

Subject Name Solutions

4331104 – Summer 2023

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Draw & explain block diagram of Communication system.

Solution

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph LR
    A[Input] --> B[Transmitter]
    B --> C[Channel]
    C --> D[Receiver]
    D --> E[Output]
    F[Noise Source] --> C
{Highlighting}
{Shaded}
```

- **Input:** Message signal originating from source
- **Transmitter:** Converts message to suitable form for transmission
- **Channel:** Medium through which signal travels
- **Receiver:** Extracts original message from received signal
- **Output:** Delivered message to destination
- **Noise Source:** Unwanted signals that interfere with communication

Mnemonic

“I Transmit Clearly Receiving Original Messages”

Question 1(b) [4 marks]

Explain need of modulation. State advantages of modulation.

Solution

Need for modulation:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph TD
    A[Practical Antenna Size] --> B[Modulation]
    C[Multiplexing] --> B
    D[Reducing Noise & Interference] --> B
    E[Signal Transmission Distance] --> B
{Highlighting}
{Shaded}
```

Advantages of modulation:

- **Reduced antenna size:** Practical antenna length = $\lambda/4$, higher frequency means smaller antenna
- **Multiplexing possible:** Multiple signals transmitted simultaneously through same channel
- **Increased range:** Modulated signals travel farther than baseband signals
- **Noise reduction:** Better SNR achieved through modulation techniques

Mnemonic

“Antennas Need Modulation For Reaching Anywhere with Noise Immunity”

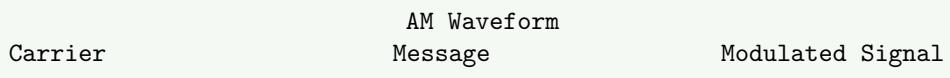
Question 1(c) [7 marks]

Define modulation. Explain Amplitude modulation with waveform and derive voltage equation for modulated signal.

Solution

Modulation: Process of varying a carrier signal's parameter (amplitude, frequency, phase) proportionally to the message signal.

Amplitude Modulation Waveform:



Derivation of AM voltage equation:

1. Carrier signal: $v_c(t) = V_c \sin(\omega_c t)$
2. Message signal: $v_m(t) = V_m \sin(\omega_m t)$
3. Modulated signal: $v_{AM}(t) = [V_c + V_m \sin(\omega_m t)] \sin(\omega_c t)$
4. Modulation index: $= V_m/V_c$
5. Final AM equation: $v_{AM}(t) = V_c[1 + M \sin(\omega_m t)] \sin(\omega_c t)$

Mnemonic

“Amplitude Modulation Makes Carrier Value Change”

Question 1(c) OR [7 marks]

Define noise. Give classification of noise and explain cause of any three internal noise.

Solution

Noise: Unwanted signals that interfere with communication signals, causing distortion or errors.

Classification of Noise:

External Noise	Internal Noise
Atmospheric	Thermal
Extraterrestrial	Shot
Industrial	Transit-time
	Flicker
	Partition

Causes of internal noise:

- **Thermal noise:**
 - Caused by random motion of electrons in conductors
 - Present in all electronic components
 - Directly proportional to temperature and bandwidth
- **Shot noise:**
 - Occurs due to random arrival of carriers at junctions
 - Found in active devices like diodes and transistors
 - Proportional to DC current flowing through device
- **Flicker noise:**
 - Results from surface defects and impurities in semiconductors
 - Inversely proportional to frequency ($1/f$ noise)
 - Significant at low frequencies

Mnemonic

“This Shooting Flicker Is Noisy Everywhere”

Question 2(a) [3 marks]

Define (1) Modulation index for AM (2) Noise Figure (3) Digital Modulation

Solution

1. **Modulation index for AM:** Ratio of amplitude of modulating signal to amplitude of carrier signal.
 - $= V_m/V_c$
 - Must be $0 \leq \leq 1$ to avoid distortion
2. **Noise Figure:** Ratio of input SNR to output SNR of a device.
 - $NF = (\text{SNR})_{\text{input}} / (\text{SNR})_{\text{output}}$
 - Indicates noise added by the system
 - Always ≥ 1 , expressed in dB
3. **Digital Modulation:** Technique that represents digital data as variations in carrier signal parameters.
 - Examples: ASK, FSK, PSK, QAM
 - Used for digital data transmission

Mnemonic

“Modulation Measures, Noise Numbers, Digital Data”

Question 2(b) [4 marks]

Derive equation for total power transmitted for amplitude modulated signal considering carrier power and modulation index.

