Indian Institute of Technology (Indian School of Mines), Dhanbad

Semester: Monsoon Session: 2024-2025

Mid Semester Examination M. Tech., 1st Sem, ECE

Time : 2 Hours Subject: Optical Fiber Communications (NECC505) Max Marks: 64

Instructions: Answer all the questions (The right side numbers indicate marks.)

Make suitable assumptions, if necessary and state them clearly. Attempt all questions in order

1. State true or false (No justification required; however, a correct answer will get +2 marks, a wrong answer will get -1 marks i.e. two wrong answers will cancel a correct answer). 14

    I. Light is guided within the core of the step-index fiber by total internal reflection at the outer surface of the cladding.
    II. For symmetric TE modes supported by a symmetrical SI planar waveguide, the stable electric-field distribution inside the guide layer takes a tangential form.
    III. Single-mode fibers support only the HE_{11} mode, also known as the fundamental mode of the fiber.
    IV. Different spectral components of the pulse travel as slightly different group velocities, a phenomenon referred to as intramodal dispersion.
    V. In single-mode fibers, intermodal dispersion is absent because the power of the launch pulse is carried by single mode.
    VI. Loss of the silica fibers becomes 0.2 dB/km at their operating wavelengths near 1.55 μm.
    VII. $\lambda = 1.275$ μm is called zero-dispersion wavelength in waveguide dispersion.

2 Explain the multimode step-index fiber and Graded index fiber with a suitable diagram. 10

3 The material dispersion in an optical fiber defined $\left(\frac{d^2 n_1}{d\lambda^2}\right)$ is $4.0 \times 10{-}2$ μm^{-2} . Estimate the pulse broadening per kilometer due to material dispersion within the fiber when it is illuminated with an LED source with a peak wavelength of 0.9 μm and an rms spectral width of 45 nm. 10

4. Describe how intramodal and intermodal dispersion may be minimized. 10

5. Consider a fiber of length 5 km kept in sea water having permittivity of $1.78\epsilon_o$. If core and cladding refractive index is 1.45 and 1.43 respectively. (ϵ_o = permittivity of air) 10

    i. Find maximum incident angle upto which light can be guided by the fiber.
    ii. Find critical angle at core-cladding interface.
    iii. Pulse broadening per unit length.
    iv. If cladding of fibre is removed, how transmission bandwidth of the fiber will get affected?

6. Derive transcendental equations. 10

$$V(1-b)^{1/2}\frac{J_{l-1}[V(1-b)^{1/2}]}{J_l[V(1-b)^{1/2}]} = -Vb^{1/2}\frac{K_{l-1}[Vb^{1/2}]}{K_l[Vb^{1/2}]}; l \geq 1.....(1)$$

$$V(1-b)^{1/2}\frac{J_1[V(1-b)^{1/2}]}{J_0[V(1-b)^{1/2}]} = Vb^{1/2}\frac{K_1[Vb^{1/2}]}{K_0[Vb^{1/2}]}; l = 0 \text{ ....}(2)$$

SEMESTER: MONSOON, SESSION-2024-25

Examination & Course: Mid Semester Examination, M.Tech./RS

Subject: Emerging Communication Systems (NECC 501)

Time: 1 Hour

Full Marks: 60

Instructions: i) There is one section in this question paper.
ii) Credit will be given to neat and precise answers.
iii) All parts of a question should appear together.

Q. No.		*Questions*	*Marks*
Q.1	(a)	State two major advantages and disadvantages of using the following schemes for improvement in cellular capacity, (i) Sectoring method, and (ii) Micro-cell zone concept.	[5]
	(b)	Consider the image shown in Figure-1. Compute the diffraction loss for the following cases, $h = 25\ m.$, $h = 0\ m.$, $h = -25\ m.$, For each of these cases, identify the Fresnel zone within which the tip of obstruction lies. Assume $\lambda = \frac{1}{3}, d_1 = 1\ km., \ d_2 = 1\ km.$	[5]

