

# 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:

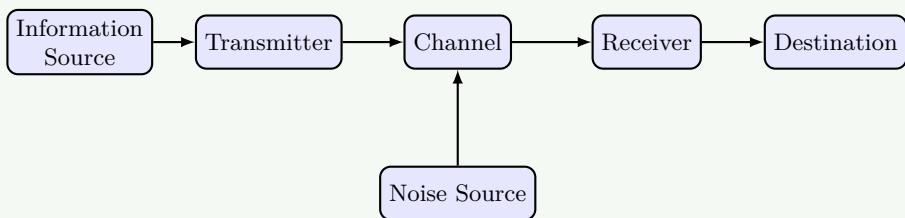


Figure 1. Communication System

#### 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.

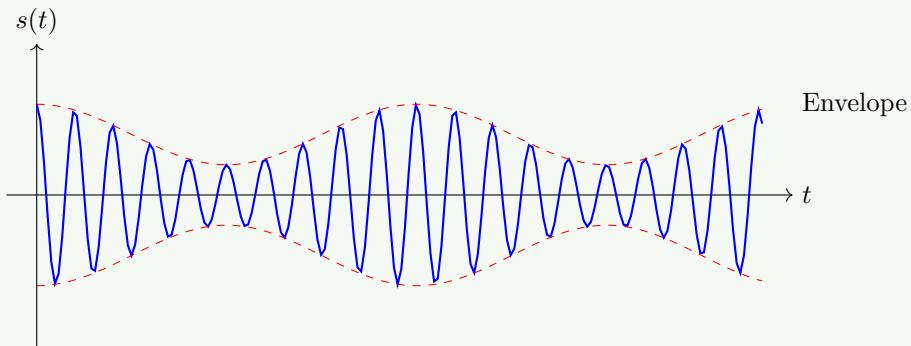
**Waveform and Equation:**

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:  $s(t) = A_c \cdot \cos(\omega_c t) + \frac{\mu A_c}{2} \cos[(\omega_c + \omega_m)t] + \frac{\mu A_c}{2} \cos[(\omega_c - \omega_m)t]$

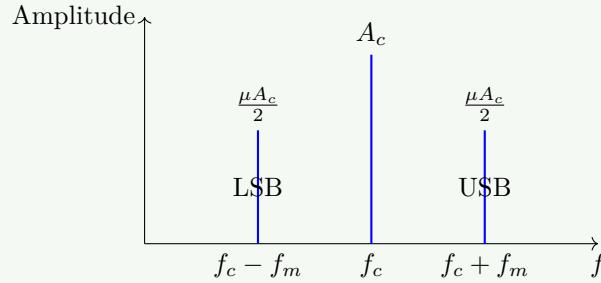
**DSBFC AM Frequency Spectrum:**

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

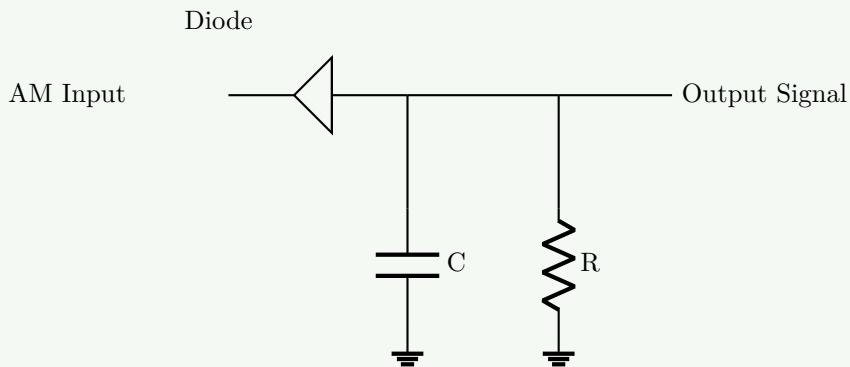
Parameter	AM	FM
<b>Definition</b>	Amplitude of carrier varies with message signal	Frequency of carrier varies with message signal
<b>Bandwidth</b>	$2 \times$ message frequency	$2 \times (\Delta f + f_m)$
<b>Noise Immunity</b>	Poor (noise affects amplitude)	Excellent (noise mainly affects amplitude)
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

