Principles of Electronic Communication (4331104) - Summer 2023 Solution

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Question 1 [a marks]

3 Draw & explain block diagram of Communication system.

Solution

Block Diagram of Communication System:

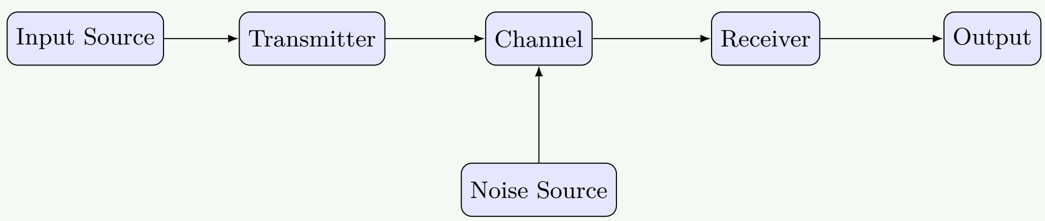


Figure 1. Block Diagram of Communication System

- **Input**: Message signal originating from source (e.g., voice, picture, data).
- **Transmitter**: Converts message to suitable form for transmission (modulation, amplification).
- **Channel**: Medium through which signal travels (e.g., wire, fiber, free space).
- **Receiver**: Extracts original message from received signal (demodulation, amplification).
- **Output**: Delivered message to destination.
- **Noise Source**: Unwanted signals that interfere with communication, adding distortion.

Mnemonic

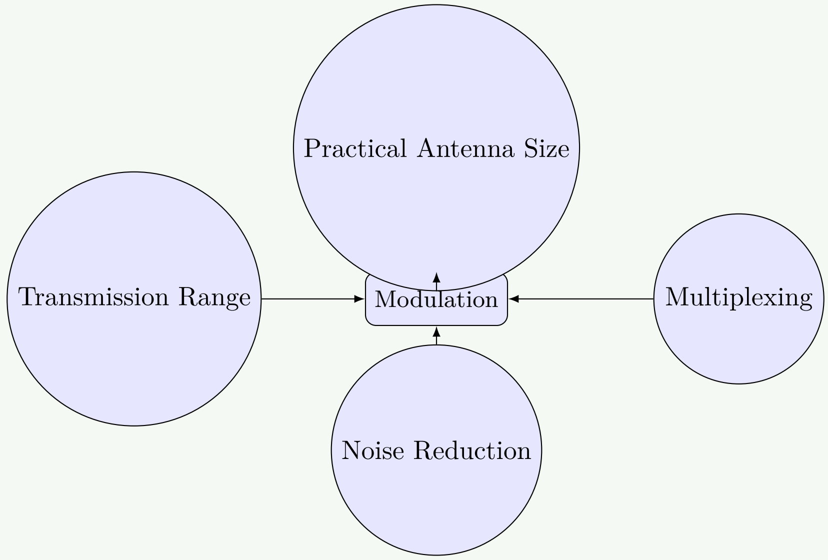
"I Transmit Clearly Receiving Original Messages"

Question 1 [b marks]

4 Explain need of modulation. State advantages of modulation.

Solution

Need for Modulation:



Advantages of Modulation:

1. **Reduced antenna size**:
   - Antenna height $h = \lambda/4 = c/4f$.
   - For audio frequencies (low f), h is impractically large (km).
   - Modulation shifts signal to high f, reducing required antenna size to meters.
2. **Multiplexing possible**:
   - Multiple signals can be transmitted simultaneously through the same channel by assigning different carrier frequencies.
3. **Increased range**:
   - Low frequency baseband signals suffer high attenuation.
   - Modulated high frequency signals travel farther with less attenuation.
4. **Noise reduction**:
   - Modulation techniques (like FM, PCM) offer better immunity to noise compared to baseband transmission, improving SNR.

Mnemonic

"Antennas Need Modulation For Reaching Anywhere with Noise Immunity"

Question 1 [c marks]

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

Solution

Modulation: The process of varying a fundamental parameter (amplitude, frequency, or phase) of a high-frequency carrier signal proportionally to the instantaneous value of the low-frequency message signal.

Amplitude Modulation Waveform:

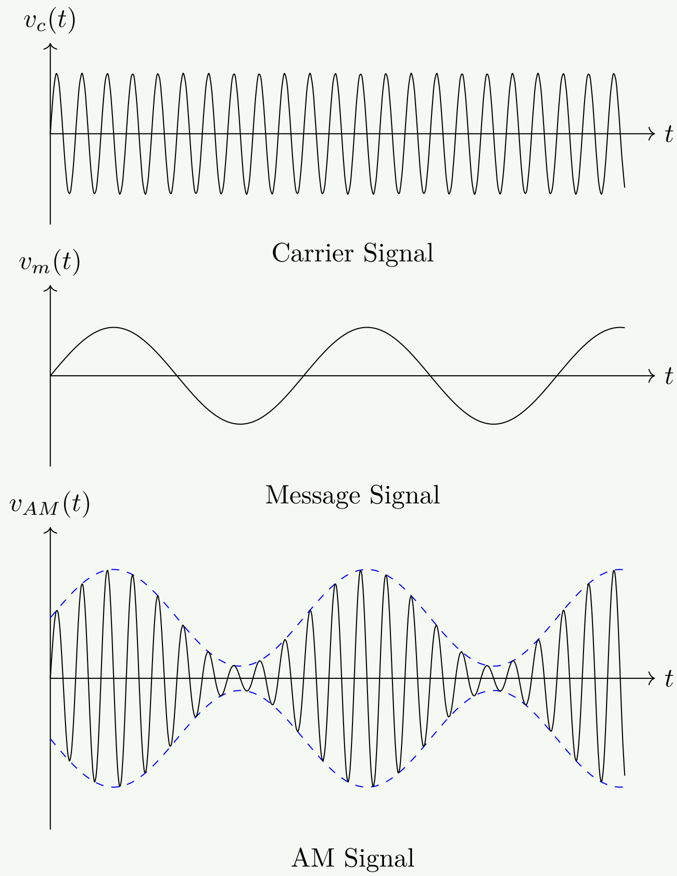


Figure 2. Amplitude Modulation Waveforms

Derivation of AM Voltage Equation:

1. Let the instantaneous value of carrier signal be:

$$v_c(t) = V_c \sin(\omega_c t)$$

2. Let the instantaneous value of modulating (message) signal be:

$$v_m(t) = V_m \sin(\omega_m t)$$

3. In AM, the amplitude of the carrier V_c is varied in accordance with the message signal $v_m(t)$. The instantaneous amplitude of the modulated wave $A(t)$ becomes:

$$A(t) = V_c + v_m(t) = V_c + V_m \sin(\omega_m t)$$

$$A(t) = V_c[1 + \frac{V_m}{V_c} \sin(\omega_m t)]$$

4. Define **Modulation Index** (μ):

$$\mu = \frac{V_m}{V_c}$$

   So, $A(t) = V_c[1 + \mu \sin(\omega_m t)]$

5. The instantaneous value of the AM wave $v_{AM}(t)$ is given by:

$$v_{AM}(t) = A(t) \sin(\omega_c t)$$

6. Substituting $A(t)$:

$$v_{AM}(t) = V_c[1 + \mu \sin(\omega_m t)] \sin(\omega_c t)$$

   This is the standard equation for an AM signal.

Mnemonic

"Amplitude Modulation Makes Carrier Value Change"

Question 1 [c marks]

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

Solution

Noise: Unwanted electrical signals that interfere with the transmission and processing of desired communication signals, causing distortion, errors, or loss of information.
Classification of Noise:

External Noise	Internal Noise
Atmospheric Noise	Thermal (Johnson) Noise
Extraterrestrial (Solar/Cosmic) Noise	Shot Noise
Industrial (Man-made) Noise	Transit-time Noise
	Flicker (1/f) Noise
	Partition Noise

Table 1. Classification of Noise

Causes of Internal Noise:

1. **Thermal (Johnson) Noise**:
   - **Cause**: Generated by the random thermal motion of free electrons inside a conductor or resistor.
   - **Characteristic**: It is present in all resistive components and is directly proportional to absolute temperature (T) and bandwidth (B).
   - Power $P_n = kTB$.
2. **Shot Noise**:
   - **Cause**: Arises from the discrete nature of charge carriers (electrons/holes). It occurs due to the random fluctuations in the arrival rate of carriers crossing a potential barrier (e.g., in PN junctions, vacuum tubes).
   - **Characteristic**: It is present in active devices like diodes and transistors. It is proportional to the DC current flowing through the device.
3. **Flicker Noise (1/f Noise)**:
   - **Cause**: Caused by variations in carrier density due to surface defects, contamination, and impurities in semiconductor materials.
   - **Characteristic**: Its power spectral density is inversely proportional to frequency ($1/f$), making it significant at low frequencies (below a few kHz).

Mnemonic

"This Shooting Flicker Is Noisy Everywhere"

Question 2 [a marks]

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

Solution

1. **Modulation Index for AM** (μ):
   - Defined as the ratio of the peak amplitude of the modulating signal (V_m) to the peak amplitude of the carrier signal (V_c).
   - Formula: $\mu = \frac{V_m}{V_c}$

- Practical range: $0 \le \mu \le 1$ to avoid overmodulation distortion.

2. **Noise Figure (NF)**:
   - A figure of merit that indicates how much noise a device (like an amplifier) adds to a signal.
   - Defined as the ratio of input Signal-to-Noise Ratio (SNR) to output Signal-to-Noise Ratio.
   - Formula: $NF = \frac{(SNR)_{input}}{(SNR)_{output}}$
   - Ideally $NF = 1$ (or 0 dB) for a noise-free device. Always ≥ 1 in practice.
3. **Digital Modulation**:
   - A technique where digital data (binary 0s and 1s) is used to modulate the parameters (amplitude, frequency, or phase) of an analog carrier signal for transmission.
   - Examples: ASK (Amplitude Shift Keying), FSK (Frequency Shift Keying), PSK (Phase Shift Keying).

