

# Subject Name Solutions

1333201 – Winter 2024

Semester 1 Study Material

*Detailed Solutions and Explanations*

## Question 1(a) [3 marks]

What is modulation? What is the need of it?

### Solution

Modulation is the process of varying one or more properties of a high-frequency carrier signal with a modulating signal containing information.

Table 1: Need for Modulation

| Reason       | Explanation   |
|--------------|---|
| Antenna Size | Reduces antenna size requirements ( $\lambda = c/f$ ) |
| Multiplexing | Allows multiple signals to share the spectrum         |
| Range        | Increases transmission distance                       |
| Interference | Reduces noise interference                            |

- **Practical transmission:** Makes low-frequency information signals suitable for wireless transmission
- **Signal separation:** Enables different signals to be transmitted simultaneously

### Mnemonic

“RARE Messages” (Range, Antenna, Reduce interference, Enable multiplexing)

**Diagram: Communication System**

## Question 1(b) [4 marks]

Compare AM and FM.

### Solution

Table 2: Comparison between AM and FM

| Parameter          | AM (Amplitude Modulation) | FM (Frequency Modulation)        |
|--------------------|---------------------------|----------------------------------|
| Parameter varied   | Amplitude of carrier      | Frequency of carrier             |
| Bandwidth          | Narrow ( $2 \times fm$ )  | Wide ( $2 \times mf \times fm$ ) |
| Noise immunity     | Poor                      | Excellent                        |
| Power efficiency   | Less efficient            | More efficient                   |
| Circuit complexity | Simple                    | Complex                          |
| Quality            | Moderate                  | High                             |
| Applications       | Medium wave broadcasting  | High-fidelity broadcasting       |

### Mnemonic

“BANC-QA” (Bandwidth, Amplitude/frequency, Noise, Complexity, Quality, Applications)

## 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 (AM) is a technique where the amplitude of a carrier wave is varied in proportion to the instantaneous amplitude of the modulating signal.

### Voltage Equation:

- Carrier signal:  $v_1(t) = A_1 \sin(ct)$
- Modulating signal:  $v_2(t) = A_2 \sin(mt)$
- Modulated signal:  $v(t) = A_1[1 + m \sin(mt)] \sin(ct)$
- Where  $m = A_2/A_1$  (modulation index)

### Diagram: AM Waveform

#### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph "AM Waveform"
        A[Carrier Wave] --{-}{-} D[Modulated Wave]}
        B[Modulating Signal] --{-}{-} D}
    end
    style D fill:#f9f,stroke:#333,stroke-width:2px}
{Highlighting}
{Shaded}
```

Carrier

```
/ { / / / / / / }
/ { / / / / / / }
```

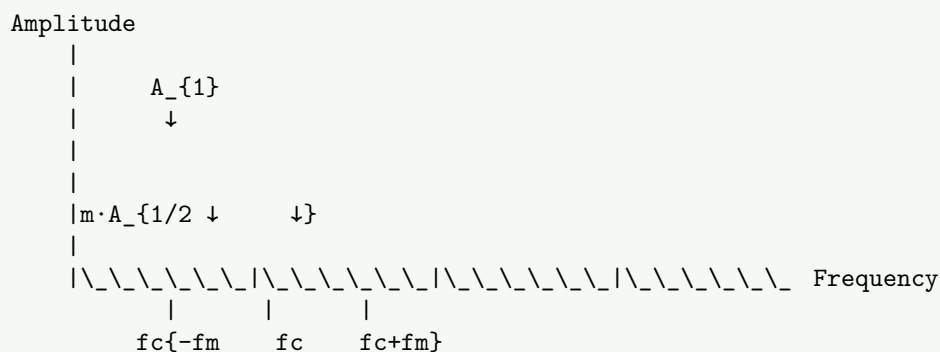
Modulating

