KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
COLLEGE OF COMPUTER SCIENCES & ENGINEERING

COMPUTER ENGINEERING DEPARTMENT

COE-543 – Mobile and Wireless Networks
May 12th, 2010 – Midterm Exam

Student Name:
Student Number:
Exam Time: 90 mins

- Do not open the exam book until instructed
- The use of programmable and cell phone calculators is not allowed – only basic are permitted
- **<u>Answer ALL Questions</u>**
- All steps must be shown
- Any assumptions made must be clearly stated

Question No.	Max Points	
1	40	
2	50	
3	50	

Total: 140

Q.1) (40 points) On the subject of RF propagation – Coherence bandwidth and Doppler Spectrum.

The uncorrelated scattering function of an indoor radio channel is defined as the product of a time function $Q(\tau)$ that represents the delay-power spectrum and a frequency function that represents the Doppler spectrum. That is

$$S(\tau, \lambda) = Q(\tau)D(\lambda)$$

Suppose for τ (in nsec) we have:

$$Q(\tau) = \begin{cases} 0.4 & \tau = 50 \\ 0.4 & \tau = 100 \\ 0.2 & \tau = 200 \end{cases}$$

and for λ (in Hz) we have:

$$D(\lambda) = \begin{cases} 0.1 & |\lambda| \le 5\text{Hz} \\ 0 & \text{otherwise} \end{cases}$$

a) (5 points) Plot $Q(\tau)$ and $D(\lambda)$ functions indicating the units on the x and y axes.

b) (2 points) What is the excess delay for the channel?

c) (5 points) Determine the RMS delay spread of the channel?

d) (3 points) What is the maximum Doppler frequency?

e) (5 points) Determine the RMS Doppler spread of the channel?

f) (10 points) In regard to the coherence bandwidth:

1. Define the coherence bandwidth, Bc?
2. What is the phenomenon that is represented by the coherence bandwidth?
3. Using the relation between coherence bandwidth and the signal bandwidth one can classify the channel into two extremes. Specify this classifications and the required relationship between coherence bandwidth and the signal bandwidth for each channel type.
4. Compute is the coherence bandwidth of the channel above?
5. List three mitigation techniques to remedy the adverse effects of the phenomenon specified in f.2?

g) (10 points) In regard to the Doppler spread:

1. Define the coherence time, T_0, for the channel.
2. What is the phenomenon that is represented by the coherence time?
3. Using the relation between coherence time and the signal element duration one can classify the channel into two extremes. Specify this classification and the required relation between coherence time and the signal element duration for each channel type.
4. Compute the coherence time for the channel specified above.
5. List three mitigation techniques to remedy the adverse effects of the phenomenon specified in g.2?

In all the computed quantities, the proper units must be clearly indicated.

Q2) (**50 points**) On the subject of RF propagation and path loss models:

Consider the scenario depicted in figure below. If the transmitter power is equal to 10 Watts, the transmit and receive antenna gains are 20 dB and 10 dB, respectively. Let the distance be equal to d = 3000 meters. Assume the central frequency used for transmission is equal to 900 MHz.

a) (10 points) Compute the amount of average received power (in Watts and dBW) at the receiver at distance d meters using the free space loss model.

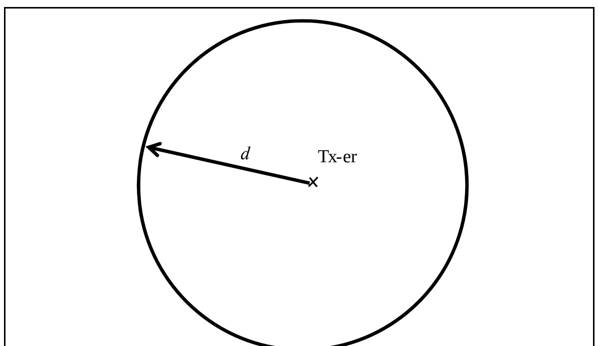
b) (5 points) Considering all the receiver locations that are at the same distance d from transmitter, the actual measured power (in linear and/or in dB) can be modeled as random variables. The actual measured power values at these locations are either higher (with 50% chance) or lower (with 50% chance) than the computed average in part (a). Specify the name of this RF propagation phenomenon and its causes.

c) (10 points) Consider the random variable (RV) X representing the measured power level in dBW in part (b). Specify and write an expression for the probability density function (PDF) of the random variable X. Sketch the PDF of X depicting the ranges and points of interest for the x-axis and y-axis. Specify the mean and standard deviation of X.

d) (10 points) Consider the random variable (RV) Y representing the measured power level in Watts in part (b). Specify and write an expression for the probability density function (PDF) of the random variable Y. Sketch the PDF of Y depicting the ranges and points of interest for the x-axis and y-axis.

e) (10 points) Compute the shadowing margin needed such that the measured power at the above location be 95% higher than the average predicted by the path loss model. Assume a shadowing standard deviation equal to 8 dB.

f) (5 points) Compute the fraction of locations that are at distance d from the transmitter and have power level less than 0.1 µWatts.