Mnemonic

"Modulation Measures, Noise Numbers, Digital Data"

Question 2 [b marks]

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

Solution

Derivation of Total Power in AM:

1. The equation for an AM wave is:

$$v_{AM}(t) = V_c \sin(\omega_c t) + \frac{\mu V_c}{2}\cos(\omega_c - \omega_m)t - \frac{\mu V_c}{2}\cos(\omega_c + \omega_m)t$$

   It consists of a Carrier component and two Sideband components (LSB and USB).

2. Power is given by $P = \frac{V_{rms}^2}{R}$. Assuming load resistance R:
3. **Carrier Power (P_c)**: Peak voltage is V_c, so $V_{rms} = \frac{V_c}{\sqrt{2}}$.

$$P_c = \frac{(V_c/\sqrt{2})^2}{R} = \frac{V_c^2}{2R}$$

4. **Sideband Power**: Both LSB and USB have peak amplitude $\frac{\mu V_c}{2}$.

$$V_{sb\_rms} = \frac{\mu V_c}{2\sqrt{2}}$$

   Power in Upper Sideband (P_{USB}) = Power in Lower Sideband (P_{LSB}):

$$P_{SB} = \frac{(\frac{\mu V_c}{2\sqrt{2}})^2}{R} = \frac{\mu^2 V_c^2}{8R}$$

5. Substituting $P_c = \frac{V_c^2}{2R}$ into sideband power equation:

$$P_{SB} = P_c \cdot \frac{\mu^2}{4}$$

6. **Total Power (P_T)**:

$$P_T = P_c + P_{USB} + P_{LSB}$$

$$P_T = P_c + P_c\frac{\mu^2}{4} + P_c\frac{\mu^2}{4}$$

$$P_T = P_c + P_c\frac{\mu^2}{2}$$

$$P_T = P_c\left(1 + \frac{\mu^2}{2}\right)$$

Mnemonic

"Power Total = Power Carrier $(1 + \text{mu}^2/2)$"

Question 2 [c marks]

7 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:

- In standard AM, the carrier consumes about 67% of total power but carries no information.
- DSBSC suppresses the carrier and transmits only the two sidebands (USB and LSB), which contain the actual information.
- **Advantage**: Improves power efficiency and reduces bandwidth usage per watt of information power.
- **Disadvantage**: Requires complex coherent detection at the receiver.

Voltage Equation Derivation:

1. Consider carrier $c(t) = V_c \sin(\omega_c t)$ and Message $m(t) = V_m \sin(\omega_m t)$.
2. DSBSC is the product of carrier and message signals:

$$v_{DSBSC}(t) = m(t) \cdot c(t)$$

$$v_{DSBSC}(t) = [V_m \sin(\omega_m t)] \cdot [V_c \sin(\omega_c t)]$$
$$v_{DSBSC}(t) = V_m V_c \sin(\omega_m t) \sin(\omega_c t)$$

3. Using trigonometric identity: $2 \sin A \sin B = \cos(A - B) - \cos(A + B)$:

$$v_{DSBSC}(t) = \frac{V_m V_c}{2} [\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t]$$

4. This equation shows two components (LSB and USB) and NO carrier component at ω_c.

Balanced Modulator Circuit Using Oscillating Diodes:

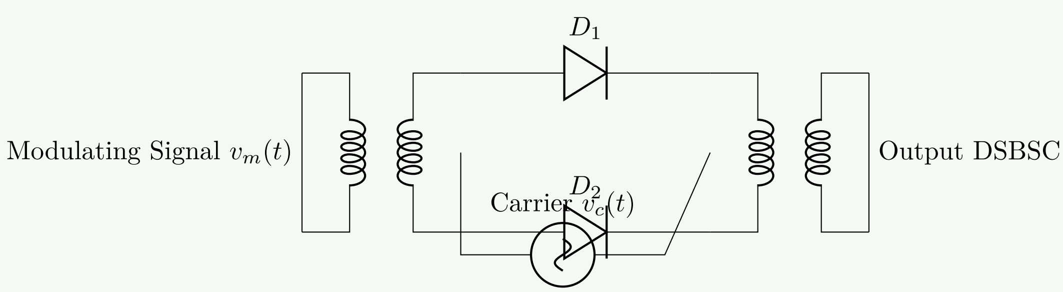


Figure 3. Ring Modulator / Balanced Modulator using Diodes

Mnemonic

"Delete Carrier, Save Bandwidth, Combine Signals"

Question 2 [a marks]

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

Solution

1. **Sensitivity**:
   - The ability of a radio receiver to pick up weak signals and amplify them to a usable level.
   - Measured in microvolts (μV). Lower value means better sensitivity (e.g., a 1 μV receiver is more sensitive than a 10 μV one).
2. **Selectivity**:
   - The ability of a receiver to select the desired frequency signal while rejecting all other adjacent unwanted signals.
   - Determined by the quality factor (Q) and bandwidth of the tuned circuits. A narrow bandwidth implies high selectivity.
3. **Fidelity**:
   - The ability of a receiver to reproduce all the frequency components of the original message signal in the output without distortion.
   - High fidelity (Hi-Fi) implies accurate reproduction of the full audio range.