```
/ { / }
/ { / }
{ / }
{ / }
```

AM Signal

```
/ { / / / }
/ { / / / }
/ { / / / }
{ / }
{ / }
{ / }
```

### Frequency Spectrum of DSBFC AM



- Bandwidth:** The bandwidth of AM signal is  $2 \times f_m$
- Sidebands:** Upper sideband (USB) at  $f_c + f_m$  and Lower sideband (LSB) at  $f_c - f_m$
- Power distribution:** In carrier and two sidebands

## Mnemonic

“CAM-SIP” (Carrier Amplitude Modified, Sidebands In Pair)

### Question 1(c) OR [7 marks]

Derive the equation for total power in AM, calculate percentage of power savings in DSB and SSB.

#### Solution

##### Derivation of Total Power in AM:

- AM signal:  $v(t) = A_1[1 + m\sin(mt)]\sin(ct)$
- Total power:  $P = P_{(carrier)} + P_{(sidebands)}$
- $P_{(carrier)} = A_1^2/2$
- $P_{(sidebands)} = A_1^2m^2/4$

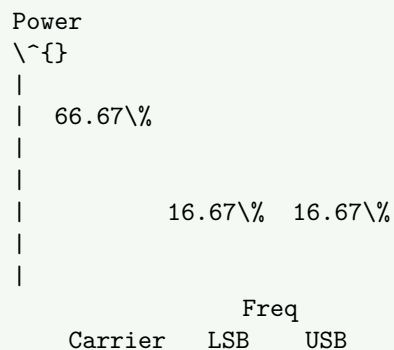
Table 3: Power Distribution in AM

| Component | Power Expression           | % of Total Power (m=1) |
|-----------|----------------------------|------------------------|
| Carrier   | $P_c = A_1^2/2$            | 66.67%                 |
| Sidebands | $P_s = A_1^2m^2/4$         | 33.33%                 |
| Total     | $P_t = A_1^2(1 + m^2/2)/2$ | 100%                   |

##### Power Savings:

- **DSB-SC:** 100% carrier power saved (66.67% of total power)
  - Only sidebands are transmitted
  - Percentage savings =  $(P_c/P_t) \times 100 = 66.67\%$
- **SSB:** 50% of sideband power + 100% carrier power saved
  - One sideband + carrier removed
  - Percentage savings =  $(P_c + P_s/2)/P_t \times 100 = 83.33\%$

##### Diagram: Power Distribution



#### Mnemonic

“CAST-83” (Carrier And Sideband Transmission, 83% saved in SSB)

### Question 2(a) [3 marks]

Define (1) Modulation index for AM (2) Modulation index For FM.

#### Solution

Table 4: Modulation Index Definitions

| Parameter  | AM Modulation Index   | FM Modulation Index                                  |
|------------|---|--|
| Definition | Ratio of peak amplitude of modulating signal to peak amplitude of carrier | Ratio of frequency deviation to modulating frequency |
| Formula    | $m = A_m/A_c$   | $m_f = \Delta f/f_m$                                 |
| Range      | $0 \leq m \leq 1$ for no distortion                                       | No specific upper limit                              |
| Effect     | Determines % modulation   | Determines bandwidth                                 |

- **AM Modulation Index:** Controls the amplitude variation and power distribution
- **FM Modulation Index:** Determines bandwidth and signal quality

### Mnemonic

“ARM-FDM” (Amplitude Ratio for Modulation, Frequency Deviation for Modulation)

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

Draw and explain block diagram for envelope detector.

#### Solution

##### Diagram: Envelope Detector

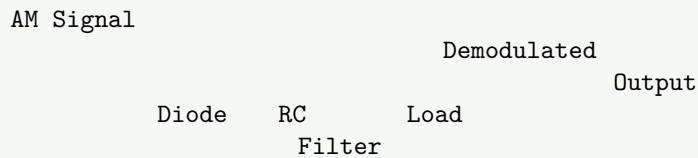


Table 5: Components and Their Functions

| Component | Function   |
|-----------|--|
| Diode     | Rectifies the AM signal (removes negative half-cycles) |
| RC Filter | Smooths the rectified signal to recover the envelope   |
| Load      | Provides output circuit and impedance matching         |

- **Working principle:** The diode conducts only during positive half-cycles
- **Time constant:** RC must be large enough to prevent ripple but small enough to follow modulation
- **Condition:**  $RC \gg 1/f_c$  but  $RC \ll 1/f_m$

### Mnemonic

“DEER” (Diode Extracts Envelope Representation)

### Question 2(c) [7 marks]

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

#### Solution

##### Diagram: FM Radio Receiver

