

# Subject Name Solutions

1333201 – Summer 2025

Semester 1 Study Material

*Detailed Solutions and Explanations*

## Question 1(a) [3 marks]

Define AM, FM and PM.

### Solution

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

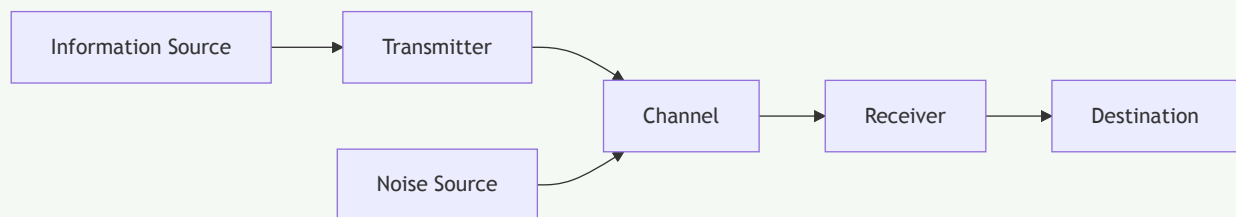
### Mnemonic

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

## Question 1(b) [4 marks]

Explain block diagram of communication system.

### Solution



### 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

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:**

#### Amplitude Modulation

$$\text{Message Signal } m(t) = A_m \cos(\omega_m \cdot t)$$

$$\text{Carrier Signal } c(t) = A_c \cos(\omega_c \cdot t)$$

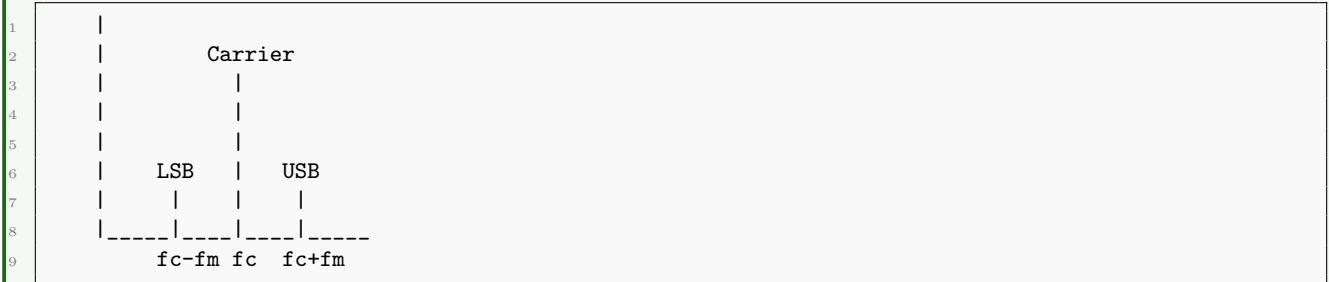
$$\text{AM Signal } s(t) = A_c [1 + \mu \cdot \cos(\omega_m \cdot t)] \cos(\omega_c \cdot t)$$

**Derivation of AM equation:**

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

- Expanding:  $s(t) = A_c \cdot \cos(c \cdot t) + \frac{1}{2} \cdot A_c \cdot \cos[(c+m)t] + \frac{1}{2} \cdot A_c \cdot \cos[(c-m)t]$

#### 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

#### Total Power in AM:

For AM signal  $s(t) = A_c[1 + \mu \cos(m \cdot t)]\cos(c \cdot t)$

## AM Power Distribution

$$\text{Carrier Power: } P_c = A_c^2 / 2$$

$$\begin{aligned} \text{Total Sideband Power:} \\ P_{USB} + P_{LSB} = P_c \cdot \mu^2 / 2 \end{aligned}$$

$$\begin{aligned} \text{Total Power: } P_t = P_c(1 + \\ \mu^2 / 2) \end{aligned}$$

### 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:

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

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

Parameter	AM	FM
<b>Definition</b>	Amplitude of carrier varies with message signal	Frequency of carrier varies with message signal
<b>Bandwidth</b>	$2 \times \text{message frequency}$	$2 \times (f + fm)$
<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

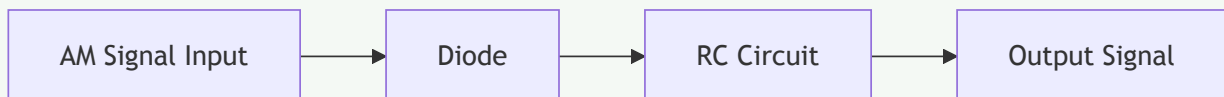
### Mnemonic

“AM Needs Power, FM Fights Noise”

### Question 2(b) [4 marks]

Draw and explain block diagram for envelope detector.

