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CITY UNIVERSITY OF HONG KONG

Course code & title : EE4036 Wireless Communications

Session : Semester A 2010-2011

Time allowed : Two hours

This paper has ELEVEN (11) pages inclusive.

1. There are FIVE questions in total.
 2. Answer FOUR questions only.
 3. Each question carries 25 marks.
 4. Use the thin answer book to answer question 5.
 5. Use the thick answer book to answer question 1 to question 4.
 6. State assumptions you have made in each question.
 7. CityU approved calculator is allowed.
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Question 1 (25 marks)

- A) Assume that you are a chief technology office of an international enterprise. You are required to build a communication link between headquarter (HQ) and the destination (BR2). HQ locates in a time zone which is an hour early than BR2. This communication is initiated from HQ and sent to BR1 (between HQ and BR2), BR1 will then forward the signal to BR2. A single-hop ionosphere wave is used (see Fig Q1) between each station communication. The atmosphere between HQ and BR1 is referred as “ZONE 1”; and the atmosphere between BR1 and BR2 is referred as “ZONE2”.

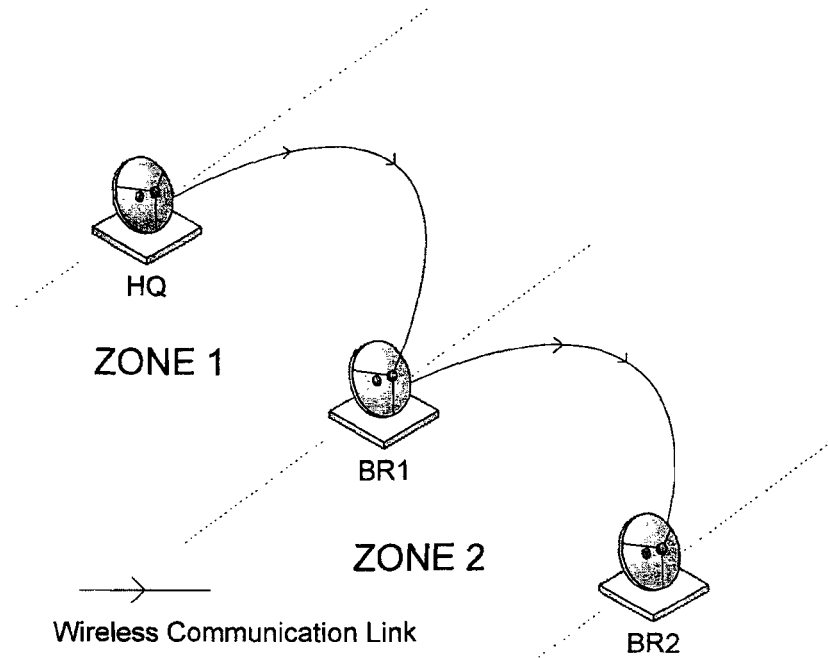


Fig Q1

- A(i) The operation frequency (OF) is 85% of maximum usable frequency (MUF). Given that the MUF is 20 MHz and the critical frequency is 8.5MHz. The communication starts at 23:00. Find the minimum distance between HQ and BR2.

(10 marks)

Assume radius of earth = 6300km

Given: $OF = \frac{f_c}{\cos \theta}$, all answers should include up two (2) decimal places.

Time	0:00	1:00	2:00	3:00	4:00	5:00
Height of Zone 1 (km)	270	270	275	280	285	290
Height of Zone 2 (km)	300	300	295	290	285	280
Time	6:00	7:00	8:00	9:00	10:00	11:00
Height of Zone 1 (km)	295	300	300	300	300	300
Height of Zone 2 (km)	275	270	270	270	270	270
Time	12:00	13:00	14:00	15:00	16:00	17:00
Height of Zone 1 (km)	300	300	300	300	300	295
Height of Zone 2 (km)	270	270	270	270	270	275
Time	18:00	19:00	20:00	21:00	22:00	23:00
Height of Zone 1 (km)	290	285	280	275	270	270
Height of Zone 2 (km)	280	285	290	295	300	300

Table 1: Height of Ionosphere in a day

(B) Skip distance refers to the distance at which no signal is received between the transmitter and the receiver for ionosphere propagation. With the aid of diagram, briefly describe the effect on the skip distance due to the variation of height of the ionosphere from the ground. (10 marks)

(C) With the aid of the diagram, prove that the maximum radio range $d_{\max} = \sqrt{2a'h_T} + \sqrt{2a'h_R}$ where a' is the fictitious radius of the earth (5 marks)

...../Question 2

Question 2 (25 marks)

- (A) Calculate the link budget of the uplink communication and the downlink communication using a passive transponder with the parameters shown in Table Q2. All answers should include up to two (2) decimal places.

