

Communication Engineering (1333201) - Summer 2025 Solution

Milav Dabgar

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Question 1(a) [3 marks]

Define AM, FM and PM.

Solution

Answer:

Table 1. Modulation Types Definition

Modulation Type	Definition
AM (Amplitude Modulation)	Process where amplitude of carrier signal varies in accordance with the instantaneous amplitude of the message signal
FM (Frequency Modulation)	Process where frequency of carrier signal varies in accordance with the instantaneous amplitude of the message signal
PM (Phase Modulation)	Process where phase of carrier signal varies in accordance with the instantaneous amplitude of the message signal

Mnemonic

"AFaP" - "Amplitude, Frequency and Phase" are the three parameters changed during modulation.

Question 1(b) [4 marks]

Explain block diagram of communication system.

Solution

Answer:

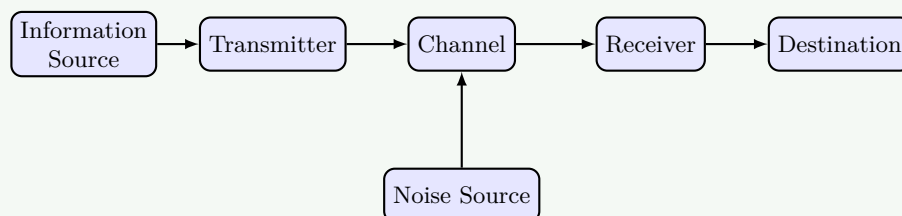


Figure 1. Communication System

Components of Communication System:

- **Information Source:** Produces message to be communicated
- **Transmitter:** Converts message to signals suitable for transmission
- **Channel:** Medium through which signals travel

- **Receiver:** Extracts original message from received signal
- **Destination:** Person/device for whom message is intended
- **Noise Source:** Unwanted signals that interfere with transmitted signal

Mnemonic

"I Transmit Communication Reliably Despite Noise"

Question 1(c) [7 marks]

Explain Amplitude modulation with waveform and derive voltage equation for modulated signal also Sketch the frequency spectrum of the DSBFC AM.

Solution

Answer: Amplitude Modulation is the process where the amplitude of a high-frequency carrier wave varies according to the instantaneous value of the modulating signal.

Waveform and Equation:

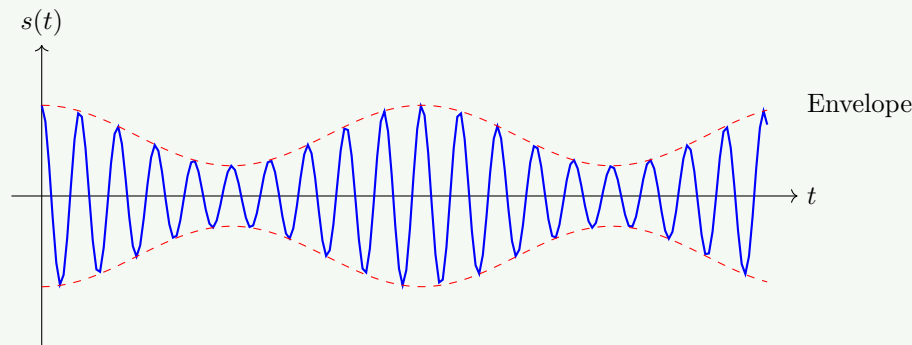


Figure 2. AM Waveform

Derivation of AM equation:

- Carrier signal: $c(t) = A_c \cos(\omega_c t)$
- Modulating signal: $m(t) = A_m \cos(\omega_m t)$
- Modulation Index: $\mu = A_m/A_c$
- AM signal: $s(t) = A_c [1 + \mu \cdot \cos(\omega_m t)] \cos(\omega_c t)$
- Expanding: $s(t) = A_c \cdot \cos(\omega_c t) + \frac{\mu A_c}{2} \cos[(\omega_c + \omega_m)t] + \frac{\mu A_c}{2} \cos[(\omega_c - \omega_m)t]$

DSBFC AM Frequency Spectrum:

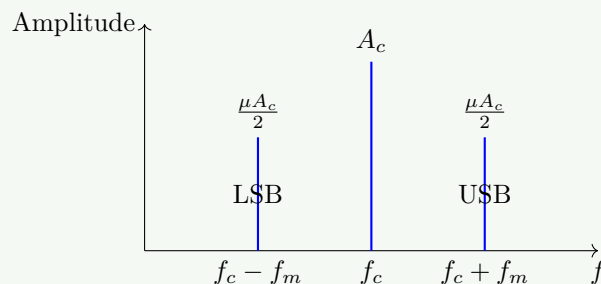


Figure 3. DSBFC AM Frequency Spectrum

Key Points:

- **LSB (Lower Sideband):** Located at $f_c - f_m$
- **USB (Upper Sideband):** Located at $f_c + f_m$
- **Bandwidth:** $2f_m$ (twice the highest modulating frequency)

Mnemonic

"CARrying Two SideBands" - DSBFC AM carries both sidebands.

Question 1(c) OR [7 marks]

Derive the equation for total power in AM, calculate percentage of power savings in DSBFC And SSBSC.

Solution

Answer:

Total Power in AM: For AM signal $s(t) = A_c[1 + \mu \cdot \cos(\omega_m t)] \cos(\omega_c t)$:

Power Calculation:

- Carrier Power: $P_c = A_c^2/2$
- Power in each sideband: $P_{USB} = P_{LSB} = P_c \cdot \mu^2/4$
- Total Sideband Power: $P_{USB} + P_{LSB} = P_c \cdot \mu^2/2$
- Total Power: $P_t = P_c + P_{USB} + P_{LSB} = P_c(1 + \mu^2/2)$

Power Savings:

Table 2. Power Savings

Modulation	Power Distribution	Power Savings
DSBFC AM	Uses carrier + both sidebands	0% (reference)
SSBSC AM	Uses only one sideband, no carrier	$\frac{2-\mu^2/2}{1+\mu^2/2} \times 100\%$

For $\mu = 1$, SSBSC saves approximately 85% power compared to DSBFC.

Mnemonic

"SSB Saves Power By Cutting Carrier"

Question 2(a) [3 marks]

Compare AM and FM.

Solution

Answer:

Table 3. Comparison of AM and FM

Parameter	AM	FM
Definition	Amplitude of carrier varies with message signal	Frequency of carrier varies with message signal
Bandwidth	$2 \times$ message frequency	$2 \times (\Delta f + f_m)$
Noise Immunity	Poor (noise affects amplitude)	Excellent (noise mainly affects amplitude)
Power Efficiency	Low (carrier contains most power)	High (all transmitted power contains information)
Circuit Complexity	Simple, inexpensive	Complex, expensive

Mnemonic

"AM Needs Power, FM Fights Noise"

Question 2(b) [4 marks]

Draw and explain block diagram for envelope detector.

Solution

Answer:

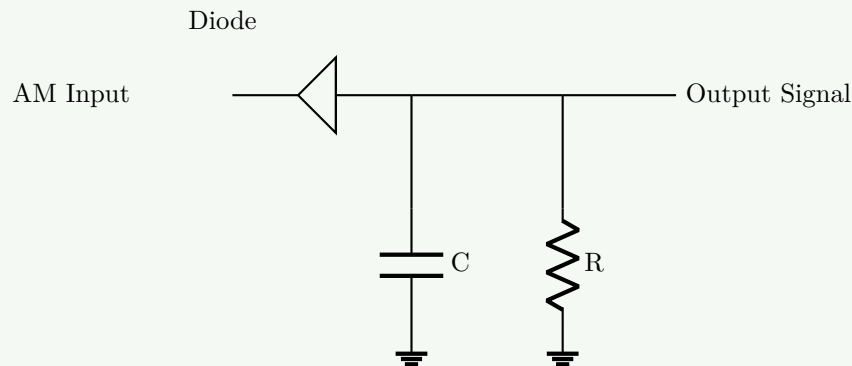


Figure 4. Envelope Detector

Components of Envelope Detector:

- **Diode:** Rectifies the AM signal (allows current flow in one direction)
- **RC Circuit:** R and C values chosen such that:
 - $RC \gg 1/f_c$ (to filter carrier frequency)
 - $RC \ll 1/f_m$ (to follow the envelope)

Working:

1. Diode conducts during positive half-cycles of carrier
2. Capacitor charges to peak value
3. When input falls, capacitor discharges through resistor
4. Output follows envelope of AM signal

Mnemonic

"Detect, Rect, and Connect" - Detection through Rectification and RC connection.

