

# Antenna & Wave Propagation (4341106) - Winter 2024 Solution

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## Question 1(a) [3 marks]

Define: (1) Directivity, (2) Gain, and (3) HPBW

### Solution

Parameter	Definition
Directivity	The ratio of radiation intensity in a given direction to the average radiation intensity in all directions.
Gain	The ratio of power radiated in a specific direction to the power that would be radiated by an isotropic antenna with the same input power.
HPBW (Half Power Beam Width)	The angular width of the main lobe where the power falls to half (-3dB) of its maximum value.

### Mnemonic

**Mnemonic:** "DGH: Direction Gets Higher power with narrow beam"

## Question 1(b) [4 marks]

List the properties of electromagnetic waves

### Solution

Property	Description
Transverse nature	Electric and magnetic fields are perpendicular to each other and to direction of propagation.
Velocity	Travel at speed of light ( $3 \times 10^8$ m/s) in free space.
Frequency range	Vary from few Hz to several THz.
Energy transport	Carry energy from one point to another without need of medium.
Reflection	Can be reflected from conducting surfaces.
Refraction	Change direction when passing between different media.
Diffraction	Can bend around obstacles.
Polarization	The orientation of electric field vector.

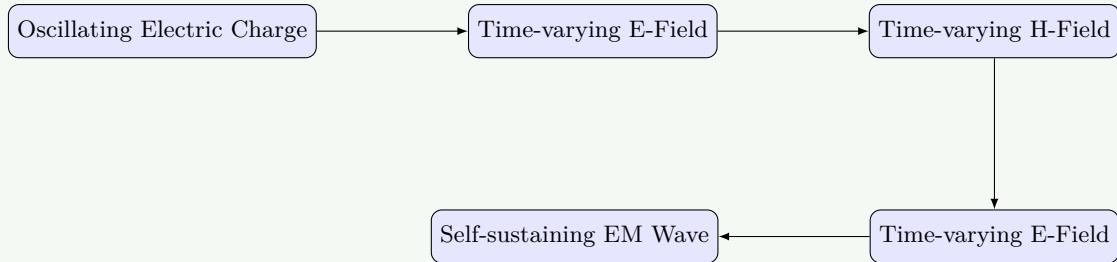
### Mnemonic

**Mnemonic:** "TVFERRDP: Travel Very Fast, Energy Reflects Refracts Diffraction Polarizes"

## Question 1(c) [7 marks]

Explain physical concept of generation of Electromagnetic wave

### Solution



**Figure 1.** Generation of Electromagnetic Wave

#### Process of EM Wave Generation:

- **Accelerating charge:** When electric charge accelerates, it produces time-varying electric field.
- **Changing electric field:** This creates a time-varying magnetic field.
- **Changing magnetic field:** In turn creates a time-varying electric field.
- **Self-propagation:** This mutual creation of fields results in self-propagating wave.
- **Energy transfer:** EM waves transfer energy from transmitter to receiver.

**Maxwell's Equations:** These four equations mathematically describe the generation and propagation of EM waves:

1. Electric field from charges (Gauss's law).
2. No magnetic monopoles exist.
3. Electric fields from changing magnetic fields (Faraday's law).
4. Magnetic fields from currents and changing electric fields (Ampere's law).

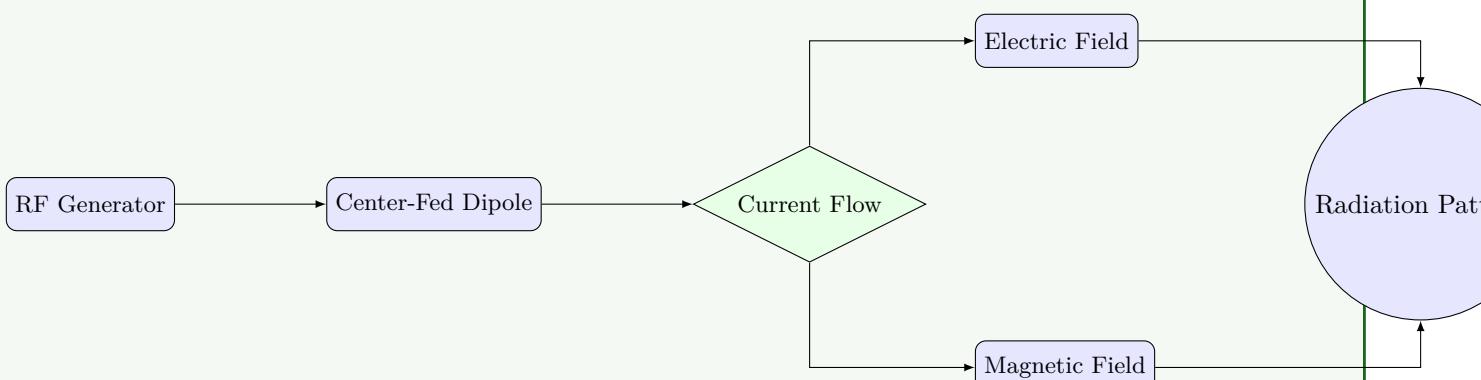
### Mnemonic

**Mnemonic:** "CASES: Charges Accelerate, Self-sustaining Electric-Magnetic fields"

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

Explain how electromagnetic field radiated from a center fed dipole

### Solution



**Figure 2.** Radiation from Center-Fed Dipole

Stage	Process
<b>1. Current excitation</b>	RF signal applied at center of dipole creates alternating current.
<b>2. Current distribution</b>	Sinusoidal current distribution forms along dipole, maximum at center, zero ends.
<b>Radiation Process:</b>	
<b>3. Electric field</b>	Oscillating charges create time-varying electric field perpendicular to dipole.
<b>4. Magnetic field</b>	Current flow creates magnetic field perpendicular to both dipole and electric field.
<b>5. Near field</b>	Complex field pattern forms close to antenna ( $< \lambda/2\pi$ ).
<b>6. Far field</b>	At distances $> 2\lambda$ , radiation stabilizes to form distinctive pattern with main side lobes.

