

# Subject Name Solutions

4341106 – Winter 2023

Semester 1 Study Material

*Detailed Solutions and Explanations*

## Question 1(a) [3 marks]

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

### Solution

Table 1: Key Antenna Parameters

Parameter	Definition
<b>Directivity</b>	Ratio of maximum radiation intensity to average radiation intensity of an antenna
<b>Gain</b>	Ratio of power radiated in a particular direction to the power that would be radiated by an isotropic antenna
<b>HPBW (Half Power Beam Width)</b>	Angular width where radiation intensity is half (3dB less) of the maximum value

### Mnemonic

“DGH: Direction Gives Half-power”

## Question 1(b) [4 marks]

List the properties of electromagnetic waves

### Solution

Table 2: Properties of Electromagnetic Waves

Property	Description
<b>Transverse Waves</b>	Electric and magnetic fields perpendicular to direction of propagation
<b>Velocity</b>	Speed of light ( $3 \times 10^8 \text{ m/s}$ ) in vacuum
<b>No Medium Required</b>	Can travel through vacuum, unlike mechanical waves
<b>Polarization</b>	Direction of electric field vector
<b>Energy Transport</b>	Carries energy through space
<b>Reflection/Refraction</b>	Can be reflected and refracted at boundaries
<b>Interference/Diffraction</b>	Show wave-like properties

### Mnemonic

“TVNPER: Transverse Velocity No-medium Polarized Energy Reflection”

## Question 1(c) [7 marks]

Explain physical concept of generation of Electromagnetic wave

### Solution

**Diagram:** Generation of Electromagnetic Wave

Mermaid Diagram (Code)

{Shaded}

```

{Highlighting} []
graph LR
    A[Accelerating Charge] -->|Produces| B[Time-varying Electric Field]
    B -->|Produces| C[Time-varying Magnetic Field]
    C -->|Produces| D[Time-varying Electric Field]
    D -->|C| C
    C -->|E| E[Self-sustaining EM Wave]
{Highlighting}
{Shaded}

```

- Charge Acceleration:** When electric charges accelerate, they generate changing electric fields
- Field Coupling:** A changing electric field produces a changing magnetic field and vice versa
- Self-Propagation:** This cyclic generation of fields allows waves to travel without a medium
- Field Orientation:** Electric and magnetic fields are perpendicular to each other and the direction of propagation
- Energy Transport:** Energy alternates between electric and magnetic fields as wave propagates

### Mnemonic

“CASES: Charge Acceleration Self-propagates Electro-magnetic Signals”

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

Explain how electromagnetic field radiated from a center fed dipole

#### Solution

Diagram: Field Radiation from Center-Fed Dipole

Mermaid Diagram (Code)

```

{Shaded}
{Highlighting} []
graph LR
    A[Alternating Current Input] -->|Creates| B[Oscillating Charges]
    B -->|Generates| C[Time-varying Electric Field]
    C -->|Generates| D[Time-varying Magnetic Field]
    D -->|E| E[EM Wave Radiation]
    E -->|E| E
{Highlighting}
{Shaded}

```

- Center Feeding:** AC signal applied at center of dipole creates oscillating current
- Charge Distribution:** Current creates opposite charges at dipole ends that change with AC frequency
- Field Generation:** Oscillating charges create time-varying electric field
- Magnetic Coupling:** Time-varying electric field generates perpendicular magnetic field
- Near/Far Fields:** Near dipole, fields are complex; far from dipole, fields form uniform radiation pattern
- Radiation Pattern:** Maximum radiation perpendicular to dipole axis, zero radiation along axis

### Mnemonic

“CORONA: Current Oscillates, Radiation Occurs, Near-far Areas”

