Communication Engineering (1333201) - Summer 2024 Solution

Milav Dabgar

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Question 1(a) [3 marks]

Define modulation and explain its need.

Solution

Answer: 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

Need	Explanation
Antenna Size Reduction	Allows practical antenna size ($\lambda/4$) by increasing frequency
Signal Propagation	Higher frequencies travel farther through atmosphere
Multiplexing	Allows multiple signals to be transmitted simultaneously
Interference Reduction	Shifts signal to band with less noise/interference
Bandwidth Allocation	Enables efficient spectrum usage by different services

Mnemonic

"ASPIM" - Antenna size, Signal propagation, Proper multiplexing, Interference reduction, Manage bandwidth

Question 1(b) [4 marks]

Draw & explain block diagram of Communication system

Solution

Answer: A communication system transfers information from source to destination through a channel.

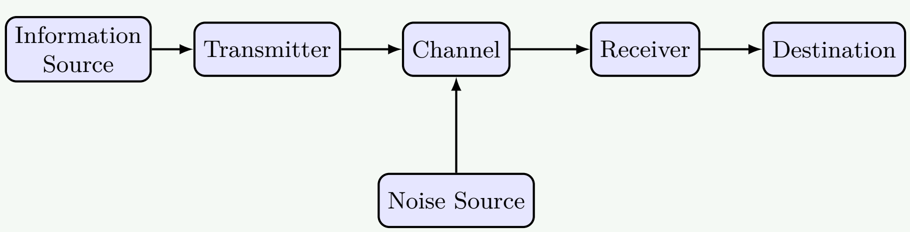

Figure 1. Communication System Block Diagram

Table 2. Communication System Components

Component	Function
Information Source	Produces message to be transmitted (voice, video, data)
Transmitter	Converts message to suitable signals (modulation, coding)
Channel	Medium through which signals travel (wire, fiber, air)
Noise Source	Unwanted signals that corrupt the transmitted signal
Receiver	Extracts original message from received signal (demodulation)
Destination	Where the message is delivered (human, machine)

Mnemonic

"I Try Communicating Neatly, Receive Data" (I-T-C-N-R-D)

Question 1(c) [7 marks]

Derive voltage equation for Amplitude modulation.

Solution

Answer: Amplitude modulation varies the amplitude of carrier signal proportionally to the message signal.
Mathematical Derivation:

- Let carrier signal be: $c(t) = A_c \cos(\omega_c t)$
- Message signal: $m(t) = A_m \cos(\omega_m t)$
- AM signal: $s(t) = A_c[1 + \mu \cdot m(t)/A_m] \cos(\omega_c t)$
- Where μ = modulation index = A_m/A_c
- Substituting $m(t)$: $s(t) = A_c[1 + \mu \cdot \cos(\omega_m t)] \cos(\omega_c t)$
- Expanding: $s(t) = A_c \cdot \cos(\omega_c t) + \mu \cdot A_c \cdot \cos(\omega_m t) \cdot \cos(\omega_c t)$
- Using identity ($\cos A \cdot \cos B$): $s(t) = A_c \cdot \cos(\omega_c t) + (\frac{\mu A_c}{2})[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t]$

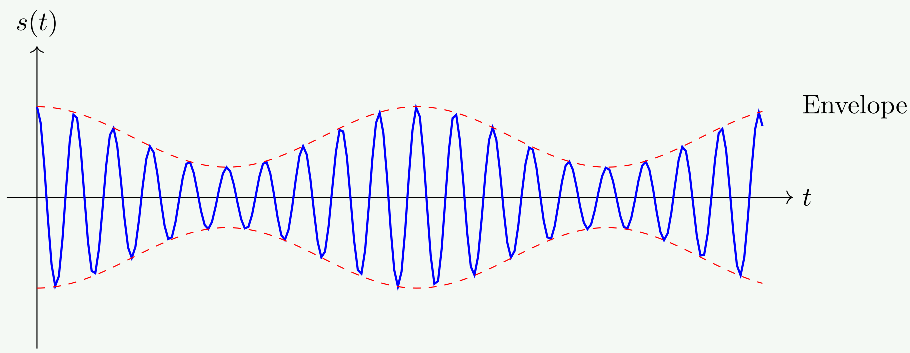

Figure 2. AM Signal in Time Domain

Mnemonic

"CAMDS" - Carrier Amplitude Modulated by Data Signal

Question 1(a) OR [7 marks]

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

Solution

Answer: For an AM signal with modulation index μ, the total power consists of carrier power and sideband power.