#### Solution



#### 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

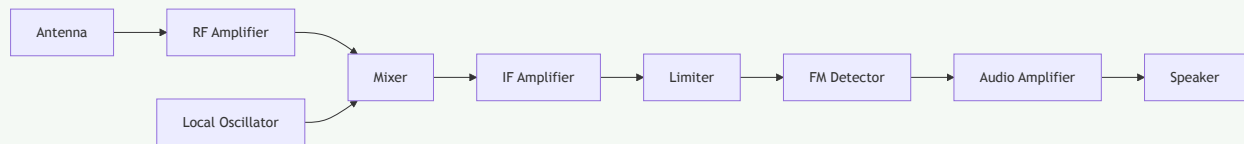
### Mnemonic

“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



### 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

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

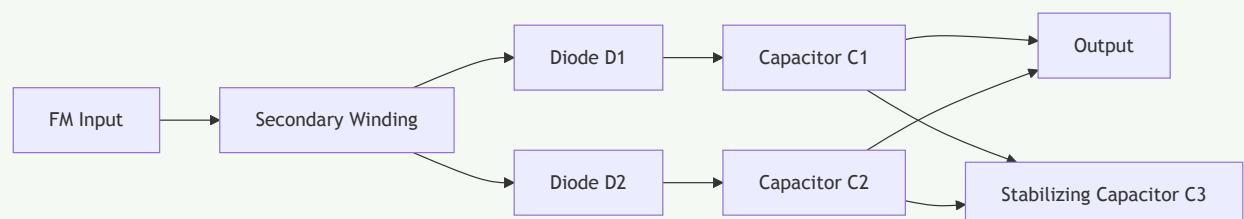
## Mnemonic

"SSF" - "Select Signals Faithfully"

## Question 2(b OR) [4 marks]

Explain ratio detector for FM.

## Solution



### 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

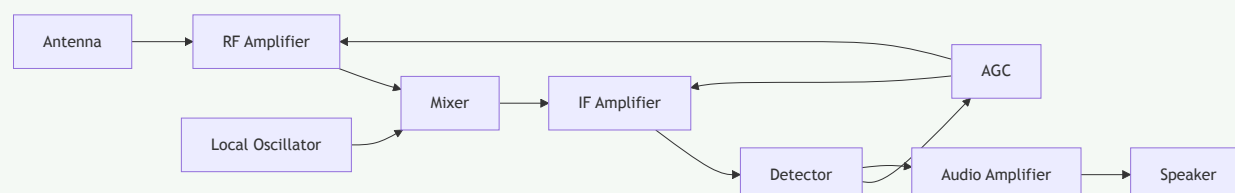
### Mnemonic

“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



### 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

**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.

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.

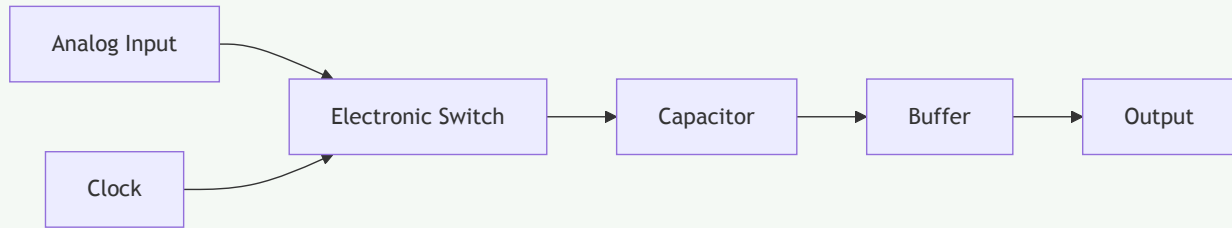
### Mnemonic

“Sample Double to Dodge Aliasing”

## Question 3(b) [4 marks]

Explain Sample and hold Circuit with Waveform.