Question 2(c) [7 marks]

Draw block diagram of FM radio receiver and explain working of each block.

Solution

Answer:

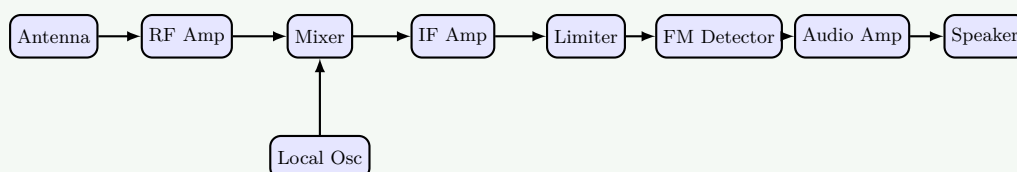


Figure 5. FM Radio Receiver

Working of Each Block:

- **Antenna:** Receives FM broadcast signals (88-108 MHz)
- **RF Amplifier:** Amplifies weak RF signals, provides selectivity
- **Mixer & Local Oscillator:** Converts RF to fixed IF (10.7 MHz) using heterodyning
- **IF Amplifier:** Provides most of receiver's gain and selectivity
- **Limiter:** Removes amplitude variations from FM signal
- **FM Detector:** Converts frequency variations to audio (uses ratio detector/PLL)
- **Audio Amplifier:** Amplifies recovered audio signal
- **Speaker:** Converts electrical signals to sound

Mnemonic

"Really Mighty Instruments Limit Frequency And Make Sound"

Question 2(a) OR [3 marks]

Define Sensitivity, Selectivity, Fidelity for radio receiver.

Solution

Answer:

Table 4. Receiver Characteristics

Parameter	Definition
Sensitivity	Ability of receiver to amplify weak signals (measured in μV)
Selectivity	Ability to separate desired signal from adjacent signals
Fidelity	Ability to reproduce the original signal without distortion

Mnemonic

"SSF" - "Select Signals Faithfully"

Question 2(b) OR [4 marks]

Explain ratio detector for FM.

Solution

Answer:

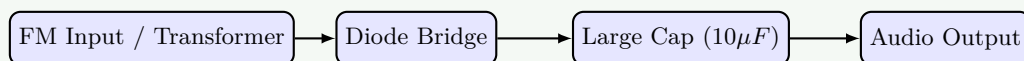


Figure 6. Ratio Detector

Working of Ratio Detector:

- Uses balanced circuit with two diodes in series
- Large stabilizing capacitor keeps sum of voltages constant
- Output voltage is proportional to frequency deviation
- Inherently insensitive to amplitude variations (no limiter needed)
- Less susceptible to impulse noise than discriminator

Mnemonic

"RADS" - "Ratio And Diodes Stabilize"

Question 2(c) OR [7 marks]

Draw block diagram of AM radio receiver and explain working of each block.

Solution

Answer:

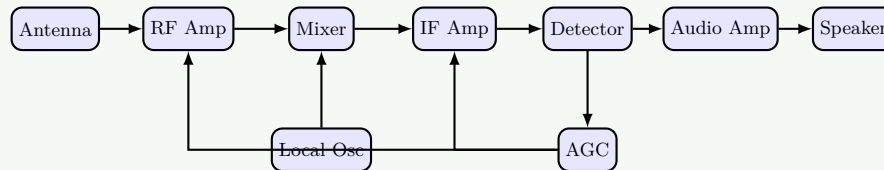


Figure 7. AM Radio Receiver

Working of Each Block:

- **Antenna:** Intercepts AM broadcast signals (535-1605 kHz)
- **RF Amplifier:** Amplifies weak RF signals with good SNR
- **Mixer & Local Oscillator:** Converts RF to fixed IF (455 kHz)
- **IF Amplifier:** Provides most gain and selectivity at 455 kHz
- **Detector:** Extracts audio from AM signal (envelope detector)
- **AGC (Automatic Gain Control):** Maintains constant output level
- **Audio Amplifier:** Boosts detected audio to drive speaker
- **Speaker:** Converts electrical signals to sound waves

Mnemonic

"ARMIDAS" - "Amplify, Mix, IF, Detect, Audio, Speak"

Question 3(a) [3 marks]

Describe the Nyquist criteria.