Table 3. Power Distribution in AM

Component	Power Formula	Percentage of Total Power
Carrier	$P_c = A_c^2/2$	$1/(1+\mu^2/2) \times 100\%$
Upper Sideband	$P_{USB} = P_c \cdot \mu^2/4$	$(\mu^2/4)/(1+\mu^2/2) \times 100\%$
Lower Sideband	$P_{LSB} = P_c \cdot \mu^2/4$	$(\mu^2/4)/(1+\mu^2/2) \times 100\%$
Total	$P_T = P_c(1+\mu^2/2)$	100%

Power Savings Calculation:

- In DSB-SC: 100% carrier suppression = $(P_c/P_T) \times 100\% = 1/(1+\mu^2/2) \times 100\%$
  - For $\mu = 1$: Saving $= 2/3 \times 100\% = 66.67\%$
- In SSB: One sideband + carrier suppression = $(P_c + P_{LSB})/P_T \times 100\% = (1+\mu^2/4)/(1+\mu^2/2) \times 100\%$
  - For $\mu = 1$: Saving $= 5/6 \times 100\% = 83.33\%$

Mnemonic

"CAPS" - Carrier And Power in Sidebands

Question 2(a) [3 marks]

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

Solution

Answer: Image frequency is an unwanted frequency that can produce the same IF (Intermediate Frequency) as the desired signal in a superheterodyne receiver.

Parameter	Formula	Example
Desired Signal	f_s	100 MHz
Local Oscillator	f_{LO}	110 MHz
IF	$f_{IF} = f_{LO} - f_s$	10 MHz
Image Frequency	$f_{image} = f_{LO} + f_{IF}$	120 MHz

Table 4. Image Frequency

If both 100 MHz and 120 MHz signals exist, both will produce 10 MHz IF, causing interference.

Mnemonic

"LIDS" - Local oscillator plus/minus IF gives Desired signal and Signal image

Question 2(b) [4 marks]

Draw and explain block diagram for envelope detector.

Solution

Answer: Envelope detector extracts the modulating signal from AM wave by following the envelope.

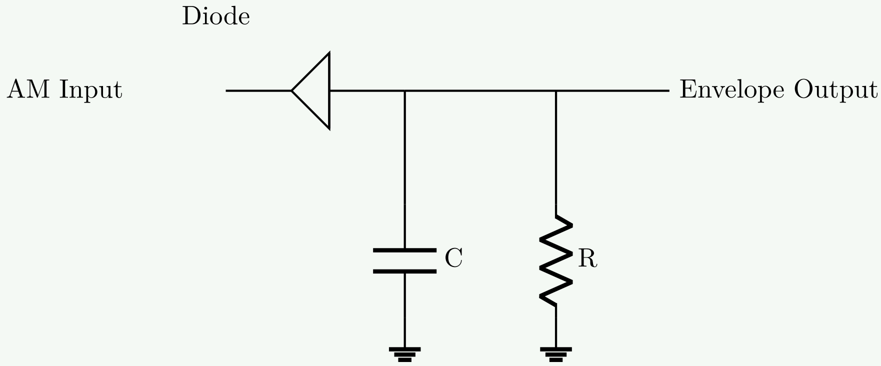

Figure 3. Envelope Detector

Table 5. Envelope Detector Components

Component	Function
Diode	Rectifies the AM signal (passes positive half)
Capacitor	Charges to peak value of rectified signal
Resistor	Discharges capacitor with time constant RC
RC Value	$1/\omega_m < RC < 1/\omega_c$ (where ω_m is message frequency, ω_c is carrier)

Mnemonic

"DRCT" - Diode Rectifies, Capacitor Tracks

Question 2(c) [7 marks]

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

Solution

Answer: AM receiver converts radio signal to audio output.