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

Differentiate the resonant and non-resonant antennas

#### Solution

Table 3: Resonant vs Non-Resonant Antennas

Feature	Resonant Antennas	Non-Resonant Antennas
<b>Length</b>	Integer multiple of $\lambda/2$	Not related to wavelength
<b>Standing Waves</b>	Present	Not present
<b>Impedance</b>	Resistive (real)	Complex (real + imaginary)
<b>Bandwidth</b>	Narrow	Wide
<b>Example</b>	Half-wave dipole	Rhombic antenna

## Mnemonic

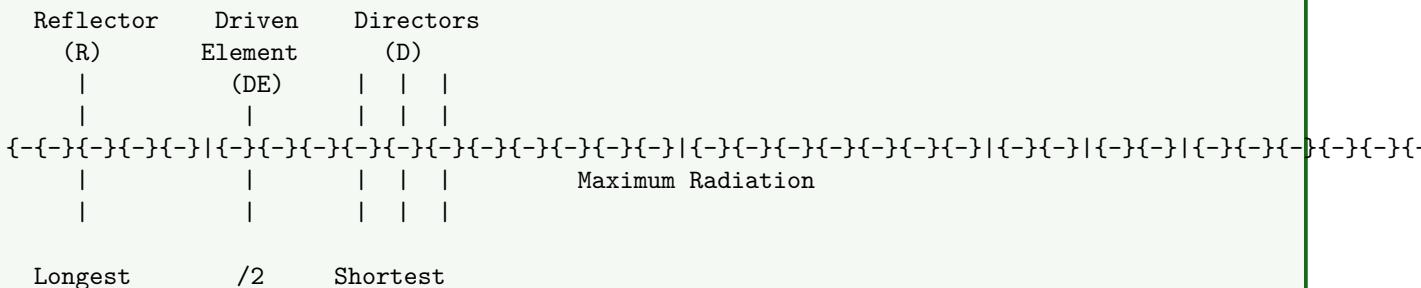
“RESI: Resonant Exhibits Standing-waves Impedance-real”

## Question 2(b) [4 marks]

Explain Yagi antenna and discuss its radiation characteristics

## Solution

## Diagram: Yagi-Uda Antenna Structure



- **Structure:** Contains one reflector, one driven element, and multiple directors
  - **Directivity:** High directivity in direction of directors (8-12dB)
  - **Gain:** Higher gain with more directors (up to 15dB)
  - **Bandwidth:** 2-5% of center frequency
  - **Applications:** TV reception, point-to-point communication, amateur radio

## Mnemonic

“DRAGONS: Directional Reflector And Gain-improving Directors Offer Narrow Signals”

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

**Describe radiation characteristics of resonant wire antennas and draw the current distribution of  $\frac{1}{2}$ ,  $\frac{3}{2}$  and  $\frac{5}{2}$  antenna**

### Solution

Diagram: Current Distribution in Resonant Wire Antennas

```

/2 Antenna:
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|           |
v           v
-{--}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}+{-}{-}{-}{-}{-}
 \^{          \^{}{}}
|           |
+{--}{-}{-}{-}{-}{-}{-}{-}{-}+
I\max at center
Zero at ends

```

### 3 / 2 Antenna:

- **Half-Wave (1/2):** Current maximum at center, zero at ends; radiation pattern is figure-eight shaped
  - **Three Half-Wave (3/2):** Three current maxima, phase reversal at  $\lambda/2$  points; multiple lobes in radiation pattern
  - **Five Half-Wave (5/2):** Five current maxima, more complex radiation pattern with multiple lobes
  - **Standing Waves:** All resonant antennas exhibit standing wave current distribution
  - **Feed Point:** Usually at current maximum for optimum impedance matching

## Mnemonic

“NODE: Number Of Distributions Equals wavelength-multiple”

