00041

THE OPEN UNIVERSITY OF SRI LANKA
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
BATCHELOR OF TECHNOLOGY

FINAL EXAMINATION - 2014/2015

ECX6239 – WIRELESS COMMUNICATION **(Closed Book)**

Answer any five questions.

Date 13.09.2015 ***Time: 09:30-12:30 hrs.***

Gaussian distribution: $N(\mu,\sigma)\sim\frac{1}{\sqrt{2\pi\sigma^2}}e^{-\frac{(x-\mu)^2}{2\sigma^2}}$ Q-function: $Q(x)=\frac{1}{\sqrt{2\pi}}\int_x^{\infty}e^{-\frac{u^2}{2}}du$

Q1. (a) Using clear diagrams and necessary formulas, briefly explain the difference between slow fading and fast fading. **(4Marks)**

(b) Define coherence time and coherence bandwidth and state their importance in communicating over fading channels. **(4Marks)**

(c) Consider a $2GHz$ cellular wireless base station with $50m$ height at the bank of a large lake transmitting a signal to a mobile on a boat with $2m$ height which is $1km$ away from the base station. Let the communication take place completely over a water surface which acts as a reflector with a reflection coefficient -1. Let the antennas be with unit gains. Model this communication system using a two-ray model and find the received signal power for a transmit power of $2W$.

(12marks)

Note: You need to consider the phase shifts introduced along the path.

Q2.

(a) Briefly explain the origin of shadowing. **(4Marks)**

(b) Shadowing may result in outages. Define outage probability. **(4Marks)**

(c) Consider a cellular communication system where propagation follows free space path loss ($P_L = 1.5d^4$) plus log normal shadowing with $\sigma = 6\ dBm$. Suppose that for acceptable voice quality, a signal-to-noise power ratio of $-100\ dB$ is required at the mobile. Assume the base station transmits at $1W$ and its antenna has a $20\ dB$ gain.There is no antenna gain at the mobile and the receiver noise in the bandwidth of interest is $-10\ dBm$. Find the maximum cell size so that a mobile on the cell boundary will have acceptable voice quality 90% of the time. **(12Marks)**

Hint: For a Standard Normal random variable z, $Pr(z \geq 1.31) = 0.1$

Q3.

(a) Briefly compare the error performance in three diversity combining techniques equal gain, selection and maximal-ratio. **(3Marks)**

(b) Prove that the maximal ratio combining provides the optimum overall SNR. **(7Marks)**

(c) Consider an AWGN channel with N-branch diversity combining and $\gamma_i = 10dB$ per branch. Assume MQAM modulation with $M = 4$ and use the approximation $p_b = 0.2\,e^{-\frac{1.5\gamma}{M-1}}$ for bit error probability where γ is the received SNR.

(i) Find P_b for $N = 1$ **(4Marks)**

(ii) Find N so that, under MRC, $P_b < 10^{-6}$ **(6Marks)**

Q4.

(a) List three uses of modulating the digital signals. **(3Marks)**

(b) Using suitable constellation diagrams and graphs compare the spectral efficiency vs. error probability trade off in PSK and QAM digital modulation schemes. **(6Marks)**

(c) Consider the octal signal constellations shown in Figure-Q4. Let the nearest neighbor signal points in both the constellations are separated by an equal distance A.

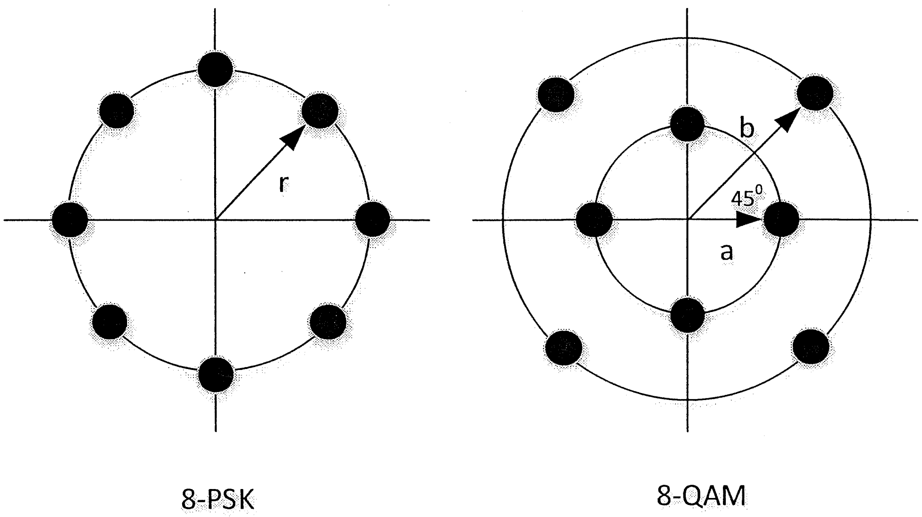

Figure-Q4

i. Calculate a, b and r in terms of A. **(5Marks)**

ii. Hence determine the average transmitter power required for two signal constellations. Compare them. Assume that all symbols are equi-probable. **(6Marks)**

Q5.