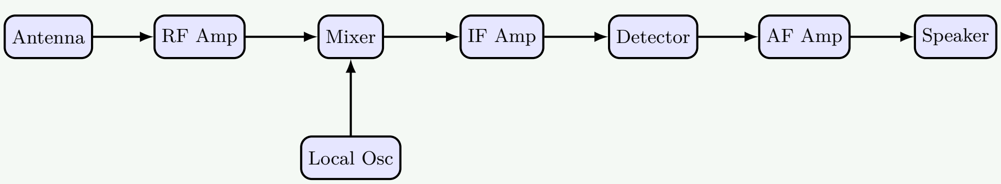

Figure 4. AM Receiver Block Diagram

Table 6. AM Receiver Blocks

Block	Function
Antenna	Captures electromagnetic signals from air
RF Amplifier	Amplifies weak RF signals, provides selectivity
Local Oscillator	Generates frequency to mix with incoming signal
Mixer	Combines RF and oscillator signals to produce IF
IF Amplifier	Amplifies fixed IF signal with high gain
Detector	Extracts audio signal from AM carrier
AF Amplifier	Boosts audio signal power to drive speaker
Speaker	Converts electrical signal to sound

Mnemonic

"ARMLIDAS" - Antenna Receives, Mixer Links Input and Detector, Audio to Speaker

Question 2(a) OR [3 marks]

Define any FOUR characteristics of radio receiver.

Solution

Answer:

Table 7. Radio Receiver Characteristics

Characteristic	Definition
Sensitivity	Minimum signal strength that produces standard output
Selectivity	Ability to separate desired signal from adjacent channels
Fidelity	Accuracy of reproducing original modulating signal
Image Rejection	Ability to reject image frequency signals
Signal-to-Noise Ratio	Ratio of desired signal power to noise power

Mnemonic

"SSFIS" - Super Sensitive Fidelity with Image Suppression

Question 2(b) OR [4 marks]

Explain Ratio detector circuit for FM detection.

Solution

Answer: Ratio detector extracts audio from FM signals while rejecting amplitude variations.

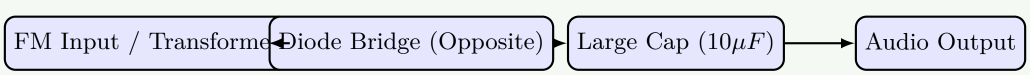

Figure 5. Ratio Detector Block Diagram

Table 8. Ratio Detector Components

Component	Function
Transformer	Creates phase shifts proportional to frequency deviation
Diodes	Arranged in opposite polarity to produce voltage ratio
Stabilizing Capacitor	Large value ($10\mu F$) to suppress AM variations
RC Network	Extracts the audio signal from ratio of voltages

Mnemonic

"RADS" - Ratio detector Avoids Disturbance from Strength variations

Question 2(c) OR [7 marks]

Draw and explain block diagram of super heterodyne receiver.

Solution

Answer: Superheterodyne receiver converts all incoming RF to fixed IF for better amplification.

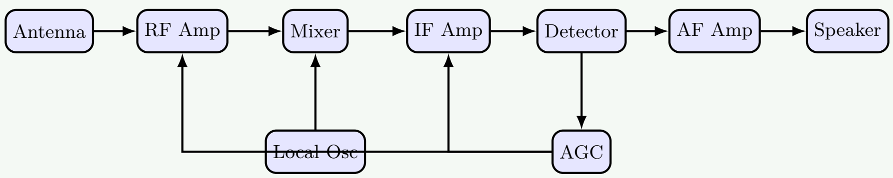

Figure 6. Superheterodyne Receiver Block Diagram

Table 9. Superheterodyne Receiver Components

Block	Function
Antenna	Captures RF signals
RF Amplifier	Amplifies and selects desired frequency band
Local Oscillator	Generates frequency above/below signal by IF value
Mixer	Heterodynes signal and oscillator to produce IF
IF Amplifier	Provides most gain and selectivity at fixed frequency
Detector	Recovers original modulating signal
AGC	Automatic Gain Control - maintains constant output level
AF Amplifier	Amplifies audio to drive speaker
Speaker	Converts electrical signal to sound

