AHMEDABAD UNIVERSITY
School of Engineering and Applied Science
Monsoon 2025

ECE310 Wireless Communications
End-Term Examination
December 5 (Friday), 2025. 11:00–13:00

Name:	Roll No	A	U	2						Marks	40

Instructions:

1. All questions are compulsory.
2. The figures on the right indicate full marks.
3. Assume suitable data wherever necessary and specify it clearly in your answers.

Que 1. Do as Directed: **[08 Marks]**

(a) True/False: Justify the Statement: "With Imperfect CSI, the lowest value of the probablity of error is $\frac{1}{2}(1-\rho^2)$." **[02]**

(b) True/False: Justify the Statement: "With a MIMO Wireless System, as the number of antennas increases on the receiver side, the number of RF chains will result in higher costs. However, the complexity of the receiver design will be reduced." **[02]**

(c) True/False: Justify the Statement: "Average RMS delay spread represents collections of wireless channels in multiple cellular cells with a radius of 2-10 Kilometers." **[02]**

(d) True/False: Justify the Statement: "For a spread spectrum system, the auto-correlation value for the N-PN sequence is $\frac{1}{N}$." **[02]**

Que 2. [16 Marks]

(a) Consider the following **outdoor** wireless channel delay profiles given in **Figure 1** below, and answer the following questions: **[04]**

i. For the delay profile, compute $\tau_{\max}$ the maximum delay spread and τ_{rms}, the RMS delay spread.

ii. Employing the average RMS delay spread as the metric T_d, what is the maximum possible symbol rate for ISI-free communication?

iii. Can a GSM system ($B = 200$ kHz) work in the above environment without an equalizer?

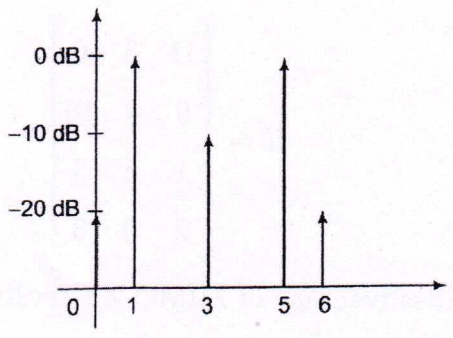


Figure 1: Outdoor Wireless Channel Power Delay Profile.

(b) Derive Maximum Likelihood (ML) detection rule and analyze the BER performance of fiber optic link. Derive the SNR distribution and find the error probability. Assume that the system is coherent in nature. Compute the SNRs (in dB) required for BERs of 10^{-8} and 10^{-10} for BPSK transmission over an AWGN channel. **[04]**

(c) Consider an OFDM system with bandwidth $BW = 10$ MHz. Let the delay spread be $\tau_d = 1\ \mu s$. **[04]**

(i) What is the minimum number of subcarriers required for the given OFDM system?

(ii) If the number of subcarriers is $N = 1024$, what is the channel subcarrier spacing?

(iii) What is the duration (T_n) of the OFDM symbol?

(iv) If the time duration of the cyclic prefix is $T_{cp} = 2\ \mu s$, find the loss in spectral efficiency.

(d) Given a 4-bit LFSR with feedback polynomial $x^4 + x + 1$ (taps at positions 4 and 1) and initial state 1001 (bits ordered as $[s_4 s_3 s_2 s_1]$). Using the convention that at each clock the output bit is the leftmost bit s_4, the feedback bit is $f = s_4 \oplus s_1$, and the register shifts left with f entering the rightmost position, generate the PN sequence until the LFSR returns to the initial state. Write the resulting binary PN sequence (first 15 bits) and verify the period. Finally, map bits such that $1 \rightarrow -1$ and $0 \rightarrow +1$. **[04]**

Que 3. [16 Marks]

(a) Orthogonal Space Time Block Coding (OSTBC) is a popular transmit diversity scheme. Consider a multiple-input single-output (MISO) system of order 1x3. The corresponding channel matrix can be given as $[h_1\ h_2\ h_3]$. Consider that the 4 transmitted symbols are $x_1, x_2, x_3 \text{and} x_4$. The coded block for the OSTBC is given as,

$$\begin{bmatrix} x_1 & -x_2 & -x_3 & -x_4 & x_1^* & -x_2^* & -x_3^* & -x_4^* \\ x_2 & x_2 & x_4 & -x_3 & x_2^* & x_1^* & x_4^* & -x_3^* \\ x_3 & -x_4 & x_1 & x_2 & x_3^* & -x_4^* & x_1^* & x_2^* \end{bmatrix}$$

Find the effective alamouti channel matrix (H) and prove that the columns are orthogonal in nature. **[08]**

(b) Compute the MIMO zero-forcing receiver for the channel matrix H given as

$$H = \begin{bmatrix} 11 & 3 & 0 \\ 9 & 4 & 10 \\ 1 & 5 & 3 \\ 2 & 0 & 3 \end{bmatrix}$$

Also mention the disadvantage of MIMO-ZF receivers and explain it with an example.**[08]**

Equation Reference Sheet:

1. PDF of Gaussian random variable (X):

$$P(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/2\sigma^2}$$

2. Q function:

$$P(X > x) = Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-\frac{u^2}{2}} du$$

3. Error function:

$$erfc(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-\frac{u^2}{2}} du$$

4. Central central Chi-square distribution with n=$2N$ degree of freedoms:

$$p_Y(y) = \frac{y^{\frac{n}{2}-1} e^{\frac{-y}{2\sigma^2}}}{\sigma^n 2^{\frac{n}{2}} \Gamma(\frac{1}{n})}$$

5. The Gamma function:

$$\Gamma(n) = \int_0^\infty x e^{-x} dx = (n-1)!$$

$$\Gamma(n+1) = n\Gamma(n)$$

$$\Gamma\left(\frac{1}{2}\right) = \sqrt{\pi}$$

6. Function of one Random Variable, $Y = g(X)$ where X and Y both are random variables:

$$f_Y(y) = \frac{f_X(y)}{|\frac{dy}{dx}|}$$

Table 1: Values of $Q(x)$ for $0 \leq x \leq 9$

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						