**Characteristics:**

- Maximum radiation:** Perpendicular to dipole axis.
- Null radiation:** Along dipole axis.
- Omnidirectional:** In azimuth plane (perpendicular to dipole).
- Polarization:** Same as orientation of dipole.

**Mnemonic**

**Mnemonic:** "COME-FR: Current Oscillates, Making Electric-magnetic Fields that Radiate"

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

Differentiate the resonant and non-resonant antennas

**Solution**

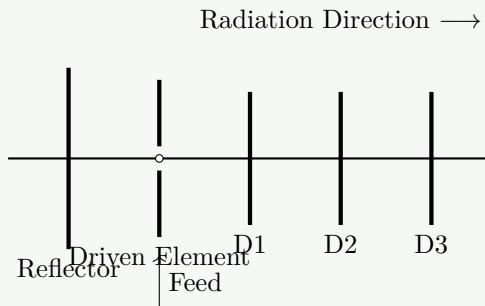
Parameter	Resonant Antennas	Non-Resonant Antennas
<b>Physical length</b>	Multiple of $\lambda/2$ (usually $\lambda/2$ or $\lambda$ )	Not related to wavelength (typically $> \lambda$ ).
<b>Standing waves</b>	Strong standing waves present.	Minimal standing waves.
<b>Current distribution</b>	Sinusoidal with maximum at center.	Traveling wave with uniform amplitude.
<b>Input impedance</b>	Resistive (at resonant frequency).	Complex (resistive + reactive).
<b>Bandwidth</b>	Narrow bandwidth.	Wide bandwidth.
<b>Examples</b>	Half-wave dipole, folded dipole.	Rhombic antenna, traveling wave antenna.

**Mnemonic**

**Mnemonic:** "SIN-CIB: Size, Impedance, Narrow vs Complex, Impedance, Broad"

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

Explain Yagi antenna and discuss its radiation characteristics

**Solution****Figure 3.** Yagi-Uda Antenna Structure**Yagi Antenna Components:**

- **Driven element:** Half-wave dipole connected to transmission line.
- **Reflector:** Slightly longer than driven element, placed behind it.
- **Directors:** Multiple elements shorter than driven element, placed in front.

**Radiation Characteristics:**

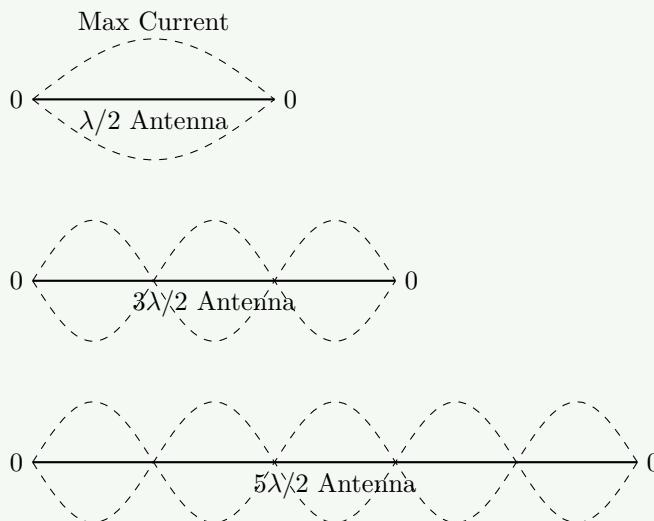
- **Directivity:** High (7-12 dBi) with more directors.
- **Radiation pattern:** Unidirectional, narrow beam along director axis.
- **Front-to-back ratio:** 15-20 dB (good rejection of signals from rear).
- **Bandwidth:** Moderate (around 5% of center frequency).
- **Gain:** Increases with number of directors (typically 3-20 dBi).

**Mnemonic**

**Mnemonic:** "DRDU: Directors Radiate, Driven powers, Unidirectional beam"

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

Describe radiation characteristics of resonant wire antennas and draw the current distribution of  $\lambda/2$ ,  $3\lambda/2$  and  $5\lambda/2$  antenna

**Solution****Figure 4.** Current Distribution on Resonant Wire Antennas**Radiation Characteristics of Resonant Wire Antennas:**

<b>Characteristic</b>	<b>Description</b>
<b>Current distribution</b>	Sinusoidal, with maximum at center
<b>Input impedance</b>	Approximately $73\Omega$ for $\lambda/2$ , varies for other lengths
<b>Radiation pattern</b>	Figure-8 pattern ( $\lambda/2$ ), more complex for longer lengths
<b>Directivity</b>	2.15 dBi for $\lambda/2$ , increases with length
<b>Polarization</b>	Linear, parallel to wire orientation.
<b>Efficiency</b>	High for properly constructed antennas

**Key Points:**

- $\lambda/2$  antenna has single current maximum at center.
- $3\lambda/2$  antenna has three half-cycles of current distribution.
- $5\lambda/2$  antenna has five half-cycles of current distribution.
- More half-wavelengths create more radiation lobes.
- Feed point is typically at current maximum for best impedance match.

**Mnemonic**

**Mnemonic:** "SIMPLE: Sinusoidal In Middle Produces Lobes Efficiently"

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

Differentiate the broad side and end fire array antennas

**Solution**

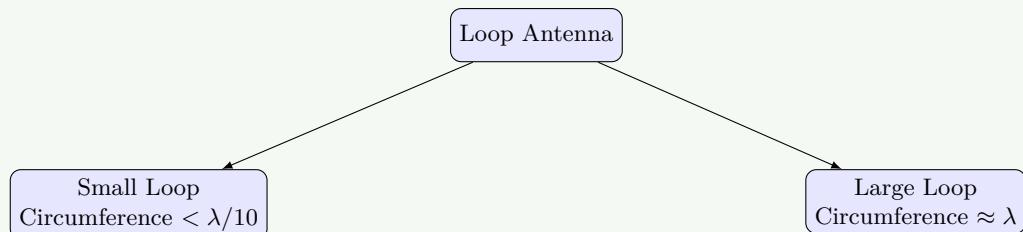
Parameter	Broadside Array	End Fire Array
Direction of max radiation	Perpendicular to the array axis.	Along the array axis.
Phase difference	0° (in-phase).	180° or progressive phase.
Element spacing	Typically $\lambda/2$ .	Typically $\lambda/4$ to $\lambda/2$ .
Radiation pattern	Narrow in plane containing array axis.	Narrow in plane perpendicular to array elements.
Directivity	High, increases with number of elements.	High, increases with number of elements.
Applications	Fixed point-to-point links.	Direction finding, radar.