```

flowchart LR
    A[Antenna] --> B[RF Amplifier]
    B --> C[Mixer]
    D[Local Oscillator] --> C
    C --> E[IF Amplifier]
    E --> F[Limiter]
    F --> G[FM Discriminator]
    G --> H[Audio Amplifier]
    H --> I[Speaker]
  
```

Table 6: Functions of Each Block

| Block            | Function                                     |
|------------------|--|
| Antenna          | Receives electromagnetic waves               |
| RF Amplifier     | Amplifies weak RF signals (88-108 MHz)       |
| Mixer            | Converts RF to IF frequency (10.7 MHz)       |
| Local Oscillator | Generates frequency for mixing (RF+10.7 MHz) |
| IF Amplifier     | Amplifies IF signal with fixed gain          |
| Limiter          | Removes amplitude variations                 |
| FM Discriminator | Converts frequency variations to voltage     |

- **Superheterodyne principle:** Uses frequency conversion to process signals at fixed IF
- **Distinctive FM feature:** Limiter removes noise in amplitude before demodulation

### Mnemonic

“RAMLIDASS” (RF, Amplifier, Mixer, Local oscillator, IF, Discriminator, Audio, Speaker System)

**Question 2(a) OR [3 marks]**

**Draw only Waveform For frequency modulation and Phase modulation.**

## Solution

### Diagram: FM and PM Waveforms

## Modulating Signal

FM Signal

$$\begin{array}{ccccccc} & / \{ // & & // // // & & // // \} & \\ / & & \{ & / & & / & \} \\ / & & \{ & / & & / & \} \end{array}$$

PM Signal

$$\begin{array}{l} \{ \{ // // // / \} \\ / \quad \quad \{ / \quad / \quad \} \\ / \quad \quad \quad \{ \} \end{array}$$

### Key Characteristics:

- **FM:** Frequency increases when modulating signal is positive
- **PM:** Phase shifts immediately with amplitude changes

### Mnemonic

“FIP-PAF” (Frequency Increases with Positive signal, Phase Advances with Faster changes)

Question 2(b) OR [4 marks]

Define any **FOUR** characteristics of radio receiver.

## Solution

Table 7: Characteristics of Radio Receiver

| Characteristic  | Definition  |
|-----------------|---|
| Sensitivity     | Ability to receive weak signals (measured in V or dBm)    |
| Selectivity     | Ability to separate desired signal from adjacent channels |
| Fidelity        | Accuracy of reproducing the original modulating signal    |
| Image Rejection | Ability to reject image frequency interference            |

**Additional characteristics:**

- **Signal-to-Noise Ratio:** Ratio of signal power to noise power
- **Bandwidth:** Range of frequencies that can be received
- **Stability:** Ability to maintain tuned frequency

**Mnemonic**

“SFIS-BSS” (Sensitivity, Fidelity, Image rejection, Selectivity - Better Signal Stability)

**Question 2(c) OR [7 marks]**

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

**Solution****Diagram: AM Radio Receiver**

flowchart LR

```

A[Antenna] --> B[RF Tuner & Amplifier]
B --> C[Mixer]
D[Local Oscillator] --> C
C --> E[IF Amplifier]
E --> F[Detector]
F --> G[AGC]
G --> E
F --> H[Audio Amplifier]
H --> I[Speaker]

```

Table 8: Functions of Each Block

| Block                | Function                                    |
|----------------------|---|
| Antenna              | Captures AM radio waves                     |
| RF Tuner & Amplifier | Selects and amplifies desired frequency     |
| Mixer                | Converts RF signal to IF (455 kHz)          |
| Local Oscillator     | Generates frequency for mixing (RF+455 kHz) |
| IF Amplifier         | Amplifies IF signal with fixed selectivity  |
| Detector             | Recovers audio from AM envelope             |
| AGC                  | Provides automatic gain control             |
| Audio Amplifier      | Amplifies audio signal                      |
| Speaker              | Converts electrical to sound waves          |

- **Superheterodyne principle:** Uses frequency conversion for better selectivity
- **AGC feedback loop:** Maintains constant output despite signal strength variations

**Mnemonic**

“ARMLESS” (Antenna, RF, Mixer, Local oscillator, Envelope detector, Sound System)

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

Define quantization. Explain non uniform quantization in brief.

**Solution**

**Quantization** is the process of converting continuous amplitude values into discrete levels for digital representation.

Table 9: Non-uniform Quantization

| Aspect     | Description   |
|------------|---|
| Definition | Assigning different step sizes for different amplitude ranges |

Advantage  
Implementation  
Example

Reduces quantization noise for small amplitude signals  
Using companding (compression-expansion) techniques  
-law and A-law companding used in telephony

- **Working principle:** Smaller step sizes for lower amplitudes, larger steps for higher amplitudes
- **Effect:** Improves SNR for weak signals at the expense of strong signals

### Mnemonic

“QUEST-CS” (QUantization with Enhanced Steps - Compressing Small signals)

## Question 3(b) [4 marks]

Explain Sample and hold Circuit with Waveform.

### Solution

#### Diagram: Sample and Hold Circuit

Analogue Input      Sample & Hold      Sampled

Clock

#### Diagram: Sample and Hold Waveform

Analogue Signal