Mnemonic

"ARMLIADS" - Antenna Receives, Mixer Links, Intermediate Amplifies, Detector Separates

Question 3(a) [3 marks]

Draw the Time and frequency domain representation of the below signals. 1. Analog signal (sine) 2. Digital signal (square).

Solution

Answer:

Signal Type	Time Domain	Frequency Domain
Sine Wave	Sinusoidal curve	Single spike at frequency f
Square Wave	Alternating levels	Fundamental and odd harmonics ($1/n$ pattern)

Table 10. Signal Representations

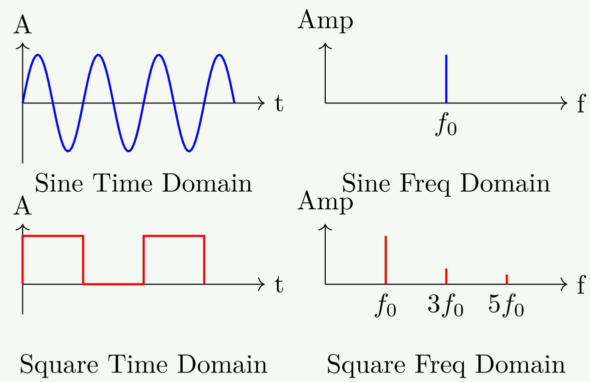

Figure 7. Signal Representations

Mnemonic

"SOFT" - Sine has One Frequency, square has Timeless harmonics

Question 3(b) [4 marks]

Explain sampling theorem.

Solution

Answer: Sampling theorem states the conditions for accurate signal reconstruction from samples.

Aspect	Description
Statement	To reconstruct a signal perfectly, sampling frequency must be at least twice the highest frequency in signal
Nyquist Rate	$f_s \geq 2f_{max}$ (minimum sampling frequency)
Aliasing	Distortion that occurs when sampling below Nyquist rate
Example	For voice (300-3400 Hz), $f_s \geq 6.8$ kHz (typically 8 kHz)

Table 11. Sampling Theorem

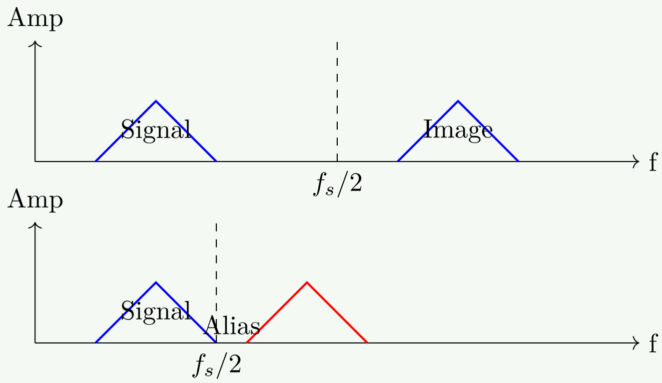

Figure 8. Aliasing Effect

Mnemonic

"SNAP" - Sample at Nyquist And Prevent aliasing

Question 3(c) [7 marks]

Explain PAM, PPM and PWM.

Solution

Answer: These are pulse modulation techniques where a parameter of pulse is varied.