Solution

Answer:

Nyquist Criteria: To accurately reconstruct a signal from its samples, the sampling frequency (f_s) must be at least twice the highest frequency (f_{max}) present in the signal.

Table 5. Nyquist Criteria

Parameter	Formula	Description
Nyquist Rate	$f_s \geq 2f_{max}$	Minimum sampling rate required
Nyquist Interval	$T_s \leq 1/2f_{max}$	Maximum time between samples

Consequence if violated: Aliasing occurs - higher frequencies appear as lower frequencies in sampled signal.

Mnemonic

"Sample Double to Dodge Aliasing"

Question 3(b) [4 marks]

Explain Sample and hold Circuit with Waveform.

Solution

Answer:

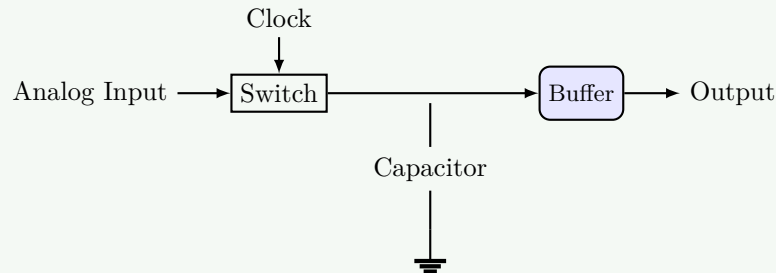


Figure 8. Sample and Hold Circuit

Sample and Hold Circuit Operation:

- **Electronic Switch:** Closes briefly during sampling
- **Capacitor:** Stores sampled voltage
- **Buffer Amplifier:** Provides high input impedance and low output impedance

Waveform:

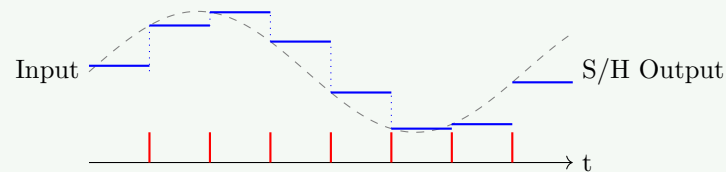


Figure 9. Sample and Hold Waveforms

Applications:

- Analog-to-Digital Conversion
- Data Acquisition Systems
- Pulse Amplitude Modulation

Mnemonic

"SCAB" - "Switch, Capacitor And Buffer"

Question 3(c) [7 marks]

Define quantization explain uniform and non-uniform quantization in details.

Solution

Answer:

Quantization: Process of mapping a large set of input values to a smaller set of discrete output values.

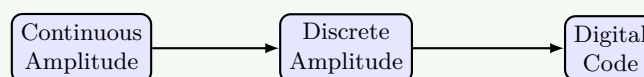


Figure 10. Quantization Process

Uniform Quantization vs Non-uniform Quantization:

Table 6. Comparison of Quantization Types

Parameter	Uniform Quantization	Non-uniform Quantization
Step Size	Equal throughout range	Varies (smaller for small signals)
Characteristic	Linear	Non-linear (logarithmic/exponential)
SNR	Poor for small signals	Better for small signals
Implementation	Simple	Complex (companding required)
Applications	Simple signals, images	Speech, audio (μ -law, A-law)

Quantization Error:

- Difference between original and quantized signal
- Maximum error = $\pm Q/2$ (where Q is quantization step size)
- Appears as quantization noise in reconstructed signal

Mnemonic

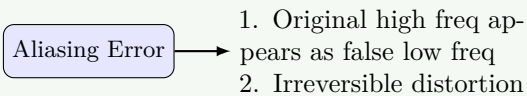
"UNIQ" - "UNIform has equal steps, non-uniform Quiets noise"

Question 3(a) OR [3 marks]

Explain aliasing error and how to overcome it.

Solution**Answer:**

Aliasing Error: Distortion that occurs when a signal is sampled at a rate lower than twice its highest frequency component.