```
/{      /}  
/ {    / }  
/ {    / }  
/ {/    }
```

Clock Pulses

```
\_ \_ \_ \_ \_  
| | | | | | | |  
| | | | | | | |  
| \_ | \_ | \_ | \_ | \_ |
```

Sampled Output

```
\_ \_ \_ \_ \_  
| | | | | |  
\_ | | \_ \_ \_ \_ / | \_ \_ \_ \_  
/ { }
```

#### Sample and Hold Operation:

- **Sampling mode:** Switch closes, capacitor charges to input voltage
- **Hold mode:** Switch opens, capacitor maintains voltage
- **Parameters:** Acquisition time, aperture time, hold time, droop rate

### Mnemonic

“CHASED” (Capacitor Holds Amplitude Samples for Extended Duration)

## Question 3(c) [7 marks]

What is sampling? Explain types of sampling in brief.

## Solution

**Sampling** is the process of converting a continuous-time signal into a discrete-time signal by taking measurements at regular intervals.

Table 10: Types of Sampling

| Type                 | Description  | Characteristics                            |
|----------------------|--|--|
| Natural Sampling     | Signal is multiplied with rectangular pulses           | Retains original signal shape during pulse |
| Flat-top Sampling    | Sample value is held constant during sampling interval | Creates a staircase-like output            |
| Ideal Sampling       | Instantaneous samples represented as impulses          | Theoretical concept with zero width pulses |
| Uniform Sampling     | Samples taken at equal time intervals                  | Most common in practice                    |
| Non-uniform Sampling | Samples taken at varying intervals                     | Used for specialized applications          |

### Diagram: Sampling Types

Original Signal

```

      /\      /\
     /  {    /  }
    /    {  /    }
   /      {/      }

```

Natural Sampling

```

   \_      \_      \_
  | |      | |      | |
 | |/{ | |      | |/{
 |/{ { | |      |/{ |}

```

Flat-top Sampling

```

   \_\_\_  \_\_\_
  |  |  |  |  |
  |  |  |  |  |

```

- **Nyquist criterion:** Sampling frequency must be at least twice the highest frequency in the signal

## Mnemonic

“INFUN” (Ideal, Natural, Flat-top, Uniform, Non-uniform)

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

Explain quantization process and its necessity.

## Solution

**Quantization Process** maps continuous amplitude values to finite discrete levels for digital representation.

Table 11: Quantization Process and Necessity

| Aspect     | Description  |
|------------|--|
| Process    | Dividing amplitude range into discrete levels      |
| Necessity  | Required for analog-to-digital conversion          |
| Effect     | Introduces quantization error/noise                |
| Parameters | Step size, number of levels ( $2^n$ for $n$ – bit) |



- **Step size calculation:** Step size =  $(V_{\max} - V_{\min})/2^n$
- **Quantization error:** Maximum error is  $/2$  where  $Q$  is step size
- **Applications:** Digital communication, audio/video processing, data storage

#### Mnemonic

“SEND” (Step-size Establishes Noise in Digitization)

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

State and explain Nyquist Criteria for sampling of signal.

#### Solution

**Nyquist Sampling Theorem** states that to perfectly reconstruct a bandlimited signal, the sampling frequency must be at least twice the highest frequency component in the signal.

Table 12: Nyquist Criteria

| Parameter        | Description                               |
|------------------|---|
| Criterion        | $f_s \geq 2f_{\max}$                      |
| Nyquist Rate     | $2f_{\max}$ (minimum sampling frequency)  |
| Nyquist Interval | $1/(2f_{\max})$ (maximum sampling period) |
| Aliasing         | Occurs when $f_s < 2f_{\max}$             |

#### Diagram: Sampling Effects

Proper Sampling ( $f_s \geq 2f_{\max}$ )

Original:  $\{ \sin(\omega t) \}$

Samples: \* \* \* \* \*

Result:  $\{ \sin(\omega t) \}$

Aliasing ( $f_s < 2f_{\max}$ )

Original:  $\{ \sin(\omega t) \}$

Samples: \* \* \* \*

Result:  $\{ \sin(\omega' t) \}$  (lower frequency)

- **Consequences of undersampling:** Aliasing (frequency folding)
- **Practical application:** Anti-aliasing filters used before sampling

#### Mnemonic

“TRAP-A” (Twice Rate Avoids Problematic Aliasing)

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

Explain PAM, PWM and PPM with waveform.

#### Solution

Table 13: Pulse Modulation Techniques

| Technique | Description                | Parameter Varied          | Application                     |
|-----------|----------------------------|---------------------------|---------------------------------|
| PAM       | Pulse Amplitude Modulation | Amplitude of pulses       | Simple ADC systems              |
| PWM       | Pulse Width Modulation     | Width/duration of pulses  | Motor control, power regulation |
| PPM       | Pulse Position Modulation  | Position/timing of pulses | High noise immunity systems     |

### Diagram: Pulse Modulation Waveforms

Modulating Signal