Solution

Derivation of total power in AM:

1. AM wave equation: $v_{AM}(t) = V_c[1 + \sin(\omega_m t)] \sin(\omega_c t)$
2. For power calculation, consider RMS values:
 - Carrier power (P_c) = $V_c^2/2R$
 - Power in each sideband (PSB) = $(V_c^2)/4R$
3. Total power equation:
 - $PT = P_c + P_{USB} + P_{LSB}$
 - $PT = P_c + 2PSB$ (since upper and lower sidebands have equal power)
 - $PT = V_c^2/2R + 2(V_c^2)/4R$
 - $PT = (V_c^2/2R)[1 + (2/2)]$
4. Final equation: $PT = P_c(1 + M^2/2)$

Mnemonic

"Power Total = Power Carrier $(1 + \frac{2}{2})^2$ "

Question 2(c) [7 marks]

Explain basic principle of double sideband suppressed carrier amplitude modulation. Derive its voltage equation & draw only balanced modulator circuit using diode.

Solution

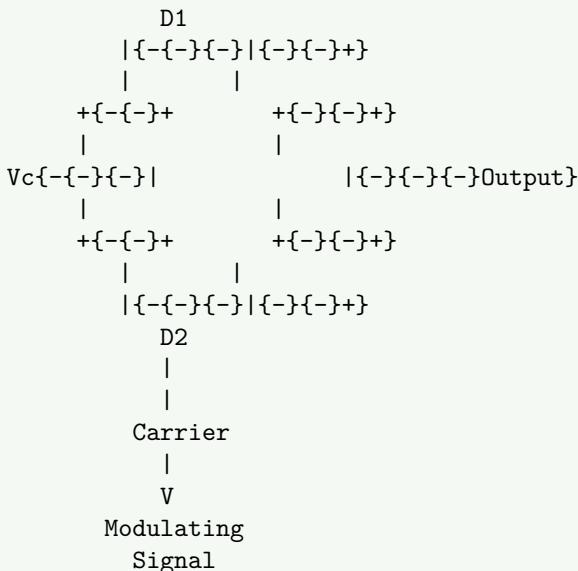
Double Sideband Suppressed Carrier (DSBSC) Principle:

- Carrier is suppressed, only sidebands transmitted
- Contains all information in sidebands
- More power efficient than AM
- Requires complex receiver for demodulation

Voltage equation derivation:

1. AM signal: $v_{AM}(t) = V_c[1 + \sin(mt)]\sin(ct)$
2. Removing carrier component: $v_{DSBSC}(t) = V_c \times \sin(mt)\sin(ct)$
2. Using trigonometric identity: $\sin(A)\sin(B) = 0.5[\cos(A-B) - \cos(A+B)]$
3. Final equation: $v_{DSBSC}(t) = (V_c/2)[\cos(c-m)t - \cos(c+m)t]$

Balanced Modulator Circuit using Diodes:



Mnemonic

"Delete Carrier, Save Bandwidth, Combine Signals"

Question 2(a) OR [3 marks]

Define only, w.r.t. radio receiver (1) Sensitivity (2) Selectivity (3) fidelity

Solution

1. **Sensitivity:** Ability of a receiver to detect and amplify weak signals.
 - Measured in microvolts (V)
 - Lower value indicates better sensitivity
 - Typically 1-10 V for commercial receivers
2. **Selectivity:** Ability to distinguish between desired signal and adjacent interfering signals.
 - Measured as bandwidth at -3dB points
 - Narrower bandwidth means better selectivity
 - Prevents adjacent channel interference
3. **Fidelity:** Accuracy with which receiver reproduces original message.

- Measures quality of reproduction
- Affected by distortion and noise
- Higher fidelity means better sound quality

Mnemonic

“Sensitive Selection Faithfully”

Question 2(b) OR [4 marks]

An AM signal has carrier power of 1 KW with 200 watt in each sideband. Find out modulation index.

Solution

Given:

- Carrier power (P_c) = 1 KW = 1000 W
- Power in each sideband (PSB) = 200 W

To find: Modulation index (m)

Solution:

1. Total sideband power: $PTSB = 2 \times PSB = 2 \times 200 = 400W$
1. Using formula: $PTSB = P_c \times^2 / 2$
1. $400 = 1000 \times^2 / 2$
1. $\frac{2}{2} = (400 \times 2) / 1000 = 800 / 1000 = 0.8$
1. $m = \sqrt{0.8} = 0.894 = 0.9(\text{approx})$

Mnemonic

“Sideband Power Reveals Modulation ”

Question 2(c) OR [7 marks]

Compare Amplitude modulation with Frequency Modulation considering minimum seven parameters/aspect.