(12 marks)

Uplink:

For Earth Station

Earth station transmitter output power at saturation	100 W
Loss between amplifier and antenna	0.5dB
Earth station back-off loss	2 dB
Tx Antenna Diameter	15m
Tx Antenna Efficiency, η	0.65
Earth station transmission frequency	14 GHz
Bit rate	120 Mbps
Modulation scheme	8-PSK
Earth station branching and feeder losses	1 dB
Additional uplink atmospheric losses	0.6 dB
Transmission Distance from earth station	350 km

For the satellite

Rx Antenna Diameter	0.7m
Rx Antenna Efficiency, η	0.6
Equivalent noise temperature	580K

Downlink:

For the satellite

Satellite transmitter output power at saturation	10 W
Loss between amplifier and antenna	1 dB
Satellite back-off loss	1 dB
Additional downlink atmospheric losses	0.4 dB
Tx Antenna Diameter	0.7 m
Tx Antenna Efficiency, η	0.6
Satellite transmission frequency	12 GHz
Bit rate	120 Mbps
Modulation scheme	8-PSK
Transmission Distance from satellite	400 km

For Earth Station

Rx Antenna Diameter	4 m
Rx Antenna Efficiency, η	0.65
Equivalent noise temperature	580K
Loss between amplifier and antenna	0.5 dB

Given:

$$\frac{C}{N_0} = \text{ERIP} \times \frac{1}{L} \times \frac{G}{T} \times \frac{1}{K}$$

$$K \text{ (Boltzman constant)} = 1.38 \times 10^{-23} \text{ J/K}$$

$$\frac{E_b}{N_0} = \frac{C}{N_0} \times \frac{1}{f_b}$$

$$E_b = P_r T_b, N_0 = K T_e$$

$$\frac{C}{N} = \frac{E_b}{N_0} \times \frac{f_b}{B} \text{ where } B = \frac{f_b}{3}$$

$$\frac{C}{N_{TOTAL}} = \frac{1}{\frac{N_1}{C} + \frac{N_2}{C} + \dots + \frac{N_n}{C}}$$

$$\text{Gain}_{\text{antenna}} = \eta \left(\frac{\pi D}{\lambda} \right)^2, D: \text{Diameter}, \lambda : \text{wavelength}$$

$$\text{Free - space path loss} = \left(\frac{4\pi d}{\lambda} \right)^2, d \text{ (meter) is the distance from the transmitter}, \lambda : \text{wavelength}$$

$$\left(\frac{E_b}{N_0} \right)_{\text{total}} = \frac{\left(\frac{E_b}{N_0} \right)_1 \left(\frac{E_b}{N_0} \right)_2}{\left(\frac{E_b}{N_0} \right)_1 + \left(\frac{E_b}{N_0} \right)_2}$$

(B) Explain why the frequency of uplink and downlink are different in typical satellite communication system.

(5 marks)

(C) With the aid of the diagram, describe briefly the functional blocks in the satellite transponder.

(8 marks)

...../Question 3

Question 3 (25 marks)

(A) A mobile terminal samples signals from six base stations (BSs) as a function of time. Table Q3 shows the handoff transition between BSs with respect to time and signal strength (in dBm). The rule for handover is that if there is more than one BS fulfilling the requirement, the BS with the strongest received signal strength (RSS) will be selected. Assuming that a mobile terminal makes handoff decision by considering the signals from the BSs after each sampling and the mobile is initially attached to BS₃, determine the handover sequence with respect to time.