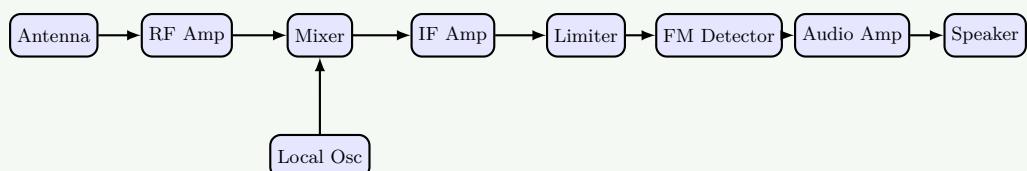
1. Diode conducts during positive half-cycles of carrier
2. Capacitor charges to peak value
3. When input falls, capacitor discharges through resistor
4. Output follows envelope of AM signal

**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

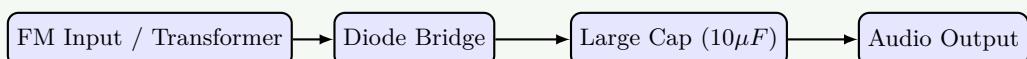
Parameter	Definition
<b>Sensitivity</b>	Ability of receiver to amplify weak signals (measured in $\mu V$ )
<b>Selectivity</b>	Ability to separate desired signal from adjacent signals
<b>Fidelity</b>	Ability to reproduce the original signal without distortion

**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:**

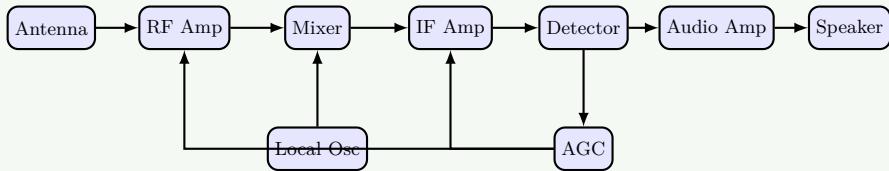
- Uses balanced circuit with two diodes in series
- Large stabilizing capacitor keeps sum of voltages constant
- Output voltage is proportional to frequency deviation
- Inherently insensitive to amplitude variations (no limiter needed)
- Less susceptible to impulse noise than discriminator

**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
<b>Nyquist Rate</b>	$f_s \geq 2f_{max}$	Minimum sampling rate required
<b>Nyquist Interval</b>	$T_s \leq 1/2f_{max}$	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:**

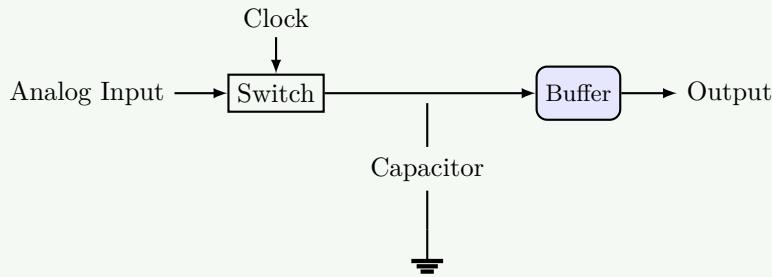


Figure 8. Sample and Hold Circuit

#### 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:

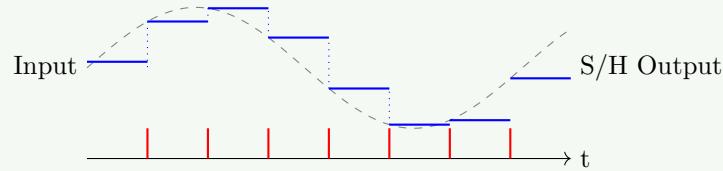


Figure 9. Sample and Hold Waveforms

#### 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.

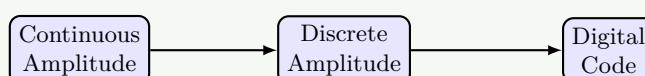


Figure 10. Quantization Process

#### Uniform Quantization vs Non-uniform Quantization:

**Table 6.** Comparison of Quantization Types

Parameter	Uniform Quantization	Non-uniform Quantization
<b>Step Size</b>	Equal throughout range	Varies (smaller for small signals)
<b>Characteristic</b>	Linear	Non-linear (logarithmic/exponential)
<b>SNR</b>	Poor for small signals	Better for small signals
<b>Implementation</b>	Simple	Complex (companding required)
<b>Applications</b>	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**

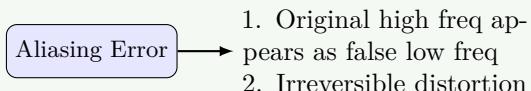
"UNIQ" - "UNIform has equal steps, non-uniform Quiets noise"