Solution

Parameter	Amplitude Modulation (AM)	Frequency Modulation (FM)
Definition	Amplitude of carrier varies with message	Frequency of carrier varies with message
Bandwidth	Narrow ($2 \times f_m$)	Wide ($2 \times f_m$)
Power	Poor (carrier contains ~66% power)	Good (all power in sidebands)
Efficiency	Poor (noise affects amplitude)	Excellent (amplitude limiters remove noise)
Noise		
Immunity	Simple transmitters and receivers	Complex transmitters and receivers
Circuit		
Complexity		
Quality	Lower fidelity	Higher fidelity
Applications	Broadcasting, aircraft communication	FM radio, TV sound, wireless mics
Spectrum	Contains carrier and two sidebands	Contains infinite sidebands

Mnemonic

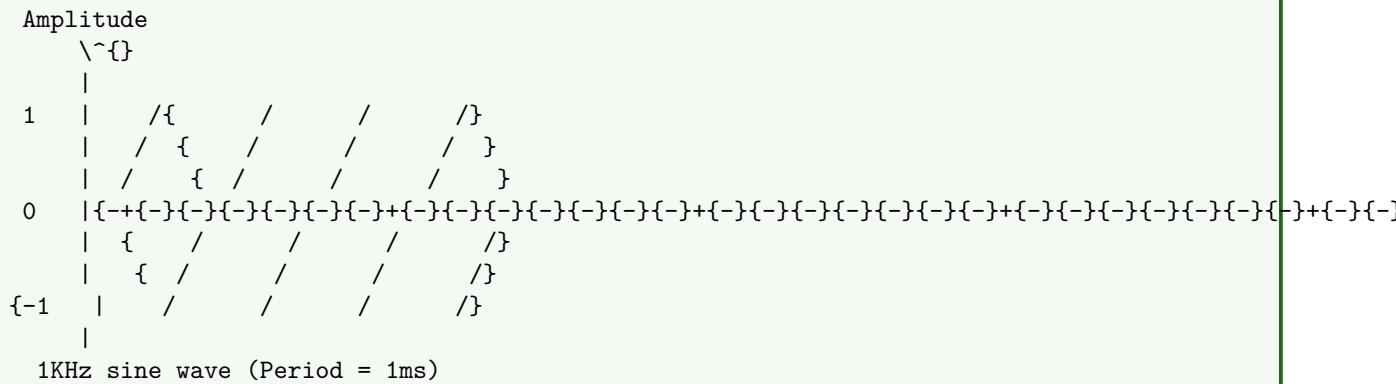
“Bandwidth, Efficiency, Noise, Quality - AM Fails Many Quality Tests”

Question 3(a) [3 marks]

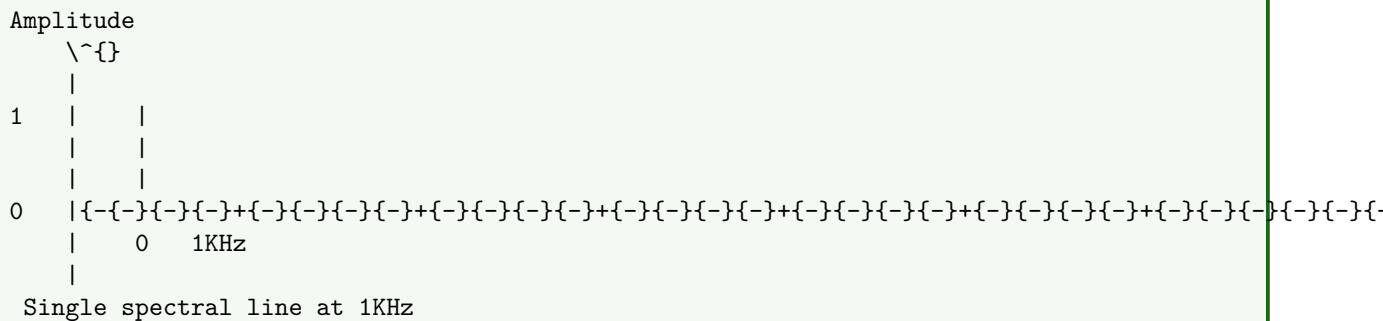
Draw and label sine wave of 1 KHZ in time domain and frequency domain. State advantage of frequency domain analysis of signal.

Solution

Time Domain Representation:



Frequency Domain Representation:



Advantages of frequency domain analysis:

- **Signal composition:** Easily identifies frequency components
- **Filter design:** Simplified filter response analysis
- **Bandwidth determination:** Direct visualization of spectrum width
- **Noise analysis:** Better separation of signal from noise

Mnemonic

“Frequency Shows Components Hidden in Time”

Question 3(b) [4 marks]

State following frequency (1) IF frequency for AM radio (2) IF frequency for FM radio (3) Frequency Band used in FM radio (4) Frequency Band of Human speech.