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

Differentiate the broad side and end fire array antennas

## Solution

Table 4: Broadside vs End Fire Array Antennas

Feature	Broadside Array	End Fire Array
<b>Maximum Radiation</b>	Perpendicular to array axis	Along array axis
<b>Element Spacing</b>	Typically $\lambda/2$	Typically $\lambda/4$ to $\lambda/2$
<b>Phase Difference</b>	$0^\circ$ (in-phase)	$180^\circ$ (opposite phase)
<b>Directivity</b>	High	High
<b>Pattern</b>	Bidirectional	Unidirectional

## Mnemonic

## “PEPS: Perpendicular Elements Produce Sideways radiation”

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

Explain loop antenna and discuss its radiation characteristics

### Solution

## Diagram: Loop Antenna

+{ - { - } { - } { - } { - } + }

```
+{--}{-}+      +{-}{-}{-}+
|           |
+{--}{-}{-}{-}{-}{-}+{--}{-}{-}{-}{-}{-}+{--}
|
Feed
Point
```

- **Structure:** Closed-loop conductor with circumference of one wavelength or less
  - **Types:** Small loops (circumference  $< \lambda/10$ ) and large loops (circumference  $\approx \lambda$ )
  - **Polarization:** Electric field polarized in plane of loop
  - **Radiation Pattern:** Figure-eight pattern for small loops, more directional for large loops
  - **Applications:** Direction finding, AM reception, RFID tags
  - **Impedance:** High impedance for small loops, resonant for large loops

## Mnemonic

## “SPIRAL: Small Patterns In Receiving And Locating signals”

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

**Describe radiation characteristics of non resonant wire antennas and draw the radiation pattern of  $\frac{1}{2}$ ,  $\frac{3}{2}$  and  $\frac{5}{2}$  antenna**

### Solution

Diagram: Radiation Patterns of Wire Antennas

## /2 Antenna Pattern:

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| / {}  
| | |  
{-{-}{-}{-}{-}+{-}{-}{-}+{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}  
| | |  
| { /}  
| {{-}}  
v
```

### 3 / 2 Antenna Pattern:

```

\^{}}
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| / X {}
| | / { |}
{--}{-}{-}{-}+{-}{-}+{-}+{-}{-}{-}{-}+{-}+{-}{-}{-}{-}{-}
| | { / |}
| { X /}
| {{-} {-}}
v

```

## 5 /2 Antenna Pattern:

- **Non-Resonant Properties:** Traveling waves rather than standing waves
- **/2 Antenna:** Simple bidirectional pattern, maximum radiation perpendicular to wire
- **3 /2 Antenna:** Multiple lobes, more complex pattern with side lobes
- **5 /2 Antenna:** Even more complex pattern with multiple main and side lobes
- **Feed Point Impedance:** Non-resonant, typically requires impedance matching
- **Bandwidth:** Wider than resonant antennas

### Mnemonic

“TWIST: Traveling Waves Increase Side-lobe Transmission”

## Question 3(a) [3 marks]

Write short note on micro strip (patch) antenna

### Solution

#### Diagram: Microstrip Patch Antenna Structure

```
+{--}{-}{-}{-}{-}{-}{-}{-}+
|   |   |
| Patch |   |
|   |   |
+{--}{-}{-}{-}{-}{-}{-}{-}+
| Substrate |
|
+{--}{-}{-}{-}{-}{-}{-}{-}+
| Ground Plane |
+{--}{-}{-}{-}{-}{-}{-}{-}+
```

- **Structure:** Metal patch on dielectric substrate with ground plane below
- **Size:** Typically half-wavelength in size
- **Profile:** Low-profile, lightweight, easy to fabricate
- **Radiation:** Radiates from patch edges, omnidirectional or directional patterns
- **Applications:** Mobile devices, satellites, GPS receivers

### Mnemonic

“PSALM: Patch Substrate Above Layer of Metal”

## Question 3(b) [4 marks]

Explain helical antenna and discuss its radiation characteristics

### Solution

#### Diagram: Helical Antenna