Type	Full Form	Parameter Varied	Characteristics
PAM	Pulse Amplitude Modulation	Amplitude	Direct sampling of analog signal
PPM	Pulse Position Modulation	Position/Time	Better noise immunity than PAM
PWM	Pulse Width Modulation	Width/Duration	Superior noise immunity, widely used in control systems

Table 12. Pulse Modulation Types

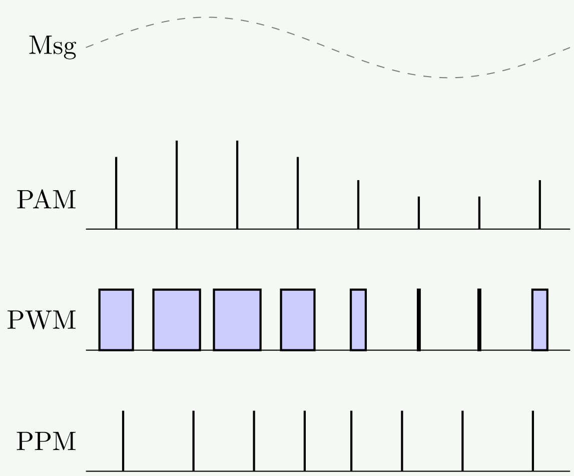

Figure 9. Pulse Modulation Techniques

Mnemonic

"AAA-PPW" - Amplitude, Position, Width are modulated in PAM, PPM, PWM

Question 3(a) OR [3 marks]

Define Nyquist rate and explain.

Solution

Answer: Nyquist rate is the minimum sampling frequency required for accurate signal reconstruction.

Table 13. Nyquist Rate

Aspect	**Description**
Definition	Minimum sampling frequency needed to avoid aliasing ($f_s = 2f_{max}$)
Implications	Sampling below Nyquist rate causes irreversible distortion
Formula	$f_s \geq 2f_{max}$ where f_{max} is highest frequency in signal
Application	CD audio: 44.1 kHz sampling for 20 kHz audio

Mnemonic

"TANS" - Twice As Needed for Sampling

Question 3(b) OR [4 marks]

Explain quantization process.

Solution

Answer: Quantization assigns discrete amplitude levels to sampled values in analog-to-digital conversion.

Table 14. Quantization Process

Step	**Description**
Sampling	Discrete-time samples taken from continuous signal
Level Assignment	Each sample assigned to nearest quantization level
Quantization Error	Difference between actual and quantized value
Quantization Noise	Statistical effect of errors in signal
Resolution	Determined by number of bits (2^n levels for n bits)

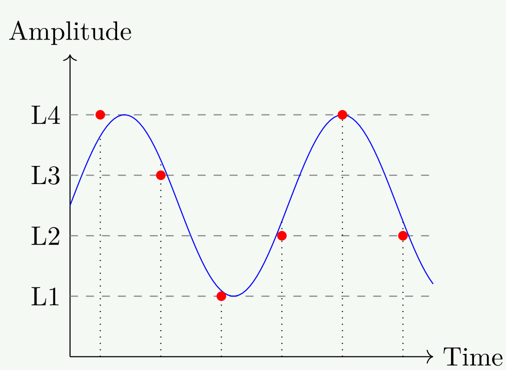

Figure 10. Quantization Process

Mnemonic

"SLERN" - Sample, Level assign, Error occurs, Resolution determines Noise

Question 3(c) OR [7 marks]

Explain Ideal, Natural and Flat top sampling.

Solution

Answer: These are different practical implementations of sampling process.

Table 15. Sampling Types Comparison

Type	Description	Characteristics	Mathematical Representation
Ideal	Instantaneous samples at zero width	Theoretical concept, not physically realizable	$s(t) = m(t) \times \sum \delta(t - nT_s)$
Natural	Samples modulate pulse train	Practical implementation using analog switch	$s(t) = m(t) \times p(t)$
Flat-top	Holds sample value until next sample	Easiest to implement, sample-and-hold circuit	$s(t) = \sum m(nT_s)[u(t - nT_s) - u(t - (n + 1)T_s)]$

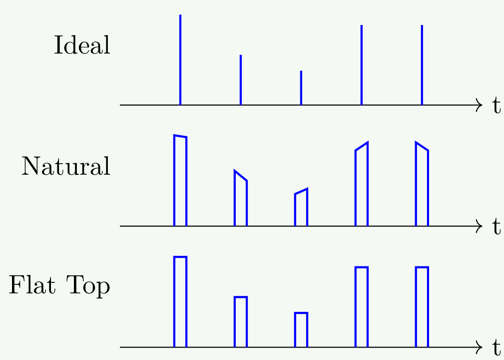

Figure 11. Sampling Types

Mnemonic

"INF" - Ideal is theoretical, Natural is practical, Flat-top holds values

Question 4(a) [3 marks]

List the advantages and disadvantages of PCM.