(a) List two differences between linear block codes and convolutional. **(2Marks)**

(b) Name a practical deployment scenario for each of these two categories of error correction codes. **(2Marks)**

(c) Consider a linear block code with a parity check matrix H,

$$H = \begin{pmatrix} 1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 0 & 0 & 0 & 1 \end{pmatrix}.$$

Find,

(i) the generator matrix **(4marks)**

(ii) the complete codeword set **(4marks)**

(iii) the minimum distance **(2marks)**

(iv) error correction capability of this code **(2marks)**

(v) syndrome vector for a an input bit vector $(0 \quad 1 \quad 1 \quad 1 \quad 1 \quad 0)$ at the decoder. **(4marks)**

Q6.

(a) Consider a cellular mobile network with hexagonal cells. Let R and D are the active cell radius and distances from interfering cells respectively. Using at least two examples show that the reuse factor N is related to R and D by,

$$\frac{D}{R} = \sqrt{3N}.$$ **(6Marks)**

(b) Let γ be the path loss exponent. Show that the worst case SIR is given by $\frac{R^{-\gamma}}{6D^{-\gamma}}$. **(4Marks)**

(c) Consider an 8 time-slot TDMA based cellular system with hexagonally shaped cells and with path loss exponent 2 for all signal propagations in the system. Find the minimum reuse factor N needed for a target SIR of $10dB$. **(6Marks)**

(d) Find the corresponding user capacity of a 25 cluster area for a total bandwidth of $20MHz$ and a required signal bandwidth of $100kHz$. **(4Marks)**

Q7.

(a) Compare three multiple access techniques, FDMA, TDMA and CDMA in terms of capacity and the spectral efficiency. **(6Marks)**

(b) "CDMA is an interference limited system". Discuss the validity of this statement. **(4Marks)**

(c) Show that for a BPSK modulated system with SNR γ_b, bit error rate is given by $P_b = Q(\sqrt{2\gamma_b})$. **(4Marks)**

(d) Consider a CDMA down link with bandwidth expansion $\frac{B_S}{B} = 100$. Assume the system is interference limited and there are no multipath on any user's channel. Use the result in (c) to find how many users the system can support under BPSK modulation such that each user has a BER less than 10^{-3}. **(6Marks)**

Note: Use the attached Q function tables.

Q8.

(a) Dynamic resource allocation is very popular in wireless communication. Explain how a dynamic power allocation can be carried out. **(4Marks)**

(b) Cognitive radio systems provide efficient use of spectrum. Explain the basic function of cognitive radio. **(4Marks)**

(c) In a cognitive radio based system, the probability of occupancy of a $10kHz$ bandwidth centered on frequency f by the primary users is given by a pdf $g(f) = \lambda e^{-\lambda f}$ where λ is a constant. Also, let the secondary users have a frequency dependent bandwidth requirement of $2f\ kHz$. Calculate the outage probability of a secondary user in this system. **(8Marks)**

