Subject Name Solutions

4331104 – Summer 2024

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Draw and explain block diagram of communication system.

Solution

```
flowchart LR
    A[Information Source] {-{-} B[Transmitter]}
    B {-{-} C[Channel/Medium]}
    C {-{-} D[Receiver]}
    D {-{-} E[Destination]}
    F[Noise Source] {-{-} C}
```

- **Information Source**: Generates message signal (voice, video, data)
- **Transmitter**: Converts message to suitable form for transmission
- **Channel**: Medium through which signal travels (wires, fiber, air)
- **Receiver**: Extracts original message from received signal
- **Destination**: End-user who receives the information

Mnemonic

"Information Travels Carefully Reaching Destination"

Question 1(b) [4 marks]

Explain applications of EM wave spectrum.

Solution

Frequency Band	Frequency Range	Applications
Radio waves	3 kHz - 300 MHz	AM/FM broadcasting, maritime communication
Microwaves	300 MHz - 300 GHz	Radar, satellite communication, microwave ovens
Infrared	300 GHz - 400 THz	Remote controls, thermal imaging, optical fibers
Visible light	400 THz - 800 THz	Fiber optic communication, photography
Ultraviolet	800 THz - 30 PHz	Sterilization, authentication, water purification
X-rays	30 PHz - 30 EHz	Medical imaging, security scanning, material analysis
Gamma rays	>30 EHz	Cancer treatment, food sterilization, industrial inspection

Mnemonic

"Radio Makes Invisible Very eXtreme Gamma signals"

Question 1(c) [7 marks]

State and explain external and internal noise.

Solution

Type	External Noise	Internal Noise
Source	Outside the communication system	Inside electronic components
Types	Atmospheric, Space, Industrial, Man-made	Thermal, Shot, Transit-time, Flicker
Control	Can be reduced by shielding, filtering	Reduced by better components, cooling
Examples	Lightning, Solar radiation, Motor sparking	Electron movement in resistors, semiconductors
Nature	Usually unpredictable, varying	More consistent and quantifiable

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Noise in Communication] {-{-}{} B[External Noise]}
    A {-{-}{} C[Internal Noise]}
    B {-{-}{} D[Atmospheric Noise]}
    B {-{-}{} E[Space Noise]}
    B {-{-}{} F[Industrial Noise]}
    B {-{-}{} G[Man{-}made Noise]}
    C {-{-}{} H[Thermal Noise]}
    C {-{-}{} I[Shot Noise]}
    C {-{-}{} J[Transit{-}time Noise]}
    C {-{-}{} K[Flicker Noise]}
{Highlighting}
{Shaded}
```

Mnemonic

"External Environmental Sources Invade; Internal Components Generate Noise"

Question 1(c) OR [7 marks]

Draw and explain the block diagram of a Superheterodyne AM receiver.

Solution

```
flowchart LR
    A[Antenna] {-{-} B[RF Amplifier]}
    B {-{-} C[Mixer]}
    D[Local Oscillator] {-{-} C}
    C {-{-} E[IF Amplifier]}
    E {-{-} F[Detector]}
    F {-{-} G[AF Amplifier]}
    G {-{-} H[Speaker]}
    I[AGC] {-{-} B}
    I {-{-} E}
    F {-{-} I}
```

Block	Function
RF Amplifier	Amplifies weak radio signals and provides selectivity
Local Oscillator	Generates frequency for mixing with incoming signal
Mixer	Combines RF and local oscillator signals to produce IF

IF Amplifier	Amplifies signal at fixed intermediate frequency (455 kHz)
Detector	Extracts audio from modulated carrier (demodulation)
AF Amplifier	Amplifies audio signal to drive speaker
AGC	Automatic Gain Control - maintains constant output level

Mnemonic

"Radio Loves Making Interesting Detected Audio Sounds"

Question 2(a) [3 marks]

Define modulation. State types of modulation.

Solution

Modulation: Process of varying one or more properties of a high-frequency carrier signal with a modulating signal containing information.
Types of Modulation:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Modulation] {-{-}{} B[Analog Modulation]}
    A {-{-}{} C[Digital Modulation]}
    A {-{-}{} D[Pulse Modulation]}
    B {-{-}{} E[AM]}
    B {-{-}{} F[FM]}
    B {-{-}{} G[PM]}
    C {-{-}{} H[ASK]}
    C {-{-}{} I[FSK]}
    C {-{-}{} J[PSK]}
    D {-{-}{} K[PAM]}
    D {-{-}{} L[PWM]}
    D {-{-}{} M[PPM]}
    D {-{-}{} N[PCM]}
{Highlighting}
{Shaded}
```