```

      /\      /\
     /\ {    /\ }
    /\ {    /\ }
   /\ {    /\ }
  /\ {    /\ }

```

PAM

```

| | | | |
| | | | |
| | | | |

```

PWM

```

| | | | |
| | | | |
| | | | |

```

PPM

```

| | | | |
| | | | |
| | | | |

```

- **PAM:** Simplest form, most susceptible to noise
- **PWM:** Better noise immunity, easy generation
- **PPM:** Best noise immunity, requires precise timing

### Mnemonic

“AWP-PAW” (Amplitude, Width, Position - Pulse Alteration Ways)

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

What is slope overload noise and granular noise in DM?

### Solution

Table 14: Noise Types in Delta Modulation

| Noise Type           | Definition  | Cause  | Solution                                 |
|----------------------|---|--|--|
| Slope Overload Noise | Error when signal slope exceeds step size capability          | Step size too small for rapidly changing signals | Increase step size or sampling frequency |
| Granular Noise       | Error due to continuous hunting around slowly varying signals | Step size too large for slowly changing signals  | Decrease step size                       |

### Diagram: DM Noise Types

Slope Overload:

Actual /  
/  
/  
/  
\\\_\\\_\\\_/  
/  
/ DM Output (steps can't keep up)}

Granular Noise:

Actual \\\_\\\_\\\_\\\_\\\_\\\_\\\_\\\_\\\_  
  
/{//// DM Output (continuous zigzag)}

**Mnemonic**

“FAST-SLOW” (Fast signals cause Slope overload, SLOW signals cause Granular noise)

**Mnemonic**

“FAST-SLOW” (Fast signals cause Slope overload, SLOW signals cause Granular noise)

Question 4(b) [4 marks]

Draw and explain TDM frame.

#### Solution

**Diagram: TDM Frame Structure**

The diagram illustrates the TDM frame structure. It shows a sequence of samples for multiple channels (CH1, CH2, CH3, ..., CHn) and Frame Sync (FS) markers. The frame synchronization process is shown, where the last channel sample is followed by the channel 3 sample, channel 2 sample, channel 1 sample, and the frame synchronization marker.

| FS | CH1 | CH2 | CH3 | ... | CHn | FS                        |
|----|-----|-----|-----|-----|-----|---------------------------|
|    |     |     |     |     |     |                           |
|    |     |     |     |     |     | Frame Sync for next frame |
|    |     |     |     |     |     | Last channel sample       |
|    |     |     |     |     |     | Channel 3 sample          |
|    |     |     |     |     |     | Channel 2 sample          |
|    |     |     |     |     |     | Channel 1 sample          |
|    |     |     |     |     |     | Frame Synchronization     |

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| FS | CH1 | CH2 | CH3 | ... | CHn | FS                        |
|----|-----|-----|-----|-----|-----|---------------------------|
|    |     |     |     |     |     |                           |
|    |     |     |     |     |     | Frame Sync for next frame |
|    |     |     |     |     |     | Last channel sample       |
|    |     |     |     |     |     | Channel 3 sample          |
|    |     |     |     |     |     | Channel 2 sample          |
|    |     |     |     |     |     | Channel 1 sample          |
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| FS | CH1 | CH2 | CH3 | ... | CHn | FS                        |
|----|-----|-----|-----|-----|-----|---------------------------|
|    |     |     |     |     |     |                           |
|    |     |     |     |     |     | Frame Sync for next frame |
|    |     |     |     |     |     | Last channel sample       |
|    |     |     |     |     |     | Channel 3 sample          |
|    |     |     |     |     |     | Channel 2 sample          |
|    |     |     |     |     |     | Channel 1 sample          |
|    |     |     |     |     |     | Frame Synchronization     |

**Mnemonic**  
“FAST-Ch” (Frame And Slots for Transmitting Channels)

**Mnemonic**  
“FAST-Ch” (Frame And Slots for Transmitting Channels)

Question 4(c) [7 marks]

Describe the function of each block of PCM transmitter and Receiver. Give application, advantage and disadvantage of PCM system.

## Solution

### Diagram: PCM System