Solution

Parameter	Frequency
IF frequency for AM radio	455 kHz
IF frequency for FM radio	10.7 MHz
Frequency Band used in FM radio	88-108 MHz
Frequency Band of Human speech	300 Hz - 3.4 kHz

Mnemonic

“AM455, FM10.7, Band88-108, Speech300-3.4”

Question 3(c) [7 marks]

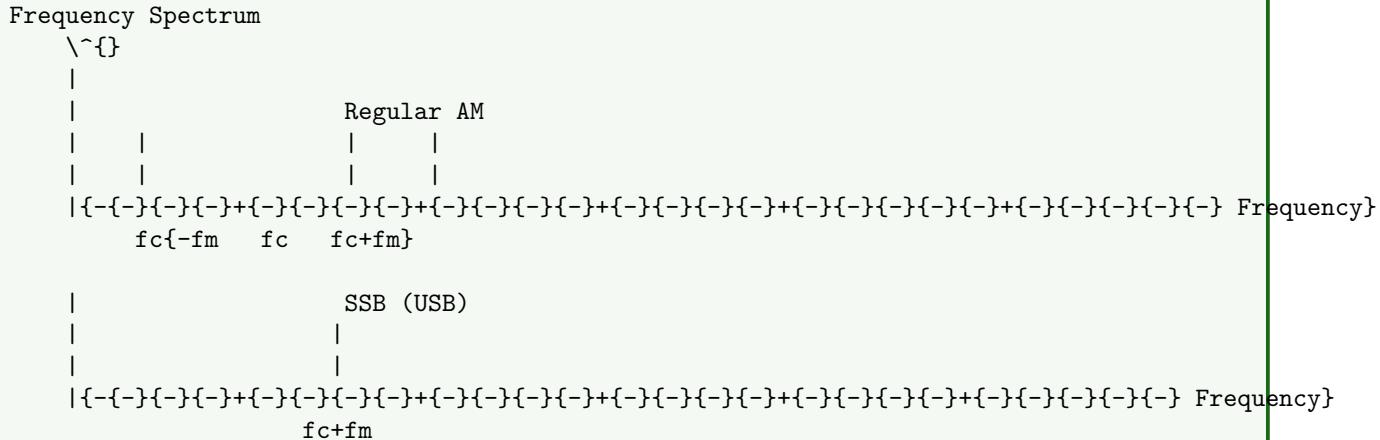
Explain Single side band (SSB) modulation with waveform and its advantages. Show how SSB transmission required only 1/6th of power with respect to double sideband full carrier amplitude modulation.

Solution

Single Side Band (SSB) Modulation:

- Transmits only one sideband (USB or LSB)
- Carrier and other sideband suppressed
- Conserves bandwidth and power

SSB Waveform:



Advantages of SSB:

- **Bandwidth efficiency:** Uses half bandwidth of AM
- **Power efficiency:** No power wasted on carrier
- **Less fading:** Improved performance in long-distance
- **Better SNR:** More power concentrated in information

Power Comparison:

1. In AM: $PT = P_c(1 + \frac{2}{2})$
1. For $\frac{2}{2} = 1$, $PT = P_c(1 + 0.5) = 1.5P_c$
2. AM power distribution: Carrier (P_c) = 67%, Sidebands = 33%
3. SSB uses only one sideband with no carrier
4. SSB power = 16.5% of total AM power = 1/6 approx.

Mnemonic

"Single Side Saves Bandwidth And Power"

Question 3(a) OR [3 marks]

State following. (1) Bandwidth of modulated signal if modulating frequency is 5 KHZ. (2) Image frequency if selected station frequency is 1000 KhZ in radio (3) Sampling frequency if baseband signal frequency is 10 KHz.

Solution

1. **Bandwidth of AM with modulating frequency 5 kHz:**
 - $BW = 2 \times fm = 2 \times 5kHz = 10kHz$
2. **Image frequency for 1000 kHz station with 455 kHz IF:**
 - For high-side injection: $f_{image} = f_{station} + 2 \times f_{IF}$
 - $f_{image} = 1000 + 2 \times 455 = 1000 + 910 = 1910kHz$
3. **Sampling frequency for 10 kHz baseband:**
 - $f_s > 2 \times f_{max}(Nyquist rate)$
 - $f_s > 2 \times 10kHz = 20kHz$
 - Sampling frequency should be > 20 kHz

Mnemonic

“Bandwidth Doubles, Image Adds Twice-IF, Sampling Needs Twice-Frequency”

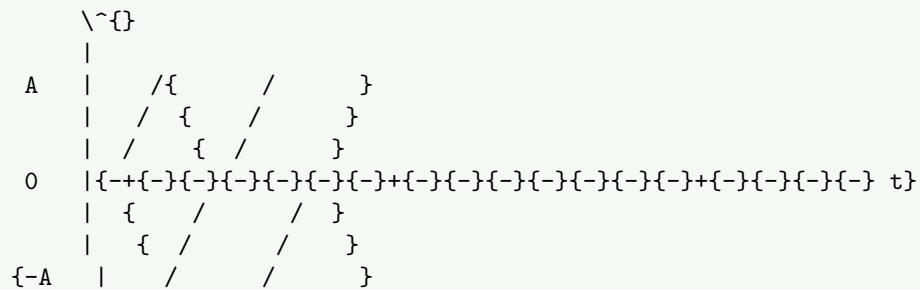
Question 3(b) OR [4 marks]

Draw following signal stating its mathematical equation. (1) Sine wave (2) Unit step signal (3) Ramp signal (4) Impulse signal.

