bandwidth $B = 200$ KHz. **(5%)**

c. Calculate the capacity of an equivalent single-input-single-output (SISO) channel and comment on the capacity enhancing ability of MIMO. **(5%)**

(Total 25%)

Appendix: Erlang B Formula Chart

(Offered Load)	A in Erlangs												
n	P_B (Blocking Probability)												
	0.01%	*0.02%*	*0.03%*	*0.05%*	*0.1%*	*0.2%*	*0.3%*	*0.4%*	*0.5%*	*0.6%*	*0.7%*	*0.8%*	*0.9%*
1	0.0001	0.0002	0.0003	0.0005	0.0010	0.0020	0.0030	0.0040	0.0050	0.0060	0.0070	0.0081	0.0091
2	0.0142	0.0202	0.0248	0.0321	0.0458	0.0653	0.0806	0.0937	0.105	0.116	0.126	0.135	0.1443
3	0.0868	0.110	0.127	0.152	0.194	0.249	0.289	0.321	0.349	0.374	0.397	0.418	0.4374
4	0.235	0.282	0.315	0.362	0.439	0.535	0.602	0.656	0.701	0.741	0.777	0.810	0.8415
5	0.452	0.527	0.577	0.649	0.762	0.900	0.994	1.07	1.13	1.19	1.24	1.28	1.326
6	0.728	0.832	0.900	0.996	1.15	1.33	1.45	1.54	1.62	1.69	1.75	1.81	1.867
7	1.05	1.19	1.27	1.39	1.58	1.80	1.95	2.06	2.16	2.24	2.31	2.38	2.448
8	1.42	1.58	1.69	1.83	2.05	2.31	2.48	2.62	2.73	2.83	2.91	2.99	3.069
9	1.83	2.01	2.13	2.30	2.56	2.85	3.05	3.21	3.33	3.44	3.54	3.63	3.7110
10	2.26	2.47	2.61	2.80	3.09	3.43	3.65	3.82	3.96	4.08	4.19	4.29	4.3811
11	2.72	2.96	3.12	3.33	3.65	4.02	4.27	4.45	4.61	4.74	4.86	4.97	5.07
12	3.21	3.47	3.65	3.88	4.23	4.64	4.90	5.11	5.28	5.43	5.55	5.67	5.78
13	3.71	4.01	4.19	4.45	4.83	5.27	5.56	5.78	5.96	6.12	6.26	6.39	6.50
14	4.24	4.56	4.76	5.03	5.45	5.92	6.23	6.47	6.66	6.83	6.98	7.12	7.24
15	4.78	5.12	5.34	5.63	6.08	6.58	6.91	7.17	7.38	7.56	7.71	7.86	7.99
16	5.34	5.70	5.94	6.25	6.72	7.26	7.61	7.88	8.10	8.29	8.46	8.61	8.75
17	5.91	6.30	6.55	6.88	7.38	7.95	8.32	8.60	8.83	9.03	9.21	9.37	9.52
18	6.50	6.91	7.17	7.52	8.05	8.64	9.03	9.33	9.58	9.79	9.98	10.1	10.3
19	7.09	7.53	7.80	8.17	8.72	9.35	9.76	10.1	10.3	10.6	10.7	10.9	11.1
20	7.70	8.16	8.44	8.83	9.41	10.1	10.5	10.8	11.1	11.3	11.5	11.7	11.9
21	8.32	8.79	9.10	9.50	10.1	10.8	11.2	11.6	11.9	12.1	12.3	12.5	12.7
22	8.95	9.44	9.76	10.2	10.8	11.5	12.0	12.3	12.6	12.9	13.1	13.3	13.5
23	9.58	10.1	10.4	10.9	11.5	12.3	12.7	13.1	13.4	13.7	13.9	14.1	14.3
24	10.2	10.8	11.1	11.6	12.2	13.0	13.5	13.9	14.2	14.5	14.7	14.9	15.1
25	10.9	11.4	11.8	12.3	13.0	13.8	14.3	14.7	15.0	15.3	15.5	15.7	15.9
26	11.5	12.1	12.5	13.0	13.7	14.5	15.1	15.5	15.8	16.1	16.3	16.6	16.8
27	12.2	12.8	13.2	13.7	14.4	15.3	15.8	16.3	16.6	16.9	17.2	17.4	17.6
28	12.9	13.5	13.9	14.4	15.2	16.1	16.6	17.1	17.4	17.7	18.0	18.2	18.4
29	13.6	14.2	14.6	15.1	15.9	16.8	17.4	17.9	18.2	18.5	18.8	19.1	19.3
30	14.2	14.9	15.3	15.9	16.7	17.6	18.2	18.7	19.0	19.4	19.6	19.9	20.1
31	14.9	15.6	16.0	16.6	17.4	18.4	19.0	19.5	19.9	20.2	20.5	20.7	21.0
32	15.6	16.3	16.8	17.3	18.2	19.2	19.8	20.3	20.7	21.0	21.3	21.6	21.8
33	16.3	17.0	17.5	18.1	19.0	20.0	20.6	21.1	21.5	21.9	22.2	22.4	22.7
34	17.0	17.8	18.2	18.8	19.7	20.8	21.4	21.9	22.3	22.7	23.0	23.3	23.5
35	17.8	18.5	19.0	19.6	20.5	21.6	22.2	22.7	23.2	23.5	23.8	24.1	24.4
36	18.5	19.2	19.7	20.3	21.3	22.4	23.1	23.6	24.0	24.4	24.7	25.0	25.3
37	19.2	20.0	20.5	21.1	22.1	23.2	23.9	24.4	24.8	25.2	25.6	25.9	26.1
38	19.9	20.7	21.2	21.9	22.9	24.0	24.7	25.2	25.7	26.1	26.4	26.7	27.0
39	20.6	21.5	22.0	22.6	23.7	24.8	25.5	26.1	26.5	26.9	27.3	27.6	27.9
40	21.4	22.2	22.7	23.4	24.4	25.6	26.3	26.9	27.4	27.8	28.1	28.5	28.7
41	22.1	23.0	23.5	24.2	25.2	26.4	27.2	27.8	28.2	28.6	29.0	29.3	29.6
42	22.8	23.7	24.2	25.0	26.0	27.2	28.0	28.6	29.1	29.5	29.9	30.2	30.5
43	23.6	24.5	25.0	25.7	26.8	28.1	28.8	29.4	29.9	30.4	30.7	31.1	31.4
44	24.3	25.2	25.8	26.5	27.6	28.9	29.7	30.3	30.8	31.2	31.6	31.9	32.3
45	25.1	26.0	26.6	27.3	28.4	29.7	30.5	31.1	31.7	32.1	32.5	32.8	33.1
46	25.8	26.8	27.3	28.1	29.3	30.5	31.4	32.0	32.5	33.0	33.4	33.7	34.0
47	26.6	27.5	28.1	28.9	30.1	31.4	32.2	32.9	33.4	33.8	34.2	34.6	34.9
48	27.3	28.3	28.9	29.7	30.9	32.2	33.1	33.7	34.2	34.7	35.1	35.5	35.8
49	28.1	29.1	29.7	30.5	31.7	33.0	33.9	34.6	35.1	35.6	36.0	36.4	36.7
50	28.9	29.9	30.5	31.3	32.5	33.9	34.8	35.4	36.0	36.5	36.9	37.2	37.6
	0.01%	*0.02%*	*0.03%*	*0.05%*	*0.1%*	*0.2%*	*0.3%*	*0.4%*	*0.5%*	*0.6%*	*0.7%*	*0.8%*	*0.9%*
N							*B*						