**How to Overcome Aliasing:**

- Use anti-aliasing filter (low-pass) before sampling
- Increase sampling rate above Nyquist rate ($f_s > 2f_{max}$)
- Bandlimit the input signal before sampling

Mnemonic

"ALIAS" - "Avoid Low sampling by Increasing And Screening"

Question 3(b) OR [4 marks]

Draw following signal in time domain and frequency domain: 1) Sawtooth signal 2) Pulse signal.

Solution**Answer:**

1. Sawtooth Signal:

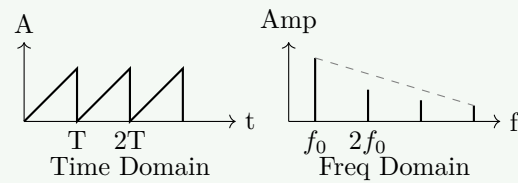


Figure 11. Sawtooth Signal

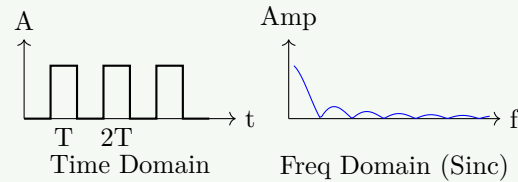
2. Pulse Signal:

Figure 12. Pulse Signal

Mnemonic

"STPF" - "SawTooth slopes down, Pulse has sinc Function"

Question 3(c) OR [7 marks]

Compare PAM, PWM and PPM with waveform.

Solution

Answer:

Table 7. Comparison of Pulse Modulation

Parameter	PAM	PWM	PPM
Full Form	Pulse Amplitude Modulation	Pulse Width Modulation	Pulse Position Modulation
Parameter Varied	Amplitude of pulses	Width/duration of pulses	Position/timing of pulses
Noise Immunity	Poor	Good	Excellent
Bandwidth	Lower	Higher	Highest
Power Efficiency	Low	Medium	High
Demodulation	Simple	Moderate	Complex

Waveforms:

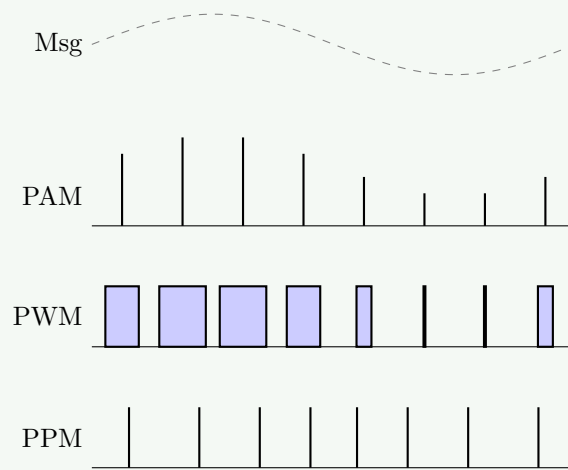


Figure 13. Pulse Modulation Waveforms

Mnemonic

"APP" - "Amplitude, Pulse-width, Position"

Question 4(a) [3 marks]

Explain Space wave propagation.

Solution

Answer:

Space Wave Propagation: Mode where radio waves travel through lower atmosphere (troposphere) directly or via ground reflection.

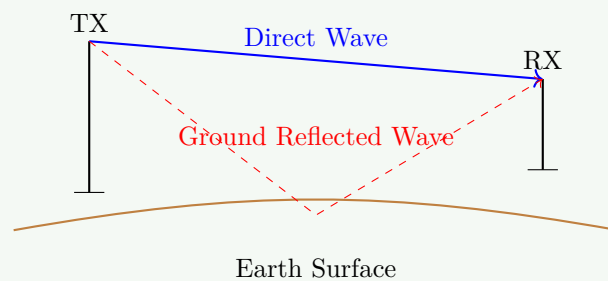


Figure 14. Space Wave Propagation

Characteristics:

- Frequency Range: VHF, UHF (30 MHz - 3 GHz)
- Limited to line-of-sight distance
- Range = $4.12(\sqrt{h_1} + \sqrt{h_2})$ km (where h_1, h_2 in meters)
- Affected by terrain, buildings, and atmospheric conditions

Mnemonic

"See Straight" - Space waves travel in straight lines.