- i) Received signal strength (RSS) (3 marks)
- ii) RSS + hysteresis of ≥ 5 dBm + threshold of ≥ -60 dBm (3 marks)

Table Q3

Time(s)	0	2.5	5	7.5	10	12.5	15
BS ₁	-49	-57	-52	-55	-60	-62	-60
BS ₂	-59	-56	-55	-54	-55	-51	-49
BS ₃	-40	-72	-75	-50	-58	-50	-60.5
BS ₄	-79	-71	-65	-60	-55	-53	-50
BS ₅	-48	-67	-53	-55	-60	-62	-60
BS ₆	-70	-72	-55	-70	-49	-70	-58.5

(B) Briefly describe the term adjacent channel interference. (3 marks)

(C) Name two strategies of Channel Assignment and state the difference between these approaches. (4 marks)

(D) City A is designed to be covered by a 28 cell cellular phone system using a 4 cell reuse pattern and City A is allocated 8MHz of spectrum with full duplex channel bandwidth 50 kHz. Assume a GOS of 1% is required for system A. If each user generates one call for every two hours and the average call holding time is 3 minutes. Calculate the following parameter for system A:

- 1) The number of channel per cell.
- 2) The traffic intensity for each cell.
- 3) The maximum carried traffic.
- 4) The offered traffic for each customer.
- 5) The total number of user supported by the system.
- 6) The GOS requirement if the total of user for the system is increased by 5%.

(12 marks)

...../Question 4

Question 4 (25 marks)

A ZigBee network is shown in Fig Q4, the address (Addr) and neighbor nodes (N) of each ZigBee nodes are indicated in Fig Q4. Assume that the network is joined with maximum number of children and router and also has reached the maximum network depth. Perform the design of ZigBee network in the following steps with reasonable assumptions:

- a) Redraw the network in tree structure. (4 marks)
- b) Calculate the addresses of node A and D if tree address assignment is used. (7 marks)
- c) Identify the node(s) of ZigBee coordinator and router(s). (3 marks)
- d) List two possible nodes of ZigBee End device. (1 marks)
- e) Node B is trying to send a message to node C,
 - i. list the route if tree routing is used;
 - ii. write the route if mesh routing is used
 - iii. give one advantage and one disadvantage of mesh routing. (4 marks)
- f) There is a zigbee application which is developed based on Non-beacon enabled network. Assumptions and information of this zigbee application are listed in Table Q4(B).

Table Q4(Bi): Assumptions of ZigBee Applications

- 1. CSMA/CA algorithm never reveals that the channel is busy
- 2. Includes subsequent reception of associated acknowledgment
- 3. No retry is required
- 4. 1 symbol period = $16\mu s$
- 5. Fundamental data rate of modem = 250kbps

Table Q4(Bii): Information of ZigBee Applications

1.	Back-off Exponential value	2
2.	A unit of back-off period	20 symbol period
3..	Clear Channel Assessment	8 symbol period
4.	Size of acknowledgement frame header	5 Bytes
5.	Size of acknowledgement frame payload	10 Bytes
6.	Switching time of hardware	$192\mu s$
7.	Size of data frame	40 Bytes
8.	Maximum data payload of ZigBee	114 Bytes

Compute the following parameters by using the information in Table Q4(B):

- (i) The worst case of channel access time, t_{ac} ;
- (ii) Acknowledgment transmission time, t_r ;

(6 marks)

Hint:

$$Cskip(d) = \begin{cases} 1 + Cm \cdot (Lm - d - 1), & \text{if } Rm = 1 \\ \frac{1 + Cm - Rm - Cm \cdot Rm^{Lm-d-1}}{1 - Rm}, & \text{otherwise} \end{cases}$$

$$A_n = A_{parent} + Cskip(d) \cdot Rm + n$$

$$s(t) = \frac{A}{\sqrt{2}} I(t) \cos 2\pi f_c t - \frac{A}{\sqrt{2}} Q\left(t - \frac{T}{2}\right) \sin 2\pi f_c t$$