Solution

Answer:

Table 16. PCM Advantages and Disadvantages

Advantages	Disadvantages
High noise immunity	Requires higher bandwidth
Better signal quality	Complex circuitry
Compatible with digital systems	Quantization noise
Secure communication possible	Higher power consumption
Can be regenerated without degradation	Synchronization required

Mnemonic

"NICHE" vs "BCQPS" - Noise immunity, Integration, Complex circuitry, Higher bandwidth, Error correction vs Bandwidth, Cost, Quantization, Power, Synchronization

Question 4(b) [4 marks]

Draw and Explain Block Diagram of Delta Modulation.

Solution

Answer: Delta modulation transmits only changes in signal level using 1-bit quantization.

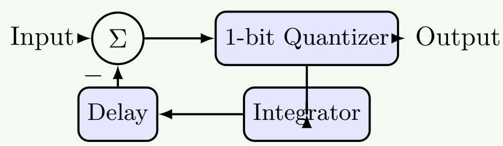

Figure 12. Delta Modulation Block Diagram

Table 17. Delta Modulation Components

Block	Function
Comparator	Compares input with predicted value
1-bit Quantizer	Outputs 1 if difference positive, 0 if negative
Integrator	Accumulates step values to track input
Delay	Provides previous output for comparison

Mnemonic

"CQID" - Compare, Quantize with 1-bit, Integrate, Delay

Question 4(c) [7 marks]

Compare PCM, DM and DPCM.

Solution

Answer:

Table 18. Comparison of Digital Modulation Techniques

Parameter	PCM	DM	DPCM
Bits per sample	8-16 bits	1 bit	4-6 bits
Bandwidth	Highest	Lowest	Medium
Signal-to-Noise Ratio	Highest	Lowest	Medium
Circuit Complexity	High	Simple	Medium
Sampling Rate	Nyquist	Multiple of Nyquist	Nyquist
Error Types	Quantization error	Slope overload, granular noise	Prediction error
Applications	CD audio, digital telephony	Low-quality voice	Speech, video coding

Mnemonic

"PCM-DM-DPCM: More Bits Better Quality, More Complexity Needed"

Question 4(a) OR [3 marks]

Explain DPCM.

Solution

Answer: Differential Pulse Code Modulation encodes difference between actual and predicted sample.

Table 19. DPCM Characteristics

Aspect	Description
Basic Principle	Encodes difference between actual and predicted value
Predictor	Uses previous samples to predict current value
Advantage	Requires fewer bits than PCM (exploits correlation)
Bit Rate Reduction	Typically 25-50% compared to PCM
Applications	Speech coding, image compression

Mnemonic

"DPCM: Difference Predicted, Correlation Matters"

Question 4(b) OR [4 marks]

List the advantages and disadvantages of Delta Modulation.

Solution

Answer:

Table 20. Delta Modulation - Pros and Cons

Advantages	Disadvantages
Simple implementation	Slope overload distortion
Low bit rate	Granular noise at low amplitudes
Single bit transmission	Limited dynamic range
Robust against channel errors	Higher sampling rate required
Low complexity hardware	Lower SNR than PCM

Mnemonic

"SLSRL" vs "SGLSH" - Simple, Low bit-rate, Single bit, Robust, Low cost vs Slope overload, Granular noise, Limited range, Sampling high, SNR low

Question 4(c) OR [7 marks]

Explain Block diagram of basic PCM-TDM system.

Solution

Answer: PCM-TDM combines multiple digitized signals into a single high-speed channel.