### Solution



#### 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:

#### 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

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



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

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 ( -law, A-law)

#### Quantization Error:

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

### Mnemonic

“UNIQ” - “UNIform has equal steps, non-uniform Quiets noise”

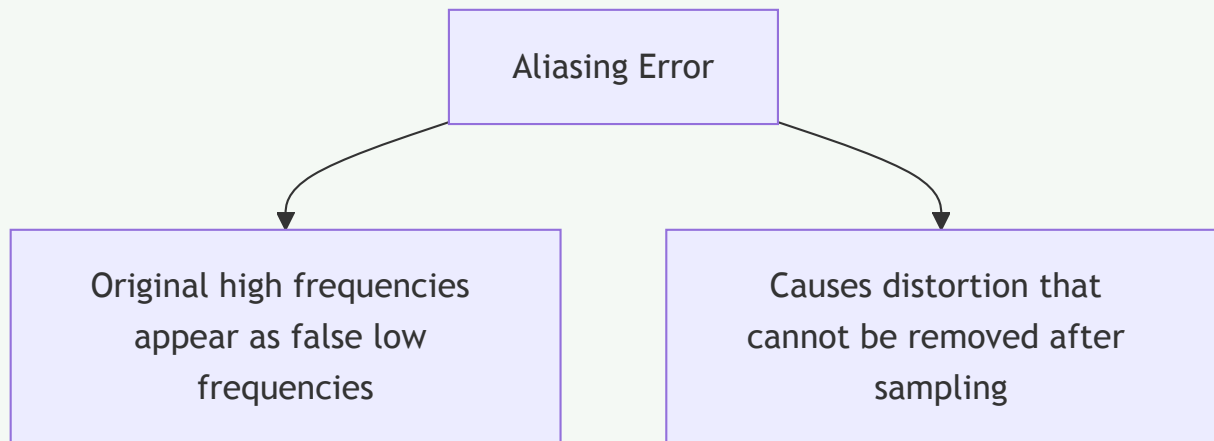
### Question 3(a OR) [3 marks]

Explain aliasing error and how to overcome it.



## Solution

**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”

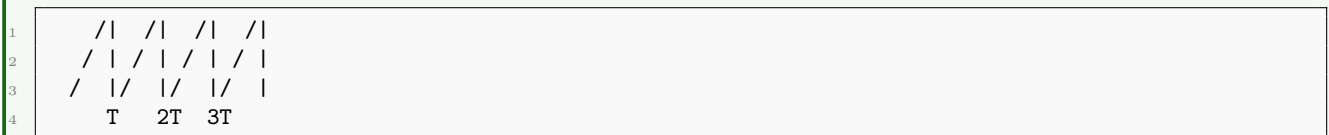
## Question 3(b OR) [4 marks]

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

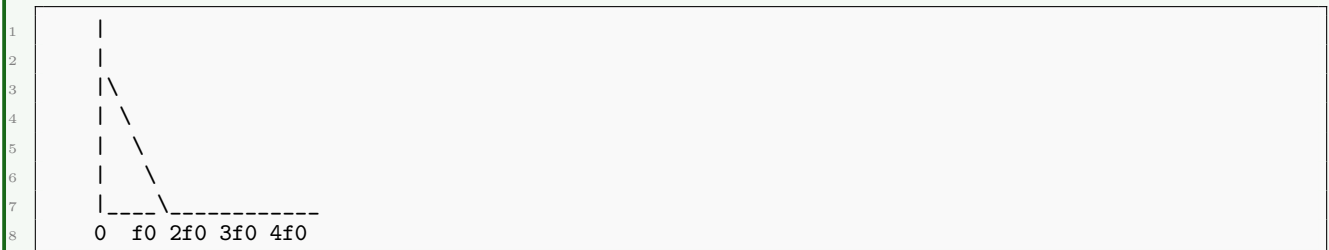
## Solution

### Sawtooth Signal:

Time Domain:



Frequency Domain:



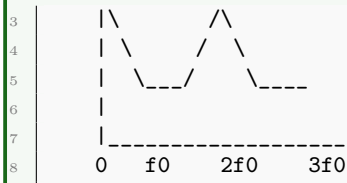
### Pulse Signal:

Time Domain:



Frequency Domain:





### Mnemonic

“STPF” - “SawTooth slopes down, Pulse has sinc Function”

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

Compare PAM, PWM and PPM with waveform.