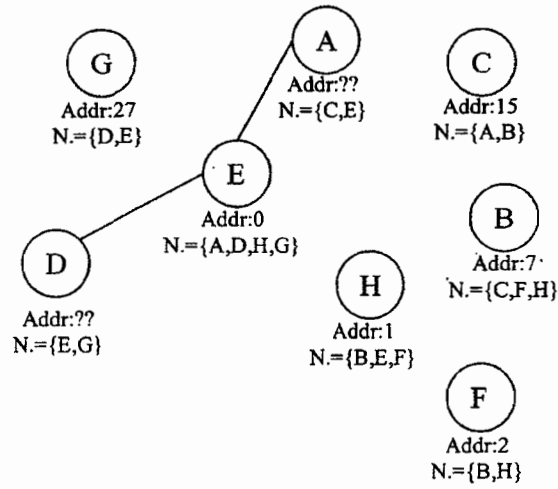


Fig Q4

...../Question 5

Question 5 (25 marks)

- (A) Describe briefly how to measure the efficiency of a small antenna using a compact range. (5 marks)
- (B) Describe the basic characteristics of a half-wave electric dipole. (5 marks)
- (C) What kinds of antennas are installed inside a typical 3G cellular phone? Describe briefly their basic characteristics. (5 marks)
- (D) What are the advantages and disadvantages of the microstrip patch antenna? (5 marks)
- (E) Describe two methods to increase the bandwidth of a probe-fed microstrip patch antenna. (5 marks)

- END-

Appendix

Erlang C Traffic Table

N/B	Maximum Offered Load Versus B and N											
	B is in %											
	0.01	0.05	0.1	0.5	1.0	2	5	10	15	20	30	40
1	.0001	.0005	.0010	.0050	.0100	.0200	.0500	.1000	.1500	.2000	.3000	.4000
2	.0142	.0319	.0452	.1025	.1465	.2103	.3422	.5000	.6278	.7403	.9390	1.117
3	.0860	.1490	.1894	.3339	.4291	.5545	.7876	1.040	1.231	1.393	1.667	1.903
4	.2310	.3533	.4257	.6641	.8100	.9939	1.319	1.653	1.899	2.102	2.440	2.725
5	.4428	.6289	.7342	1.065	1.259	1.497	1.905	2.313	2.607	2.847	3.241	3.569
6	.7110	.9616	1.099	1.519	1.758	2.047	2.532	3.007	3.344	3.617	4.062	4.428
7	1.026	1.341	1.510	2.014	2.297	2.633	3.188	3.725	4.103	4.406	4.897	5.298
8	1.382	1.758	1.958	2.543	2.866	3.246	3.869	4.463	4.878	5.210	5.744	6.178
9	1.771	2.208	2.436	3.100	3.460	3.883	4.569	5.218	5.668	6.027	6.600	7.065
10	2.189	2.685	2.942	3.679	4.077	4.540	5.285	5.986	6.469	6.853	7.465	7.959
11	2.634	3.186	3.470	4.279	4.712	5.213	6.015	6.765	7.280	7.688	8.336	8.857
12	3.100	3.708	4.018	4.896	5.363	5.901	6.758	7.554	8.099	8.530	9.212	9.761
13	3.587	4.248	4.584	5.529	6.028	6.602	7.511	8.352	8.926	9.379	10.09	10.67
14	4.092	4.805	5.166	6.175	6.705	7.313	8.273	9.158	9.760	10.23	10.98	11.58
15	4.614	5.377	5.762	6.833	7.394	8.035	9.044	9.970	10.60	11.09	11.87	12.49
16	5.150	5.962	6.371	7.502	8.093	8.766	9.822	10.79	11.44	11.96	12.77	13.41
