# Communication Engineering (1333201) - Summer 2025 Solution

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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**:

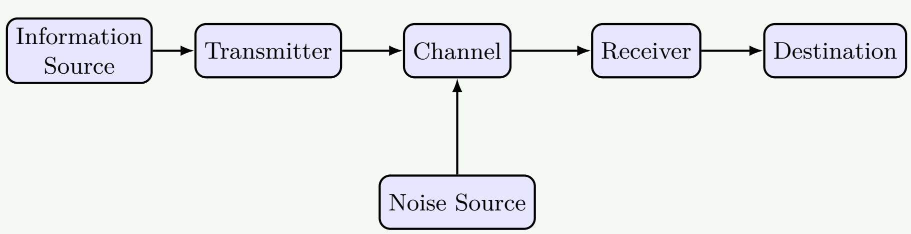



**Figure 1.** Communication System

**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:**

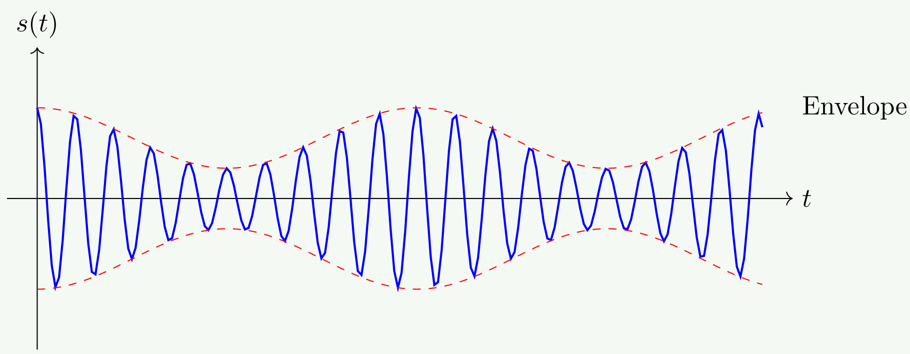



**Figure 2.** AM Waveform

**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:**

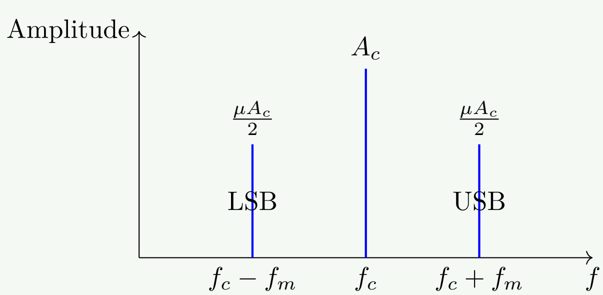



**Figure 3.** DSBFC AM Frequency Spectrum

**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 × 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**:

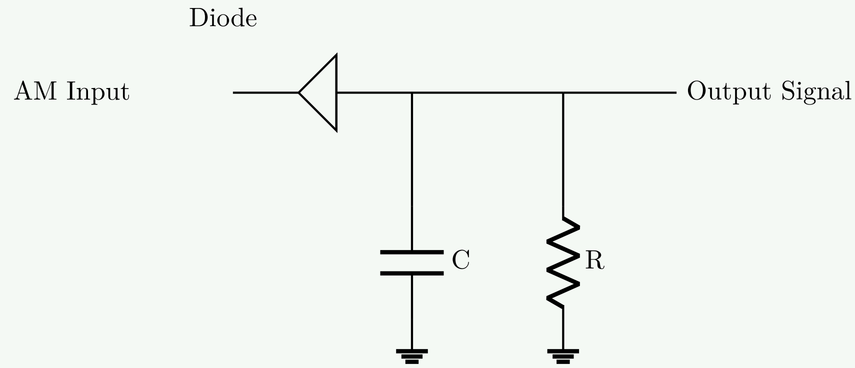



**Figure 4.** Envelope Detector

**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**:

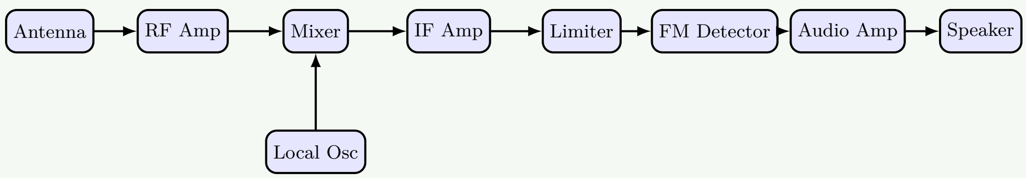



**Figure 5.** FM Radio Receiver

**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 $\mu V$) |
| **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**:

