UNIVERSITY EXAMINATION 2021/2022

FIRST YEAR SECOND SEMESTER EXAMINATION FOR THE DEGREE OF MASTER OF SCIENCE IN TELECOMMUNICATIONS ENGINEERING

EEE 6109: WIRELESS COMMUNICATIONS

DATE: SEPTEMBER 2021 **TIME: 3 HOURS**

Instructions

This examination paper contains **SIX** questions. Attempt **ANY FIVE** questions.

QUESTION 1

Consider a flat fading channel in which, for a fixed transmit power. *P*, the received SNR is one of four values: $\gamma_1 = 30$ dB, $\gamma_2 = 20$ dB, $\gamma_3 = 10$ dB, and $\gamma_4 = 0$ dB. The probabilities associated with each state are $p_1 = 0.2$, $p_2 = 0.3$, $p_3 = 0.3$, and $p_4 = 0.2$. Assume that both transmitter and receiver have CSI.

a) Find the optimal power adaptation policy $P[i]/\overline{P}$ for this channel and its corresponding Shannon capacity per unit hertz (C/B). **(5 marks)**

a) Find the channel inversion power adaptation policy for this channel and associated zero-outage capacity per unit bandwidth. **(5 marks)**

b) Find the truncated channel inversion power adaptation policy for this channel and associated outage capacity per unit bandwidth for three different outage probabilities: $P_{out} = 0.1$, $P_{out} = 0.25$, and P_{out} (and the associated cutoff γ_0) equal to the value that achieves maximum outage capacity. **(10 marks)**

QUESTION 2

a) Find the median path loss under the Hata model assuming $f_c = 900$ MHz, $h_t = 20$ m, $h_r = 5$m, and d = 100 m for:

- i) a large urban city. **(3 marks)**
- ii) a small urban city. **(3 marks)**
- iii) a suburb **(3 marks)**
- iv) a rural area. **(3 marks)**
- v) Explain qualitatively the path-loss differences for these four environments. **(2 marks)**

b) Fading is prevalent in wireless communication systems and this leads to reduction in the quality of the signal at the receiver. One of these fading techniques is small scale fading and according to your understanding discuss the various physical factors that influence this fading technique in a wireless channel. **(6 marks)**

QUESTION 3

a) Given the definition of the fading channel capacity with average power constraint as

$$C = \max_{P(\gamma):\int P(\gamma)d\gamma=\overline{P}} \int_0^\infty B\log_2(1+\frac{P(\gamma)\gamma}{P})P(\gamma)d\gamma$$

Show using Lagrangian techniques that the optimal power allocation to

maximize the capacity of a time-invariant block fading channel is given by the water filling formula. **(10 marks)**

$$\frac{P(\gamma)}{\overline{P}} = \begin{cases} 1/\gamma_0 - 1/\gamma & \gamma \geq \gamma_0 \\ 0 & \gamma < \gamma_0 \end{cases}$$

b) Pilot signals are reused in multicell communication and because of this, pilot signal contamination occurs in multicell MU-MIMO and this makes it difficult to use Matched filter precoding (MF) in multicell MU-MIMO, discuss:

i) How the pilot contamination occurs **(4 marks)**

ii) How Regularized Zero Forcing operates in addressing the short comings of MF in multicell MU-MIMO. **(2 marks)**

c) Discuss the two challenges that a multipath channel will cause for OFDMA System. **(4 marks)**

QUESTION 4

a) consider a base station employing M antennas serving K users with a single antenna. Assume the channel coefficient from the i^{th} user to the j^{th} antenna of the base station as

$$h_{ji} = g_{ji}\sqrt{d_i}$$

where g_{ji} and d_i are the small-scale channel gain coefficients and large-scale fading coefficients. Show that **(6 marks)**

$$\left(\mathbf{H}^{uplink}\right)^H \mathbf{H}^{uplink} = \mathbf{MD}$$

State all the assumptions made to arrive at this answer and state the matrix representation of **H** and **G** and explain why the matrix of **D** is a diagonal matrix. **(6 marks)**

b) Consider a voice system with acceptable BER when the received signal power is at or above half its average value. If the BER is below its acceptable level for more than 120 ms, users will turn off their phone. Find the range of Doppler values in a Rayleigh fading channel such that the average time duration when users have unacceptable voice quality is less than *t* = 60 ms. **(8 marks)**

QUESTION 5

The sum constraint given by $R_1 + R_2 < \log\left(1 + \frac{P_1+P_2}{N_0}\right)$ applies because the two users send independent information and cannot cooperate in the encoding.
If they could cooperate, what is the maximum sum rate they can achieve, assuming still individual power constraints P_1 and P_2 on the two users? In the case $P_1 = P_2$, quantify the cooperation gain at:

a) low SNR. **(8 marks)**
b) high SNR. **(8 marks)**
c) In which regime is the gain more significant **(4 marks)**

QUESTION 6

a) A plot of P_r as a function of distance is shown in **Fig. 6a** for *f* = 900 MHz, *R* = −1, h_t = 50 m, h_r = 2 m, G_l = 1, G_r = 1, and transmit power normalized so that the plot starts at 0 dBm.

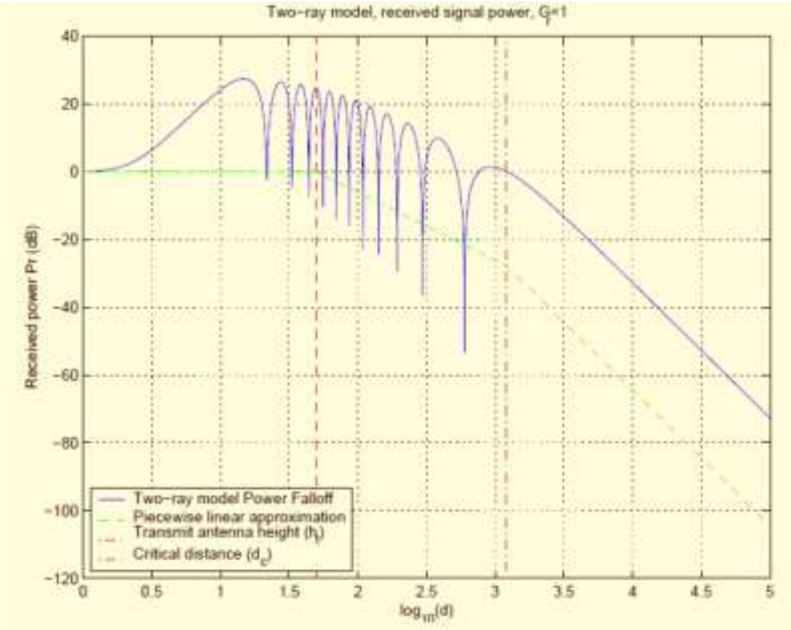

Fig.6a

With the help of **Fig. 6a** clearly explain how the two rays interact in these three segments for:

i) $d < h_t$ **(5 marks)**
ii) $h_t < d < d_c$ **(5 marks)**
iii) $d > d_c$ **(5 marks)**

b) Find the median path loss using Okumura's model for d = 50 km, h_{te} = 100 m, h_{re} = 10 m in a suburban environment. If the base station transmitter radiates an EIRP of 1 kW at a carrier frequency of 900 MHz, find the power at the receiver (Assume a unity gain receiving antenna). **(5 marks)**