南方科技大学
SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Course Name: Wireless Communications Dept.: Electronic & Electrical Engineering

Exam Duration: 2 hours **Exam Paper Setter: WANG Rui**

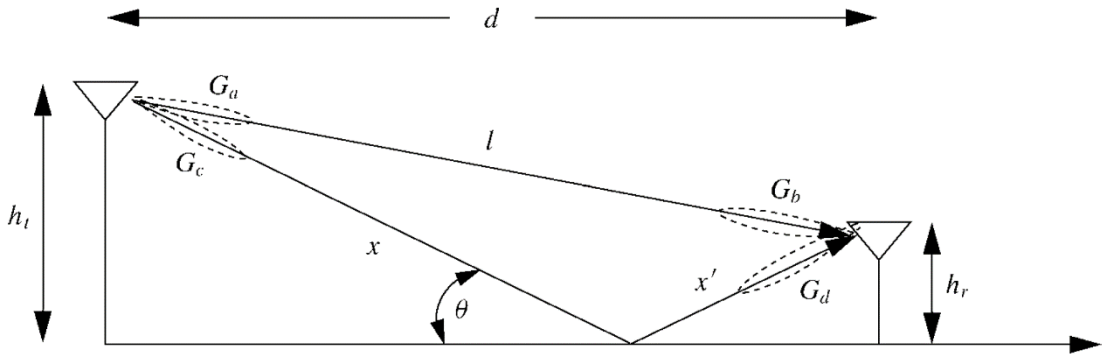
Question No.	1	2	3	4	5	6	7	8	9	10
Score	25	25	30	20						

This exam paper contains 4 questions and the score is 100 in total. (Please hand in your exam paper, answer sheet, and your scrap paper to the proctor when the exam ends.)

Q1. Channel Model

(a) Please discuss the relation between narrowband/wideband signals and flat/frequency selective fading channels.

(b) For the following two-ray model with $d = 100m$, $h_t = 10m$, and $h_r = 2m$, please estimate the delay spread between two signals (light speed $c = 3 \times 10^8 m/s$).



(c) Given a cellular system with central frequency at 900MHz. The transmit power of base station is $1W$.

1. Consider the simplified path-loss model with the path-loss exponent, constant of antenna and channel attenuation characteristics, reference distance as $\gamma = 4, K = 15$ dB, $d_0 = 2$m. Suppose a user is 100 m away from the base station with environment noise -40 dBm. What's the receive SNR? ($\log_{10} 2 \approx 0.301$)
2. Based on problem (1), assuming log-normal shadowing with standard deviation $\sigma = 5$ dB, please compute the probability that the user could receive data with a SNR above 10dB. ($Q(3.408) \approx 0.0003, Q(2.408 \approx 0.008), Q(1.408) \approx 0.0796, Q(0.408) \approx 0.3416$)

3. If there no LOS component exists from the base station to user, and the environment is filled with scatters, please tell which channel model is appropriate – Rayleigh or Rician? With the channel model and average received signal power 80 dBm, please find the outage probability relative to a threshold $P_0 = -90$ dBm.

Q2. Channel Capacity

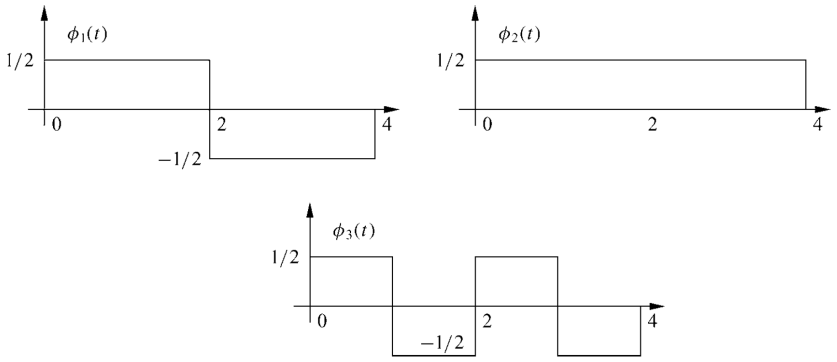
Assume an i.i.d. channel with a flat fading channel amplitude gain $\sqrt{g[i]}$, which can take on three possible values: $\sqrt{g_1}$ = 0.1 with probability p_1= 0.2, $\sqrt{g_2}$ = 0.3 with probability p_2 = 0.5, and $\sqrt{g_3}$ = 1 with probability p_3= 0.3. The average transmit power is 1mW, the noise power spectral density is $\frac{N_0}{2}$ with $N_0 = 10^{-9}\, W/Hz$, and the channel bandwidth is 20 kHz. Assume both the receiver and the transmitter have knowledge of CSI.