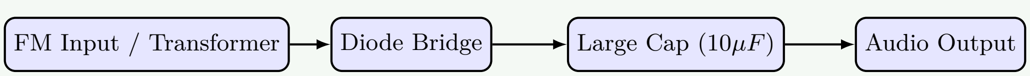



**Figure 6.** Ratio Detector

**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**:

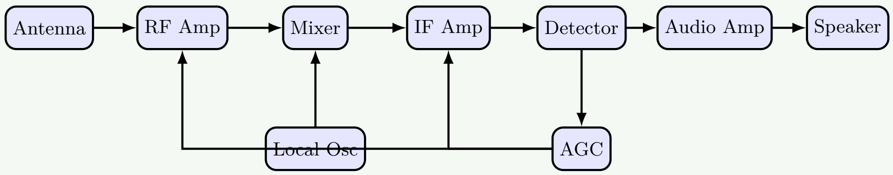



**Figure 7.** AM Radio Receiver

**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**:

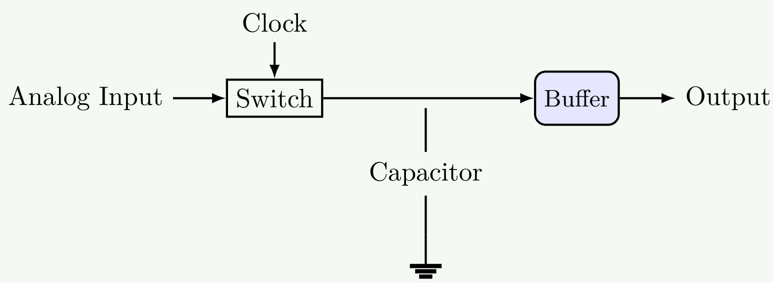



**Figure 8.** Sample and Hold Circuit

**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:**

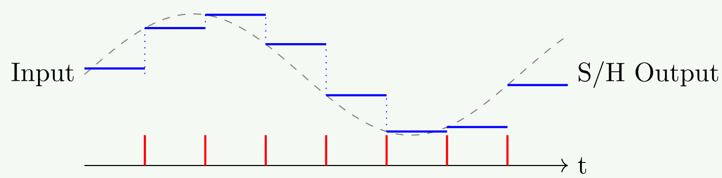



**Figure 9.** Sample and Hold Waveforms

**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.

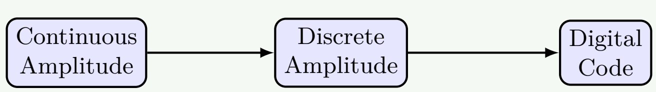



**Figure 10.** Quantization Process

**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 ($\mu$-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.

Aliasing Error $\rightarrow$ 1. Original high freq appears as false low freq 2. Irreversible distortion