```
flowchart LR
    subgraph "PCM Transmitter"
        A[Sampler] --> B[Quantizer]
        B --> C[Encoder]
        C --> D[Line Coder]
    end
    subgraph "PCM Receiver"
        E[Line Decoder] --> F[Decoder]
        F --> G[Reconstruction Filter]
    end
    D --> E
```

Table 16: PCM Block Functions

| Block                 | Function                                  |
|-----------------------|---|
| Sampler               | Converts analog signal to PAM signal      |
| Quantizer             | Assigns discrete levels to samples        |
| Encoder               | Converts quantized levels to binary code  |
| Line Coder            | Converts binary to transmission format    |
| Line Decoder          | Recovers binary from received signal      |
| Decoder               | Converts binary back to quantized levels  |
| Reconstruction Filter | Smooths decoded output into analog signal |

### Applications, Advantages and Disadvantages:

Table 17: PCM System Characteristics

| Category      | Description  |
|---------------|--|
| Applications  | Telephone systems, CD audio, Digital TV, Mobile communications                 |
| Advantages    | Immune to noise, Signal regeneration possible, Compatible with digital systems |
| Disadvantages | Requires higher bandwidth, Higher complexity, Quantization noise               |

## Mnemonic

“SEQUEL-DR” (Sample, Quantize, Encode - Line code, Decode, Reconstruct)

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

Give difference between DM and ADM modulation.

## Solution

Table 18: Comparison between DM and ADM

| Parameter        | Delta Modulation (DM)                          | Adaptive Delta Modulation (ADM)   |
|------------------|--|-----------------------------------|
| Step Size        | Fixed  | Variable (adapts to signal slope) |
| Tracking Ability | Limited  | Better signal tracking            |
| Noise            | Suffers from slope overload and granular noise | Reduced noise problems            |
| Performance      |  |                                   |
| Complexity       | Simpler  | More complex                      |

### Diagram: DM vs ADM Tracking

Input Signal: / {}  
/ {}  
/ {}  
/ {}  
DM Output: / {/ / }  
/ {/ / }  
ADM Output: / {/ }  
/ { / }  
(larger steps for steep slopes)

### Mnemonic

“FAST-VAR” (Fixed And Simple Tracking vs Variable Adaptive Response)

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

Explain Block diagram of basic PCM-TDM system.

### Solution

#### Diagram: PCM-TDM System