### Solution

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:

```

1 Message:  /\ /\ /\
2
3 PAM:      ||  ||  ||  ||  ||
4           ||  ||  ||  ||  ||
5
6 PWM:      ||||| |||  || ||||| |||  ||
7
8 PPM:      ||  ||  ||  ||  ||
9           |--|---| |-|--|---| |
  
```

### Mnemonic

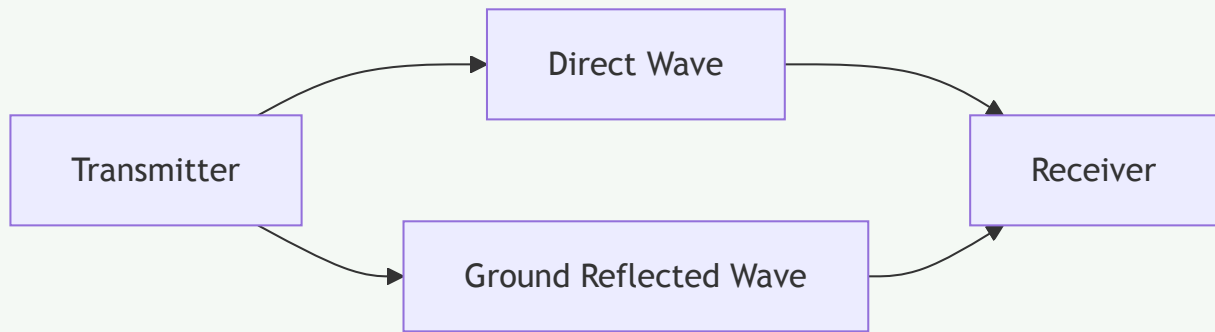
“APP” - “Amplitude, Pulse-width, Position”

## Question 4(a) [3 marks]

Explain Space wave propagation.

### Solution

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



**Characteristics:**

- Frequency range: VHF, UHF (30 MHz - 3 GHz)
- Limited to line-of-sight distance
- Range =  $4.12(1+h_1^2+h_2^2)km$  (where  $h_1, h_2$  = heights in meters)
- Affected by terrain, buildings, and atmospheric conditions

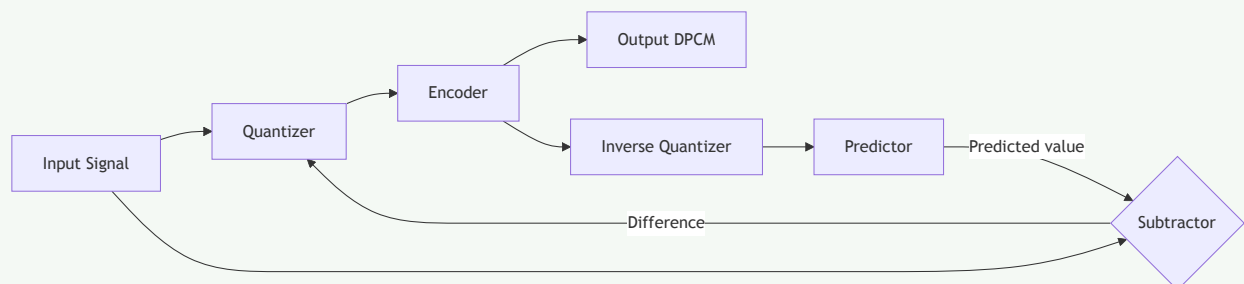
**Mnemonic**

“SLOT” - “Straight Line Over Terrain”

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

Explain working of Differential PCM (DPCM) transmitter.

**Solution**



**Working of DPCM Transmitter:**

- **Predictor:** Estimates current sample based on previous samples
- **Subtractor:** Computes difference between actual and predicted value
- **Quantizer:** Converts difference signal to discrete levels
- **Encoder:** Converts quantized values to binary code
- **Feedback Loop:** Reconstructs signal as receiver would see it