Receiver locations at distance d from transmitter.

Q3) (**50 points**) Assume a cellular AMPS system covering an area of 10,000 km2 using a frequency reuse pattern of N = 7. Let the overall bandwidth in each direction be 12.5 MHz. For AMPS, the total number of channels available for voice is equal to 395. Assume the pathloss exponent of 4 and single sector per cell unless specified otherwise. Assume also that system is operating to provide 2% blocking probability.

a) (5 points) Compute the SIR for the provided cellular configuration.

b) (15 points) Compute the spectral efficiency (in term of cell radius R) for the system in Erlangs/km2/MHz.

c) (15 points) Assume the AMPS system is upgraded to it digital successor IS-54 where the TDMA frame using the 30 kHz is divided into three slots to server three independent voice subscribers. In addition, the cells are also upgraded to have 6 sectors per cell.

c.1) Compute the provide SIR by the cellular configuration after the upgrade.

c.2) Compute the spectral efficiency (in term of cell radius R) for the upgraded system in Erlangs/km2/MHz.

c.3) Compare the spectral efficiency of the original system (part b) to the spectral efficiency of the upgraded system (part c.2). Which system has more capacity?

d) (15 points) How would you increase the capacity for the upgraded system utilizing the upgrades mentioned above? Explain and show the new capacity.

Appendix A:

Table for STANDARD Normal probability numbers: Prob [$Z < z_p$] = p. For given p value, the table entries represent the corresponding z_p.

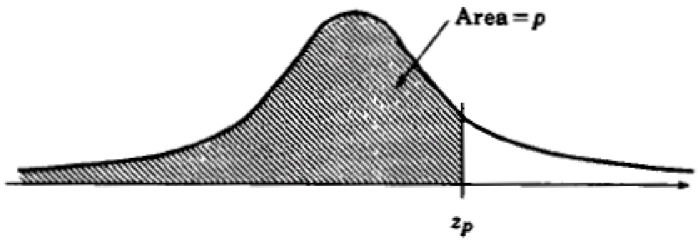


TABLE A.2 Quantiles of the Unit Normal Distribution

p	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.5	0.000	0.025	0.050	0.075	0.100	0.126	0.151	0.176	0.202	0.228
0.6	0.253	0.279	0.305	0.332	0.358	0.385	0.412	0.440	0.468	0.496
0.7	0.524	0.553	0.583	0.613	0.643	0.674	0.706	0.739	0.772	0.806
0.8	0.842	0.878	0.915	0.954	0.994	1.036	1.080	1.126	1.175	1.227

p	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.90	1.282	1.287	1.293	1.299	1.305	1.311	1.317	1.323	1.329	1.335
0.91	1.341	1.347	1.353	1.359	1.366	1.372	1.379	1.385	1.392	1.398
0.92	1.405	1.412	1.419	1.426	1.433	1.440	1.447	1.454	1.461	1.468
0.93	1.476	1.483	1.491	1.499	1.506	1.514	1.522	1.530	1.538	1.546
0.94	1.555	1.563	1.572	1.580	1.589	1.598	1.607	1.616	1.626	1.635
0.95	1.645	1.655	1.665	1.675	1.685	1.695	1.706	1.717	1.728	1.739
0.96	1.751	1.762	1.774	1.787	1.799	1.812	1.825	1.838	1.852	1.866
0.97	1.881	1.896	1.911	1.927	1.943	1.960	1.977	1.995	2.014	2.034
0.98	2.054	2.075	2.097	2.120	2.144	2.170	2.197	2.226	2.257	2.290

p	0.0000	0.0001	0.0002	0.0003	0.0004	0.0005	0.0006	0.0007	0.0008	0.0009
0.990	2.326	2.330	2.334	2.338	2.342	2.346	2.349	2.353	2.357	2.362
0.991	2.366	2.370	2.374	2.378	2.382	2.387	2.391	2.395	2.400	2.404
0.992	2.409	2.414	2.418	2.423	2.428	2.432	2.437	2.442	2.447	2.452
0.993	2.457	2.462	2.468	2.473	2.478	2.484	2.489	2.495	2.501	2.506
0.994	2.512	2.518	2.524	2.530	2.536	2.543	2.549	2.556	2.562	2.569
0.995	2.576	2.583	2.590	2.597	2.605	2.612	2.620	2.628	2.636	2.644
0.996	2.652	2.661	2.669	2.678	2.687	2.697	2.706	2.716	2.727	2.737
0.997	2.748	2.759	2.770	2.782	2.794	2.807	2.820	2.834	2.848	2.863
0.998	2.878	2.894	2.911	2.929	2.948	2.968	2.989	3.011	3.036	3.062
0.999	3.090	3.121	3.156	3.195	3.239	3.291	3.353	3.432	3.540	3.719