Mnemonic

"Sensitive Selection Faithfully"

Question 2 [b marks]

4 OR: 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 (P_{SB}) = 200 W (This usually means power in *one* sideband)

To Find:
- Modulation Index (μ)

Solution:
1. Total Sideband Power (P_{TSB}) is the sum of power in both USB and LSB.
$$P_{TSB} = P_{USB} + P_{LSB} = 2 \times P_{SB}$$
$$P_{TSB} = 2 \times 200 = 400 \text{ W}$$
2. Formula relating sideband power to carrier power:
$$P_{TSB} = P_c \cdot \frac{\mu^2}{2}$$
Alternatively, using single sideband formula: $P_{SB} = P_c \cdot \frac{\mu^2}{4}$.
3. Substitute values:
$$400 = 1000 \cdot \frac{\mu^2}{2}$$
4. Solve for μ^2:
$$\frac{\mu^2}{2} = \frac{400}{1000} = 0.4$$
$$\mu^2 = 0.4 \times 2 = 0.8$$
5. Solve for μ:
$$\mu = \sqrt{0.8} \approx 0.8944$$

Answer: The modulation index is approximately **0.89** or **89.4%**.

Question 2 [c marks]

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

Solution

Parameter	**Amplitude Modulation (AM)**	**Frequency Modulation (FM)**
1. Definition	Amplitude of carrier varies with message amplitude.	Frequency of carrier varies with message amplitude.
2. Modulation Index	$\mu = V_m/V_c$ (Range 0 to 1).	$\beta = \Delta f/f_m$ (Usually > 1).
3. Bandwidth	Low: $BW = 2f_m$.	High: $BW = 2(f_m + \Delta f)$ (Carson's Rule).
4. Noise Immunity	Poor. Noise affects amplitude directly.	Excellent. Amplitude variations are clipped; frequency carries info.
5. Power Efficiency	Poor. Carrier takes up to 67% power.	Good. Power is constant and efficient.
6. Complexity	Simple transmitters and receivers.	Complex transmitters and receivers (uses PLL, discriminators).
7. Fidelity (Quality)	Moderate capability.	High fidelity (Hi-Fi), better sound quality.
8. Application	LW/MW/SW Broadcasting, Video transmission.	FM Radio Broadcasting, TV Audio, Satellite.

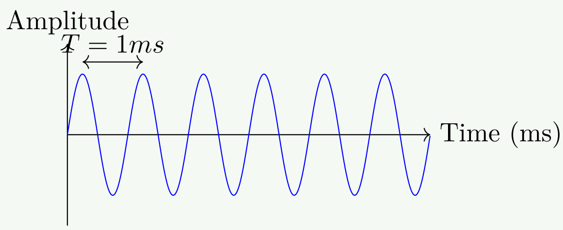
Table 2. Comparison of AM and FM

Question 3 [a marks]

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

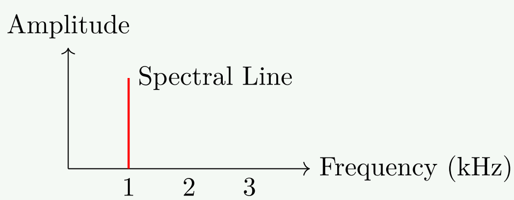
Solution

Time Domain Representation (1 kHz):



Period $T = 1/f = 1ms$

Frequency Domain Representation:



Advantages of Frequency Domain Analysis:

- **Signal decomposition**: Easily identifies individual frequency components and bandwidth usage.
- **Filter design**: Essential for designing filters (Low Pass, High Pass) as response is defined in frequency.
- **Bandwidth efficiency**: Helps in understanding spectrum occupancy and maximizing channel usage.

Question 3 [b marks]

4 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	Standard Frequency Value
1. IF frequency for AM radio	455 kHz
2. IF frequency for FM radio	10.7 MHz
3. Frequency Band used in FM broadcasting	88 MHz to 108 MHz
4. Frequency Band of Human speech (Voice)	300 Hz to 3.4 kHz (Telephone standard)

Table 3. Standard Frequencies in Communication

Question 3 [c marks]

7 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 Sideband (SSB) Modulation:

- SSB is a form of amplitude modulation where the carrier and one of the sidebands are suppressed.
- Only **one sideband** (either Upper Sideband - USB or Lower Sideband - LSB) is transmitted.
- This saves bandwidth and power without losing any information.

SSB Spectrum Waveform:

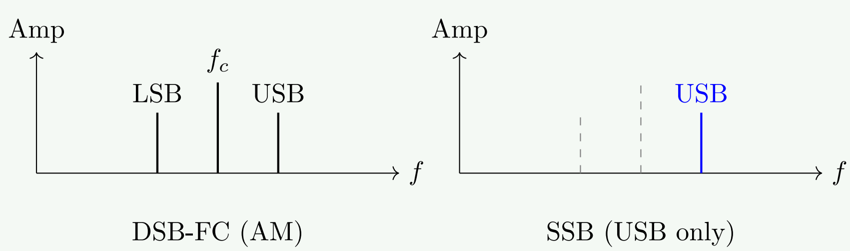


Figure 4. Comparison of AM and SSB Spectra

Advantages of SSB:

1. **Bandwidth Saving**: Requires only half the bandwidth (f_m) compared to AM ($2f_m$).
2. **Power Efficiency**: No power wasted on carrier or redundant sideband.
3. **Reduced Fading**: Less susceptible to selective fading in ionospheric propagation.
4. **Better SNR**: Transmission power is concentrated in information-bearing sideband.