```
\^{}}
|
+{--}{-}{-}+
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+
/|   | {}
+ |   | +
| |   | | {--{-}}
+ |   | +
{|   | /}
+   +
{   /}
+{--}{-}{-}+
```

### Ground Plane

- **Structure:** Conducting wire wound in helix shape above ground plane
- **Modes:** Axial mode (end-fire) and normal mode (broadside)
- **Axial Mode:** When circumference  $\approx$ , radiation along helix axis
- **Normal Mode:** When circumference  $\ll$ , radiation perpendicular to axis
- **Polarization:** Circular polarization in axial mode
- **Applications:** Satellite communication, space telemetry, radio astronomy

### Mnemonic

“MOCHA: Mode Of Circular Helix Antennas”

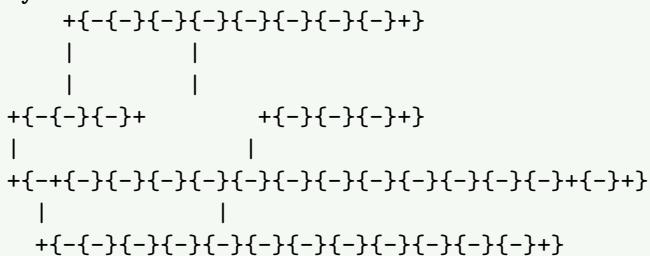
### Question 3(c) [7 marks]

Explain horn antenna and discuss its radiation characteristics

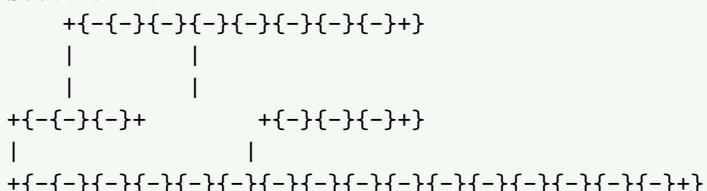
### Solution

#### Diagram: Horn Antenna Types

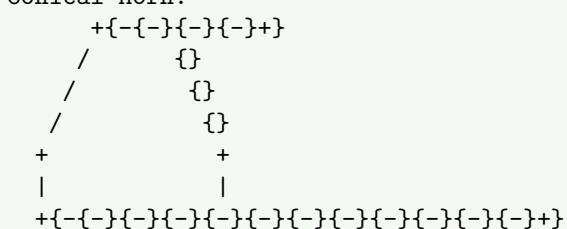
Pyramidal Horn:



Sectoral Horn:



Conical Horn:



- **Structure:** Waveguide with flared end to match impedance with free space
- **Types:** Pyramidal (rectangular), sectoral (E-plane or H-plane), and conical (circular)
- **Directivity:** 10-20 dB, higher than waveguide alone
- **Bandwidth:** Very wide bandwidth
- **Radiation Pattern:** Main lobe with small side lobes
- **Applications:** Microwave communications, radar, satellite tracking, EMC testing
- **Advantages:** High gain, simple construction, low VSWR

### Mnemonic

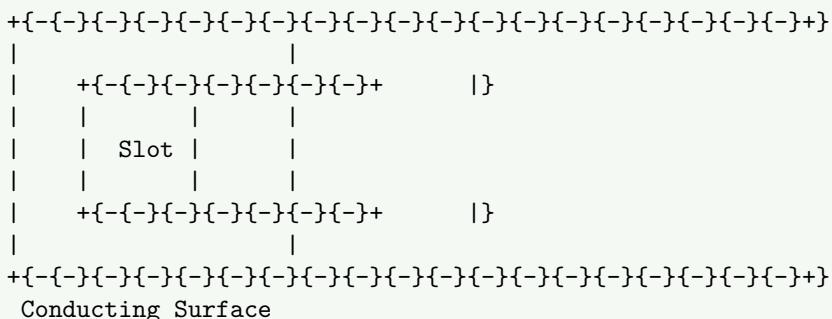
“POWERS: Pyramidal Or Widening End Radiates Strongly”

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

Write short note on slot antenna

#### Solution

##### Diagram: Slot Antenna



- **Structure:** Rectangular/circular slot cut in conducting surface
- **Babinet's Principle:** Complementary to dipole antenna
- **Radiation Pattern:** Similar to dipole but with E and H fields interchanged
- **Polarization:** Electric field perpendicular to slot length
- **Impedance:** High impedance compared to dipole
- **Applications:** Aircraft, spacecraft, base stations, flush mounting

#### Mnemonic

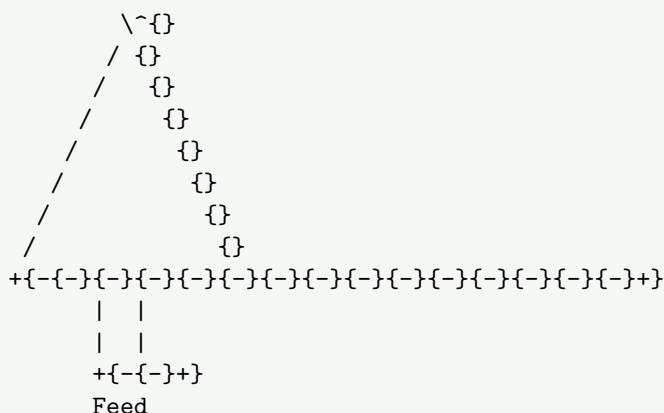
"CROPS: Complementary Radiation Opening Perpendicular to Surface"

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

Explain parabolic reflector antenna and discuss its radiation characteristics

#### Solution

##### Diagram: Parabolic Reflector Antenna



- **Structure:** Parabolic reflector with feed at focal point
- **Working Principle:** Parallel rays from reflector converge at focal point
- **Directivity:** Very high (30-40 dB)
- **Beamwidth:** Very narrow, inversely proportional to diameter
- **Efficiency:** 50-70% depending on feed design
- **Applications:** Satellite communications, radio astronomy, radar systems