**Mnemonic**

**Mnemonic:** "BEPODS: Broadside-End, Perpendicular-Or-Direction, Spacing"

**Question 2(b) OR [4 marks]**

Explain loop antenna and discuss its radiation characteristics

**Solution**

**Figure 5.** Types of Loop Antennas

**Loop Antenna Characteristics:**

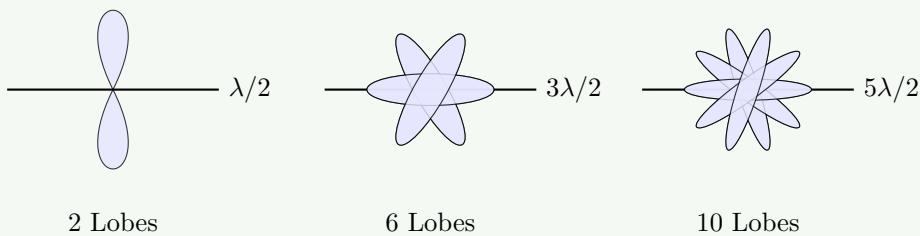
Parameter	Small Loop	Large Loop
Current distribution	Uniform around loop.	Varies around circumference.
Radiation pattern	Figure-8 (perpendicular to loop plane).	More complex with multiple lobes.
Directivity	Low (1.5 dBi).	Higher (3-4 dBi).
Polarization	Magnetic field perpendicular to loop.	Electric field in plane.
Input impedance	Very low (< 10Ω).	Higher (50-200Ω).
Applications	Direction finding, AM receivers.	HF communications, LF.

**Mnemonic**

**Mnemonic:** "SCALED: Size Changes Antenna's Lobes, Efficiency, and Direction"

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

Describe radiation characteristics of non resonant wire antennas and draw the radiation pattern of  $\lambda/2$ ,  $3\lambda/2$  and  $5\lambda/2$  antenna

**Solution****Figure 6.** Radiation Patterns of Resonant Wire Antennas (Simplified)**Non-Resonant Wire Antenna Characteristics:**

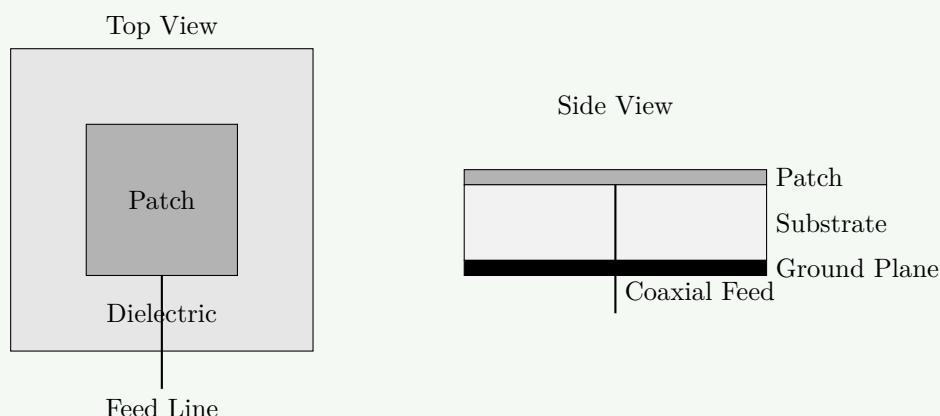
Characteristic	Description
<b>Current distribution</b>	Traveling waves with minimal standing waves.
<b>Termination</b>	Usually terminated with resistive load to prevent reflections.
<b>Bandwidth</b>	Wide bandwidth operation.
<b>Input impedance</b>	More constant across frequency range.
<b>Radiation pattern</b>	$\lambda/2$ : Single main lobe on each side (tilted). $3\lambda/2$ : Three main lobes on each side (tilted). $5\lambda/2$ : Five main lobes on each side (tilted).
<b>Directivity</b>	Increases with length but divided among multiple lobes.
<b>Efficiency</b>	Lower than resonant antennas due to resistive termination.

**Mnemonic**

**Mnemonic:** "TRIBE-WL: Traveling Resistance Improves Bandwidth, Efficiency Worse, Lobes multiply"

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

Write short note on micro strip (patch) antenna

**Solution****Figure 7.** Microstrip Patch Antenna Structure**Microstrip Patch Antenna:**

- Structure:** Metal patch on dielectric substrate with ground plane.

- Size:** Typically  $\lambda/2 \times \lambda/2$  or  $\lambda/2 \times \lambda/4$ .
- Feed methods:** Microstrip line, coaxial probe, aperture coupling.
- Radiation:** From fringing fields at patch edges.
- Polarization:** Linear or circular depending on patch shape.
- Bandwidth:** Narrow (3-5% of center frequency).
- Applications:** Mobile devices, satellites, aircraft, RFID.

#### Mnemonic

**Mnemonic:** "SLIM-PCB: Small, Lightweight, Integrable Microwave Printed Circuit Board"

## Question 3(b) [4 marks]

Explain helical antenna and discuss its radiation characteristics

#### Solution

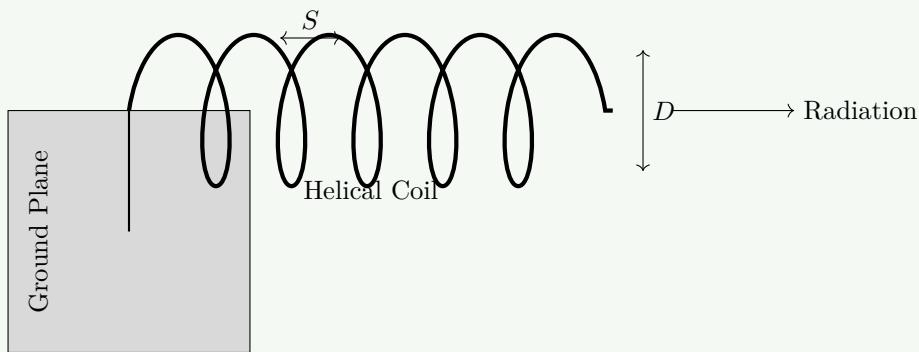


Figure 8. Helical Antenna (Axial Mode)