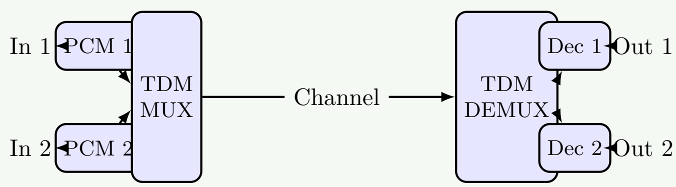

Figure 13. PCM-TDM System Block Diagram

Table 21. PCM-TDM System Components

Block	Function
PCM Encoder	Converts analog signal to digital (sampling, quantization, coding)
TDM Multiplexer	Combines multiple PCM streams into single high-speed stream
Transmission Channel	Medium for signal transmission
TDM Demultiplexer	Separates time-multiplexed stream back into individual channels
PCM Decoder	Converts digital back to analog (decoding, filtering)
Synchronization	Clock and frame sync signals ensure proper demultiplexing
Frame Structure	Contains samples from all channels plus sync bits

Mnemonic

"PETDSF" - PCM Encodes, TDM combines, Digital transmits, Separation occurs, Frames synchronize

Question 5(a) [3 marks]

Explain Adaptive Delta Modulation.

Solution

Answer: Adaptive Delta Modulation adjusts step size based on signal characteristics.

Table 22. Adaptive Delta Modulation

Feature	Description
Basic Principle	Varies step size according to signal slope
Step Size Control	Increases when same bit pattern repeats (signal changing rapidly)
Advantages	Reduced slope overload and granular noise
Implementation	Uses shift register to detect bit patterns
Performance	Better SNR than standard DM

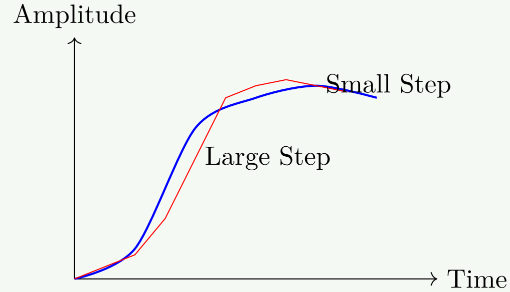

Figure 14. Step Size Adaptation

Mnemonic

"ASSG" - Adaptive Step Size Gives better performance

Question 5(b) [4 marks]

Define the terms: 1. Radiation Pattern 2. Antenna Gain.

Solution

Answer:

Table 23. Antenna Terms

Term	Definition	Characteristics
Radiation Pattern	Graphical representation of radiation properties of antenna in space	Shows directional dependencies of radiated power
Antenna Gain	Measure of antenna's ability to direct or concentrate radio energy in a particular direction	Expressed in dB, compared to isotropic radiator (dBi)

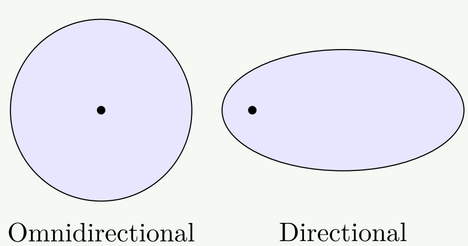

Figure 15. Radiation Pattern Types

Mnemonic

"RPGD" - Radiation Pattern shows Gain Direction

Question 5(c) [7 marks]

Explain Base station and mobile station antennas.

Solution

Answer: Different antenna designs serve different purposes in wireless communication systems.

Table 24. Comparison of Base Station and Mobile Station Antennas

Parameter	Base Station Antenna	Mobile Station Antenna
Height	15-50 meters	Less than 2 meters
Gain	Higher (10-20 dBi)	Lower (0-3 dBi)
Pattern	Sectoral (120° sectors)	Omnidirectional
Size	Larger arrays	Compact, integrated
Types	Panel, Yagi, Collinear	Monopole, PIFA, chip
Polarization	Vertical, cross-polarized	Typically vertical
Beamforming	Often used	Rarely used in basic devices
Diversity	Space/polarization diversity	Rarely implemented

Mnemonic

"BHPSTBD" - Base stations Have Power, Size, Tower mounting, Beamforming, Diversity

Question 5(a) OR [3 marks]

Write frequency range for HF, VHF and UHF.