Mnemonic

"All Modulations Alter Properties: Frequency, Amplitude, Phase"

Question 2(b) [4 marks]

Define: Signal to noise ratio and Noise figure.

Solution

Parameter	Definition	Formula	Unit	Significance
Signal to Noise Ratio (SNR)	Ratio of signal power to noise power	SNR = P_signal / P_noise	Expressed in dB	Higher value indicates better signal quality
Noise Figure (NF)	Measure of degradation of SNR as signal passes through system	NF = SNR_input / SNR_output	Expressed in dB	Lower value indicates better performance

Mnemonic

"SNR Shows Necessary Reception; Noise Figure Finds Fault"

Question 2(c) [7 marks]

Compare PAM, PWM and PPM techniques.

Solution

Parameter	PAM	PWM	PPM
Full Form	Pulse Amplitude Modulation	Pulse Width Modulation	Pulse Position Modulation
Modulated Parameter	Amplitude of pulses	Width/duration of pulses	Position/timing of pulses
Noise Immunity	Poor	Good	Excellent
Bandwidth	Low	Medium	High
Circuit Complexity	Simple	Moderate	Complex
Power Efficiency	Poor	Good	Excellent
Applications	Simple data sampling	Motor control, power regulation	Precision timing, optical communication

Diagram:

```
Original:


PAM:


PWM:


PPM:
```

Mnemonic

"Amplitude varies height, Width varies length, Position varies timing"

Question 2(a) OR [3 marks]

Differentiate between bit, symbol and Baud rate.

Solution

Parameter	Bit	Symbol	Baud Rate
Definition	Binary digit (0 or 1)	Group of bits	Number of symbols transmitted per second
Unit	No unit	No unit	Symbols per second (Baud)
Relationship	Basic unit of digital information	Multiple bits form one symbol	Baud rate $\times bitspersymbol = bitrate$
Example	0, 1	In 4-QAM, each symbol represents 2 bits	1200 baud means 1200 symbols per second

Mnemonic

"Bits Build Symbols, Bauds Show Speed"

Question 2(b) OR [4 marks]

State advantages and disadvantage of SSB over DSB.

Solution

Advantages of SSB over DSB	Disadvantages of SSB over DSB
Bandwidth: Requires only half the bandwidth	**Circuit Complexity**: More complex modulation and demodulation
Power Efficiency: Transmits only one sideband, saving power	**Receiver Design**: Requires precise frequency synchronization
Less Fading: Reduced selective fading effects	**Low Frequency Loss**: May lose low frequency components
Less Interference: Reduced adjacent channel interference	**Cost**: More expensive implementation

Mnemonic

"SSB Saves Bandwidth Power but Costs Complex Hardware"

Question 2(c) OR [7 marks]

Compare Amplitude Modulation (AM) and Frequency Modulation (FM).

Solution

Parameter	AM	FM
Modulated Parameter	Amplitude of carrier	Frequency of carrier
Bandwidth	Narrow (2 $\times highestmodulatingfrequency$)	Wide (2 $\times (highestmodulatingfrequency + deviation)$)
Noise Immunity	Poor	Excellent
Power Efficiency	Poor (carrier contains most power)	Good
Circuit Complexity	Simple	Complex
Quality	Lower	Higher
Applications	Broadcasting (MW), Aircraft communication	FM radio, TV sound, Mobile communications

Diagram:

```
Carrier:

AM:

FM:
```

Mnemonic

"AM Alters strength, FM Fluctuates timing"

Question 3(a) [3 marks]

Compare AM receiver with FM receiver.