Power Saving Calculation (1/6th Power):

1. Total power in standard AM (DSB-FC) with 100% modulation ($\mu = 1$):

$$P_{AM} = P_c(1 + \frac{\mu^2}{2}) = P_c(1 + \frac{1}{2}) = 1.5P_c$$

2. Power distribution in AM:

- Carrier Power = P_c
- Total Sideband Power = $0.5P_c$
- Power per Sideband = $0.25P_c$

3. Power in SSB (one sideband only):

$$P_{SSB} = P_{SB\_one} = 0.25P_c$$

4. Ratio of SSB Power to AM Power:

$$\frac{P_{SSB}}{P_{AM}} = \frac{0.25P_c}{1.5P_c} = \frac{1/4}{3/2} = \frac{1}{4} \times \frac{2}{3} = \frac{2}{12} = \frac{1}{6}$$

5. **Conclusion**: SSB requires only **1/6th (16.7%)** of the power required for DSB-FC AM to transmit the same information with the same signal-to-noise ratio.

Mnemonic

"Single Side Saves Bandwidth And Power"

Question 3 [a marks]

3 OR: 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**:
   - $f_m = 5$ kHz
   - $BW = 2f_m = 2 \times 5$ kHz $= 10$ kHz
2. **Image frequency for 1000 kHz station**:
   - Signal frequency $f_s = 1000$ kHz
   - Standard Intermediate Frequency $f_{IF} = 455$ kHz
   - Image Frequency $f_{im} = f_s + 2f_{IF}$
   - $f_{im} = 1000 + 2(455) = 1000 + 910 = 1910$ kHz
3. **Sampling frequency for 10 kHz baseband**:
   - Maximum frequency $f_{max} = 10$ kHz
   - According to Nyquist Criterion, Sampling Frequency $f_s \geq 2f_{max}$
   - $f_s \geq 2 \times 10$ kHz $= 20$ kHz
   - So, minimum sampling frequency required is 20 kHz.

Mnemonic

"Bandwidth Doubles, Image Adds Twice-IF, Sampling Needs Twice-Frequency"

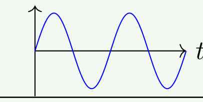
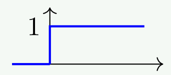
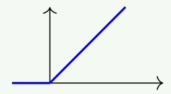
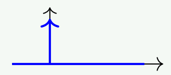
Question 3 [b marks]

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

Solution

Signal Representations:

Signal Name	Mathematical Equation	Waveform

1. Sine Wave	$f(t) = A\sin(\omega t + \phi)$	
2. Unit Step Signal	$u(t) = \begin{cases} 1 & t \geq 0 \\ 0 & t < 0 \end{cases}$	
3. Ramp Signal	$r(t) = \begin{cases} t & t \geq 0 \\ 0 & t < 0 \end{cases}$	
4. Impulse Signal	$\delta(t) = \begin{cases} \infty & t = 0 \\ 0 & t \neq 0 \end{cases}$	

Mnemonic

"Sine Oscillates, Step Jumps, Ramp Climbs, Impulse Spikes"

Question 3 [c marks]

7 OR: 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 and De-emphasis:

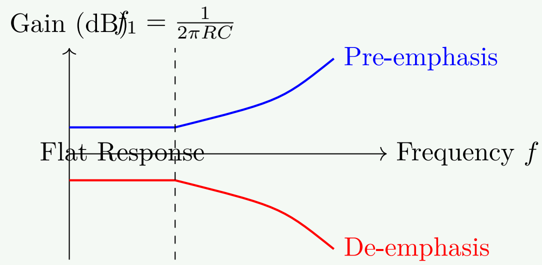
- **Need**: In FM, high-frequency components of the message signal have a lower modulation index compared to low-frequency components, making them more susceptible to noise (as noise power density increases with frequency in FM demodulator output).
- **Solution**: We artificially boost (amplify) high frequencies at the transmitter (**Pre-emphasis**) and attenuate them correspondingly at the receiver (**De-emphasis**) to improve SNR.

Circuits:

Pre-emphasis (Transmitter) **De-emphasis (Receiver)**

Figure 5. Pre-emphasis and De-emphasis Circuits

Characteristic Graph:



Comparison of FM and AM Receivers:

Parameter	AM Receiver	FM Receiver
1. Operating Frequencies	MF/HF Range (535-1605 kHz)	VHF Range (88-108 MHz)
2. IF Frequency	455 kHz	10.7 MHz
3. Bandwidth	10 kHz	200 kHz
4. Demodulation	Envelope Detector	Discriminator / Ratio Detector
5. Amplitude Limiter	Not required	Essential to remove amplitude noise
6. Pre/De-emphasis	Not used	Used to improve SNR
7. Audio Quality	Moderate, mono	High fidelity, often stereo

Mnemonic

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

Question 4 [a marks]

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

Solution

Image Frequency: An unwanted input frequency located equidistant from the Local Oscillator (LO) frequency as the desired signal frequency, which, when mixed with the LO, produces the same Intermediate Frequency (IF).

