00023

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

FINAL EXAMINATION - 2015/2016

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

Answer any five questions.

Date 14.12.2016 ***Time: 9:30-12:30 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) Define the following. **(4x2Marks)**

i. Coherence time
ii. Coherence bandwidth
iii. Doppler spread
iv. Flat fading

(b) A certain communication system deploying macrodiversity has a mobile placed at the mid-point between two identical base stations transmitting at $W\ dBW$. The received signals at the mobile in dBW are $P_1 = W + Z_1$ and $P_2 = W + Z_2$. Here Z_1 and Z_2 are independently and identically distributed Gaussian random variables with zero mean and σ^2 variance.

i. Interpret the terms Z_1 and Z_2. What phenomena contribute to Z_1 and Z_2? **(4Marks)**

ii. If the threshold received level is $T\ dBW$, show that the outage probability at the mobile is given by,

$$P_{out} = \left[Q\left(\frac{W-T}{\sigma}\right)\right]^2.$$ **(8Marks)**

Q2.

(a) Briefly explain the origin of the three adverse effects fading, shadowing and noise. **(6Marks)**

(b) Differentiate fast fading and slow fading. **(4Marks)**

(c) Consider a cellular 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. **(10Marks)**

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

Q3. A certain wireless communication system with a noise power spectral density $\frac{N_0}{2}$ has the same signal communicated in two independent paths and the received signals are r_1 and r_2. Let the two received signals are co-phased, weighted and combined to form a signal $r = w_1 r_1 + w_2 r_2$.

(a) What are the possible values of w_1 and w_2 in equal gain and selection combining respectively? **(2Marks)**

(b) Write an expression for the overall signal to noise ratio at the output of the combiner. **(5Marks)**

(c) Using the expression in (b) prove that the maximum combined SNR is achieved when $w_1^2 = \frac{r_1^2}{N_0}$ and $w_2^2 = \frac{r_2^2}{N_0}$. **(8Marks)**

(d) Show that the optimum combined signal SNR is equal to the sum of individual signal SNRs corresponding to the two paths. **(5Marks)**

Q4.

(a) List two advantages in modulating the digital signals. **(4Marks)**

(b) Using the constellation diagrams explain how QAM modulation provides a better bandwidth efficiency-error tradeoff compared to PAM and PSK modulation schemes. **(6Marks)**

(c) A 16-point QAM signal configuration is shown in Figure Q4. Assuming that all symbols are equiprobable and AWGN noise, determine the error probability. (You may express your final answer as a Q function.) **(10Marks)**

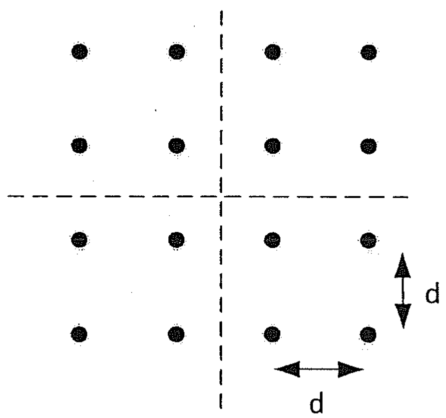

Figure Q4

Q5.

(a) Compare and contrast the linear block codes and the convolutional codes (highlight the encoding, decoding techniques). **(4Marks)**

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

(c) A certain (6,3) systematic linear block code has three data bits d_1, d_2, d_3 and three parity check digits c_4, c_5, c_6 where

$$c_4 = d_1 \oplus d_2 \oplus d_3$$
$$c_5 = d_1 \oplus d_2$$
$$c_6 = d_1 \oplus d_3.$$

(i) Construct an appropriate generator matrix for this code. **(3marks)**

(ii) Construct the total codeword set. **(3marks)**

(iii) Determine the error correcting capability of this code **(2marks)**

(iv) Determine the parity check matrix. **(4marks)**

(v) Find the syndrome vector for the decoder input vector $(1 \quad 0 \quad 1 \quad 0 \quad 1 \quad 0)$. **(2marks)**

Q6.

(a) Define the terms co-channel interference and adjacent-channel interference. Explain how these can be minimized in cellular systems. **(6Marks)**

(b) Consider a cellular system having hexagonal cells and the system deploys clustering. Let the distance to a mobile from the serving base station be d_S and the distance from closest other interfering base station be d_I.

i. Assuming a free space path loss model with a path loss exponent of 2 , show that signal to interference ratio $\left(\frac{S}{I}\right) = 20 \log\left(\frac{d_I}{6d_S}\right)\ dB$. **(6Marks)**

ii. Thus, determine a suitable reuse factor for a threshold $\frac{S}{I} = -4dB$. **(4Marks)**

iii. If the cellular system uses a total bandwidth of $60MHz$ and a subscriber requires $30kHz$ (simplex), calculate the system capacity for 100 base stations. **(4Marks)**

Q7.

(a) Compare four different generations of cellular communication systems focusing on the multiple access technique, capacity and the efficiency. **(4Marks)**

(b) Taking a system with 3 simultaneous users, clearly explain how the CDMA systems achieve multiple access. **(6Marks)**

(c) A certain CDMA downlink system with a spreading gain of 100 uses BPSK modulation. Assume that the system is only interference limited and neglect the effects of multipath components. Find the maximum number of simultaneous users this system can support under BPSK modulation such that each user has a BER less than 10^{-3}.

[Note: You may use the fact that for a BPSK modulated system with SNR γ_b, bit error rate is given by $P_b = Q\left(\sqrt{2\gamma_b}\right)$.] **(10Marks)**

Q8. Write short notes on the following. Your notes should include an introduction to the technique, deployment details and also the pros & cons of the technique under each case.

(a) Non orthogonal multiple access (NOMA)
(b) Hybrid-ARQ
(c) Cognitive radio
(d) Ultra wide band radio
(e) Dynamic power control

(5x4Marks)

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}