Solution

Parameter	AM Receiver	FM Receiver
IF Frequency	455 kHz	10.7 MHz
Detector	Envelope detector	Discriminator/Ratio detector/PLL
Bandwidth	Narrow ($\pm 5kHz$)	Wide ($\pm 75kHz$)
Special Circuits	Simple	Limiter, De-emphasis
Complexity	Simple	Complex

Mnemonic

"AM Accepts Minimal bandwidth; FM Features More circuits"

Question 3(b) [4 marks]

Define sampling? Explain types of sampling in brief.

Solution

Sampling: Process of converting continuous-time signal into discrete-time signal by taking samples at regular intervals.

Type of Sampling	Description	Characteristics
Ideal Sampling	Instantaneous samples of the signal	Perfect but theoretical, uses impulse function
Natural Sampling	Signal is sampled for short durations	Top of pulses follow original signal
Flat-top Sampling	Samples held constant until next sample	Creates staircase approximation, easier to implement

Diagram:

```
Original:

Ideal:


Natural:


Flat{-top:                }
```

Mnemonic

"Ideal takes Instants, Natural follows Nicely, Flat stays Fixed"

Question 3(c) [7 marks]

Draw and explain the block diagram of FM receiver. What is the use of Limiter in FM receiver?

Solution

```
flowchart LR
    A[Antenna] {-{-} B[RF Amplifier]}
```

```
    B {-{-} C[Mixer]}
    D[Local Oscillator] {-{-} C}
    C {-{-} E[IF Amplifier]}
    E {-{-} F[Limiter]}
    F {-{-} G[Discriminator]}
    G {-{-} H[De{-}emphasis]}
    H {-{-} I[AF Amplifier]}
    I {-{-} J[Speaker]}
```

Block	Function
RF Amplifier	Amplifies weak RF signal and provides selectivity
Mixer/Local Oscillator	Converts RF to IF (10.7 MHz)
IF Amplifier	Provides gain and selectivity at fixed frequency
Limiter	Removes amplitude variations, preserves frequency variations
Discriminator	Converts frequency variations to amplitude variations
De-emphasis	Reduces high-frequency noise
AF Amplifier	Amplifies recovered audio for speaker

Limiter Function: Removes amplitude variations from the FM signal before demodulation to ensure noise immunity, as information in FM is contained in frequency variations, not amplitude.

Mnemonic

"Radio Mixers Increase Frequency; Limiters Discriminate Audio Sound"

Question 3(a) OR [3 marks]

Describe the concept of single side band (SSB) transmission.

Solution

Single Sideband (SSB) Transmission: Technique where only one sideband (upper or lower) is transmitted while suppressing the carrier and other sideband.

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[AM Signal] {-{-}{} B[DSBFC]}
    A {-{-}{} C[DSBSC]}
    A {-{-}{} D[SSB]}
    D {-{-}{} E[USB]}
    D {-{-}{} F[LSB]}
{Highlighting}
{Shaded}
```

- **Bandwidth**: Requires only half the bandwidth (fc $\pm fm$)
- **Power Efficiency**: More efficient as power concentrated in one sideband
- **Types**: USB (Upper Sideband) and LSB (Lower Sideband)

Mnemonic

"SSB Saves Spectrum Bandwidth"

Question 3(b) OR [4 marks]

Explain pre-emphasis & de-emphasis circuit.

Solution

Parameter	Pre-emphasis	De-emphasis
Location	Transmitter	Receiver
Circuit Type	High-pass RC network	Low-pass RC network
Function	Boosts high frequencies before transmission	Attenuates high frequencies after reception
Purpose	Improves SNR for high frequencies	Restores original frequency response

Circuit Diagram:

```
Pre{-emphasis:                De{-}emphasis:}

    R                            R




          C                            C
```

Mnemonic

"Pre Pushes highs, De Drops them"

Question 3(c) OR [7 marks]

Illustrate generation of FM signal using Phase lock loop technique.

Solution