Explanation with Example:

- Let desired Station Frequency $f_s = 1000$ kHz.
- Standard IF $f_{IF} = 455$ kHz.
- Local Oscillator Frequency (High side injection) $f_{LO} = f_s + f_{IF} = 1000 + 455 = 1455$ kHz.
- The mixer produces difference frequencies: $|f_{LO} - f_{in}| = f_{IF}$.
- **Case 1**: $f_{in} = f_s = 1000$ kHz $\Rightarrow |1455 - 1000| = 455$ kHz (Desired).
- **Case 2**: $f_{in} = f_{si}$ (Image) $= f_s + 2f_{IF} = 1000 + 2(455) = 1910$ kHz.
- Check: $|1455 - 1910| = |-455| = 455$ kHz.
- Thus, if a station exists at 1910 kHz, it will interfere with the 1000 kHz station.

Equation: $f_{si} = f_s + 2f_{IF}$

Mnemonic

"Image In radio Is Interfering 2IF away"

Question 4 [b marks]

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

Solution

Envelope Detector Circuit:

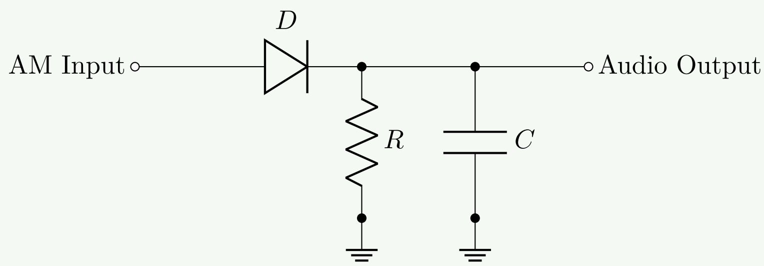


Figure 6. Simple Diode Envelope Detector

Working Principle:

1. **Rectification**: During the positive half-cycle of the AM input, the diode D becomes forward biased and charges the capacitor C to the peak value of the input voltage.
2. **Discharging**: As the input voltage drops below the peak, the diode becomes reverse biased. The capacitor discharges slowly through resistor R.
3. **Envelope Tracking**: If the RC time constant is chosen correctly, the capacitor voltage follows the envelope of the AM wave (which represents the message signal) rather than the high-frequency RF carrier variations.
4. **Time Constant Selection**: The time constant $\tau = RC$ must satisfy:

$$\frac{1}{f_c} \ll RC \ll \frac{1}{f_m}$$

This ensures it filters out the carrier (f_c) but retains the message (f_m).

Mnemonic

"Diode Rectifies, RC Smooths Envelope"

Question 4 [c marks]

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

Solution

Superheterodyne AM Receiver Block Diagram:

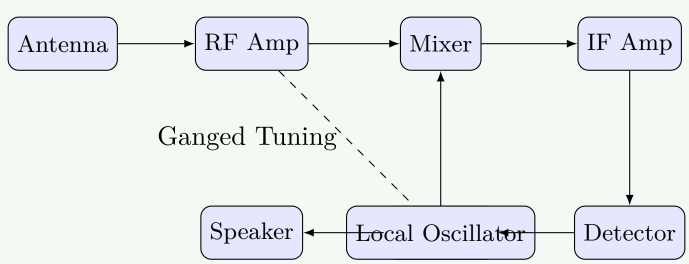


Figure 7. Superheterodyne AM Receiver

Working of Each Block:

- **RF Amplifier**: Selects the desired station frequency (f_s) and rejects others. Improves signal-to-noise ratio.
- **Local Oscillator**: Generates a high-frequency sine wave (f_{LO}) such that $f_{LO} = f_s + f_{IF}$. It tracks the tuning of the RF stage.
- **Mixer**: Mixes f_s and f_{LO} to produce the Intermediate Frequency (f_{IF} = 455 kHz) using the principle of heterodyning (beat frequency).

- **IF Amplifier**: A high-gain tuned amplifier fixed at 455 kHz. It provides most of the receiver's gain and selectivity.
- **Detector**: Demodulates the constant-IF AM signal to recover the original audio message signal. Usually includes AGC (Automatic Gain Control).
- **AF Amplifier**: Amplifies the weak audio signal to a level sufficient to drive the loudspeaker.
- **Speaker**: Transducer that converts electrical audio signals into sound waves.

Mnemonic

"Radio Mixing Intermediate Detected Audio For Speaker"

Question 4 [a marks]

3 OR: State and explain Nyquist Criteria for sampling of signal.

Solution

Nyquist Sampling Theorem:

> "A continuous-time signal can be completely reconstructed from its samples if and only if the sampling frequency (f_s) is greater than or equal to twice the maximum frequency component (f_{max}) present in the signal."

Mathematical Condition:

$$f_s \geq 2f_{max}$$

Explanation:

- **Nyquist Rate**: The minimum sampling rate required, which is $2f_{max}$.
- **Aliasing**: If $f_s < 2f_{max}$, the high-frequency components "fold over" into the low-frequency spectrum, causing distortion known as aliasing. The original signal cannot be recovered.
- **Guard Band**: In practice, f_s is chosen slightly higher than $2f_{max}$ to allow for practical anti-aliasing filters (e.g., $f_s = 44.1$ kHz for audio with $f_{max} = 20$ kHz).