**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:**

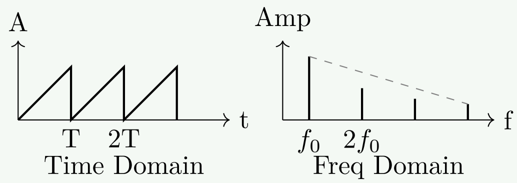



**Figure 11.** Sawtooth Signal

**2. Pulse Signal:**

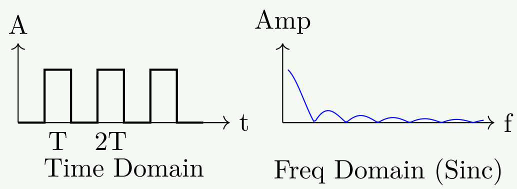



**Figure 12.** Pulse Signal

**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:**

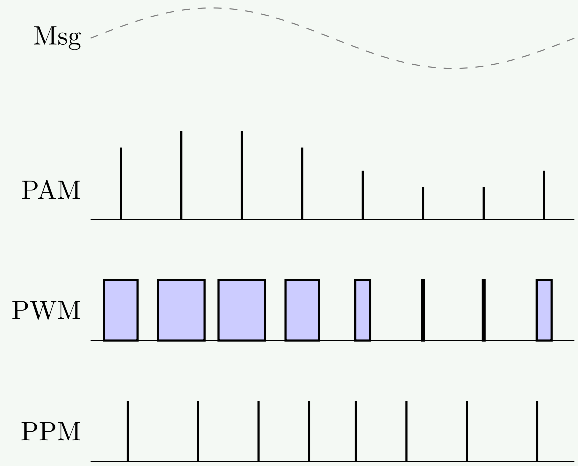



**Figure 13.** Pulse Modulation Waveforms

**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.

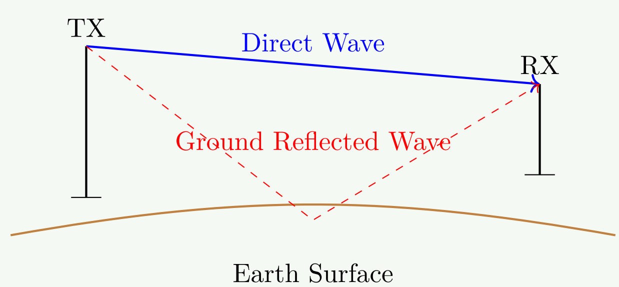



**Figure 14.** Space Wave Propagation

**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**:

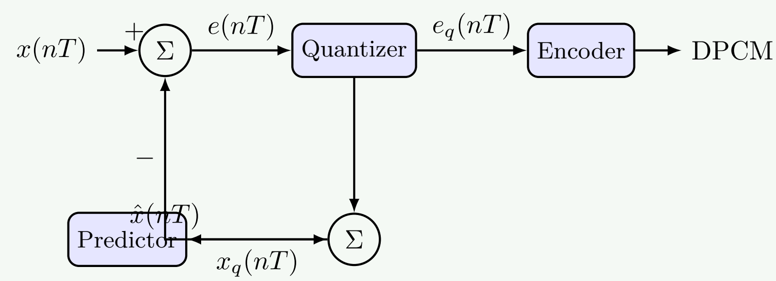



**Figure 15.** DPCM Transmitter

**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.

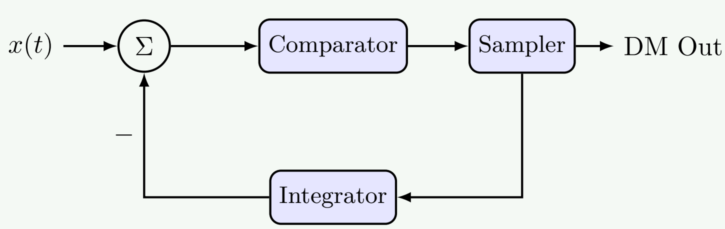



**Figure 16.** Delta Modulator

**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 ($\delta$) is fixed

**Noise in Delta Modulation:**

**Table 8.** Noise in Delta Modulation

| Noise Type | Cause | Remedy |
|---|---|---|
| **Slope Overload Noise** | Input signal changes faster than $\delta$ 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.