Solution

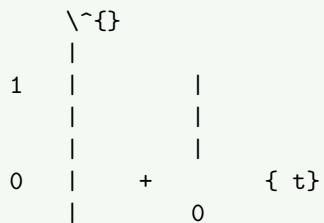
1. Sine Wave:

- Equation: $f(t) = A \sin(t + \phi)$



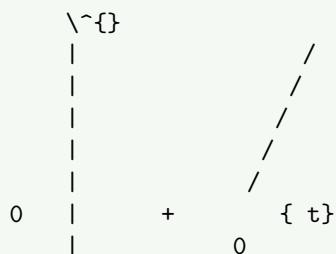
2. Unit Step Signal:

- Equation: $u(t) = 1 \text{ for } t \geq 0, 0 \text{ for } t < 0$



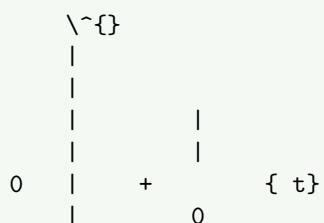
3. Ramp Signal:

- Equation: $r(t) = t \text{ for } t \geq 0, 0 \text{ for } t < 0$



4. Impulse Signal:

- Equation: $\delta(t) = \infty \text{ for } t = 0, 0 \text{ for } t \neq 0$



Mnemonic

“Sine Oscillates, Step Jumps, Ramp Climbs, Impulse Spikes”

Question 3(c) OR [7 marks]

Draw and explain Pre emphasis and De emphasis circuit with its need & characteristic graph. Also compare FM receiver with AM receiver in detail.

Solution

Pre-emphasis Circuit:

R

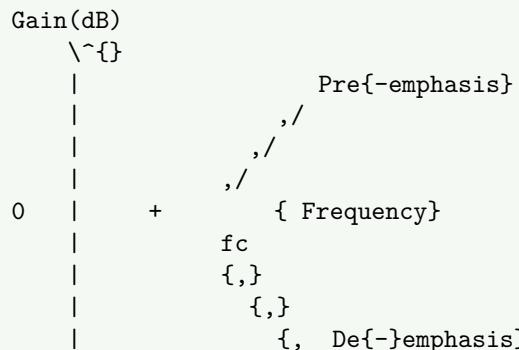
C

De-emphasis Circuit:

R

C

Characteristic Graph:



Need for Pre/De-emphasis:

- **Noise reduction:** Higher frequencies more susceptible to noise
- **Improves SNR:** Boosts high frequencies at transmitter, attenuates at receiver
- **Time constant:** Typically 75 s in FM broadcasting

Comparison between FM and AM Receiver:

Parameter	FM Receiver	AM Receiver
IF Frequency	10.7 MHz	455 kHz
Bandwidth	200 kHz	10 kHz
Limiter Stage	Present	Absent
Demodulator	Discriminator/ratio detector	Envelope detector
Pre/De-emphasis	Present	Absent
Audio Quality	Superior	Moderate
Noise Immunity	High	Low
Complexity	More complex	Simpler

Mnemonic

“Pre Boosts Highs, De Cuts Them; FM Filters Noise Better Than AM”

Question 4(a) [3 marks]

Define Image frequency in a radio receiver and explain it with suitable example.

Solution

Image Frequency: Unwanted signal frequency that produces the same IF as the desired signal when mixed with local oscillator signal.

Explanation:

- For high-side injection: $f_{image} = f_{signal} + 2 \times f_{IF}$
- For low-side injection: $f_{image} = f_{signal} - 2 \times f_{IF}$

Example:

- Desired signal: 1000 kHz
- IF: 455 kHz
- Local oscillator frequency (high-side): $f_{LO} = 1000 + 455 = 1455$ kHz
- Image frequency: $f_{image} = f_{LO} + 455 = 1455 + 455 = 1910$ kHz
- Both 1000 kHz and 1910 kHz will produce 455 kHz IF when mixed with 1455 kHz

Mnemonic

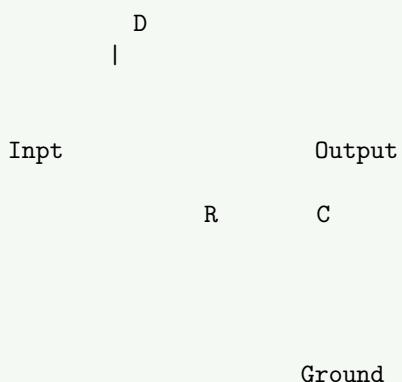
“Image In radio Is Interfering 2IF away”

Question 4(b) [4 marks]

Draw and explain envelope detector circuit for demodulation of Amplitude modulated signal.