```
flowchart LR
    A[Modulating Signal] {-{-} B[Loop Filter]}
    B {-{-} C[VCO]}
    C {-{-} D[FM Output]}
    C {-{-} E[Phase Detector]}
    F[Reference Oscillator] {-{-} E}
    E {-{-} B}
```

Component	Function
Phase Detector	Compares reference and VCO signals, generates error voltage
Loop Filter	Filters error voltage and combines with modulating signal
VCO (Voltage Controlled Oscillator)	Generates frequency based on control voltage
Reference Oscillator	Provides stable reference frequency

Working Process:

1. Modulating signal is applied to loop filter
2. VCO frequency shifts proportional to modulating signal
3. Phase detector generates error signal
4. Loop maintains lock while allowing frequency modulation
5. Output of VCO is the FM signal

Mnemonic

"Phase Locks, Voltage Controls, Frequency Modulates"

Question 4(a) [3 marks]

Explain quantization process and its importance.

Solution

Quantization: Process of mapping continuous amplitude values to a finite set of discrete levels in analog-to-digital conversion.

Aspect	Description
Process	Dividing amplitude range into fixed levels and assigning digital values
Types	Uniform (equal steps) and Non-uniform (variable steps)
Error	Difference between actual and quantized value (quantization noise)

Importance:

- Enables digital representation of analog signals
- Determines resolution and accuracy of digital signal
- Affects signal-to-noise ratio in digital systems

Mnemonic

"Quantization Creates Digital from Analog"

Question 4(b) [4 marks]

Explain different characteristics of Radio receiver.

Solution

Characteristic	Definition	Significance
Sensitivity	Ability to receive weak signals	Determines reception range
Selectivity	Ability to separate adjacent channels	Prevents interference
Fidelity	Accuracy of reproduction	Determines sound quality
Image Rejection	Ability to reject image frequency	Prevents unwanted reception

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Radio Receiver Characteristics] {-{-}{} B[Sensitivity]}
    A {-{-}{} C[Selectivity]}
    A {-{-}{} D[Fidelity]}
    A {-{-}{} E[Image Rejection]}
    B {-{-}{} F[Measured in  V]}
    C {-{-}{} G[Bandwidth and Q factor]}
    D {-{-}{} H[Frequency response]}
    E {-{-}{} I[Image ratio]}
{Highlighting}
{Shaded}
```

Mnemonic

"Sensitive Selection Faithfully Images"

Question 4(c) [7 marks]

Draw and explain the block diagram of PCM transmitter and receiver.

Solution

PCM Transmitter:

```
flowchart LR
    A[Input Signal] {-{-} B[Anti{-}aliasing Filter]}
    B {-{-} C[Sample \& Hold]}
    C {-{-} D[Quantizer]}
    D {-{-} E[Encoder]}
    E {-{-} F[Line Coder]}
    F {-{-} G[Transmission Channel]}
```

PCM Receiver:

```
flowchart LR
    A[Received Signal] {-{-} B[Line Decoder]}
    B {-{-} C[Regenerative Repeater]}
    C {-{-} D[Decoder]}
    D {-{-} E[Reconstruction Filter]}
    E {-{-} F[Output Signal]}
```

Block	Function
Anti-aliasing Filter	Limits input bandwidth to prevent aliasing
Sample & Hold	Converts continuous signal to discrete-time samples
Quantizer	Converts sample amplitudes to discrete levels
Encoder	Converts quantized values to binary code
Line Coder	Formats binary data for transmission
Decoder	Converts binary code back to quantized values
Reconstruction Filter	Smooths the stepped output to recover original signal

Mnemonic

"Sample, Quantize, Encode, Transmit; Decode, Reconstruct, Output"

Question 4(a) OR [3 marks]

Compare Natural and Flat top sampling.

Solution

Parameter	Natural Sampling	Flat-top Sampling
Shape	Top of pulses follow input signal	Constant amplitude during sampling interval
Implementation	More difficult (analog switch)	Easier (sample and hold circuit)
Spectrum	Less harmonics	More harmonics
Reconstruction	Easier, more accurate	Requires compensation for distortion

Diagram:

```
Signal:

Natural:


Flat{-top:                  }
```

Mnemonic

"Natural Follows, Flat Freezes"

Question 4(b) OR [4 marks]

Explain Diode Detector circuit.