Mnemonic

"Sample at least Twice as Fast as Highest Frequency"

Question 4 [b marks]

4 OR: Explain slope overload and granular noise for a delta modulation.

Solution

In Delta Modulation (DM), the analog signal is approximated by a staircase function with a fixed step size (δ). Two types of quantization errors occur:

1. Slope Overload Distortion:

- **Cause**: Occurs when the analog input signal changes (rises or falls) very rapidly, i.e., it has a high slope.
- **Effect**: The staircase approximation cannot keep up with the steep slope of the input signal because the step size is too small or sampling rate is too low.
- **Remedy**: Increase the step size (δ) or the sampling frequency (f_s).

2. Granular Noise:

- **Cause**: Occurs when the analog input signal is relatively flat or changes very slowly.
- **Effect**: The staircase output oscillates above and below the true signal level by the step size δ, creating a noise-like variation even when silence exists.
- **Remedy**: Decrease the step size (δ).

Trade-off: Increasing step size fixes slope overload but worsens granular noise, and vice versa. **Adaptive Delta Modulation (ADM)** solves this by varying the step size dynamically.

Mnemonic

"Slopes Need Bigger Steps, Flats Need Smaller Steps"

Question 4 [c marks]

7 OR: Draw and explain PCM transmitter and receiver in detail.

Solution

Block Diagram of PCM System:

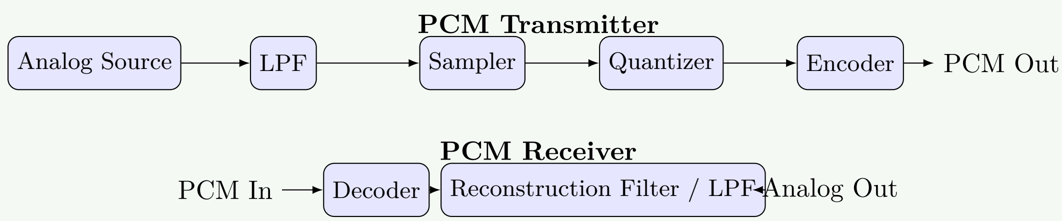


Figure 8. Pulse Code Modulation (PCM) Block Diagram

Explanation of Blocks:

1. **Low Pass Filter (Anti-aliasing)**: Band-limits the input signal to f_{max} to strictly satisfy Nyquist criteria ($f_s \geq 2f_{max}$).
2. **Sampler (Sample & Hold)**: Discretizes the specific time instants. Converts continuous-time signal to discrete-time PAM (Pulse Amplitude Modulation) pulses.
3. **Quantizer**: Discretizes the amplitude. Approximates each sample value to the nearest standard voltage level from a finite set of L levels. This introduces Quantization Noise.
4. **Encoder**: Converts each quantized level into a unique n-bit binary code word (e.g., 01101).
5. **Decoder**: Used at the receiver to convert the binary stream back into discrete voltage levels (DAC operation).
6. **Reconstruction Filter**: A low-pass filter that smooths the staircase output of the decoder to recover the original continuous analog signal.

Mnemonic

"Sample, Quantize, Encode; Decode, Convert, Reconstruct"

Question 5 [a marks]

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

Solution

- **Bit**: The fundamental unit of digital information, representing a binary state of 0 or 1.
- **Bit Rate (R_b)**: The speed of data transfer, measured as the number of bits transmitted per second.
- Unit: bps (bits per second).
- Example: If a system transmits '101' in 1 second, $R_b = 3$ bps.
- **Baud Rate**: The rate of signal changes per second (symbol rate).
- Unit: Baud.
- Relationship: $R_b = \text{Baud Rate} \times \text{bits per symbol}$.
- Example: In QPSK Modulation, each symbol carries 2 bits. If Baud Rate is 1000 Baud, Bit Rate is 2000 bps.

Mnemonic

"Bits Build Data, Baud Brings Symbols"

Question 5 [b marks]

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

Solution

Multiplexing: The process of simultaneously transmitting multiple message signals over a single communication channel without interference.

Types:

1. Frequency Division Multiplexing (FDM) - Analog
2. Time Division Multiplexing (TDM) - Digital/Analog
3. Wavelength Division Multiplexing (WDM) - Optical

Frequency Division Multiplexing (FDM):

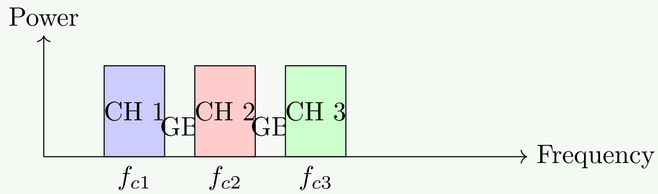


Figure 9. Spectrum of FDM System

Explanation:

- The total bandwidth of the channel is divided into non-overlapping frequency bands.
- Each user signal modulates a different carrier frequency ($f_{c1}, f_{c2}, \ldots$).
- **Guard Bands** (GB) are unused frequency gaps kept between channels to prevent crosstalk overlap.
- All signals are transmitted simultaneously.
- Used in FM/AM Radio broadcasting and Cable TV.