- **Types:** Prime focus, Cassegrain, offset feed

#### Mnemonic

"DISH: Directing Incoming Signals to Hub"

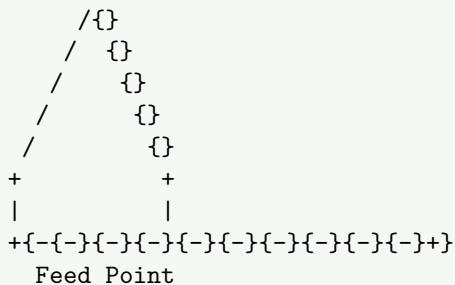
### Question 3(c) OR [7 marks]

Describe V and inverted V antenna

#### Solution

##### Diagram: V and Inverted V Antennas

V Antenna:



Inverted V Antenna:

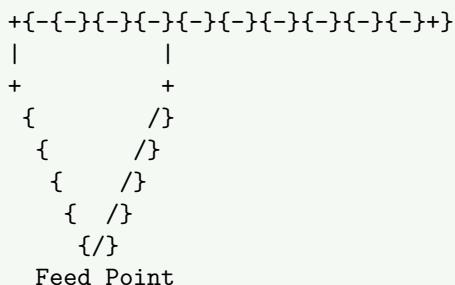


Table 5: Comparison of V and Inverted V Antennas

Feature	V Antenna	Inverted V Antenna
<b>Shape</b>	Arms extend upward from feed	Arms extend downward from apex
<b>Angle</b>	Typically $90^\circ$ between arms	Typically $90\text{-}120^\circ$ between arms
<b>Height</b>	Requires two tall supports	Requires one tall support
<b>Impedance</b>	40-50 ohms	20-30 ohms
<b>Radiation Pattern</b>	Bidirectional	More omnidirectional
<b>Applications</b>	Directional HF communications	HF amateur radio, limited space

#### Mnemonic

“VIVA: V Is Vertical Arrangement, Inverted V Aims downward”

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

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

#### Solution

Table 6: Wave Phenomenon Definitions

Phenomenon	Definition
<b>Reflection</b>	Bouncing back of waves when they strike the boundary between two media
<b>Refraction</b>	Bending of waves when they pass from one medium to another with different propagation velocity
<b>Diffraction</b>	Bending of waves around obstacles or through openings

## Mnemonic

"RRD: Rebounding, Redirecting, Detour"

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

List HAM radio application for communication

#### Solution

Table 7: HAM Radio Applications

Application	Description
<b>Emergency Communication</b>	Disaster relief when normal infrastructure fails
<b>DX Communication</b>	Long-distance international communications
<b>Satellite Communication</b>	Using amateur radio satellites for extended range
<b>Digital Modes</b>	Text/data transmission (RTTY, PSK31, FT8)
<b>Morse Code</b>	Traditional CW communication
<b>Voice Communication</b>	Using SSB, FM, AM modulation
<b>Public Service</b>	Supporting events like marathons, parades

## Mnemonic

"EDSDMVP: Emergency DX Satellite Digital Morse Voice Public-service"

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

Explain ionosphere's layers and sky wave propagation

#### Solution

Diagram: Ionospheric Layers and Sky Wave Propagation

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph TD
    A[Transmitter] -->|Sky Wave| B[F2 Layer: 250{-}400 km]
    A -->|Sky Wave| C[F1 Layer: 150{-}250 km]
    A -->|Sky Wave| D[E Layer: 90{-}150 km]
    A -->|Sky Wave| E[D Layer: 60{-}90 km]
    B -->|Reflection| F[Receiver at long distance]
    C -->|Reflection| F
    D -->|Reflection/Absorption| F
    E -->|Absorption| G[Signal Loss]
{Highlighting}
{Shaded}
```