Solution

Envelope Detector Circuit:



Working Principle:

- **Diode:** Rectifies AM signal, removing negative half-cycles
- **RC Circuit:** Acts as low-pass filter

- **Time Constant:** $RC \gg 1/fm$
- **Output:** Envelope of AM signal, which is the original message

Envelope Detection Process:

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

Mnemonic

“Diode Rectifies, RC Smooths Envelope”

Question 4(c) [7 marks]

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

Solution

AM Radio Receiver (Superheterodyne) Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph LR
    A[RF Amplifier] --> B[Mixer]
    G[Local Oscillator] --> B
    B --> C[IF Amplifier]
    C --> D[Detector]
    D --> E[AF Amplifier]
    E --> F[Speaker]
{Highlighting}
{Shaded}
```

Functions of each block:

- **RF Amplifier:**
 - Selects desired station signal using tuned circuit
 - Provides initial amplification
 - Improves sensitivity and selectivity
 - Reduces image frequency interference
- **Local Oscillator:**
 - Generates frequency higher than incoming by IF value
 - Typically $f_{LO} = f_{RF} + 455\text{ kHz}$
 - Tuned simultaneously with RF amplifier
- **Mixer:**
 - Combines RF signal with local oscillator
 - Produces sum and difference frequencies
 - Outputs intermediate frequency (IF)
- **IF Amplifier:**
 - Fixed-frequency amplifier (455 kHz)
 - Provides majority of receiver gain
 - Determines selectivity of receiver
- **Detector:**
 - Extracts original audio from IF signal
 - Usually envelope detector with diode
 - Removes RF component, recovers audio
- **AF Amplifier:**
 - Amplifies recovered audio signal
 - Includes volume control
 - Drives speaker to audible levels
- **Speaker:**
 - Converts electrical signals to sound waves

Mnemonic

“Radio Mixing Intermediate Detected Audio For Speaker”

Question 4(a) OR [3 marks]

State and explain Nyquist Criteria for sampling of signal.

Solution

Nyquist Criteria: To reconstruct a bandlimited signal without distortion, sampling frequency must be at least twice the highest frequency component in the signal.

Mathematical statement:

- $f_s \geq 2f_{max}$
- f_s = sampling frequency
- f_{max} = maximum frequency in signal

Explanation:

- Ensures no aliasing (frequency overlap) occurs
- Minimum sampling rate called Nyquist rate
- Sampling below Nyquist rate causes irreversible distortion
- In practice, $f_s > 2.2f_{max}$ used to allow for filtering

Example:

- For audio with $f_{max} = 20$ kHz
- Nyquist rate = $2 \times 20\text{kHz} = 40\text{kHz}$
- CD sampling rate = 44.1 kHz (> 40 kHz)

Mnemonic

“Sample at least Twice as Fast as Highest Frequency”

Question 4(b) OR [4 marks]

Explain slope overload and granular noise for a delta modulation.

Solution

Delta Modulation Issues:

Mermaid Diagram (Code)

```
{Shaded}  
{Highlighting} []  
graph LR  
    A[Delta Modulation Problems] --> B[Slope Overload]  
    A --> C[Granular Noise]  
    B --> D[Step size too small]  
    C --> E[Step size too large]  
{Highlighting}  
{Shaded}
```

Slope Overload:

- Occurs when input signal changes faster than DM can track
- Step size too small for rapidly changing signals
- DM output cannot “catch up” with input
- Creates distortion at sharp transitions
- Solution: Increase step size or sampling rate

Granular Noise:

- Occurs during relatively constant signal portions
- Step size too large for slowly changing signals
- Output oscillates around input value
- Creates “roughness” in reconstructed signal
- Solution: Decrease step size

Adaptive Delta Modulation (ADM): Dynamically adjusts step size to minimize both problems.

Mnemonic

“Slopes Need Bigger Steps, Flats Need Smaller Steps”

Question 4(c) OR [7 marks]

Draw and explain PCM transmitter and receiver in detail.

Solution

PCM Transmitter:

Mermaid Diagram (Code)

```
{Shaded}  
{Highlighting} []  
graph LR  
    A[Input Signal] --> B[Anti{-}aliasing Filter]  
    B --> C[Sample & Hold]  
    C --> D[Quantizer]  
    D --> E[Encoder]  
    E --> F[Digital Output]  
{Highlighting}  
{Shaded}
```

PCM Receiver:

Mermaid Diagram (Code)