```
flowchart LR
    A[Input 1] --> B[Low-pass Filter]
    C[Input 2] --> D[Low-pass Filter]
    E[Input n] --> F[Low-pass Filter]
    B --> G[Multiplexer]
    D --> G
    F --> G
    G --> H[PCM Encoder]
    H --> I[Transmission Channel]
    I --> J[PCM Decoder]
    J --> K[Demultiplexer]
    K --> L[Output 1]
    K --> M[Output 2]
    K --> N[Output n]
```

Table 19: PCM-TDM System Components

| Component            | Function                                       |
|----------------------|--|
| Low-pass Filters     | Limit bandwidth of input signals               |
| Multiplexer          | Combines multiple signals into time slots      |
| PCM Encoder          | Converts to digital (sample, quantize, encode) |
| Transmission Channel | Carries digitized, multiplexed signal          |
| PCM Decoder          | Reconstructs quantized samples                 |
| Demultiplexer        | Separates channels from time slots             |

- **Working principle:** Combines time division multiplexing with pulse code modulation
- **Applications:** Digital telephony, digital audio broadcasting, communication networks

### Mnemonic

“FLIMPED” (Filter, Limit, Multiplex, PCM Encode, Decode)

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

Explain DPCM modulator with equation and waveform.

## Solution

**Differential Pulse Code Modulation (DPCM)** encodes the difference between the current sample and a predicted value based on previous samples.

**Equation:**

- Error signal:  $e(n) = x(n) - \hat{x}(n)$
- Where  $x(n)$  is current sample,  $\hat{x}(n)$  is predicted sample
- Prediction:  $\hat{x}(n) = \Sigma(a \times x(n-i))$
- Transmitted signal: DPCM output =  $Q[e(n)]$

**Diagram: DPCM Modulator**

flowchart LR

```

    A[Input x\_n] --> B[Add]
    B --> C[Quantizer]
    C --> D[Encoder]
    D --> E[Output]
    E --> F[Predictor]
    F --> G[Subtract]
    G --> B
  
```

**Diagram: DPCM Waveform**

Original Samples:

```

    *   *   *   *   *
    |   |   |   |   |
    |   |   |   |   |
    |   |   |   |   |
  
```

Predicted Samples:

```

    o   o   o   o
    |   |   |   |
    |   |   |   |
    |   |   |   |
  
```

Difference (DPCM):

(smaller values)

Table 20: DPCM Characteristics

| Feature     | Description                                    |
|-------------|--|
| Advantage   | Reduced bit rate (30-50% compared to PCM)      |
| Prediction  | Uses previous sample(s) for current prediction |
| Complexity  | Higher than PCM but lower than ADPCM           |
| Application | Speech coding, image compression               |

## Mnemonic

“PQED” (Predict, Quantize Error, Encode Difference)

## Question 5(a) [3 marks]

Define Antenna and radiation pattern and polarization.

## Solution

Table 21: Antenna Definitions

| Term              | Definition  |
|-------------------|---|
| Antenna           | A device that converts electrical energy into electromagnetic waves and vice versa                |
| Radiation Pattern | Graphical representation of radiation properties of an antenna as a function of space coordinates |

Polarization

Orientation of the electric field vector of the electromagnetic wave radiated by the antenna

**Types of Polarization:**

- **Linear:** Electric field oscillates in one direction (vertical, horizontal)
- **Circular:** Electric field rotates with constant amplitude (RHCP, LHCP)
- **Elliptical:** Electric field rotates with varying amplitude

**Mnemonic**

“WAVE-PRO” (Wireless Antenna Validates Electromagnetic Propagation, Radiation, Orientation)

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

Explain Microstrip Antenna with sketch.

**Solution**

**Diagram: Microstrip Patch Antenna**

(radiating element)

substrate

plane

Feed point

Table 22: Microstrip Antenna Components

| Component    | Function                                     |
|--------------|--|
| Patch        | Radiating element (usually copper)           |
| Substrate    | Dielectric material between patch and ground |
| Ground Plane | Metal layer at bottom                        |
| Feed Point   | Connection point for signal                  |

- **Working principle:** Fringing fields at edges cause radiation
- **Advantages:** Low profile, lightweight, easy fabrication, compatible with PCB
- **Applications:** Mobile devices, satellites, aircraft, RFID tags

**Mnemonic**

“SPGF” (Substrate, Patch, Ground, Feed)

**Question 5(c) [7 marks]**

Explain delta modulation with necessary sketch and waveform.

**Solution**

Delta Modulation (DM) is the simplest form of differential pulse code modulation where the difference between successive samples is encoded into a single bit.

**Diagram: Delta Modulator**

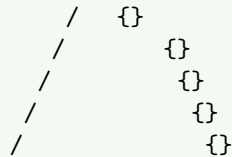
```