#### Helical Antenna Characteristics:

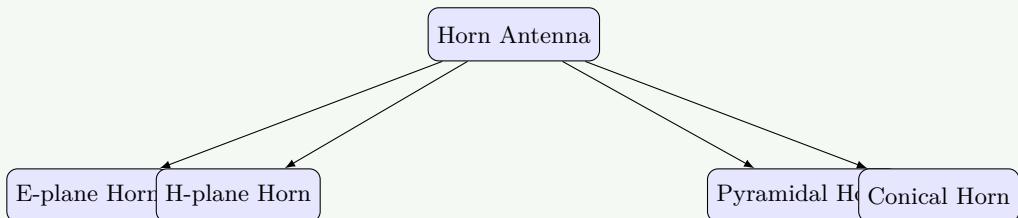
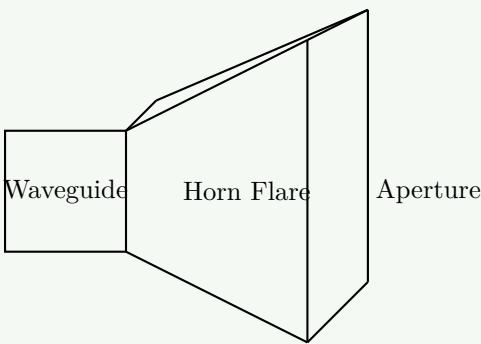
Parameter	Normal Mode	Axial Mode
<b>Helix circumference</b>	Small ( $< \lambda/\pi$ ).	About $\lambda$ .
<b>Radiation pattern</b>	Omnidirectional (like dipole).	Directional (end-fire).
<b>Polarization</b>	Linear, perpendicular to helix axis.	Circular (RHCP or LHC)
<b>Input impedance</b>	High (120-200 $\Omega$ ).	100-200 $\Omega$ .
<b>Bandwidth</b>	Narrow.	Wide (up to 70%).
<b>Applications</b>	Mobile phones, FM radio.	Satellite comms, space to

#### Mnemonic

**Mnemonic:** "NASA-CP: Normal Axial Spacing Affects Circular Polarization"

## Question 3(c) [7 marks]

Explain horn antenna and discuss its radiation characteristics

**Solution****Figure 9.** Types of Horn Antennas**Figure 10.** Pyramidal Horn Antenna Structure

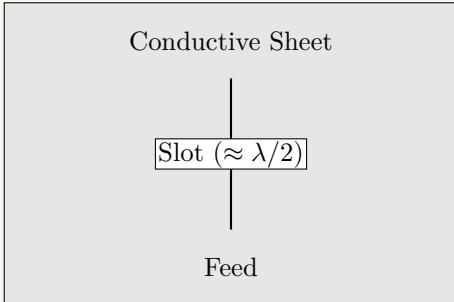
Characteristic	Description
<b>Operating principle</b>	Gradual transition from waveguide to free space.
<b>Frequency range</b>	Microwave and mm-wave (1-300 GHz).
<b>Directivity</b>	Medium to high (10-20 dBi).
<b>Radiation pattern</b>	Directional with main lobe in forward direction.
<b>Beamwidth</b>	E-plane: 40-50°, H-plane: 40-50°.
<b>Polarization</b>	Linear (matches waveguide).
<b>Bandwidth</b>	Very wide (> 100%).
<b>Efficiency</b>	Very high (> 90%).
<b>Applications</b>	Radar, satellite communications, EMC testing.

**Mnemonic**

**Mnemonic:** "POWER-HF: Pyramidal Or Waveguide Extended, Radiates High Frequencies"

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

Write short note on slot antenna

**Solution****Figure 11.** Slot Antenna**Slot Antenna:**

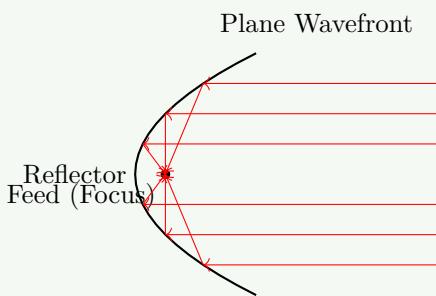
- **Structure:** Narrow slot cut in conductive sheet/plane.
- **Size:** Typically  $\lambda/2$  long for resonance.
- **Feed method:** Across the slot at center or offset.
- **Radiation pattern:** Similar to dipole but rotated 90° (Babinet's principle).
- **Polarization:** Linear, perpendicular to slot length.
- **Impedance:** High (several hundred ohms).
- **Applications:** Aircraft, satellites, base stations.

**Mnemonic**

**Mnemonic:** "SCRAP: Slot Cut Radiates Alternating Polarization"

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

Explain parabolic reflector antenna and discuss its radiation characteristics

**Solution****Figure 12.** Parabolic Reflector Ray Tracing

**Parabolic Reflector Antenna Characteristics:**

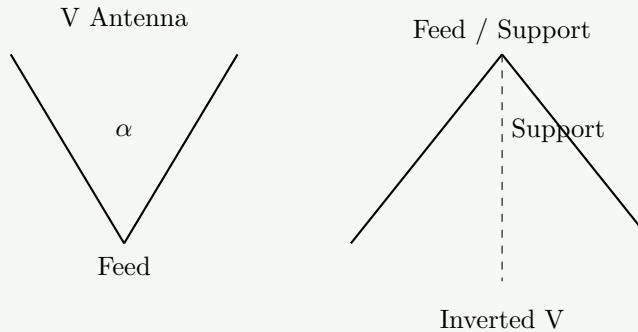
Characteristic	Description
<b>Operating principle</b>	Focuses parallel incoming waves to focal point (refraction).
<b>Frequency range</b>	From UHF to millimeter waves (300 MHz - 300 GHz).
<b>Directivity</b>	Very high (30-40 dBi for large dishes).
<b>Radiation pattern</b>	Highly directional, narrow main beam.
<b>Beamwidth</b>	Inversely proportional to diameter ( $\theta \approx 70\lambda/D$ ).
<b>Feed types</b>	Prime focus, Cassegrain, Gregorian, offset.
<b>Efficiency</b>	50-70% depending on feed design and blockage.