```
{Shaded}  
{Highlighting} []  
graph LR  
    A[Digital Input] --> B[Decoder]  
    B --> C[D/A Converter]  
    C --> D[Reconstruction Filter]  
    D --> E[Output Signal]  
{Highlighting}  
{Shaded}
```

Transmitter Components:

- **Anti-aliasing filter:** Limits input bandwidth to prevent aliasing
- **Sample & Hold:** Captures instantaneous values at regular intervals
- **Quantizer:** Approximates samples to predefined discrete levels
- **Encoder:** Converts quantized values to binary code

Receiver Components:

- **Decoder:** Converts binary code back to quantized values
- **D/A Converter:** Transforms discrete values to continuous voltage
- **Reconstruction filter:** Removes sampling frequency components, smooths output

PCM Parameters:

- **Resolution:** Determined by bits per sample (n)
- **Quantization levels:** $L = 2^n$
- **Bit rate:** $R = n \times fs$ (bits per second)
- **SNR:** Improves by ~ 6 dB per bit added

Mnemonic

“Sample, Quantize, Encode; Decode, Convert, Reconstruct”

Question 5(a) [3 marks]

Define Bit, Bit rate and Baud rate with suitable example.

Solution

- **Bit:** Smallest unit of digital information, representing either 0 or 1.
 - Example: 10110 contains 5 bits
- **Bit Rate:** Number of bits transmitted per second.
 - Unit: bps (bits per second)
 - Example: 9600 bps means 9600 bits transmitted in one second
- **Baud Rate:** Number of signal changes (symbols) per second.
 - Unit: Baud
 - Example: In QPSK, each symbol represents 2 bits, so 9600 bps = 4800 Baud

Relationship:

- Bit Rate = Baud Rate \times number of bits per symbol
- For binary signaling (1 bit/symbol): Bit Rate = Baud Rate
- For multilevel coding: Bit Rate > Baud Rate

Mnemonic

“Bits Build Data, Baud Brings Symbols”

Question 5(b) [4 marks]

Define multiplexing. State its types. Explain Frequency division multiplexing with suitable diagram.

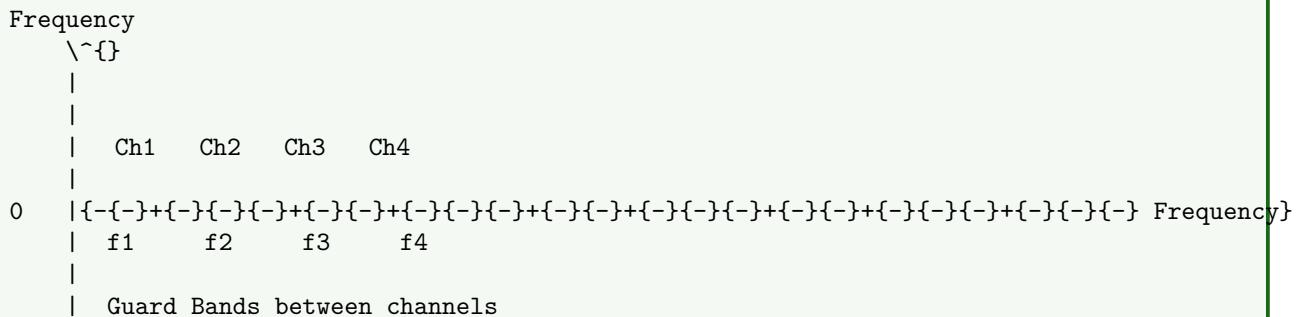
Solution

Multiplexing: Technique that allows multiple signals to share a common transmission medium.

Types of Multiplexing:

- Frequency Division Multiplexing (FDM)
- Time Division Multiplexing (TDM)
- Code Division Multiplexing (CDM)
- Wavelength Division Multiplexing (WDM)

Frequency Division Multiplexing:



FDM Working Principle:

- Each signal modulated to different carrier frequency
- Bandwidth allocated to each channel with guard bands
- All channels transmitted simultaneously
- Receiver uses filters to separate channels
- Used in radio/TV broadcasting, cable systems

Mnemonic

“Frequency Divides Multiple Signals Simultaneously”

Question 5(c) [7 marks]

Draw and explain basic PCM-TDM diagram with diagram.

Solution

PCM-TDM System Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph LR
    \%\% Transmitter
    A1[Source 1] --- B1[LPF 1]
    A2[Source 2] --- B2[LPF 2]
    A3[Source 3] --- B3[LPF 3]
    B1 --- C[Commutator/MUX]
    B2 --- C
    B3 --- C
    C --- D[Sampler]
    D --- E[Quantizer]
    E --- F[Encoder]
    F --- G[TDM Output]

    \%\% Receiver
    G --- H[Decoder]
    H --- I[DEMUX]
    I --- J1[LPF 1]
    I --- J2[LPF 2]
    I --- J3[LPF 3]
    J1 --- K1[Output 1]
    J2 --- K2[Output 2]
    J3 --- K3[Output 3]

{Highlighting}
{Shaded}
```

PCM-TDM System Operation:

Transmitter Side:

- **Input Sources:** Multiple analog signals
- **Low-Pass Filters:** Limit bandwidth of input signals
- **Commutator/MUX:** Sequentially samples each input
- **Sampler:** Converts continuous signals to discrete samples
- **Quantizer:** Approximates samples to nearest discrete levels
- **Encoder:** Converts quantized values to binary code
- **TDM Output:** Transmits frames containing samples from all channels

Receiver Side:

- **Decoder:** Converts binary code back to quantized values
- **DEMUX:** Distributes samples to appropriate channel paths
- **Low-Pass Filters:** Reconstruct original signals, remove sampling components
- **Outputs:** Recovered original signals

TDM Frame Format:

Sync Ch 1 Ch 2 Ch 3 Ch 1 Ch 2 ...