Question 4(b) [4 marks]

Explain working of differential PCM transmitter.

Solution

Answer:

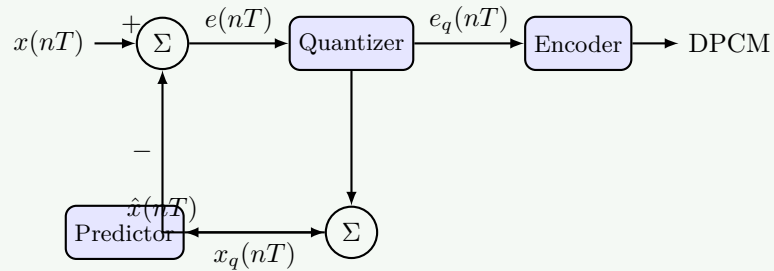


Figure 15. DPCM Transmitter

DPCM Transmitter Working:

- **Predictor:** Estimates current sample based on previous samples
 - **Subtractor:** Calculates difference between actual and predicted value
 - **Quantizer:** Converts difference signal to discrete levels
 - **Encoder:** Converts quantized values to binary code
 - **Feedback Loop:** Reconstructs signal exactly as receiver will see it
- Advantage:** Only difference signal is transmitted, requiring fewer bits.

Mnemonic

"Predict Difference Encode"

Question 4(c) [7 marks]

Explain delta modulator in details also explain slop overload noise and granular noise.

Solution

Answer:

Delta Modulation (DM): Simplest form of differential PCM where difference signal is encoded with 1 bit.

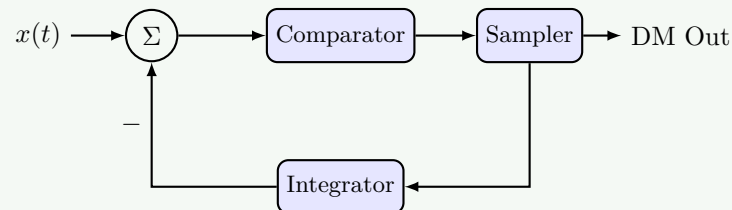


Figure 16. Delta Modulator

Working Principle:

- Compares input signal with integrated version of previous output
- If input > integrated value: Transmit 1
- If input < integrated value: Transmit 0
- Step size (δ) is fixed

Noise in Delta Modulation:

Table 8. Noise in Delta Modulation

Noise Type	Cause	Remedy
Slope Overload Noise	Input signal changes faster than δ can track	Increase step size or sampling frequency
Granular Noise	Step size is too large for slowly varying signals	Decrease step size

Mnemonic

"Slog" - "Slope and Granular in DM"

Question 4(a) OR [3 marks]

Explain Ground wave propagation.

Solution

Answer:

Ground Wave Propagation: Radio wave propagation that follows the curvature of the earth.

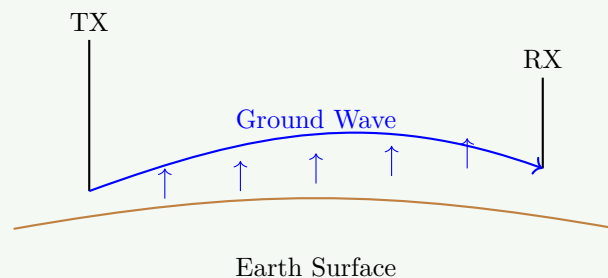


Figure 17. Ground Wave Propagation

Characteristics:

- Frequency Range: LF, MF (30 kHz - 3 MHz)
- Propagates along earth's surface (vertically polarized)
- Range depends on tx power, ground conductivity, frequency
- Signal strength decreases with distance and frequency
- Used for AM broadcasting, marine communication

Mnemonic

"Ground Hugger" - Waves hug the ground.

Question 4(b) OR [4 marks]

Explain ADM Transmitter.

Solution

Answer:

Adaptive Delta Modulation (ADM): Improved version of DM where step size varies according to signal characteristics.