(d) Discuss two common issues arise in a cognitive radio system. **(4Marks)**

Table : Values of $Q(x)$

x	$Q(x)$	x	$Q(x)$	x	$Q(x)$	x	$Q(x)$
0.00	0.5	2.30	0.010724	4.55	2.6823×10^{-6}	6.80	5.231×10^{-12}
0.05	0.48006	2.35	0.0093867	4.60	2.1125×10^{-6}	6.85	3.6925×10^{-12}
0.10	0.46017	2.40	0.0081975	4.65	1.6597×10^{-6}	6.90	2.6001×10^{-12}
0.15	0.44038	2.45	0.0071428	4.70	1.3008×10^{-6}	6.95	1.8264×10^{-12}
0.20	0.42074	2.50	0.0062097	4.75	1.0171×10^{-6}	7.00	1.2798×10^{-12}
0.25	0.40129	2.55	0.0053861	4.80	7.9333×10^{-7}	7.05	8.9459×10^{-13}
0.30	0.38209	2.60	0.0046612	4.85	6.1731×10^{-7}	7.10	6.2378×10^{-13}
0.35	0.36317	2.65	0.0040246	4.90	4.7918×10^{-7}	7.15	4.3389×10^{-13}
0.40	0.34458	2.70	0.003467	4.95	3.7107×10^{-7}	7.20	3.0106×10^{-13}
0.45	0.32636	2.75	0.0029798	5.00	2.8665×10^{-7}	7.25	2.0839×10^{-13}
0.50	0.30854	2.80	0.0025551	5.05	2.2091×10^{-7}	7.30	1.4388×10^{-13}
0.55	0.29116	2.85	0.002186	5.10	1.6983×10^{-7}	7.35	9.9103×10^{-14}
0.60	0.27425	2.90	0.0018658	5.15	1.3024×10^{-7}	7.40	6.8092×10^{-14}
0.65	0.25785	2.95	0.0015889	5.20	9.9644×10^{-8}	7.45	4.667×10^{-14}
0.70	0.24196	3.00	0.0013499	5.25	7.605×10^{-8}	7.50	3.1909×10^{-14}
0.75	0.22663	3.05	0.0011442	5.30	5.7901×10^{-8}	7.55	2.1763×10^{-14}
0.80	0.21186	3.10	0.0009676	5.35	4.3977×10^{-8}	7.60	1.4807×10^{-14}
0.85	0.19766	3.15	0.00081635	5.40	3.332×10^{-8}	7.65	1.0049×10^{-14}
0.90	0.18406	3.20	0.00068714	5.45	2.5185×10^{-8}	7.70	6.8033×10^{-15}
0.95	0.17106	3.25	0.00057703	5.50	1.899×10^{-8}	7.75	4.5946×10^{-15}
1.00	0.15866	3.30	0.00048342	5.55	1.4283×10^{-8}	7.80	3.0954×10^{-15}
1.05	0.14686	3.35	0.00040406	5.60	1.0718×10^{-8}	7.85	2.0802×10^{-15}
1.10	0.13567	3.40	0.00033693	5.65	8.0224×10^{-9}	7.90	1.3945×10^{-15}
1.15	0.12507	3.45	0.00028029	5.70	5.9904×10^{-9}	7.95	9.3256×10^{-16}
1.20	0.11507	3.50	0.00023263	5.75	4.4622×10^{-9}	8.00	6.221×10^{-16}
1.25	0.10565	3.55	0.00019262	5.80	3.3157×10^{-9}	8.05	4.1397×10^{-16}
1.30	0.0968	3.60	0.00015911	5.85	2.4579×10^{-9}	8.10	2.748×10^{-16}
1.35	0.088508	3.65	0.00013112	5.90	1.8175×10^{-9}	8.15	1.8196×10^{-16}
1.40	0.080757	3.70	0.0001078	5.95	1.3407×10^{-9}	8.20	1.2019×10^{-16}
1.45	0.073529	3.75	8.8417×10^{-5}	6.00	9.8659×10^{-10}	8.25	7.9197×10^{-17}
1.50	0.066807	3.80	7.2348×10^{-5}	6.05	7.2423×10^{-10}	8.30	5.2056×10^{-17}
1.55	0.060571	3.85	5.9059×10^{-5}	6.10	5.3034×10^{-10}	8.35	3.4131×10^{-17}
1.60	0.054799	3.90	4.8096×10^{-5}	6.15	3.8741×10^{-10}	8.40	2.2324×10^{-17}
1.65	0.049471	3.95	3.9076×10^{-5}	6.20	2.8232×10^{-10}	8.45	1.4565×10^{-17}
1.70	0.044565	4.00	3.1671×10^{-5}	6.25	2.0523×10^{-10}	8.50	9.4795×10^{-18}
1.75	0.040059	4.05	2.5609×10^{-5}	6.30	1.4882×10^{-10}	8.55	6.1544×10^{-18}
1.80	0.03593	4.10	2.0658×10^{-5}	6.35	1.0766×10^{-10}	8.60	3.9858×10^{-18}
1.85	0.032157	4.15	1.6624×10^{-5}	6.40	7.7688×10^{-11}	8.65	2.575×10^{-18}
1.90	0.028717	4.20	1.3346×10^{-5}	6.45	5.5925×10^{-11}	8.70	1.6594×10^{-18}
1.95	0.025588	4.25	1.0689×10^{-5}	6.50	4.016×10^{-11}	8.75	1.0668×10^{-18}
2.00	0.02275	4.30	8.5399×10^{-6}	6.55	2.8769×10^{-11}	8.80	6.8408×10^{-19}
2.05	0.020182	4.35	6.8069×10^{-6}	6.60	2.0558×10^{-11}	8.85	4.376×10^{-19}
2.10	0.017864	4.40	5.4125×10^{-6}	6.65	1.4655×10^{-11}	8.90	2.7923×10^{-19}
2.15	0.015778	4.45	4.2935×10^{-6}	6.70	1.0421×10^{-11}	8.95	1.7774×10^{-19}
2.20	0.013903	4.50	3.3977×10^{-6}	6.75	7.3923×10^{-12}	9.00	1.1286×10^{-19}
2.25	0.012224						