**Advantage:** Only difference signal is transmitted, which requires fewer bits

**Mnemonic**

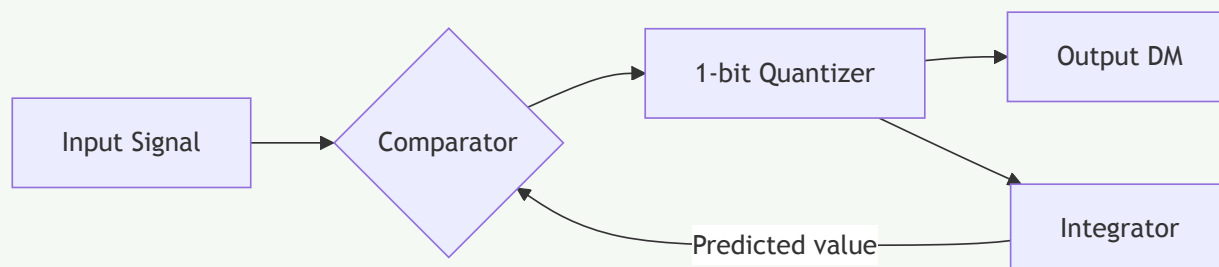
“SPEQIF” - “Subtract, Predict, Encode, Quantize In Feedback”

**Question 4(c) [7 marks]**

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

**Solution**

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



#### 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 ( ) is fixed

#### Noise in Delta Modulation:

Type of Noise	Cause	Solution
<b>Slope Overload Noise</b>	Input signal changes faster than can track	Increase step size or sampling frequency
<b>Granular Noise</b>	Step size too large for slowly varying signals	Decrease step size

#### Mnemonic

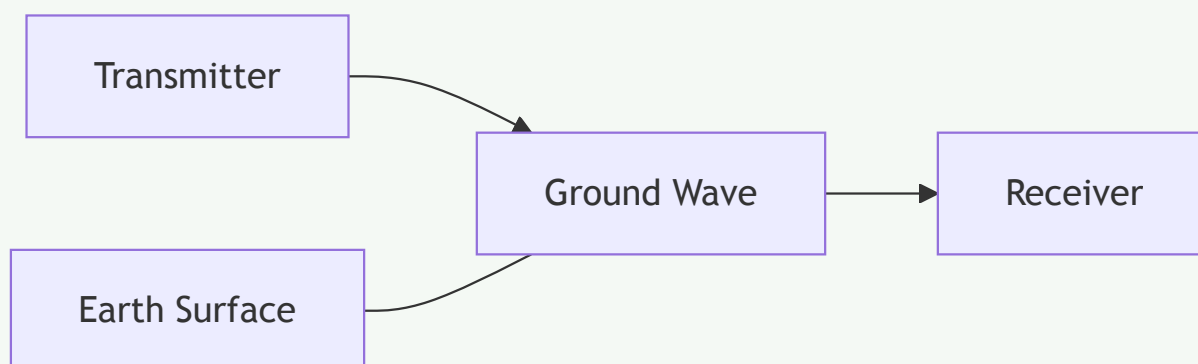
“DOGS” - “Delta modulation has Overload and Granular noiseS”

### Question 4(a OR) [3 marks]

Explain Ground wave propagation.

#### Solution

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



#### Characteristics:

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

#### Mnemonic

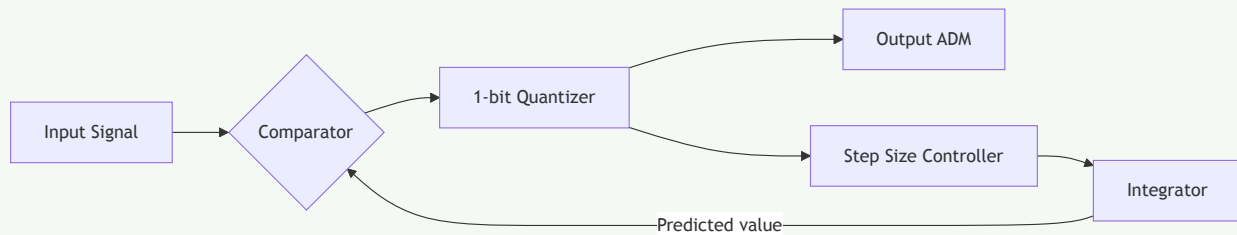
“GEL” - “Ground waves follow Earth at Low frequencies”

### Question 4(b OR) [4 marks]

Explain ADM transmitter.