17	5.699	6.560	6.991	8.182	8.801	9.505	10.61	11.61	12.29	12.83	13.66	14.33
18	6.261	7.169	7.622	8.871	9.518	10.25	11.40	12.44	13.15	13.70	14.56	15.25
19	6.835	7.788	8.263	9.568	10.24	11.01	12.20	13.28	14.01	14.58	15.47	16.18
20	7.419	8.417	8.914	10.27	10.97	11.77	13.00	14.12	14.87	15.45	16.37	17.10
21	8.013	9.055	9.572	10.99	11.71	12.53	13.81	14.96	15.73	16.34	17.28	18.03
22	8.616	9.702	10.24	11.70	12.46	13.30	14.62	15.81	16.60	17.22	18.19	18.96
23	9.228	10.36	10.91	12.43	13.21	14.08	15.43	16.65	17.47	18.11	19.10	19.89
24	9.848	11.02	11.59	13.16	13.96	14.86	16.25	17.51	18.35	19.00	20.02	20.82
25	10.48	11.69	12.28	13.90	14.72	15.65	17.08	18.36	19.22	19.89	20.93	21.76
26	11.11	12.36	12.97	14.64	15.49	16.44	17.91	19.22	20.10	20.79	21.85	22.69
27	11.75	13.04	13.67	15.38	16.26	17.23	18.74	20.08	20.98	21.68	22.77	23.63
28	12.40	13.73	14.38	16.14	17.03	18.03	19.57	20.95	21.87	22.58	23.69	24.57
29	13.05	14.42	15.09	16.89	17.81	18.83	20.41	21.82	22.75	23.48	24.61	25.50
30	13.71	15.12	15.80	17.65	18.59	19.64	21.25	22.68	23.64	24.38	25.54	26.44
31	14.38	15.82	16.52	18.42	19.37	20.45	22.09	23.56	24.53	25.29	26.46	27.38
32	15.05	16.53	17.25	19.18	20.16	21.26	22.93	24.43	25.42	26.19	27.39	28.33
33	15.72	17.24	17.97	19.95	20.95	22.07	23.78	25.30	26.32	27.10	28.31	29.27
34	16.40	17.95	18.71	20.73	21.75	22.89	24.63	26.18	27.21	28.01	29.24	30.21
35	17.09	18.67	19.44	21.51	22.55	23.71	25.48	27.06	28.11	28.92	30.17	31.16
36	17.78	19.39	20.18	22.29	23.35	24.53	26.34	27.94	29.00	29.83	31.10	32.10
37	18.47	20.12	20.92	23.07	24.15	25.36	27.19	28.82	29.90	30.74	32.03	33.05
38	19.17	20.85	21.67	23.86	24.96	26.18	28.05	29.71	30.80	31.65	32.97	34.00
39	19.87	21.59	22.42	24.65	25.77	27.01	28.91	30.59	31.71	32.57	33.90	34.94
40	20.58	22.33	23.17	25.44	26.58	27.84	29.77	31.48	32.61	33.48	34.83	35.89
41	21.28	23.07	23.93	26.23	27.39	28.68	30.63	32.37	33.51	34.40	35.77	36.84
42	22.00	23.81	24.69	27.03	28.21	29.51	31.50	33.26	34.42	35.32	36.70	37.79
43	22.71	24.56	25.45	27.83	29.02	30.35	32.36	34.15	35.33	36.23	37.64	38.74