Solution

Answer:

Table 25. Frequency Bands

Band	Frequency Range	Wavelength	Notable Applications
HF	3-30 MHz	100-10 m	Shortwave radio, amateur radio, aviation
VHF	30-300 MHz	10-1 m	FM radio, TV channels 2-13, air traffic
UHF	300-3000 MHz	1-0.1 m	TV channels 14-83, mobile phones, Wi-Fi

Mnemonic

"3-30-300-3000" - Each band starts at 3 times a power of 10 MHz

Question 5(b) OR [4 marks]

Define the terms: 1. Antenna Directivity 2. Polarization.

Solution

Answer:

Table 26. Antenna Properties

Term	Definition	Characteristics
Directivity	Ratio of radiation intensity in a given direction to average radiation intensity	Measured in dBi, indicates focus of antenna
Polarization	Orientation of electric field vector of radiated wave	Linear (vertical/horizontal), circular, elliptical

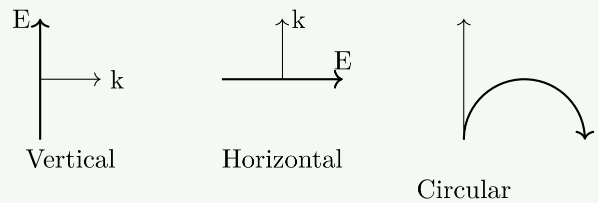

Figure 16. Antenna Directivity and Polarization

Mnemonic

"DIVE POLE" - DIrectivity shows Vector Excellence, POLarization shows Electric field

Question 5(c) OR [7 marks]

Explain Ground wave and Space wave propagation in detail.

Solution

Answer: These are two primary modes of radio wave propagation in the lower atmosphere.

Table 27. Wave Propagation Comparison

Parameter	Ground Wave	Space Wave
Frequency Range	Below 2 MHz	Above 30 MHz
Distance Coverage	100-300 km	Limited to line-of-sight + diffraction
Path	Follows earth's curvature	Direct and ground-reflected paths
Mechanism	Diffraction around earth's surface	Line-of-sight propagation with reflection
Attenuation	Higher (increases with frequency)	Lower at VHF/UHF ranges
Polarization	Vertical polarization preferred	Both vertical and horizontal usable
Applications	AM broadcasting, navigation beacons	TV, FM radio, microwave links
Factors Affecting	Ground conductivity, terrain	Antenna height, terrain, obstacles

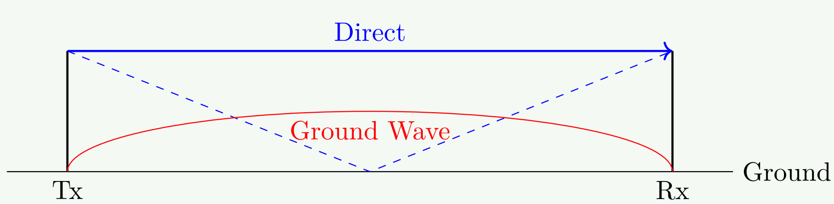

Figure 17. Ground Wave vs Space Wave Propagation

Ground Wave Propagation:

- Travels along the surface of the earth.
- Signal strength decreases with distance.
- Better propagation over sea than land.
- Affected by ground conductivity and dielectric constant.
- Used for AM broadcasting, Maritime communication.

Space Wave Propagation:

- Involves Direct Wave and Ground-Reflected Wave.
- Range extended by atmospheric refraction.
- Range formula: $d = \sqrt{2Rh}$ where R is earth radius, h is antenna height.
- Affected by diffraction over obstacles.
- Used for Line-of-sight communication like TV, FM, Microwave links.

Mnemonic

"GAFFS" - Ground Adheres to earth, Follows surface, Frequencies low, Short wavelengths