**Mnemonic**

**Mnemonic:** "FIND-SHF: Focused, Intense Narrow Directivity for Super High Frequencies"

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

Describe V and inverted V antenna

**Solution**

**Figure 13.** V and Inverted V Antennas

	<b>V Antenna</b>	<b>Inverted V Antenna</b>
<b>Comparison:</b>	<b>Construction</b>	Two equal length wires in V-shape.
	<b>Angle</b>	10-90° (affects directivity).
	<b>Leg Length</b>	Multiple wavelengths (1 – 6λ).
	<b>Pattern</b>	Bidirectional/Unidirectional.
	<b>Impedance</b>	300-900Ω.
	<b>Mounting</b>	Horizontal.

**Mnemonic**

**Mnemonic:** "VOVO: V Outward (radiation), V One-support (inverted)"

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

Define: (1) Reflection, (2) Refraction and (3) Diffraction

**Solution**

Phe-nomenon	Definition
<b>Reflection</b>	The bouncing back of electromagnetic waves when they strike a boundary between two different media without penetrating the second medium.
<b>Refraction</b>	The bending of electromagnetic waves when they pass from one medium to another due to change in wave velocity.
<b>Diffraction</b>	The bending of electromagnetic waves around obstacles or through openings, allowing waves to propagate into shadowed regions.

**Mnemonic**

**Mnemonic:** "RRD: Rays Rebound, Redirect, Disperse"

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

List HAM radio application for communication

**Solution**

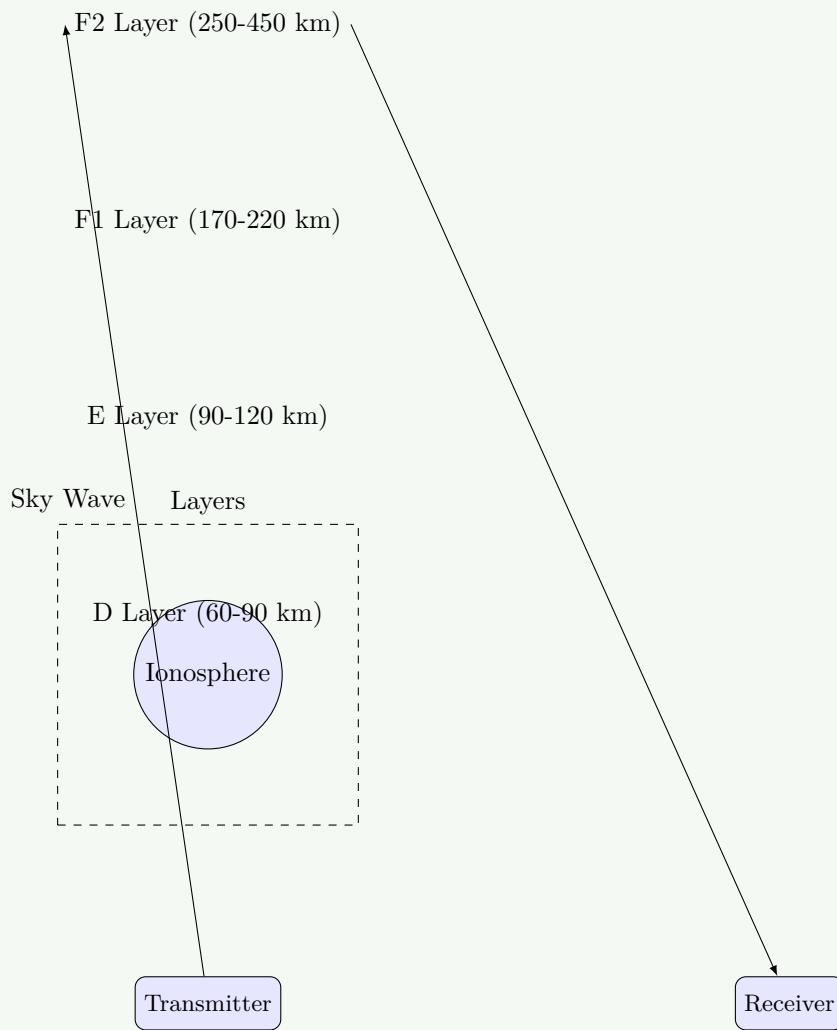
Application Category	Specific Applications
<b>Emergency communications</b>	Disaster relief, emergency response, weather reporting.
<b>Public service</b>	Community events, search and rescue, traffic monitoring.
<b>Technical experimentation</b>	Antenna design, propagation studies, digital modes testing.
<b>International goodwill</b>	DX communication, contesting, international friendship.
<b>Personal recreation</b>	Casual conversations, hobby groups, radio clubs.
<b>Educational outreach</b>	School programs, STEM activities, training new operators.
<b>Space communication</b>	Satellite operation, ISS contact, EME (moon bounce).
<b>Digital communication</b>	APRS, packet radio, FT8, RTTY, PSK31.

**Mnemonic**

**Mnemonic:** "EPTIPS-D: Emergency, Public, Technical, International, Personal, Space, Digital"

**Question 4(c) [7 marks]**

Explain ionosphere's layers and sky wave propagation

**Solution****Figure 14.** Ionospheric Layers and Sky Wave Propagation

	<b>Layer</b>	<b>Altitude</b>	<b>Characteristics</b>	<b>Effect on Radio Waves</b>
<b>Ionospheric Layers:</b>	<b>D Layer</b>	60-90 km	Low ionization, exists only during daylight.	Absorbs LF/MF signals, minimal refraction.
	<b>E Layer</b>	90-120 km	Medium ionization, stronger during day.	Refracts HF waves up to 5 MHz.
	<b>F1 Layer</b>	170-220 km	Present only during day, merges with F2 at night.	Refracts higher HF frequencies.
	<b>F2 Layer</b>	250-450 km	Highest ionization, present day and night.	Main layer for long-distance HF communication.