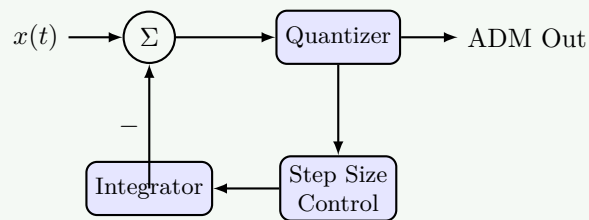


Figure 18. ADM Transmitter

ADM Transmitter Working:

- **Basic Operation:** Similar to standard DM
- **Step Size Control:** Analyzes recent sequence of output bits
- **Adaptation Logic:**
 - If consecutive bits are same: Increase step size
 - If consecutive bits are alternate: Decrease step size

Advantages over DM:

- Reduces both slope overload and granular noise
- Better signal tracking
- Improved SNR

Mnemonic

"Adapt to Step" - Step size adapts to signal slope.

Question 4(c) OR [7 marks]

Explain block diagram of basic PCM-TDM System.

Solution**Answer:**

PCM-TDM System: Combines Pulse Code Modulation with Time Division Multiplexing to transmit multiple digital signals over a single channel.

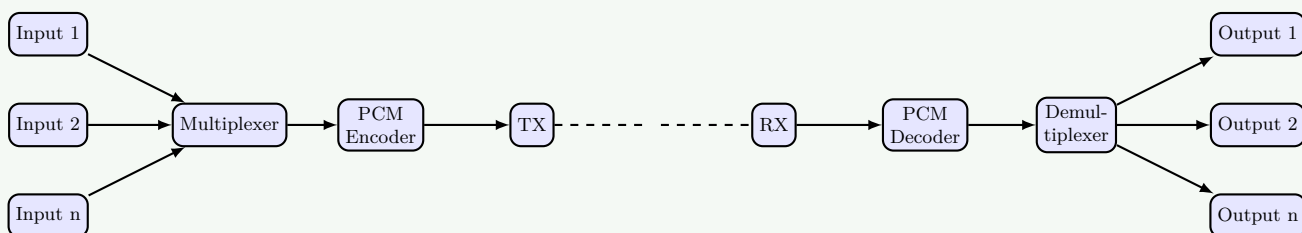


Figure 19. PCM-TDM System Block Diagram

PCM-TDM System Working:

- **Transmitter:**
 - Multiple analog signals are sampled sequentially
 - Samples are time-multiplexed into a single stream
 - Stream is quantized and encoded into PCM format
 - Framing bits added for synchronization
- **Receiver:**
 - Frame sync is detected for alignment
 - PCM stream is decoded to recover samples
 - Demultiplexer separates samples to individual channels
 - Low-pass filters reconstruct original analog signals

Mnemonic

"Sample, Code, Multiplex" - SCM order

Question 5(a) [3 marks]

Compare TDM and FDM.

Solution

Answer:

Table 9. Comparison of TDM and FDM

Feature	TDM (Time Division Multiplexing)	FDM (Frequency Division Multiplexing)
Definition	Signals sent at different times on same frequency	Signals sent at same time on different frequencies
Signal Type	Best for digital signals	Best for analog signals
Synchronization	Critical (pulse sync)	Not critical (carrier sync)
Complexity	Lower	Higher (needs filters)
Noise	Less susceptible	More susceptible (crosstalk)

Mnemonic

"T-Time, F-Freq" - TDM splits time, FDM splits frequency.

Question 5(b) [4 marks]

Explain construction of Fiber optic cable.

Solution

Answer:

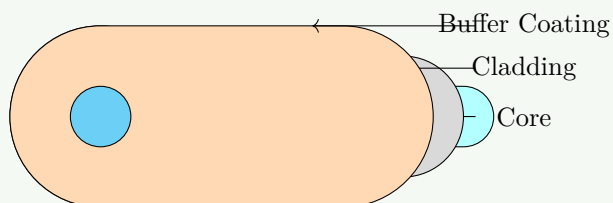


Figure 20. Fiber Optic Cable Construction

Main Components:

- **Core:**
 - Central part where light travels
 - Made of pure silica/glass
 - High refractive index (n_1)
- **Cladding:**
 - Surrounds the core
 - Lower refractive index than core ($n_2 < n_1$)
 - Reflects light back into core (TIR)
- **Buffer/Jacket:**

- Protective plastic covering
- Protects from physical damage and moisture

Mnemonic

"CCB" - "Core, Cladding, Buffer"

Question 5(c) [7 marks]

Draw Block Diagram of optical fiber communication and Explain.