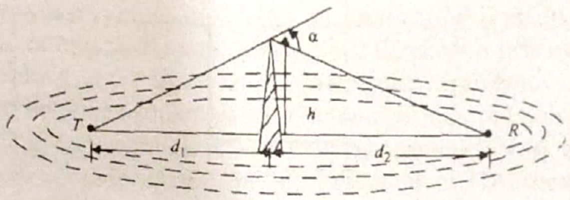


Figure-1

Q.2	(a)	The frequency hopping signal has following parameters: Number of bits per MFSK signal, K=2, Length of PN segment per Hop, m=2 Assume binary data sequence as x=[011 100 111 101 1001] and the PN sequence be p=[001 101 10 00] Draw the variation of frequency hopped signal for given PN sequence. Assume that carrier hops for every 2 MFSK symbols.	[5]
	(b)	Generate a PN sequence using a 3-bit$\{x_2, x_1, x_0\}$linear-feedback shift register (LFSR) employing $x_0 \oplus x_2$. Assume the initial value of registers are $\{1,0,0\}$. Is the generated PN sequence a max length sequence? If yes, then test the generated sequence, for all properties of a PN-sequence.	[5]
Q.3	(a)	Sketch the PSD of BPSK, QPSK and MSK. Discuss the preference of GMSK over others for cellular communication.	[5]
	(b)	Sketch an Offset-QPSK (OQPSK) transmitter scheme. How much offset is being provided? Justify your answer.	[5]
Q.4	(a)	Sketch the typical block diagram of OFDM transmitter. Briefly explain each block involved in it.	[5]
	(b)	If a signal to interference ration of 15dB is required for the satisfactory operatio of a cellular system, what is the frequency reuse factor and cluster size that should be used for maximum,	[5]

capacity, if the path loss exponent is n=3? Assume there are 6-co-channels cells in the first tier and all of them are at the same distance from the mobile.

Q.5 (a) Sketch a 2-ray path model for ground reflected signal and obtain the expressions of path-difference, phase- difference and time delay. [5]

(b) For the same 2-ray model, if primary path distance is d_1 and reflected path distance is d_2, then obtain the received electric field evaluated at some time, $t = {d_2}/{c}$, where c being velocity of light. [5]

Q.6 Using Gram-Schmidt orthogonalization procedure, obtain a set of orthonormal set of basis functions for the set of signals present in Figure-2. Also present their corresponding signal space diagram. [7+3]

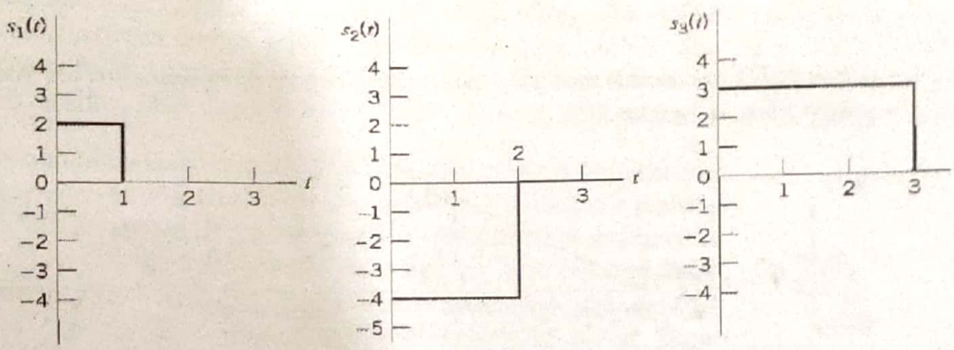


Figure-2

Mid Semester Examination

MS 2024-2025

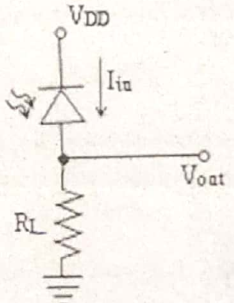
Sub: Integrated Circuits for Optical Communication (NECD 510)

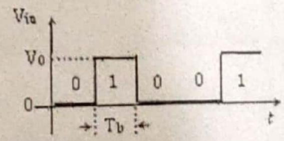
F.M: 32 **Time: 2 hours**

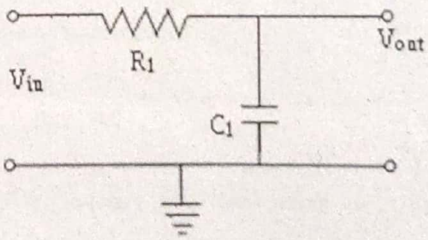
Instructions:

1) All questions are compulsory. All parts of a question should be answered in order and consecutively.
2) All steps for calculation and derivation need to be shown clearly and units should be mentioned for numerical problems.