**Sky Wave Propagation Parameters:**

- Virtual Height:** Apparent height where reflection seems to occur (higher than actual due to gradual refraction).
- Critical Frequency:** Maximum frequency that can be reflected when transmitted vertically.
- Maximum Usable Frequency (MUF):** Highest frequency that can be used for communication between two points.
- Skip Distance:** Minimum distance from transmitter where sky waves return to Earth.
- Lowest Usable Frequency (LUF):** Minimum frequency that provides reliable communication.
- Optimum Working Frequency (OWF):** Typically 85% of MUF, provides most reliable communication.

**Mnemonic**

**Mnemonic:** "DEFMSL: During day, Every Frequency Makes Somewhat Longer paths"

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

Define: (1) MUF, (2) LUF and (3) Skip distance

**Solution**

Term	Definition
<b>MUF (Maximum Usable Frequency)</b>	The highest frequency that can be used for reliable communication between two specific points via ionospheric reflection.
<b>LUF (Lowest Usable Frequency)</b>	The minimum frequency that provides adequate signal strength for reliable communication despite D-layer absorption.
<b>Skip Distance</b>	The minimum distance from a transmitter at which a sky wave of a specific frequency returns to Earth.

**Mnemonic**

**Mnemonic:** "MLS: Maximum frequency Leaps, Lowest frequency Seeps, Skip distance Spans"

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

List HAM radio digital modes of communication

**Solution**

Digital Mode	Description	Typical Frequency Bands
<b>FT8</b>	Low power, narrow bandwidth, automated exchange.	HF bands (especially 20m, 40m, 80m).
<b>PSK31</b>	Phase Shift Keying, keyboard-to-keyboard.	HF bands (especially 20m, 40m).
<b>RTTY</b>	Radio Teletype, oldest digital mode.	HF bands.
<b>APRS</b>	Automatic Packet Reporting System, position reporting.	VHF (typically 144.39 MHz in US).
<b>SSTV</b>	Slow Scan Television, image transmission.	HF bands (especially 20m).
<b>JT65/JT9</b>	Weak signal modes for EME and DX.	HF and VHF bands.
<b>WINLINK</b>	Email over radio.	HF and VHF bands.
<b>DMR</b>	Digital Mobile Radio, voice digital mode.	VHF and UHF bands.

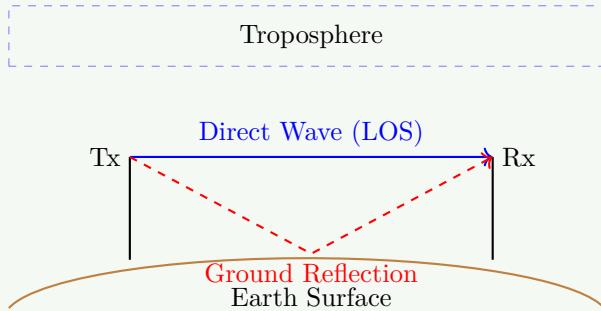
**Mnemonic**

**Mnemonic:** "PRAW-JDW: PSK, RTTY, APRS, WINLINK, JT65, DMR"

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

Explain space wave propagation

### Solution



**Figure 15.** Space Wave Propagation Mechanisms

**Space Wave Propagation:** Space wave propagation refers to radio waves that travel through the troposphere (lower atmosphere) rather than via ionospheric reflection. It includes:

1. **Direct wave:** Travels in straight line from transmitter to receiver (line-of-sight).
2. **Ground-reflected wave:** Reflects off Earth's surface before reaching receiver.
3. **Surface wave:** Follows Earth's curvature due to diffraction.

#### Types of Space Wave Propagation:

- **Tropospheric Scatter Propagation:**
  - **Mechanism:** Signal scattering by irregularities in troposphere.
  - **Frequency range:** VHF, UHF, SHF (100 MHz - 10 GHz).
  - **Distance:** 100-800 km (beyond horizon).
- **Duct Propagation:**
  - **Mechanism:** Trapping of waves in atmospheric ducts (layers with abnormal refractive index).
  - **Distance:** Up to 2000 km (far beyond horizon).

#### Factors Affecting Space Wave Propagation:

- **Height of antennas:** Higher antennas increase range.
- **Frequency:** Higher frequencies experience less diffraction.
- **Terrain:** Obstacles block signals (Fresnel zone clearance needed).
- **Weather:** Temperature inversions, humidity affect ducting.
- **Earth's curvature:** Limits line-of-sight distance.