Solution

Answer:

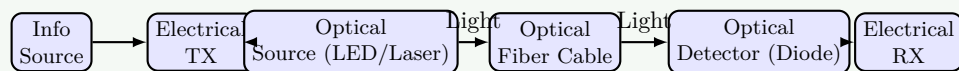


Figure 21. Optical Fiber Communication

Operation:

- **Electrical TX:** Encodes input signal into drive current
- **Optical Source:** Converts electrical signal to light pulses (E/O conversion)
- **Optical Fiber:** Carries light via Total Internal Reflection
- **Optical Detector:** Converts light back to electrical signal (O/E conversion) (e.g., Photodiode)
- **Electrical RX:** Amplifies and shapes signal

Advantages: High bandwidth, low loss, immune to EMI.

Mnemonic

"ET-OS-Cable-OD-ER" - "Electrical TX, Optical Source, Cable, Optical Detector, Electrical RX"

Question 5(a) OR [3 marks]

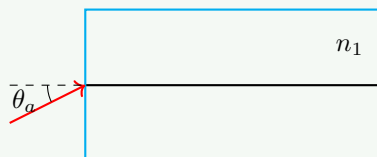
Explain Numerical Aperture.

Solution

Answer:

Numerical Aperture (NA): Measure of light-gathering ability of an optical fiber.

- It is the sine of the acceptance angle (θ_a) of the fiber
- Formula: $NA = \sin \theta_a = \sqrt{n_1^2 - n_2^2}$
- Where n_1 = core refractive index, n_2 = cladding refractive index
- Higher NA means more light gathering capability



Acceptance Cone

Mnemonic

"No Sign Theta" - " $\text{NA} = \sin(\theta)$ "

Question 5(b) OR [4 marks]

Explain PWM generation and demodulation.

Solution

Answer:

PWM Generation:

- Generated using a comparator
- Sine wave (message) is compared with a sawtooth wave
- When Message > Sawtooth → Output High
- When Message < Sawtooth → Output Low

PWM Demodulation:

- Simple method: Pass PWM signal to an integrator circuit
- Integrator produces voltage proportional to pulse width
- Follow with Low Pass Filter to smooth signal

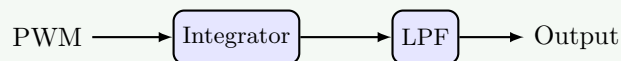


Figure 22. PWM Demodulator

Mnemonic

"Gen Compare, Demod Integrate"

Question 5(c) OR [7 marks]

Draw Block Diagram of satellite communication and Explain.

Solution

Answer:

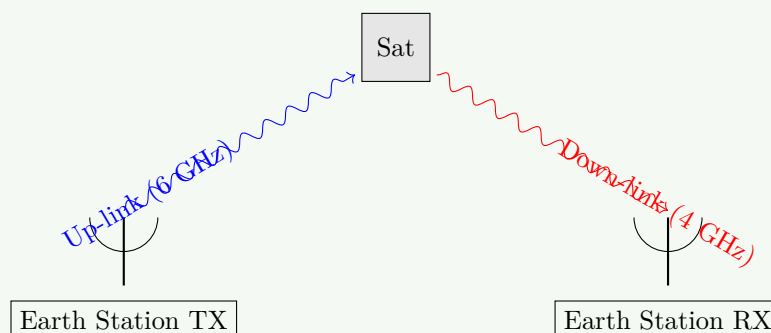


Figure 23. Satellite Communication

Components:

1. **Earth Station (TX):** Transmits high power signal to sky (Up-link)
2. **Satellite (Transponder):**
 - Receives signal
 - Changes frequency (Up-link → Down-link)

- Amplifies signal
- Retransmits to earth

3. **Earth Station (RX):** Receives weak signal and processes it (Down-link)

Frequencies: Up-link frequency is always higher than Down-link frequency (e.g. 6/4 GHz).

Mnemonic

"Up High, Down Low" - Up freq higher, Down freq lower