- **D Layer (60-90 km):** Exists during daylight, absorbs HF signals below 10 MHz
- **E Layer (90-150 km):** Reflects signals 3-5 MHz, stronger during day, sporadic-E in summer
- **F1 Layer (150-250 km):** Daytime only, merges with F2 at night
- **F2 Layer (250-400 km):** Main reflecting layer, enables long-distance HF communication
- **Propagation Factors:**
  - **Virtual Height:** Apparent height of reflection
  - **Critical Frequency:** Maximum frequency reflected vertically
  - **MUF:** Maximum Usable Frequency for a given distance
  - **Skip Distance:** Minimum distance for sky wave reception

## Mnemonic

“DEFV: D-absorbs, E-reflects, F-provides Very-long-distance”

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

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

## Solution

Table 8: Ionospheric Propagation Terms

Term	Definition
<b>MUF (Maximum Usable Frequency)</b>	Highest frequency that can be reflected by ionosphere for a given distance and time
<b>LUF (Lowest Usable Frequency)</b>	Lowest frequency that provides adequate signal strength for communication
<b>Skip Distance</b>	Minimum distance from transmitter where sky wave returns to Earth

## Mnemonic

“MLS: Maximum-highest, Lowest-minimum, Skip-nearest”

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

List HAM radio digital modes of communication

## Solution

Table 9: HAM Radio Digital Modes

Digital Mode	Characteristics
<b>FT8</b>	Weak signal, narrow bandwidth, automated exchanges
<b>PSK31</b>	Keyboard-to-keyboard text communication, narrow bandwidth
<b>RTTY</b>	Radio teletype, robust older digital mode
<b>SSTV</b>	Slow Scan Television for image transmission
<b>JT65/JT9</b>	Very weak signal modes for extreme distance
<b>Packet Radio</b>	Computer-based data transmission with error correction
<b>APRS</b>	Automatic Position Reporting System with GPS
<b>Digital Voice</b>	DMR, D-STAR, Fusion, P25 digital voice protocols