#### Mnemonic

**Mnemonic:** "DRIFT-SD: Direct Routes, Irregular Formations of Troposphere, Scatter and Ducts"

## Question 5(a) [3 marks]

Define: (1) Beam area (2) Beam efficiency, and (3) Effective aperture

### Solution

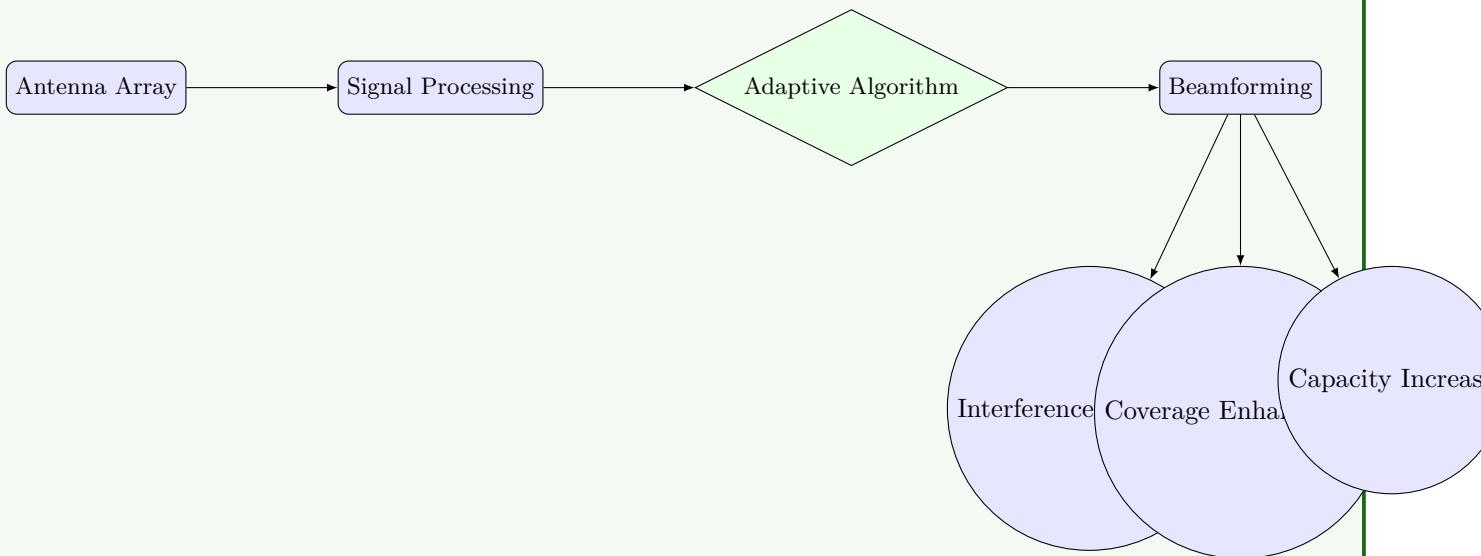
Parameter	Definition
<b>Beam Area</b>	The solid angle through which all of the power radiated by the antenna would pass if the radiation intensity was constant at its maximum value.
<b>Beam Efficiency</b>	The ratio of power radiated in the main beam to the total power radiated by the antenna.
<b>Effective Aperture</b>	The ratio of power received by the antenna to the power density of the incident wave.

**Mnemonic**

**Mnemonic:** "BEA: Beam area Encloses, efficiency Excludes sidelobes, Aperture Extracts power"

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

Describe need of smart antenna

**Solution**

**Figure 16.** Smart Antenna System Concept

**Need for Smart Antennas:**

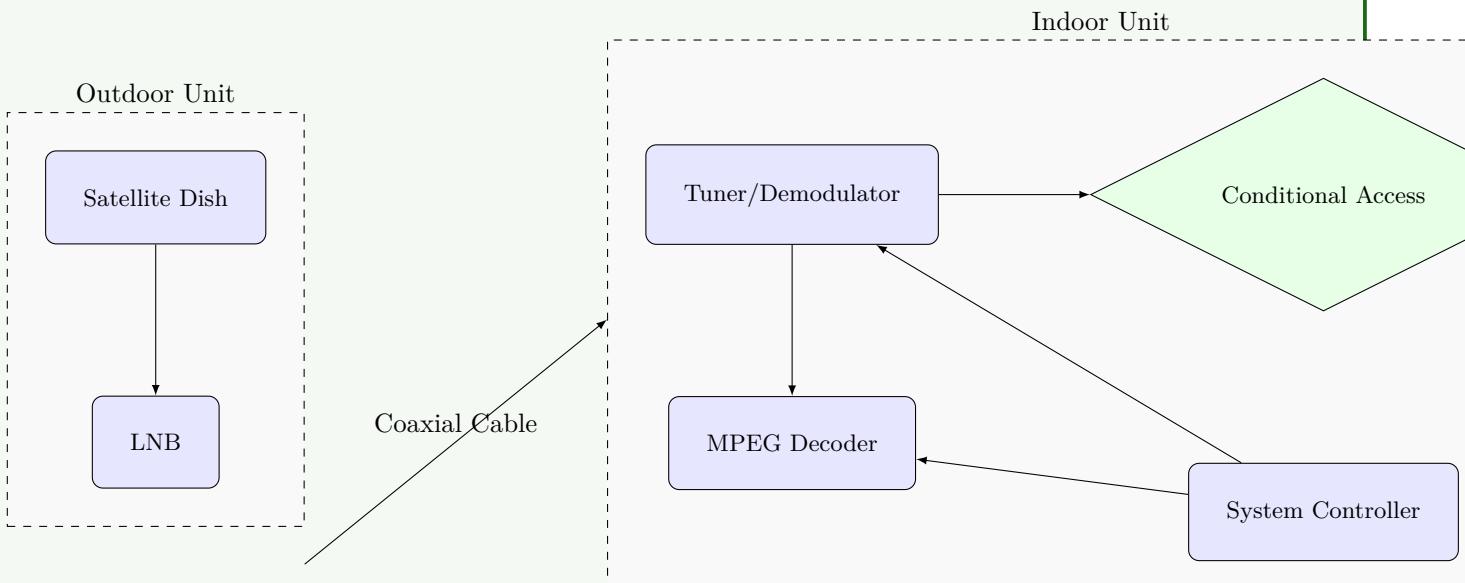
Need	Description
<b>Spectrum efficiency</b>	Reuse frequencies more effectively in same geographic area.
<b>Capacity enhancement</b>	Support more users in same bandwidth through spatial separation.
<b>Coverage extension</b>	Increase range by focusing energy in desired directions.
<b>Interference reduction</b>	Minimize effects of co-channel interference and jammers.
<b>Energy efficiency</b>	Reduce transmitted power by focusing energy only where needed.
<b>Multipath mitigation</b>	Reduce fading by selecting optimal signal paths.
<b>Location services</b>	Enable direction finding and positioning applications.
<b>Signal quality</b>	Improve SNR through spatial filtering.

**Mnemonic**

**Mnemonic:** "SLIM-ACES: Spectrum efficiency, Location services, Interference reduction, Multipath mitigation, Adaptive beams, Capacity, Energy, Signal quality"

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

Draw the DTH Receiver indoor and outdoor block diagram and discuss its functions

**Solution****Figure 17.** DTH Receiver System Block Diagram**DTH Receiver System Components and Functions:****Outdoor Unit Components:**

- **Satellite Dish:** Collects and reflects weak satellite signals to focal point.
- **LNB (Low Noise Block):** Receives signals from dish, amplifies them with minimal noise addition, and converts high frequency (10-12 GHz) to lower IF frequency (950-2150 MHz).

