Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
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SIXTH SEMESTER B.TECH. (E & C) DEGREE END SEMESTER EXAMINATION
AUGUST 2021
SUBJECT: WIRELESS COMMUNICATION (ECE - 3252)

TIME: 2 HOURS **MAX. MARKS: 40**

Instructions to candidates
- Answer **any four** full questions.
- Missing data may be suitably assumed.

1A. Consider a time-invariant block fading channel with frequency response

$$H(f)=\begin{cases}1 & f_c-20\text{MHz}\le f<f_c-10\text{MHz}\\ .5 & f_c-10\text{MHz}\le f<f_c\\ 2 & f_c\le f<f_c+10\text{MHz}\\ .25 & f_c+10\text{MHz}\le f<f_c+20\text{MHz}\\ 0 & \text{else}\end{cases}$$

For a transmit power of 10mW and a noise power spectral density of .001μW per Hertz, find the optimal power allocation and corresponding Shannon capacity of this channel.

1B. For a cellular system the reference distance for the antenna far field is 100 m and the path-loss exponent is a random variable taking on values 2, 2.5, 3 and 4 with probabilities 0.4, 0.3, 0.2 and 0.1 respectively. Assume a receiver at a distance of 1000 m from the transmitter with average transmit power constraint of 100 mW and a receiver noise power of 1mW. (i) Assuming that both transmitter and receiver have CSI, find the distribution of the received SNR (ii) Assuming only receiver CSI, determine the ergodic capacity per unit bandwidth for this channel (iii) Assuming both receiver and transmitter CSI, derive the optimal power adaptation policy for this channel and its corresponding Shannon capacity per unit bandwidth (iv) Assuming both receiver and transmitter CSI, determine the zero outage capacity per unit bandwidth of this channel.

(5+5)

2A. Consider a flat fading channel of bandwidth 20MHz and where, for a fixed transmit power $\overline{P}$, the received SNR is one of three values: γ_1 = 20dB, γ_2 = 10dB, γ_3 = -5dB. The probabilities associated with each state are p_1 = 0.25, p_2 = 0.4 and p_3 = 0.35. Assume that only the receiver has CSI. (a) Find the Shannon capacity of this channel. (b) Plot the capacity versus outage for $0 \le P_{out} \le 1$ and find the maximum average rate that can be correctly received (maximum C_{out}).

2B. Consider a cellular system where the received power is lognormal distribution with mean μ dBm and standard deviation σ_ψ dBm. Assume the received signal power must be above 10dBm for acceptable performance

i. What is the outage probability when lognormal distribution has μ_ψ=12 dBm and $\sigma_{\psi dB}$=6 dBm
ii. For $\sigma_{\psi dB}$=8 dBm find μ_ψ required for the outage probability to be less than 5%

(5+5)

3A. Consider the set of empirical measurements as shown in the below table. For indoor system at 900MHz.

Path Loss Measurements	
Distance from the Transmitter	Pr/Pt
10m	-75dB
20m	-95dB
45m	-110dB
65m	-130dB
85m	-150dB

i. Find the path loss exponent that minimizes the mean square error between simplified model and the empirical dB measurements. Assume d_0=1m and K is determined from free space path gain formula at this d_0.

ii. Find the variance of a log normal shadowing about the mean path loss based on empirical measurements.

iii. Find the received power at 250m for the simplified path loss model with this path loss exponent and transmitter power of 1mW. Justify your answer.

3B. Consider two wireless systems. For the first one, its signal bandwidth is much smaller than the coherence bandwidth of the channel whereas the second one employs a signal bandwidth that is much larger than the coherence bandwidth of the channel. Which system is best suited for employing frequency diversity techniques? Justify your answer with sufficient diagrams.

(5+5)

4A. Sketch power delay profile for below mentioned situations
a) multiple obstructions close to each other b) multiple obstruction with separation c) no obstruction d) weak multipath with lesser delay and strong multipath with higher delay

4B. Determine the average bit error probability for a binary communication system using non-coherent FSK, if the system uses 3 independent diversity branches with selection combining (SC). The mean SNR is 20dB in all the branches. Suppose, if the same communication system employs a DPSK system, what happens to the average probability of error. With suitable equations, comment on the SNR required for a DPSK in comparison to non-coherent FSK system.

(4+6)

5A. A wireless scheme has to be designed by considering the following attributes of a system. Diversity order preserved should be 2, Rank of a system should be 2, and the system should not use CSI at the Transmitter. Design the above system with proper mathematical calculations for each attribute defined, and also prove that this system suffers a 3dB deterioration in SNR.

