University of KwaZulu Natal

School of Electrical, Electronic and Computer Engineering

Examinations: October 2015

Selected Topics in Electronic Engineering: ENEL4TBH2

(Advanced Wireless Communication)

Duration: **1 Hours** Marks: **50**

Examiners : Prof. H. Xu (Internal)

: Prof. K Ouahaka (External)

Instructions : 1. Answer all questions.

2. This is not an open book exam and no notes may be used, either electronic or handwritten. Calculator is allowed.

Question 1: Wireless Channel Model (10 marks)

(1) (**6 marks**) In a fading channel, assume the fading coefficient $(t) = x(t) + jy(t) = ae^{j\varphi}$, where $x \sim N(0, \sigma^2)$ and $y \sim N(0, \sigma^2)$. x and y are independent Gaussian random variables. Prove the probability density function of the amplitude a is $f_a = \frac{a}{\sigma^2} exp\left(-\frac{a^2}{2\sigma^2}\right)$.

(2) (**2 marks**) What is the main difference between Rayleigh and Rician fading?

(3) (**2 marks**) Does fading always cause destructive result? Use an example to explain your answer.

Question 2: Performance Analysis in Fading Channel (10 marks)

Consider a transmission system in Rayleigh fading channel: $y = hx + n$, where h is the fading coefficient with amplitude a, x is an MSPK symbol and n is the additive white Gaussian noise (AWGN) with zero mean and variance N_0. The MPSK symbol error probability (SER) in AWGN is $p_s = 2Q\left(\sqrt{2SNR} sin(\pi/M)\right)$, where SNR is signal-to-noise ratio, and $Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-y^2/2} dy$. The pdf of instantaneous SNR in a Rayleigh fading channel is given by $f_\gamma(\gamma) = \frac{1}{\bar{\gamma}} exp(-\gamma/\bar{\gamma})$, where $\bar{\gamma} = E[\gamma] = E[a^2 E/N_0]$, E is the transmitted power, and the approximation of Q(x) is given by

$$Q(x) = \frac{1}{2n}\left\{\frac{e^{-x^2/2}}{2} + \sum_{k=1}^{n-1} exp\left(-\frac{x^2}{2sin^2(k\pi/(2n))}\right)\right\}$$

where n is the number of summation.

(1) (**3 marks**) The MGF is defined as $M_s(s) = \int_0^\infty e^{-st} f(t)dt$. Derive MGF for $f_\gamma(\gamma)$.

(2) (**7 marks**) Derive the average symbol error probability in terms of MGF for MPSK over a Rayleigh fading Channel.

Question 3: Space-Time Coding (10 marks)

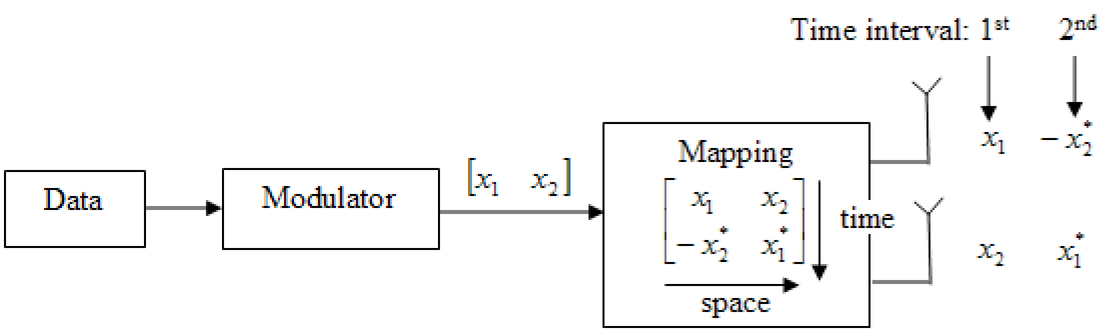

Fig. 1

Assume that an *M*–ary modulation scheme is used. Each group of $m = \log_2 M$ information bits is grouped and mapped to modulation symbols. The Alamouti encoder shown in Fig. 1 takes a block of two modulated symbols and maps them to the transmit antennas according to a matrix given by

$$\begin{array}{cc} & \xrightarrow{\text{space}} \\ X= & \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix} \Big\downarrow \quad \text{time} \end{array}$$

Also assume that only one receiver antenna is employed at the receiver. Under the assumption that fading coefficients are constant over two symbol periods, the received signal for two consecutive time intervals are given

$$r_1 = \alpha_1 x_1 + \alpha_2 x_2 + z_1$$
$$r_2 = \alpha_1\left(-x_2^*\right) + \alpha_2 x_1^* + z_2$$

where α_1 and α_2 are channel fading coefficients, which are constant for every two time slots.

(1) (**2 marks**) Prove $X = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix}$ is orthogonal.

(2) (**6 marks**) Assume perfect channel state information (CSI) is available at the receiver. Use orthogonality of Alamouti's scheme to decode (or decouple) x_1 and x_2 from the received signals

$$r_1 = \alpha_1 x_1 + \alpha_2 x_2 + z_1$$
$$r_2 = \alpha_1 \left(-x_2^*\right) + \alpha_2 x_1^* + z_2$$

(3) (**2 marks**) Explain what Alamouti scheme only achieves spatial diversity, but no time diversity.

Question 4 Signal Space Diversity (10 marks)

(1) (**2 marks**) In signal space diversity, explain why there is no space diversity for MQAM achieved if without signal rotation.

(2) (**8 marks**) Use mathematics to explain how to implement modulation for signal space diversity, including all assumptions, received signals, and detection or demodulation of the transmitted signals.

Question 5 Spatial Modulation (10 marks)

(1) (**2 marks**) In spatial modulation, we assume fading channel $\boldsymbol{H}$ **is complex (it means that the fading includes both amplitude and phase).** Can we assume the fading channel is only amplitude? Explain your reason.

(2) (**2 marks**) Most of multiple-input multiple-output (MIMO) systems provide spatial diversity. Spatial modulation is also a MIMO system. Does the conventional spatial modulation provide spatial diversity? Explain your reason.

(3) (**3 marks**) In space-time block coded (STBC) spatial modulation consider a MIMO system with four transmit antennas which transmits the Alamouti STBC using one of the following codewords:

$$\boldsymbol{\chi_1} = \{\boldsymbol{X}_{11}, \boldsymbol{X_{12}}\} = \left\{\begin{pmatrix} x_1 & x_2 & 0 & 0 \\ -x_2^* & x_1^* & 0 & 0 \end{pmatrix}, \begin{pmatrix} 0 & 0 & x_1 & x_2 \\ 0 & 0 & -x_2^* & x_1^* \end{pmatrix}\right\}$$
$$\boldsymbol{\chi_2} = \{\boldsymbol{X}_{21}, \boldsymbol{X_{22}}\} = \left\{\begin{pmatrix} 0 & x_1 & x_2 & 0 \\ 0 & -x_2^* & x_1^* & 0 \end{pmatrix}, \begin{pmatrix} x_2 & 0 & 0 & x_1 \\ x_1^* & 0 & 0 & -x_2^* \end{pmatrix}\right\} \boldsymbol{e^{j\theta}}$$

Explain why $\boldsymbol{e^{j\theta}}$ is used in the above codewords.

(4) (**3 marks**) Use 4x4 4QAM to explain space-time block coded spatial modulation assume the input sequence is 10110011.