(a) Find the ergodic capacity of this channel without power adaptation.
(b) Find the ergodic capacity of this channel with power adaptation (Using water-filling method).
(c) Find the zero-outage capacity of this channel.
(d) Which one is the largest? Why?

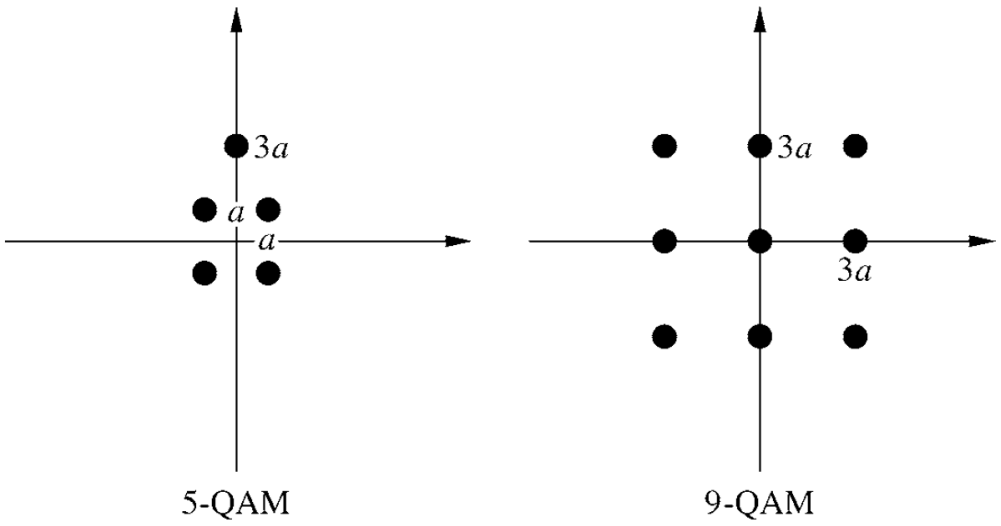
Q3. Digital Modulation

(a) What's the dimensions of signal spaces for digital modulation schemes: BPSK, QPSK, 2048QAM, 4-FSK?
(b) Please explain why the Rayleigh fading channel leads to larger error probability than the AWGN channel for the same transmit signal and average receive signal power.
(c) Consider the three signal waveforms $\{\phi_1(t), \phi_2(t), \phi_3(t)\}$ as follows. Please
    1. Show that these waveforms are orthonormal
    2. Express the waveform $x(t)$ as a linear combination of $\{\phi_1(t), \phi_2(t), \phi_3(t)\}$ and find the coefficients, where $x(t)$ is given as

$$x(t) = \begin{cases} 2 & 0 \le t < 2 \\ 4 & 2 \le t \le 4 \end{cases}$$



(d) Please use union bound to derive the average error probabilities of the following two constellations for AWGN channel. The variance of noise per signal-space dimension is $N_0/2$. Assume all the constellation points are transmitted with equal probability.



Q4. MIMO

Consider a 3×3 narrowband MIMO channel matrix $\boldsymbol{H}$ with the following SVD form:

$$\boldsymbol{H} = \boldsymbol{U\Sigma V}^H = [\boldsymbol{u_1}, \boldsymbol{u_2}, \boldsymbol{u_3}] \begin{bmatrix} \sigma_1 & 0 & 0 \\ 0 & \sigma_2 & 0 \\ 0 & 0 & \sigma_3 \end{bmatrix} [\boldsymbol{v_1}, \boldsymbol{v_2}, \boldsymbol{v_3}]^H,$$

where the singular values are $\sigma_1 = \sqrt{3},\ \sigma_2 = \sqrt{2},\ \sigma_3 = 1$. Let P and σ^2 be total transmit power of all antennas and average noise power, respectively. $P/\sigma^2 = 10dB$. Assuming channel state information is known at both transmitter and receiver, please find the channel capacities of this channel with bandwidth B=10KHz for the following three power allocation schemes.

(a) Equal power allocation on all the three decomposed SISO channel;

(b) Water-filling power allocation;

(c) Allocate all the power to the channel with largest gain σ_1.

What's the water-filling power allocation for $\frac{P}{\sigma^2} = 100dB$ and $\frac{P}{\sigma^2} = -100dB$? Please provide approximate values of power allocation on the three decomposed channels.