Solution

Diode Detector Circuit: Used for demodulation of AM signals by extracting the envelope of the modulated wave.

```
                  D

Input
                           Output

                       C     R
```

Component	Function
Diode (D)	Rectifies the AM signal, passes only positive half
Capacitor (C)	Charges to peak value, smooths out carrier
Resistor (R)	Controls discharge time of capacitor

Working:

1. Diode rectifies AM signal
2. Capacitor charges to peak value
3. RC time constant allows capacitor to follow envelope
4. Output follows the original modulating signal

Mnemonic

"Diode Detects, Capacitor Captures"

Question 4(c) OR [7 marks]

Draw and explain the block diagram of Delta Modulation.

Solution

Delta Modulation Transmitter:

```
flowchart LR
    A[Input Signal] {-{-} B[Comparator]}
    B {-{-} C[1{-}bit Quantizer]}
    C {-{-} D[Transmission Channel]}
    C {-{-} E[Integrator]}
    E {-{-} B}
    D {-{-} F[To Receiver]}
```

Delta Modulation Receiver:

```
flowchart LR
    A[Received Signal] {-{-} B[Integrator]}
    B {-{-} C[Low{-}pass Filter]}
    C {-{-} D[Output Signal]}
```

Component	Function
Comparator	Compares input with predicted value
1-bit Quantizer	Outputs binary 1 if input > predicted, 0 if input < predicted
Integrator	Generates predicted value by integrating previous output
Low-pass Filter	Smooths stepped output to recover original signal

Limitations:

- **Slope Overload**: Occurs when signal changes faster than step size can track
- **Granular Noise**: Occurs during idle or constant parts of signal

Mnemonic

"Delta Detects Differences, Integrator Increments"

Question 5(a) [3 marks]

Illustrate working of DPCM.

Solution

DPCM (Differential Pulse Code Modulation): Encodes the difference between current sample and predicted value.

```
flowchart LR
    A[Input] {-{-} B[Sampler]}
    B {-{-} C[Difference Generator]}
    D[Predictor] {-{-} C}
    C {-{-} E[Quantizer]}
    E {-{-} F[Encoder]}
    F {-{-} G[Transmission]}
    E {-{-} H[Inverse Quantizer]}
    H {-{-} D}
```

- **Predictor**: Estimates current sample based on previous samples
- **Difference**: Only difference between actual and predicted is encoded
- **Advantage**: Reduces bit rate compared to PCM by exploiting signal correlation

Mnemonic

"Differences Predicted Create Minimized bits"

Question 5(b) [4 marks]

Illustrate Adaptive Delta Modulation.

Solution

Adaptive Delta Modulation (ADM): Improved version of DM that varies step size based on signal characteristics.

```
flowchart LR
    A[Input] {-{-} B[Comparator]}
    B {-{-} C[Pulse Generator]}
    C {-{-} D[Step Size Adapter]}
    D {-{-} E[Integrator]}
    E {-{-} B}
    C {-{-} F[Transmission]}
```

Component	Function
Comparator	Compares input with approximated signal
Step Size Adapter	Adjusts step size based on consecutive bit patterns
Integrator	Creates approximated signal from step-adjusted pulses
Pulse Generator	Generates binary output based on comparator

Operation:
1. If multiple 1's detected: increase step size to avoid slope overload
2. If multiple 0's detected: increase step size to track falling signal
3. If alternating 1's and 0's: decrease step size to reduce granular noise

Mnemonic

"Adapting Delta Makes Slopes Trackable"

Question 5(c) [7 marks]

Illustrate TDM frame.

Solution

TDM (Time Division Multiplexing) Frame: Structure used to combine multiple signals by assigning time slots.
Frame Structure:

```
                    TDM FRAME

   Frame    CH 1    CH 2    CH 3    CH 4       ...
   Sync    Sample  Sample  Sample  Sample      CH N



            TS1      TS2     TS3     TS4        TSn
```

Component	Description
Frame Sync	Pattern to identify frame boundaries

Channel Sample	Data from individual channel
Time Slot (TS)	Dedicated period for each channel
Frame Duration	Inversely proportional to sampling rate