Frame header Channel samples repeat

Mnemonic

“Pulse Code TDM: Sample, Quantize, Encode, Multiplex”

Question 5(a) OR [3 marks]

State types of TDM and explain any one of them.

Solution

Types of TDM:

- Synchronous TDM
- Asynchronous TDM (Statistical TDM)
- Intelligent TDM

Synchronous TDM:

- Fixed time slots allocated to each channel
- Time slots transmitted in fixed sequence
- Time slots remain empty if channel has no data
- Simpler implementation but less efficient
- Example: T1 carrier system ($24 \text{ channels} \times 8\text{bits} \times 8000\text{samples/sec} = 1.544Mbps$)

Frame Structure:

Sync	Ch 1	Ch 2	Ch 3	Ch 4
Fixed slots regardless of activity				

Mnemonic

“Synchronous Slots Stay Steady”

Question 5(b) OR [4 marks]

Explain TDM. Also State its advantages and disadvantages.

Solution

Time Division Multiplexing (TDM): Technique where multiple signals share same transmission medium by allocating different time slots to each signal.

Working Principle:

- Each signal sampled at regular intervals
- Samples interleaved in time domain
- Complete frame contains one sample from each channel
- Receiver separates samples to reconstruct original signals

Advantages of TDM:

- **Single medium:** Efficiently uses one transmission path
- **Digital compatibility:** Naturally suits digital systems
- **Crosstalk elimination:** No interference between channels
- **Flexible capacity:** Easy to add/remove channels
- **Cost-effective:** Reduces hardware requirements

Disadvantages of TDM:

- **Synchronization critical:** Timing errors cause major problems
- **Complex equipment:** Requires precise timing circuits
- **Bandwidth limitation:** High bit rate needed for many channels
- **Inefficiency:** Wastes capacity when channels inactive (in synchronous TDM)
- **Buffer delays:** Can cause latency issues

Mnemonic

“Time Divided Multiple signals Save costs But Need Precise timing”

Question 5(c) OR [7 marks]

State desirable properties of line coding. Draw waveform in time relation for unipolar RZ, Polar NRZ, and Manchester line coding for a 8 bit digital data 01001110.

Solution

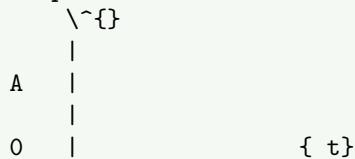
Desirable Properties of Line Coding:

- **DC component:** Should be minimal or absent
- **Self-synchronization:** Should provide timing information
- **Error detection:** Should allow detection of transmission errors
- **Bandwidth efficiency:** Should require minimum bandwidth
- **Noise immunity:** Should be resistant to noise and interference
- **Cost & complexity:** Should be simple to implement

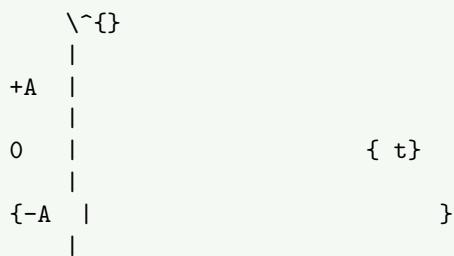
Line Coding Waveforms for 01001110:

Bit pattern: 0 1 0 0 1 1 1 0

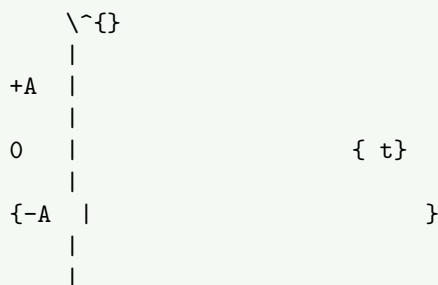
Unipolar RZ:



Polar NRZ:



Manchester:



Legend: 0 = Low, 1 = High

Key characteristics:

- **Unipolar RZ:** Returns to zero in middle of bit, only positive voltages
- **Polar NRZ:** No return to zero, uses positive and negative voltages
- **Manchester:** Mid-bit transition, rising edge = 0, falling edge = 1

Mnemonic

“Unipolar Rises then Zeros, Polar Never Returns, Manchester Always Transitions”