**Indoor Unit Components:**

- **Tuner/Demodulator:** Selects desired channel frequency, demodulates signal to extract digital data stream.
- **MPEG-2/4 Decoder:** Decodes compressed video/audio signals into viewable/audible content.
- **Conditional Access Module:** Provides security and decryption for subscribed channels.
- **System Controller/CPU:** Manages overall operation, processes user commands, updates software.
- **User Interface:** Provides on-screen display, receives remote control inputs.

**Signal Flow Process:**

1. Satellite dish collects signals and focuses them to LNB.
2. LNB amplifies, filters and converts signals to lower frequency.
3. Coaxial cable carries IF signals to indoor unit.
4. Tuner selects channel and demodulates signal.
5. Conditional access module decrypts authorized content.

**Mnemonic**

**Mnemonic:** "SALT-DCU: Satellite dish And LNB Transmit, Demodulator Converts and Unscrambles"

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

**Define:** (1) Antenna, (2) Folded dipole, and (3) Antenna array

**Solution**

<b>Term</b>	<b>Definition</b>
<b>Antenna</b>	A device that converts electrical signals into electromagnetic waves for transmission or electromagnetic waves into electrical signals for reception.
<b>Folded Dipole</b>	A dipole antenna modified by adding a second conductor connected at both ends to the first, forming a narrow loop with feed point at the bottom center.
<b>Antenna Array</b>	A system of multiple antenna elements arranged in a specific geometric pattern to achieve desired radiation characteristics.

**Mnemonic**

**Mnemonic:** "AFD: Antenna Feeds, Folded Doubles impedance, Directivity increases with Arrays"

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

Describe application of smart antenna

**Solution**

<b>Application Area</b>	<b>Specific Applications</b>
<b>Mobile Communications</b>	Base stations for 4G/5G networks, capacity enhancement, coverage improvement.
<b>Wi-Fi Systems</b>	MIMO routers, extended range access points, interference mitigation.
<b>Radar Systems</b>	Phased array radars, target tracking, electronic warfare, weather radars.
<b>Satellite Communications</b>	Adaptive beamforming, tracking earth stations, interference rejection.
<b>Military/Defense</b>	Jammers, secure communications, reconnaissance, surveillance.
<b>IoT Networks</b>	Low-power wide-area networks, directional coverage for sensors.
<b>Vehicle Communications</b>	V2X communications, autonomous vehicles, collision avoidance.
<b>Indoor Positioning</b>	Location-based services, asset tracking, emergency services.

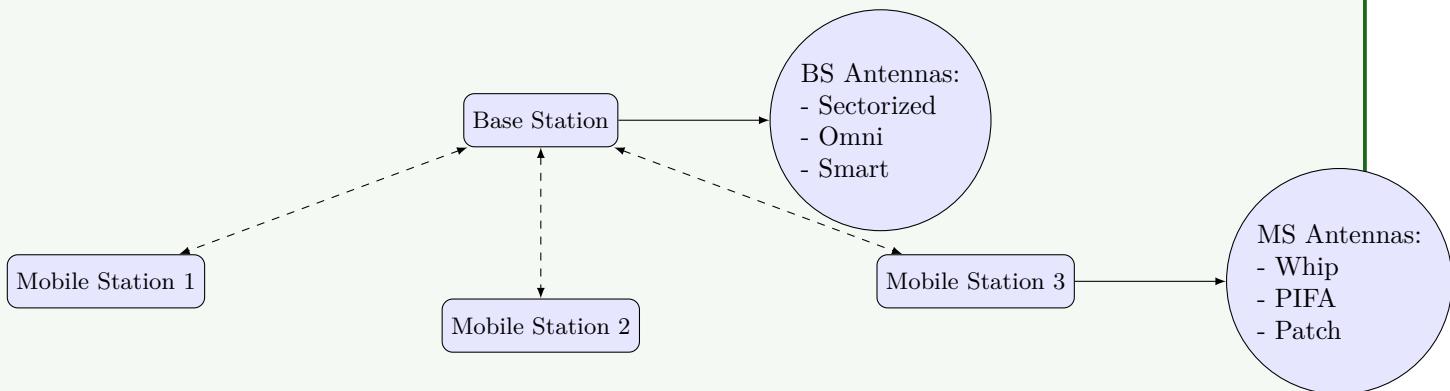
**Mnemonic**

**Mnemonic:** "SWIM-MIV: Satellite, Wireless, IoT, Military, Mobile, Indoor positioning, Vehicles"

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

Explain Terrestrial mobile communication antennas and also discuss about base station and mobile station antennas

## Solution



**Figure 18.** Terrestrial Mobile Communication System

Antenna Type	Characteristics	Applications
<b>Omnidirectional</b>	360° horizontal coverage, 6-12 dBi gain.	Rural areas, low traffic density.
<b>Sectorized</b>	65-120° sector coverage, 12-20 dBi gain.	Urban/suburban areas, frequency reuse.
<b>Diversity Antennas</b>	Multiple elements, space/polarization diversity.	Multipath environments, high reliability.
<b>Smart Antennas</b>	Adaptive beamforming, 15-25 dBi gain.	High capacity areas, 4G/5G.

Antenna Type	Characteristics	Applications
<b>Whip/Monopole</b>	External, $\lambda/4$ , omnidirectional.	Vehicle-mounted phones, early mobile phones.
<b>Helical</b>	Compact, good bandwidth, flexible.	Portable radios, early mobile phones.
<b>PIFA (Planar Inverted-F)</b>	Internal, compact, multiband.	Modern smartphones, tablets.
<b>Patch/Microstrip</b>	Low profile, directional, dual pol.	Data cards, fixed terminals.

### Key Considerations:

- Base Station:** High gain, focused beams, interference control (downtilt).
- Mobile Station:** Small size, multiband, SAR compliance, design integration.

### Mnemonic

**Mnemonic:** "BOMBS-WHIP: Base Omni/Multi-Beam/Smart, Whip/Helical/Inverted-F/Patch"