flowchart LR
    A[Input Signal] --{-}-> B((+))
    B --{-}-> C[1{-}bit Quantizer]
    C --{-}-> D[Output]
    C --{-}-> E[Delay]
    E --{-}-> F[Integrator]
    F --{-}-> G((-))
    G --{-}-> B

```

#### Diagram: Delta Modulation Waveform

Input Signal:



Clock Pulses:



DM Output (bits):

1 1 1 1 0 0 0 0 1 1 1 0 0 0 0

Step Approximation:

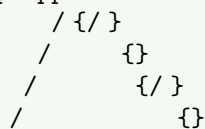


Table 23: Delta Modulation Characteristics

| Characteristic | Description  |
|----------------|--|
| Bit Rate       | 1 bit per sample   |
| Step Size      | Fixed (major limitation)                                   |
| Slope Overload | Occurs when signal changes faster than step size can track |
| Granular Noise | Occurs in slowly changing signals (continuous hunting)     |
| Advantages     | Simplicity, low bit rate                                   |
| Disadvantages  | Limited dynamic range, noise problems                      |

#### Mnemonic

“SIGN-UP” (SInGLE bit, Next step Up or down, Predict)

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

What is smart antenna? list application of it.

#### Solution

A **Smart Antenna** is an adaptive array system that uses digital signal processing algorithms to dynamically adjust its radiation pattern to enhance communication performance.

Table 24: Smart Antenna Applications

| Application              | Benefit                                      |
|--------------------------|--|
| Cellular Base Stations   | Increased capacity and coverage              |
| Wireless LAN             | Improved throughput and reduced interference |
| Satellite Communications | Better signal quality and power efficiency   |



Military Communications  
IoT Networks

Enhanced security and jam resistance  
Extended battery life, improved connectivity

- **Working principle:** Uses beamforming to focus signal energy toward desired users
- **Types:** Switched beam systems and adaptive array systems

#### Mnemonic

“SWIM-CM” (Smart Wireless In Mobile-Cellular-Military)

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

Explain parabolic reflector antenna With Sketch.

#### Solution

Diagram: Parabolic Reflector Antenna

Feed  
Point

Table 25: Parabolic Reflector Components

| Component            | Function                                   |
|----------------------|--|
| Parabolic Dish       | Reflects and focuses signals               |
| Feed Horn            | Radiates/receives signals at focal point   |
| Supporting Structure | Maintains geometry and stability           |
| Waveguide            | Connects feed horn to transmitter/receiver |

- **Working principle:** Incoming parallel rays are reflected to focus at focal point
- **Characteristics:** High gain, directivity, narrow beamwidth
- **Applications:** Satellite communication, radio astronomy, radar, microwave links

#### Mnemonic

“PFGH” (Parabolic Focus Gives High-gain)

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

Explain Adaptive Delta modulation with necessary sketch and waveform.

#### Solution

Adaptive Delta Modulation (ADM) improves on standard DM by dynamically adjusting the step size according to the input signal characteristics.

**Diagram: Adaptive Delta Modulator**

flowchart LR

A[Input Signal] --{-{-} B((+))-->

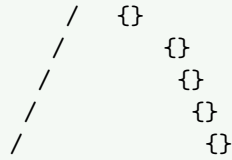
```

B {-{-} C[1{-}bit Quantizer]]
C {-{-} D[Output]]
C {-{-} E[Step Size Control]]
E {-{-} F[Integrator]]
F {-{-}|Approximated Signal| G((-))}
G {-{-} B}

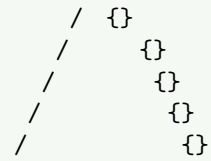
```

### Diagram: ADM Waveform

Input Signal:



ADM Output (variable step):



(larger steps for steep slopes)

Table 26: ADM Characteristics

| Aspect        | Description                                   |
|---------------|---|
| Step Size     | Variable (adapts to signal slope)             |
| Control Logic | Increases step size for consecutive same bits |
| Advantages    | Reduced slope overload and granular noise     |
| Disadvantages | More complex than DM                          |
| Applications  | Speech coding, telemetry, digital telephony   |
| Performance   | Better SNR than DM at same bit rate           |

- **Step size adaptation:**  $(n) = (n-1) \times K$  if consecutive bits are same
- **Step size adaptation:**  $(n) = (n-1) / K$  if consecutive bits change

### Mnemonic

“ADVISED” (ADaptive Variable Increment Step for Enhanced Delta modulation)