## Mnemonic

“FIRST PAD: FT8 Is RTTY SSTV Then Packet APRS Digital-voice”

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

Explain space wave propagation

## Solution

Diagram: Space Wave Propagation

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting} []
graph LR
A[Transmitter] -->|Direct Wave| B[Receiver]
A -->|Ground Reflected Wave| B
```

```

A {-{-}{}}|Tropospheric Scatter| C[Extended Range Receiver]
A {-{-}{}}|Ducting| D[Very Extended Range]

```

```

subgraph Troposphere
A
B
C
D
E[Temperature Inversion Layer]
end

A {-{-}{}}|Follows| E {-}{-}{-}{-}|Waveguide Effect| D
{Highlighting}
{Shaded}

```

- **Components:** Direct wave, ground-reflected wave, tropospheric waves
- **Line of Sight:** Primary mechanism limited by Earth's curvature
- **Frequency Range:** VHF, UHF, and microwave frequencies
- **Tropospheric Scattering:** Forward scattering extends range beyond horizon
- **Duct Propagation:**
  - Occurs in temperature inversion layers
  - Creates waveguide effect trapping signals
  - Enables very long distance VHF/UHF propagation
- **Factors Affecting:** Antenna height, terrain, atmospheric conditions
- **Applications:** TV broadcasting, microwave links, mobile communications

### Mnemonic

“DRIFT: Direct Reflection Inversion Forward Tropospheric”

### Question 5(a) [3 marks]

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

### Solution

Table 10: Antenna Beam Parameters

Parameter	Definition
<b>Beam Area</b>	Solid angle through which all power radiated by antenna would flow if radiation intensity was constant
<b>Beam Efficiency</b>	Ratio of power in main beam to total radiated power
<b>Effective Aperture</b>	Area over which antenna captures RF energy, related to gain

### Mnemonic

“BEA: Beam Efficiency Aperture”

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

**Describe need of smart antenna**

### Solution

**Diagram: Smart Antenna Benefits**

Mermaid Diagram (Code)

```

{Shaded}
{Highlighting} []

```

```

graph TD
    A[Smart Antenna] -->|Provides| B[Increased Capacity]
    A -->|Provides| C[Enhanced Coverage]
    A -->|Reduces| D[Interference]
    A -->|Improves| E[Signal Quality]
    A -->|Saves| F[Battery Power]
    A -->|Enables| G[Spatial Multiplexing]
    {Highlighting}
    {Shaded}

```

- **Capacity Improvement:** Serves more users in same bandwidth
- **Coverage Enhancement:** Extends range by focusing energy
- **Interference Reduction:** Nulls out unwanted signals
- **Signal Quality:** Better SNR through beam focusing
- **Energy Efficiency:** Lower transmit power requirements
- **Spatial Multiplexing:** Multiple data streams in same frequency
- **Adaptive Operation:** Dynamically adapts to changing environment

### Mnemonic

“PRECISE: Power Reduction, Enhanced Coverage, Interference Suppression, Enhanced Signal”

## Question 5(c) [7 marks]

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

### Solution

#### Diagram: DTH System Block Diagram

#### Mermaid Diagram (Code)

```

{Shaded}
{Highlighting} []
graph LR
    subgraph Outdoor Unit
        A[Dish Antenna] -->|Collects| B[LNB {"-"} Low Noise Block]
    end

    subgraph Indoor Unit
        C[Tuner] -->|{"-"}{}| D[Demodulator]
        D -->|{"-"}{}| E[Decoder]
        E -->|{"-"}{}| F[MPEG Processor]
        F -->|{"-"}{}| G[Video/Audio Output]
        H[Smart Card] -->|{"-"}{}| E
        I[User Interface] -->|{"-"}{}| E
    end