Erlang B Traffic Table

N/B	Maximum Offered Load Versus B and N											
	B is in %											
	0.01	0.05	0.1	0.5	1.0	2	5	10	15	20	30	40
1	.0001	.0005	.0010	.0050	.0101	.0204	.0526	.1111	.1765	.2500	.4286	.6667
2	.0142	.0321	.0458	.1054	.1526	.2235	.3813	.5954	.7962	1.000	1.449	2.000
3	.0868	.1517	.1938	.3490	.4555	.6022	.8994	1.271	1.603	1.930	2.633	3.480
4	.2347	.3624	.4393	.7012	.8694	1.092	1.525	2.045	2.501	2.945	3.891	5.021
5	.4520	.6486	.7621	1.132	1.361	1.657	2.219	2.881	3.454	4.010	5.189	6.596
6	.7282	.9957	1.146	1.622	1.909	2.276	2.960	3.758	4.445	5.109	6.514	8.191
7	1.054	1.392	1.579	2.158	2.501	2.935	3.738	4.666	5.461	6.230	7.856	9.800
8	1.422	1.830	2.051	2.730	3.128	3.627	4.543	5.597	6.498	7.369	9.213	11.42
9	1.826	2.302	2.558	3.333	3.783	4.345	5.370	6.546	7.551	8.522	10.58	13.05
10	2.260	2.803	3.092	3.961	4.461	5.084	6.216	7.511	8.616	9.685	11.95	14.68
11	2.722	3.329	3.651	4.610	5.160	5.842	7.076	8.487	9.691	10.86	13.33	16.31
12	3.207	3.878	4.231	5.279	5.876	6.615	7.950	9.474	10.78	12.04	14.72	17.95
13	3.713	4.447	4.831	5.964	6.607	7.402	8.835	10.47	11.87	13.22	16.11	19.60
14	4.239	5.032	5.446	6.663	7.352	8.200	9.730	11.47	12.97	14.41	17.50	21.24
15	4.781	5.634	6.077	7.376	8.108	9.010	10.63	12.48	14.07	15.61	18.90	22.89
16	5.339	6.250	6.722	8.100	8.875	9.828	11.54	13.50	15.18	16.81	20.30	24.54
17	5.911	6.878	7.378	8.834	9.652	10.66	12.46	14.52	16.29	18.01	21.70	26.19
18	6.496	7.519	8.046	9.578	10.44	11.49	13.39	15.55	17.41	19.22	23.10	27.84
19	7.093	8.170	8.724	10.33	11.23	12.33	14.32	16.58	18.53	20.42	24.51	29.50
20	7.701	8.831	9.412	11.09	12.03	13.18	15.25	17.61	19.65	21.64	25.92	31.15
21	8.319	9.501	10.11	11.86	12.84	14.04	16.19	18.65	20.77	22.85	27.33	32.81
22	8.946	10.18	10.81	12.64	13.65	14.90	17.13	19.69	21.90	24.06	28.74	34.46
23	9.583	10.87	11.52	13.42	14.47	15.76	18.08	20.74	23.03	25.28	30.15	36.12
24	10.23	11.56	12.24	14.20	15.30	16.63	19.03	21.78	24.16	26.50	31.56	37.78
25	10.88	12.26	12.97	15.00	16.13	17.51	19.99	22.83	25.30	27.72	32.97	39.44
26	11.54	12.97	13.70	15.80	16.96	18.38	20.94	23.89	26.43	28.94	34.39	41.10
27	12.21	13.69	14.44	16.60	17.80	19.27	21.90	24.94	27.57	30.16	35.80	42.76
28	12.88	14.41	15.18	17.41	18.64	20.15	22.87	26.00	28.71	31.39	37.21	44.41
29	13.56	15.13	15.93	18.22	19.49	21.04	23.83	27.05	29.85	32.61	38.63	46.07
30	14.25	15.86	16.68	19.03	20.34	21.93	24.80	28.11	31.00	33.84	40.05	47.74
31	14.94	16.60	17.44	19.85	21.19	22.83	25.77	29.17	32.14	35.07	41.46	49.40
32	15.63	17.34	18.21	20.68	22.05	23.73	26.75	30.24	33.28	36.30	42.88	51.06
33	16.34	18.09	18.97	21.51	22.91	24.63	27.72	31.30	34.43	37.52	44.30	52.72
34	17.04	18.84	19.74	22.34	23.77	25.53	28.70	32.37	35.58	38.75	45.72	54.38
35	17.75	19.59	20.52	23.17	24.64	26.44	29.68	33.43	36.72	39.99	47.14	56.04
36	18.47	20.35	21.30	24.01	25.51	27.34	30.66	34.50	37.87	41.22	48.56	57.70
37	19.19	21.11	22.08	24.85	26.38	28.25	31.64	35.57	39.02	42.45	49.98	59.37
38	19.91	21.87	22.86	25.69	27.25	29.17	32.62	36.64	40.17	43.68	51.40	61.03
39	20.64	22.64	23.65	26.53	28.13	30.08	33.61	37.72	41.32	44.91	52.82	62.69
40	21.37	23.41	24.44	27.38	29.01	31.00	34.60	38.79	42.48	46.15	54.24	64.35
41	22.11	24.19	25.24	28.23	29.89	31.92	35.58	39.86	43.63	47.38	55.66	66.02
42	22.85	24.97	26.04	29.09	30.77	32.84	36.57	40.94	44.78	48.62	57.08	67.68
43	23.59	25.75	26.84	29.94	31.66	33.76	37.57	42.01	45.94	49.85	58.50	69.34