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

FINAL EXAMINATION - 2013/2014

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

Answer any five questions.

Date 31.08.2014 ***Time: 13:30-16:30 hrs.***

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

Q1.

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

(b) Macrodiversity is a technique to reduce the effect of fading. Explain the principle of macrodiversity. **(4Marks)**

(c) 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) Fading/shadowing may result in outages. Define outage probability. **(4Marks)**

(c) A certain cellular base station with a cell radius of $1km$ transmits $80mW$ and the path loss follows a model $P_r = P_t\left(\frac{1}{r^3}\right)$. The system also suffers from lognormal shadowing with $\sigma = 16dB$ (distribution of $10\log\left(\frac{P_t}{P_r}\right)$ follows a normal distribution). Let the minimum received power requirement of the mobile stations be $-100dBm$. Calculate the coverage area within the cell. [You may state your answer in terms of a Q function] **(10Marks)**

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Q3. A certain wireless communication system with a noise power spectral density $\frac{N_0}{2}$ has the same signal communicated in two independent time slots 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 possible combinations of w_1 and w_2 weights are being practically used in different combining techniques? **(3Marks)**

(b) Write an expression for the overall SNR at the output of the combiner. **(4Marks)**

(c) Hence 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. **(5Marks)**

Q4.

(a) List the advantages in modulating the digital signals. **(3Marks)**

(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) Consider a binary transmission system which uses $\frac{A}{2}$ and $-\frac{A}{2}$ levels to represent **1** and **0** respectively. The data rate is $R_b bps$.

i. What is the minimum bandwidth required. **(3Marks)**

ii. This data stream is to be transmitted by a M-ary PAM scheme maintaining the same noise immunity. If each of the **1** and **0** are equally probable, show that the transmit power requirement is $P = \frac{(M^2-1)A^2}{12 log_2 M}$. **(8Marks)**

[Hint: $\sum_{i=1}^{n}(2i-1)^2 = \frac{n}{3}(4n^2-1)$]

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) Consider a linear block code with a generator matrix G,

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

Find,

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

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

(iii) parity check matrix **(4marks)**

(iv) syndrome vector for a an input bit vector (1 0 1 0 1 0) at the decoder. **(4marks)**

Q6.

(a)

i. What is OFDM? Explain how OFDM achieves higher spectral efficiencies in cellular communication. **(4Marks)**

ii. List three OFDM using networks and compare their spectral efficiencies. **(3Marks)**

(b) A certain cellular system has hexagonal cells and system deploys clustering to avoid co-channel interference. Let the distance to a mobile from the serving base station be d_S and the distance from closest other base station using the same channel be d_I.

i. Assuming a free space path loss model with a path loss exponent 2 , show that signal to interference ratio $\left(\frac{S}{I}\right) = 20\log\left(\frac{d_I}{6d_S}\right)\ dB$. **(5Marks)**

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 $50MHz$ and a subscriber requires $50kHz$ (simplex), calculate the system capacity for 100 base stations. **(4Marks)**

Q7.

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

(b) "CDMA is an interference limited system". Discuss. **(6Marks)**

(c) Consider a CDMA system occupying a 10MHz spectrum. Assume an interference limited system with a spreading gain of G and code correlation ξ.

i. Find a formula for the signal to interference ratio (SIR) of the received signal for a K number of subscribers. Assume that all subscribers transmit at the same power and the power control mechanism ensures that all subscribers have the same received power. **(5Marks)**

ii. Hence find the maximum number of simultaneous users which can be supported if threshold SIR is 7dB, $G = 100$ and $\xi = 0.67$. **(5Marks)**

Q8.

(a)

i. What is MIMO? What are the advantages of deploying MIMO? **(4Marks)**

ii. Consider a $M_r \times M_t$MIMO channel with the gain matrix H. Let the singular value decomposition of H is given by $U\Sigma V^H$ where U and V are unitary matrices and Σ is a diagonal matrix with singular values of H. Show that $\tilde{y} = Uy$ transformation converts the MIMO system to a set of SISO systems. **(6Marks)**

(b)

i. Why is dynamic resource allocation beneficial in cellular systems? What resources can be dynamically allocated? **(4Marks)**

ii. Cognitive radio supports dynamic resource allocation. Explain the concept of cognitive radio. **(6Marks)**