TDM Hierarchy:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Primary Multiplexing 2.048 Mbps] {-{-}{} B[Secondary Multiplexing 8.448 Mbps]}
    B {-{-}{} C[Tertiary Multiplexing 34.368 Mbps]}
    C {-{-}{} D[Quaternary Multiplexing 139.264 Mbps]}
{Highlighting}
{Shaded}
```

Mnemonic

"Frames Synchronize Time Slots During Multiplexing"

Question 5(a) OR [3 marks]

State difference between DM and ADM.

Solution

Parameter	Delta Modulation (DM)	Adaptive Delta Modulation (ADM)
Step Size	Fixed step size	Variable step size
Slope Overload	Common problem	Reduced by adaptive step size
Granular Noise	High during slow variations	Reduced by adaptive step size
Circuit Complexity	Simpler	More complex
Signal Quality	Lower	Higher

Mnemonic

"DM's Fixed Steps; ADM Adapts"

Question 5(b) OR [4 marks]

Explain the need of line coding. Explain AMI technique.

Solution

Need for Line Coding:

- **DC Component**: To eliminate DC component for AC-coupled systems
- **Synchronization**: To provide timing information for clock recovery
- **Error Detection**: To enable detection of transmission errors
- **Spectral Efficiency**: To shape signal spectrum for efficient bandwidth use
- **Noise Immunity**: To provide resistance against channel noise

AMI (Alternate Mark Inversion) Technique:

Parameter	Description
Encoding Rule	Binary 0 $\rightarrow Zerovoltage, Binary 1 \rightarrow Alternatingpositive/negativevoltage$

DC Component	No DC component (balanced code)
Error Detection	Can detect violations in alternating pattern
Bandwidth	Requires less bandwidth than NRZ codes

Diagram:

```
Binary:   1   0   1   1   0   0   1   0   1   0   1   1

AMI:        \_          \_   \_      \_      \_
```

Mnemonic

"Alternating Marks Invert Polarity"

Question 5(c) OR [7 marks]

Draw and explain block diagram of basic PCM-TDM system.

Solution

```
flowchart TD
    subgraph "PCM{-TDM Transmitter"}
    A1[Channel 1] {-{-} B1[Low{-}pass Filter]}
    A2[Channel 2] {-{-} B2[Low{-}pass Filter]}
    A3[Channel 3] {-{-} B3[Low{-}pass Filter]}
    B1 {-{-} C1[Sample \& Hold]}
    B2 {-{-} C2[Sample \& Hold]}
    B3 {-{-} C3[Sample \& Hold]}
    C1 {-{-} D[Multiplexer]}
    C2 {-{-} D}
    C3 {-{-} D}
    D {-{-} E[Quantizer]}
    E {-{-} F[Encoder]}
    F {-{-} G[Line Coder]}
    end

    G {-{-} H[Transmission Channel]}

    subgraph "PCM{-TDM Receiver"}
    H {-{-} I[Line Decoder]}
    I {-{-} J[Regenerator]}
    J {-{-} K[Decoder]}
    K {-{-} L[Demultiplexer]}
    L {-{-} M1[Hold Circuit]}
    L {-{-} M2[Hold Circuit]}
    L {-{-} M3[Hold Circuit]}
    M1 {-{-} N1[Low{-}pass Filter]}
    M2 {-{-} N2[Low{-}pass Filter]}
    M3 {-{-} N3[Low{-}pass Filter]}
    N1 {-{-} O1[Channel 1]}
    N2 {-{-} O2[Channel 2]}
    N3 {-{-} O3[Channel 3]}
    end
```

Block	Function
Low-pass Filter (Input)	Limits bandwidth to satisfy sampling theorem
Sample & Hold	Captures instantaneous values of analog signals
Multiplexer	Combines samples from different channels into a single stream
Quantizer	Assigns discrete levels to sampled values
Encoder	Converts quantized values to binary code
Line Coder	Formats binary data for transmission
Regenerator	Restores signal degraded by noise and attenuation
Decoder	Converts binary code back to quantized values
Demultiplexer	Separates combined signal back into individual channels
Hold Circuit	Maintains sample value until next sample arrives
Low-pass Filter (Output)	Reconstructs original signal by removing sampling harmonics

Mnemonic

"Multiple Channels Sample, Quantize, Encode; Decode, Demultiplex, Filter"