Mnemonic

"Frequency Divides Multiple Signals Simultaneously"

Question 5 [c marks]

7 Draw and explain basic PCM-TDM diagram with diagram.

Solution

PCM-TDM System: Time Division Multiplexing (TDM) is often used with Pulse Code Modulation (PCM) to transmit multiple digitized voice/data channels over a single link.

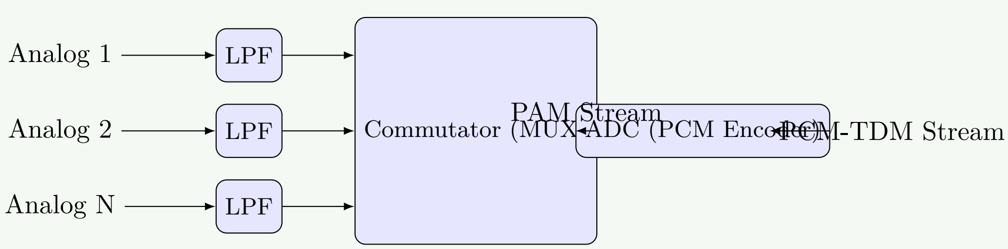


Figure 10. PCM-TDM Transmitter Block Diagram

Operation:

1. **Input Filtering**: Each analog input is passed through a Low Pass Filter (LPF) to restrict bandwidth.
2. **Commutation (Multiplexing)**: An electronic switch (commutator) connects to each input sequentially at a sampling rate f_s. This creates an interleaved train of PAM pulses.
3. **Encoding**: This single PAM stream is fed to a PCM Encoder (ADC), which quantizes and converts each pulse into an n-bit digital code.
4. **Transmission**: The resulting high-speed digital stream contains bits from Channel 1, then Channel 2, etc., in a repeating frame structure.
5. **Frame**: One complete cycle of scanning all inputs constitutes a TDM Frame. Synchronization bits are usually added to identify frame start.

Mnemonic

"Pulse Code TDM: Sample, Quantize, Encode, Multiplex"

Question 5 [a marks]

3 OR: State types of TDM and explain any one of them.

Solution

Types of TDM:

1. Synchronous TDM
2. Asynchronous TDM (or Statistical TDM)

Synchronous TDM:

- **Concept**: Each input source is assigned a fixed time slot in every frame, regardless of whether the source has data to send or not.
- **Operation**: The multiplexer scans inputs in a round-robin fashion. If a device is idle, its time slot is transmitted empty (wasted bandwidth).
- **Advantage**: Simple design, no addressing overhead needed for data fragments (position determines owner).
- **Disadvantage**: Inefficient bandwidth usage if many devices are idle.

Mnemonic

"Synchronous Slots Stay Steady"

Question 5 [b marks]

4 OR: Explain TDM. Also State its advantages and disadvantages.

Solution

Time Division Multiplexing (TDM): A digital/analog technique where multiple low-speed signals are interleaved in time to share a single high-speed transmission channel. The time axis is divided into slots, and each user gets the full bandwidth for a fraction of time.

Advantages:

- No crosstalk between channels (separated in time).
- Utilizes the full bandwidth of the channel.
- Circuitry is digital, reliable, and easy to integrate (VLSI).
- Flexible: Can handle different data rates with buffering.

Disadvantages:

- Requires strict **Synchronization** between transmitter and receiver.

- Complexity in clock recovery and framing circuits.
- Bandwidth waste in Synchronous TDM if channels are inactive.
- Propagation delay affects timing.

Mnemonic

"Time Divided Multiple signals Save costs But Need Precise timing"

Question 5 [c marks]

7 OR: 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:

1. **Self-Synchronization**: Enough transitions for clock recovery.
2. **No DC Component**: To allow AC coupling (transformers/capacitors).
3. **Error Detection**: Capability to detect bit errors.
4. **Bandwidth Efficiency**: Should use minimum channel bandwidth.
5. **Low cross-talk**: Reduced interference.

Line Coding Waveforms for Data: 0 1 0 0 1 1 1 0

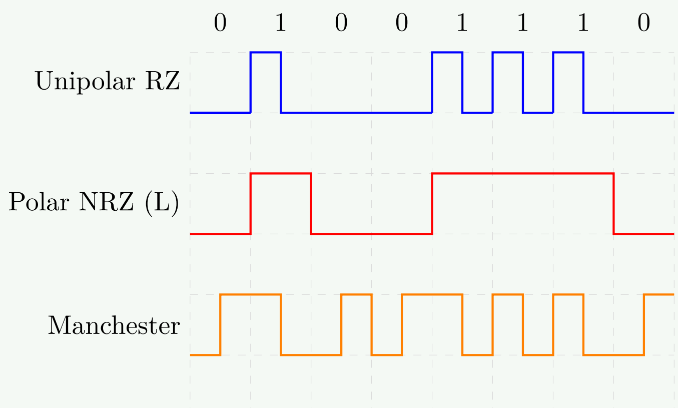


Figure 11. Line Coding Waveforms

Mnemonic

"Unipolar Rises then Zeros, Polar Never Returns, Manchester Always Transitions"