Appendix B:

Offered Loads (in Erlangs) for various Blocking Objectives – According to the Erlang-B model

C	Blocking Probability							C	Blocking Probability						
	0.1	0.5	1	1.5	2	2.5	3		0.1	0.5	1	1.5	2	2.5	3
10	3.07	3.95	4.45	4.80	5.08	5.31	5.52	36	21.30	24.01	25.51	26.53	27.34	28.03	28.65
11	3.64	4.60	5.15	5.54	5.84	6.10	6.33	37	22.08	24.85	26.38	27.42	28.25	28.96	29.59
12	4.22	5.27	5.87	6.29	6.61	6.89	7.14	38	22.86	25.69	27.25	28.32	29.17	29.89	30.53
13	4.83	5.96	6.61	7.05	7.40	7.70	7.97	39	23.65	26.53	28.13	29.22	30.08	30.82	31.47
14	5.44	6.66	7.35	7.82	8.20	8.52	8.80	40	24.44	27.38	29.01	30.12	31.00	31.75	32.41
15	6.08	7.37	8.11	8.61	9.01	9.35	9.65	41	25.24	28.23	29.89	31.02	31.92	32.68	33.36
16	6.72	8.10	8.87	9.41	9.83	10.19	10.51	42	26.04	29.08	30.77	31.92	32.84	33.61	34.30
17	7.38	8.83	9.65	10.21	10.66	11.03	11.37	43	26.84	29.94	31.66	32.83	33.76	34.55	35.25
18	8.05	9.58	10.44	11.02	11.49	11.89	12.24	44	27.64	30.80	32.54	33.73	34.68	35.49	36.20
19	8.72	10.33	11.23	11.84	12.33	12.75	13.11	45	28.45	31.66	33.43	34.64	35.61	36.43	37.16
20	9.41	11.09	12.03	12.67	13.18	13.61	14.00	46	29.25	32.52	34.32	35.55	36.53	37.37	38.11
21	10.11	11.86	12.84	13.51	14.04	14.49	14.89	47	30.07	33.38	35.21	36.47	37.46	38.31	39.06
22	10.81	12.63	13.65	14.35	14.90	15.36	15.78	48	30.88	34.25	36.11	37.38	38.39	39.25	40.02
23	11.52	13.42	14.47	15.19	15.76	16.25	16.68	49	31.69	35.11	37.00	38.30	39.32	40.20	40.97
24	12.24	14.20	15.29	16.04	16.63	17.13	17.58	50	32.51	35.98	37.90	39.21	40.26	41.14	41.93
25	12.97	15.00	16.12	16.89	17.50	18.02	18.48	51	33.33	36.85	38.80	40.13	41.19	42.09	42.89
26	13.70	15.79	16.96	17.75	18.38	18.92	19.39	52	34.15	37.72	39.70	41.05	42.12	43.04	43.85
27	14.44	16.60	17.80	18.62	19.26	19.82	20.31	53	34.98	38.60	40.60	41.97	43.06	43.99	44.81
28	15.18	17.41	18.64	19.48	20.15	20.72	21.22	54	35.80	39.47	41.50	42.89	44.00	44.94	45.78
29	15.93	18.22	19.49	20.35	21.04	21.62	22.14	55	36.63	40.35	42.41	43.82	44.94	45.89	46.74
30	16.68	19.03	20.34	21.23	21.93	22.53	23.06	56	37.46	41.23	43.31	44.74	45.88	46.84	47.70
31	17.44	19.85	21.19	22.10	22.83	23.44	23.99	57	38.29	42.11	44.22	45.67	46.82	47.80	48.67
32	18.20	20.68	22.05	22.98	23.72	24.36	24.91	58	39.12	42.99	45.13	46.59	47.76	48.75	49.63
33	18.97	21.50	22.91	23.87	24.63	25.27	25.84	59	39.96	43.87	46.04	47.52	48.70	49.71	50.60
34	19.74	22.34	23.77	24.75	25.53	26.19	26.78	60	40.79	44.76	46.95	48.45	49.64	50.66	51.57
35	20.52	23.17	24.64	25.64	26.43	27.11	27.71								