**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.

**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**

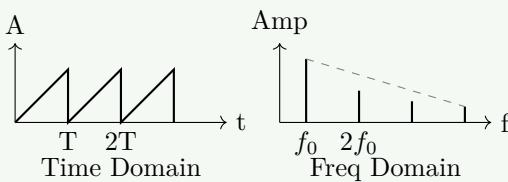
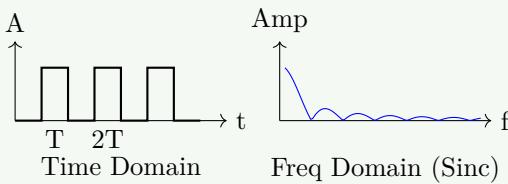
"ALIAS" - "Avoid Low sampling by Increasing And Screening"

**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"

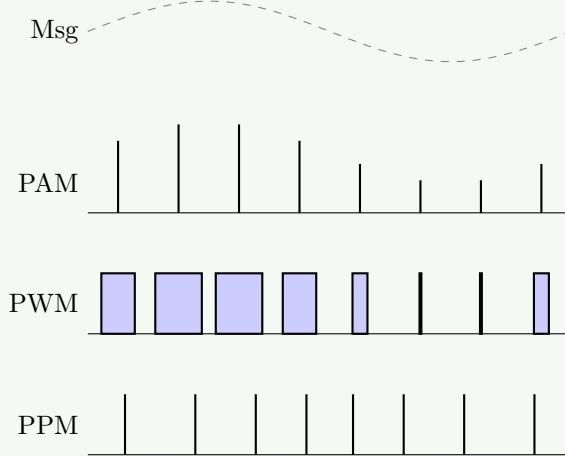
**Question 3(c) OR [7 marks]**

Compare PAM, PWM and PPM with waveform.

**Solution****Answer:****Table 7.** Comparison of Pulse Modulation

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

Waveforms:

**Figure 13.** Pulse Modulation Waveforms**Mnemonic**

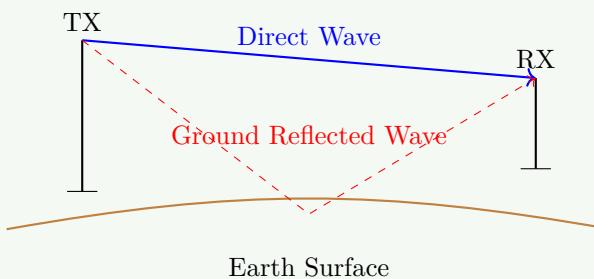
”APP” - ”Amplitude, Pulse-width, Position”

**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:**

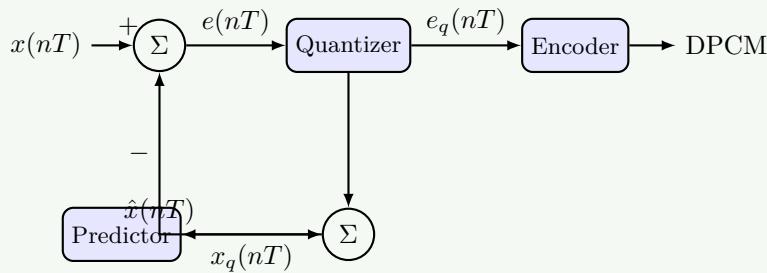


Figure 15. DPCM Transmitter

#### 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.

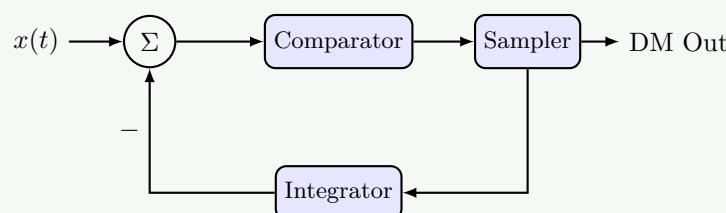


Figure 16. Delta Modulator

#### 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
<b>Slope Overload Noise</b>	Input signal changes faster than $\delta$ can track	Increase step size or sampling frequency
<b>Granular Noise</b>	Step size is too large for slowly varying signals	Decrease step size

**Mnemonic**

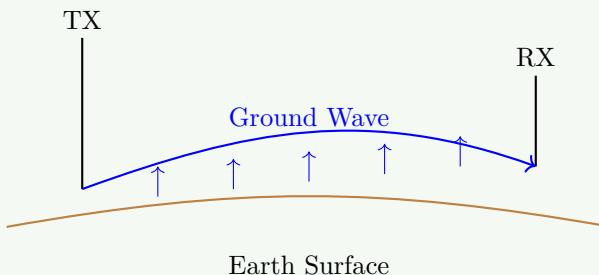
"Slog" - "Slope and Granular in DM"