#### Solution

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



#### Working of ADM Transmitter:

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

#### Advantages over DM:

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

#### Mnemonic

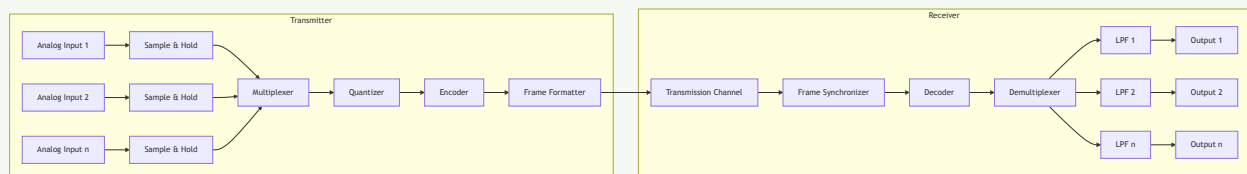
“ASIC” - “Adapt Step-size, Improve Coding”

### Question 4(c OR) [7 marks]

Explain Block diagram of basic PCM-TDM system.

#### Solution

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



#### Working of PCM-TDM System:

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

#### Mnemonic

“SAMPLE-CODE-MUX” - Sampling, Coding, and Multiplexing

Question 5(a) [3 marks]

Define radiation pattern, Directivity and Gain for antenna.

Solution

Parameter	Definition
Radiation Pattern	Graphical representation of radiation properties (field strength or power) as function of space coordinates
Directivity	Ratio of maximum radiation intensity to average radiation intensity
Gain	Product of directivity and efficiency (practical measure of antenna performance)

Relationship:  $\text{Gain} = \text{Directivity} \times \text{Efficiency}$

Mnemonic

“RDG” - “Radiation Directs with Gain”

Question 5(b) [4 marks]

Explain Microstrip Antenna with sketch.

Solution

**Microstrip (Patch) Antenna:** Low-profile antenna consisting of a metal patch on a substrate with ground plane.

Microstrip Antenna Structure

```
graph LR; A[Feed Point] --> B[Radiating Patch]; B --> C[Dielectric Substrate]; C --> D[Ground Plane]
```

**Key Features:**

- **Patch:** Typically rectangular or circular (  $\lambda/2$  in length)
- **Substrate:** Low-loss dielectric material (  $\epsilon_r = 2.2$  to  $12$ )
- **Feeding Methods:** Microstrip line, coaxial probe, aperture coupling
- **Radiation:** Primarily from fringing fields at patch edges

**Applications:** Mobile devices, GPS, RFID, satellite communications

Mnemonic

“PSDG” - “Patch on Substrate with Dielectric over Ground”

Question 5(c) [7 marks]

Explain PCM transmitter and receiver in details.

Solution

**PCM (Pulse Code Modulation) Transmitter:**

```
graph LR; A[Analog Input] --> B[Anti-aliasing Filter]; B --> C[Sample & Hold]; C --> D[Quantizer]; D --> E[Encoder]; E --> F[Parallel to Serial]; F --> G[Line Coder]; G --> H[PCM Output]
```

**PCM Receiver:**

```
graph LR; A[PCM Input] --> B[Regenerative Repeater]; B --> C[Line Decoder]; C --> D[Serial to Parallel]; D --> E[Decoder]; E --> F[Reconstruction Filter]; F --> G[Analog Output]
```

### Working Details:

Block	Function
<b>Anti-aliasing Filter</b>	Limits bandwidth to prevent aliasing
<b>Sample &amp; Hold</b>	Takes samples at regular intervals
<b>Quantizer</b>	Assigns discrete amplitude levels
<b>Encoder</b>	Converts levels to binary codes
<b>Line Coder</b>	Converts digital data to transmission format
<b>Regenerative Repeater</b>	Restores signal quality
<b>Decoder</b>	Converts binary to amplitude levels
<b>Reconstruction Filter</b>	Smoothens staircase output to analog