Sl. No.	Questions	Marks
1. (a)	Explain with necessary drawings, the origin of random turn-on delay, frequency chirping and relaxation oscillation of a laser. Why laser source is driven by constant current source rather than voltage source? Briefly describe with necessary explanation, two important and desired characteristics of a laser driver circuit.	6+1+2
1. (b)	What technique is used to alleviate the problem caused by relaxation oscillation and random turn-on delay of laser source? Suppose the output power levels of a laser diode for logic 'ONE' and logic 'ZERO' are P_H and αP_H respectively. The extinction ratio (ER) is defined as ratio between power levels correspond to logic "ONE' and logic 'ZERO' and the detectability is a measure of difference between these power levels. What should be the ER in dB to allow SNR degradation of 80%? [Given: SNR degradation (in fraction) =$(1-\alpha)$]	1+2
2. (a)	Why trans-impedance amplifier (TIA) is necessary at the front end of the receiver of optical communication link? Consider a resistor type TIA as shown in the figure. If the photodiode capacitance is C_D. Show that the mean square value of total input referred noise current is $kT/(R_L^2C_D)$, symbols have their usual meanings. Now, if the input bit rate is made equal to the 3dB bandwidth of TIA, show that the mean square input referred noise current will be $4\pi^2 kTC_D R_B^2$ [Given: $\int \frac{dp}{1+p^2} = \tan^{-1}p$]	1+4+1
2 (b)	Explain the trade-off between speed and noise. Consider C_D = 0.2 pF. If maximum root mean square noise current at input is allowed as 2 μA, find out the maximum bit rate that the circuit can support.	2+2
2(c)	Explain with necessary sketch, the concept and importance of noise bandwidth of TIA.	2
3.(a)	Consider a single pole low pass filter (LPF) as shown in figure below. Consider the input data is 01001. Show that error between V_{out} at $t = T_b$ (assuming that the starting time of the bit 'ONE' after 'ZERO's is t = 0) and V_0 can be expressed as $\epsilon = V_0 \exp\left(\frac{-2\pi f_{3dB}}{R_b}\right)$ where f_{3dB} indicates 3dB bandwidth of LPF and R_b indicates input bit rate. Sketch the error as a function of the bit rate.	3
3. (b)	Explain the trade-off between noise and ISI by mentioning the variation of eye-closure (in eye-diagram) with the ratio of 3dB bandwidth of LPF and input bit rate. Show that the total eye-closure will be 0.216 dB when the bandwidth (f_{3dB}) is set to $0.7R_b$	3+2







Mid Semester Examination

Session: 2024-2025

Semester: Monsoon

Time: 2 Hours

NECD509: Machine Learning

Maximum Marks: 64

1. Let us consider a housing price prediction scenario where we want to predict the price of the house on the basis of single input feature, i.e, size of the house. Further, we decide to fit the training data of size N of housing price against the size of each house with the polynomial function of the form given as $\sum_{j=0}^{M} \theta_j x^j$, where M is the polynomial order, x represents the size of the house. and θ_j is the weight associated with the j^{th} order polynomial. Furthermore, we are unable to gather more training data and thus, we have the situation where $N = M = 10$. With this, we move on to run the gradient descent algorithm so as to minimize the least square cost function. Based on this, answer the following

   (a) What trend can we expect for the training error ? Can we expect our trained algorithm would make good predictions on unseen testing data? (4 marks)

   (b) Mention the necessary modifications in the cost function if the trained algorithm works very badly on the testing data set. (4 marks)

   (c) Based on the modified cost function, derive the update rule for θ's considering both the batch gradient descent as well as stochastic gradient descent algorithm. (10 marks)

   (d) Without resorting to an iterative algorithm, derive the optimum vector $\bar{\theta}_{\text{optimum}}$ that minimizes the modified cost function. (4 marks)

2. Suppose that you have the following training data set : $\{(\bar{x}^{(1)}, z^{(1)}), (\bar{x}^{(2)}, z^{(2)}), \ldots, (\bar{x}^{(n)}, z^{(n)})\}$. Further, we have $\bar{x}^{(i)} \in \mathbb{R}^d$ and $z^{(i)} \in \mathbb{R}$ for $i \in \{1, 2, \ldots, n\}$. We are trying to fit the training data with the linear function of the form $\sum_{j=0}^{d} \theta_j x_j = (\bar{\theta})^T \bar{x}$. Furthermore, we have the following relation

$$z^{(i)} = (\bar{\theta})^T \bar{x}^{(i)} + w^{(i)}, \quad i \in \{1, 2, \ldots, n\}$$

where each $w^{(i)}$ is independent and identically distributed (IID) Gaussian with zero mean and unit variance. The notation $(\cdot)^T$ denotes the transpose operation. Find the maximum likelihood estimate of $\bar{\theta}$. (10 marks)

3. Let us consider the following training data set : $\{ (\bar{x}^{(1)}, y^{(1)}), (\bar{x}^{(2)}, y^{(2)}), \ldots, (\bar{x}^{(m)}, y^{(m)}) \}$, i.e., we have m independent training examples. Further, we have $\bar{x}^{(i)} \in \mathbb{R}^n$ and $y^{(i)} \in \{0, 1\}$ for $i \in \{1, 2, \ldots, m\}$. Based on this, consider the following tasks

(a) For the aforementioned training data, suggest the appropriate hypothesis function. (2 marks)

(b) Derive the cost function expression for the problem and thereafter, compute the stochastic gradient descent rule for updation of the weight parameters, i.e. θ's. (10 marks)