**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.

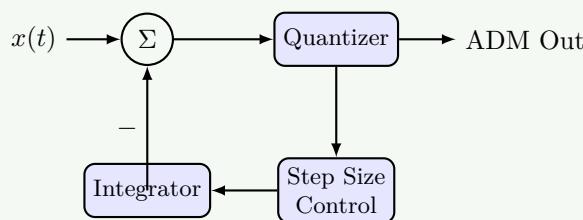


Figure 18. ADM Transmitter

**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.

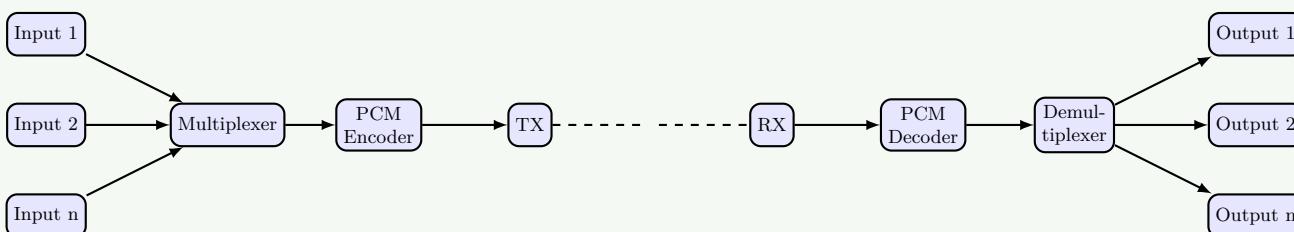


Figure 19. PCM-TDM System Block Diagram

**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

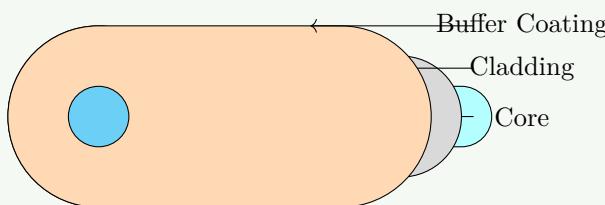
Feature	TDM (Time Division Multiplexing)	FDM (Frequency Division Multiplexing)
<b>Definition</b>	Signals sent at different times on same frequency	Signals sent at same time on different frequencies
<b>Signal Type</b>	Best for digital signals	Best for analog signals
<b>Synchronization</b>	Critical (pulse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

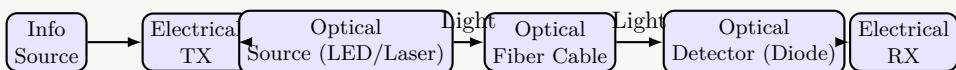
- Protective plastic covering
- Protects from physical damage and moisture

**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"

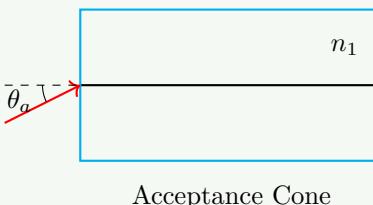
**Question 5(a) OR [3 marks]**

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



**Mnemonic**

"No Sign Theta" - "NA = sin(theta)"

**Question 5(b) OR [4 marks]**

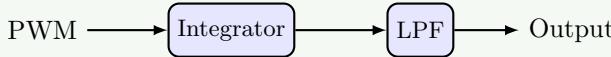
Explain PWM generation and demodulation.

**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



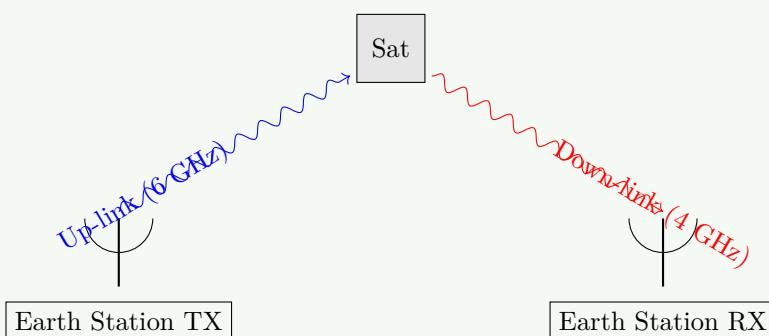
**Figure 22.** PWM Demodulator

**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:**

- Earth Station (TX):** Transmits high power signal to sky (Up-link)
- 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