### Mnemonic

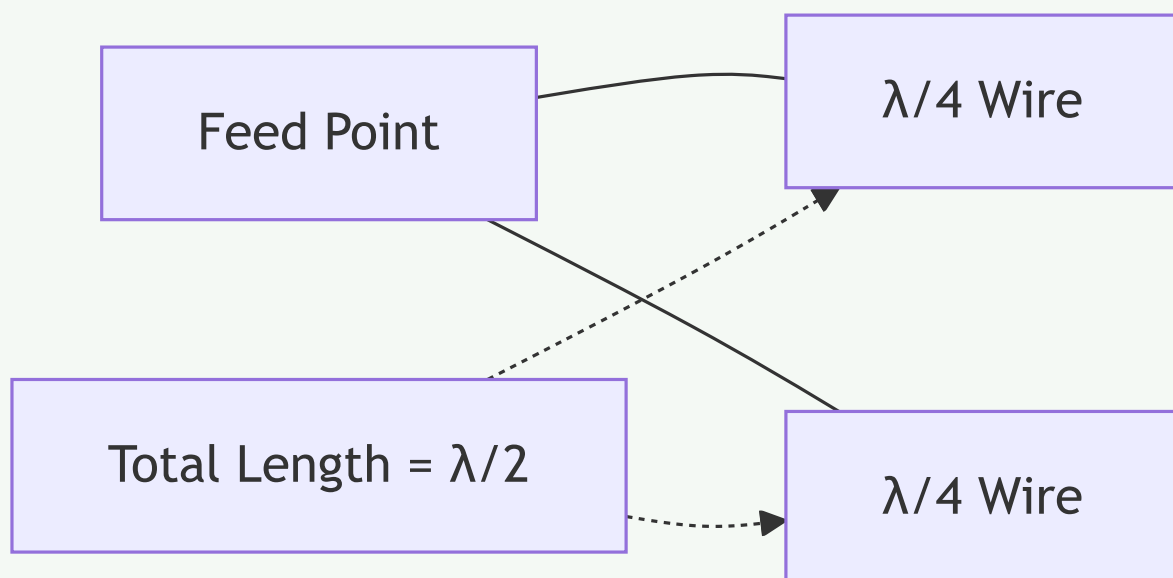
“SAFE PCR” - “Sample, Amplify, Filter, Encode, Pulse Code Receiver”

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

Explain dipole antenna with sketch.

### Solution

**Dipole Antenna:** Simplest and most widely used antenna consisting of two conducting elements.



### Key Characteristics:

- **Length:** Typically  $\lambda/2$  (half-wavelength dipole)
- **Radiation Pattern:** Figure-8 pattern perpendicular to antenna axis
- **Impedance:**  $\sim 73 \Omega$  for half-wave dipole
- **Polarization:** Same as the orientation of the antenna

**Applications:** Radio broadcasting, TV reception, amateur radio

### Mnemonic

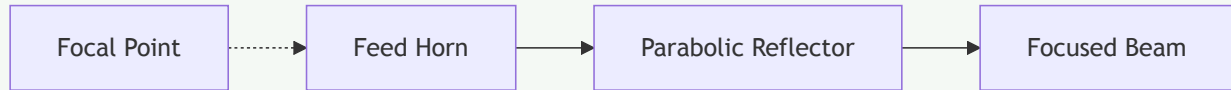
“HALF” - “Half-wavelength Antenna Leads Field”

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

Explain parabolic reflector antenna With Sketch.

### Solution

**Parabolic Reflector Antenna:** High-gain antenna using parabolic dish to focus electromagnetic waves.



#### Working Principle:

- **Feed:** Located at focal point of parabola
- **Reflector:** Parabolic surface reflects waves in parallel direction
- **Reflection Property:** All paths from focal point to reflector to parallel line are equal

#### Applications:

- Satellite communications
- Radio astronomy
- Radar systems
- Microwave links

### Mnemonic

“PROF” - “Parabola Reflects On Focus”

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

Compare PCM, DM, ADM and DPCM.

### Solution

Parameter	PCM	DM	ADM	DPCM
<b>Full Form</b>	Pulse Code Modulation	Delta Modulation	Adaptive Delta Modulation	Differential PCM
<b>Bits per Sample</b>	8-16 bits	1 bit	1 bit	3-4 bits
<b>Step Size</b>	Fixed quantization levels	Fixed step size	Variable step size	Fixed quantization of difference
<b>Bandwidth Requirement</b>	Highest	Lowest	Low	Medium
<b>Signal Quality</b>	Excellent	Poor to moderate	Moderate	Good
<b>Implementation Complexity</b>	Moderate	Very simple	Moderate	Complex
<b>Applications</b>	Digital audio, telephony	Simple telemetry	Voice communication	Video, speech

#### Key Differences:

- **PCM:** Encodes absolute amplitude values
- **DM:** Encodes only 1-bit difference with fixed step
- **ADM:** Improves DM by adapting step size
- **DPCM:** Encodes multi-bit difference signal

### Mnemonic

“PAID” - “PCM, ADM, Integrate in DPCM”