5B Consider the 4×4 MIMO channels given below. What is the maximum multiplexing gain and diversity gain of each, how many independent scalar data streams can be supported reliably? Use a pictorial representation to show the working scheme.

$$H_1 = \begin{bmatrix} 1 & 2 & 5 & 6 \\ 3 & 1 & 5 & 4 \\ 5 & 1 & 1 & 2 \\ 0 & -1 & 1 & -1 \end{bmatrix}, H_2 = \begin{bmatrix} 1 & 1 & -1 & 1 \\ 1 & -1 & -1 & 1 \\ -1 & -1 & 1 & 1 \\ -1 & 1 & 1 & -1 \end{bmatrix}$$

(5+5)

6A A radio communication system is to be designed to work on a radio channel exposed to Rayleigh fading. A time availability of 99% is required for the system to operate properly. The receiver is assumed to work satisfactorily with a signal power of 5 dB above the noise power.

i. Calculate the required mean SNR to obtain the time availability.

ii. What is the required mean SNR if a two branch diversity scheme with selection combining is introduced?

iii. Is it possible to use MRC instead of selection combining? If so what is the mean SNR required to obtain 99% time availability? Comment on the improved/ deteriorated performance.

6B Consider a cellular system where path loss follows the simplified model with $\gamma = 6$, and there is also log normal shadowing with σ = 8dB. If the received power at the cell boundary due to path loss is 20 dB higher than the minimum required received power for non-outage, find the cell coverage area.

(5+5)

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}
1.10	0.13567	3.40	0.00033693	5.65	8.0224×10^{-9}	7.90	1.3945×10^{-15}
1.15	0.12507	3.45	0.00028029	5.70	5.9904×10^{-9}	7.95	9.3256×10^{-16}
1.20	0.11507	3.50	0.00023263	5.75	4.4622×10^{-9}	8.00	6.221×10^{-16}
1.25	0.10565	3.55	0.00019262	5.80	3.3157×10^{-9}	8.05	4.1397×10^{-16}
1.30	0.0968	3.60	0.00015911	5.85	2.4579×10^{-9}	8.10	2.748×10^{-16}
1.35	0.088508	3.65	0.00013112	5.90	1.8175×10^{-9}	8.15	1.8196×10^{-16}
1.40	0.080757	3.70	0.0001078	5.95	1.3407×10^{-9}	8.20	1.2019×10^{-16}
1.45	0.073529	3.75	8.8417×10^{-5}	6.00	9.8659×10^{-10}	8.25	7.9197×10^{-17}
1.50	0.066807	3.80	7.2348×10^{-5}	6.05	7.2423×10^{-10}	8.30	5.2056×10^{-17}
1.55	0.060571	3.85	5.9059×10^{-5}	6.10	5.3034×10^{-10}	8.35	3.4131×10^{-17}
1.60	0.054799	3.90	4.8096×10^{-5}	6.15	3.8741×10^{-10}	8.40	2.2324×10^{-17}
1.65	0.049471	3.95	3.9076×10^{-5}	6.20	2.8232×10^{-10}	8.45	1.4565×10^{-17}
1.70	0.044565	4.00	3.1671×10^{-5}	6.25	2.0523×10^{-10}	8.50	9.4795×10^{-18}
1.75	0.040059	4.05	2.5609×10^{-5}	6.30	1.4882×10^{-10}	8.55	6.1544×10^{-18}
1.80	0.03593	4.10	2.0658×10^{-5}	6.35	1.0766×10^{-10}	8.60	3.9858×10^{-18}
1.85	0.032157	4.15	1.6624×10^{-5}	6.40	7.7688×10^{-11}	8.65	2.575×10^{-18}
1.90	0.028717	4.20	1.3346×10^{-5}	6.45	5.5925×10^{-11}	8.70	1.6594×10^{-18}
1.95	0.025588	4.25	1.0689×10^{-5}	6.50	4.016×10^{-11}	8.75	1.0668×10^{-18}
2.00	0.02275	4.30	8.5399×10^{-6}	6.55	2.8769×10^{-11}	8.80	6.8408×10^{-19}
2.05	0.020182	4.35	6.8069×10^{-6}	6.60	2.0558×10^{-11}	8.85	4.376×10^{-19}
2.10	0.017864	4.40	5.4125×10^{-6}	6.65	1.4655×10^{-11}	8.90	2.7923×10^{-19}
2.15	0.015778	4.45	4.2935×10^{-6}	6.70	1.0421×10^{-11}	8.95	1.7774×10^{-19}
2.20	0.013903	4.50	3.3977×10^{-6}	6.75	7.3923×10^{-12}	9.00	1.1286×10^{-19}
2.25	0.012224						