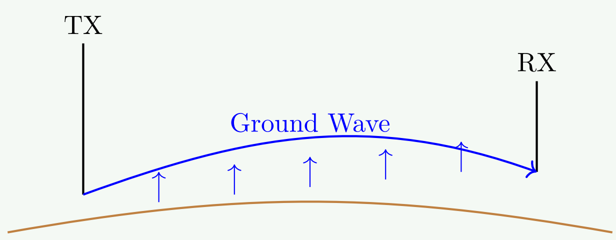



**Figure 17.** Ground Wave Propagation

**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.

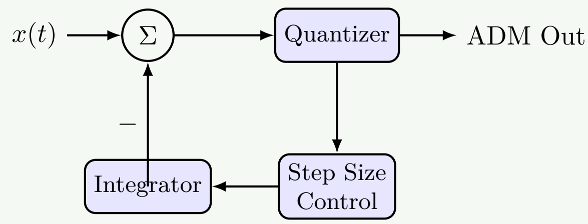



**Figure 18.** ADM Transmitter

**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.

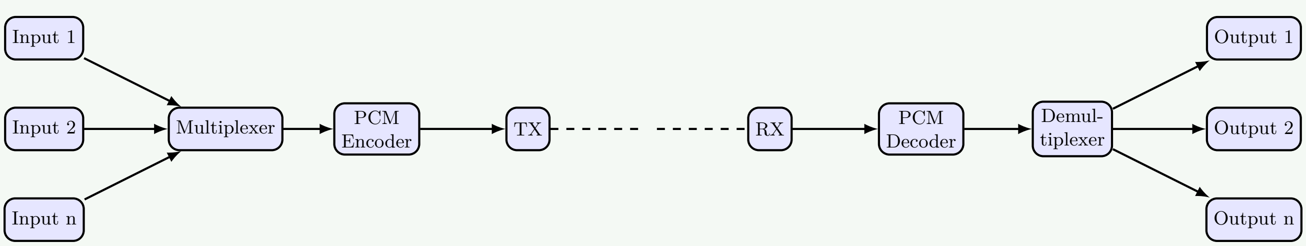



**Figure 19.** PCM-TDM System Block Diagram

**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**:

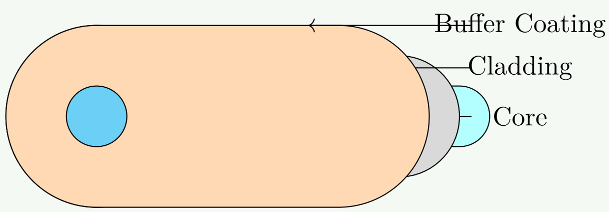



**Figure 20.** Fiber Optic Cable Construction

**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**:

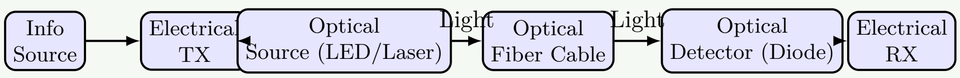



**Figure 21.** Optical Fiber Communication

**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]

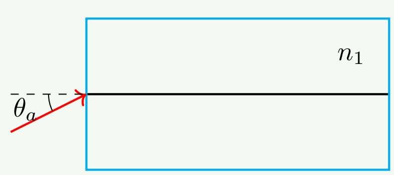
### Explain Numerical Aperture.

**Solution**

**Answer**:

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

- It is the sine of the acceptance angle ($\theta_a$) 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" - "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

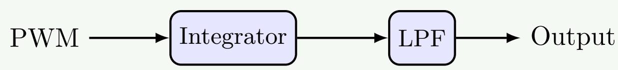



**Figure 22.** PWM Demodulator

**Mnemonic**

"Gen Compare, Demod Integrate"

## Question 5(c) OR [7 marks]

### Draw Block Diagram of satellite communication and Explain.

**Solution**

**Answer**:

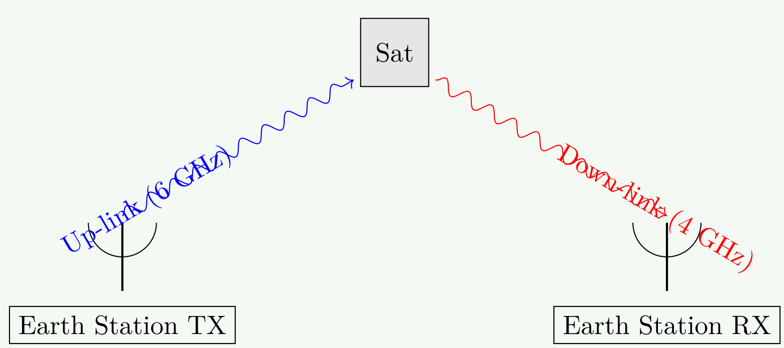



**Figure 23.** Satellite Communication

**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