4. (a) Let us consider a Poisson distributed discrete random variable Y with probability mass function (PMF) given by

$$f(y; \lambda) = \mathbb{P}(Y = y) = \frac{\lambda^y e^{-\lambda}}{y!}, \lambda > 0, \ \mathbb{E}[Y] = \lambda, \text{ and } y = 0, 1, 2, \ldots,$$

Here $\mathbb{E}[\cdot]$ denotes the Expectation operator. Show that the random variable Y falls under the category of exponential distribution. (5 marks)

(b) Considering the regression using the generalised linear models (GLMs) with Poisson distributed response variable, i.e., the output labels are Poisson distributed. compute the canonical response function. (5 marks)

(c) Considering m independent training examples $\{ (\bar{x}^{(1)}, y^{(1)}), (\bar{x}^{(2)}, y^{(2)}), \ldots, (\bar{x}^{(m)}, y^{(m)}) \}$ where $f(y^{(i)} | \bar{x}^{(i)}; \bar{\theta})$ is Poisson distributed and using the canonical response function derived in (b), derive the stochastic gradient ascent update rule for $\bar{\theta}$. (10 marks)

Monsoon Mid-semester Exam -Wireless Networks (NECC503)

Time: 2 Hr.

Total Marks: 64

** All questions are compulsory

1. Answer the following questions.
   a. Which condition should satisfy to ensure frequency-selective fading? **[02]**
   b. Alamouti coding scheme can be applicable for wireless systems having 2 transmit antennas and r receive antennas, where $r \geq 1$. Is this statement **True** or **False** **[02]**
   c. If the channel impulse response is given as $h(\tau) = h_1 e^{-j2\pi f_c \tau_1}\delta(\tau - \tau_1) + h_2 e^{-j2\pi f_c \tau_2}\delta(\tau - \tau_2)$, then mention the condition that should satisfy to make this channel as to be **uncorrelated scattering**. **[02]**
   d. If $X_1, X_2, \ldots X_n$ are iid random variables having uniform distribution over the interval $[1, 3]$, then find the value of Y for $n \to \infty$. Here $Y = \frac{1}{n}\sum_{i=1}^{n} X_i$. **[02]**
   e. If $X \sim \mathcal{N}\left(2, \frac{1}{4}\right)$, then express the probability $P(X < 3)$ in the form of Q-function. **[04]**
2. Consider a SISO wireless system having flat-slow fading, where the channel tap h follows circularly symmetric complex Gaussian with zero mean and variance σ^2. The received signal $y = hx + n$, where the transmit symbol $x \in \{-2, 2\}$ and the noise $n \sim \mathcal{N}(0, N_0)$. Answer the following questions. Clearly mention all steps.
   a. Derive probability density function of $a = |h|$. **[06]**
   b. Derive the probability of deep fade for this system. Also simplify this for high SNR. **[06]**
3. Consider a flat-slow fading wireless system, having one transmit antenna and 4 receive antennas. Here, the **pdf** of the amplitude for the l^{th} fading channel $a_l = |h_l|$ is $f_{A_l}(a_l) = K a_l^2 e^{-a_l^2}$. Considering this system, answer the following questions.
   a. Find the value of K. **[05]**
   b. Considering MRC equalizer, derive the average BER for this system using Chernoff bound. Here the transmit symbol power $E\{x^2\} = P$ and the noise power is σ^2. **[07]**
4. Considering an AWGN channel with output $Y = X + N$, where the transmit symbol $X \in \{-4, 4\}$, with the probability $P(X = -4) = 0.8$, and the noise $N \sim \mathcal{N}(0, 4)$, answer the following questions.
   a. What are the likelihood functions $f(y|X = -4)$ and $f(y|X = 4)$? **[04]**
   b. What is the maximum likelihood detection rule corresponding to the observation y? Do simplification as much as you can. **[06]**
5. Compute the velocity of a mobile in Km/h if the correlation between the channel coefficient is 0.3 for a time interval $\Delta t = 3.9\ ms$ at carrier frequency $1.6\ GHz$. Use jake's model to answer this question. It is given that $J_0(7) = 0.3$. **[06]**

6. Considering the power-delay profile data given in the following table, compute the RMS delay spread σ_τ. If we consider this RMS delay spread in place of the delay-spread to determine the condition of inter-symbol-interference (ISI), then what will be the maximum possible symbol rate for ISI-free communication? **[06]**

Delay (τ_i)	0 μs	1 μs	3 μs	5 μs	6 μs
Power (g_i)	−20 dB	0 dB	−10 dB	0 dB	−20 dB

7. Consider an $L = 3$ transmit antennas-based MISO system with complex fading (flat-slow) channel coefficients $h_1 = 1 + 2j$, $h_2 = 1 + j$ and $h_3 = 2 - j$. Find the precoder for maximum ratio transmission (MRT). Find the mathematical expression of receive signal with MRT. Also compute the instantaneous SNR with MRT. **[06]**