    B -->|Coaxial Cable| C
    {Highlighting}
    {Shaded}

```

#### Outdoor Unit Components and Functions:

- **Dish Antenna:** Collects satellite signals, typically 45-90 cm diameter
- **LNB (Low Noise Block):**
  - Converts high frequency satellite signals (10-12 GHz) to lower IF frequencies (950-2150 MHz)
  - Amplifies weak signals with minimal noise
  - Contains local oscillator and polarization selection

#### Indoor Unit Components and Functions:

- **Tuner:** Selects desired transponder frequency
- **Demodulator:** Extracts digital signal from modulated carrier
- **Decoder:** Decrypts encrypted channels using smart card authorization

- **MPEG Processor:** Decompresses video/audio data streams
- **User Interface:** On-screen menus, program guide, channel selection
- **Smart Card:** Contains subscription details and decryption keys

#### Mnemonic

“COLD-TDUMS: Collection, Oscillator, Low-noise, Downconversion - Tuner Demodulator Unscrambler MPEG Smart-card”

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

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

#### Solution

Table 11: Antenna Definitions

Term	Definition
<b>Antenna</b>	Device that converts electrical energy to radio waves and vice versa
<b>Folded Dipole</b>	Dipole with ends folded back and connected, forming a loop with higher impedance
<b>Antenna Array</b>	Multiple antennas arranged in specific pattern for improved directivity/gain

#### Mnemonic

“AFA: Antenna Folded Array”

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

Describe application of smart antenna

#### Solution

Table 12: Smart Antenna Applications

Application	Description
<b>Mobile Communications</b>	Increases capacity, reduces interference in cellular networks
<b>Base Stations</b>	Sector-specific coverage, adaptive beamforming
<b>MIMO Systems</b>	Multiple-input-multiple-output for spatial multiplexing
<b>Radar Systems</b>	Improved target detection and tracking
<b>Satellite Communications</b>	Spot beam generation, interference mitigation
<b>Wi-Fi Networks</b>	Enhanced range and throughput for wireless LANs
<b>IoT Networks</b>	Low-power, long-range connectivity for IoT devices

#### Mnemonic

“MBMRSWI: Mobile Base MIMO Radar Satellite Wi-Fi IoT”

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

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

## Solution

### Diagram: Mobile Communication Antenna Types

#### Mermaid Diagram (Code)

```
{Shaded}  
{Highlighting} []  
graph TD  
    A[Terrestrial Mobile Antennas] --> B[Base Station Antennas]  
    A --> C[Mobile Station Antennas]  
  
    B --> D[Panel Antennas]  
    B --> E[Sector Antennas]  
    B --> F[Omnidirectional Antennas]  
    B --> G[Smart Antennas]  
  
    C --> H[Whip Antennas]  
    C --> I[Helical Antennas]  
    C --> J[Planar Inverted{-}F Antennas]  
    C --> K[Internal PCB Antennas]  
  
{Highlighting}  
{Shaded}
```

#### Base Station Antennas:

- **Panel/Sector Antennas:**  $65^\circ - 120^\circ$  coverage per sector, typically three sectors per site
- **Characteristics:**
  - High gain (10-18 dBi)
  - Vertical polarization
  - Downtilt capability (mechanical or electrical)
  - Multi-band operation
- **Height:** Mounted on towers 15-50m high for maximum coverage
- **Pattern Control:** Minimizes interference to adjacent cells

#### Mobile Station Antennas:

- **External Antennas:** Less common today, mainly for vehicles or rural areas
  - Whip antennas ( $\frac{1}{4}$  monopoles)
  - Helical designs for flexibility
- **Internal Antennas:** Now dominant in handsets
  - PIFA (Planar Inverted-F Antenna)s
  - PCB trace antennas
  - Characteristics:
    - \* Small size
    - \* Multi-band operation
    - \* Omnidirectional pattern
    - \* Lower efficiency (typically -3 to -6 dBi)

## Mnemonic

“BEST-POMME: Base-station External Sector Tower - Portable Omnidirectional Multi-band Mobile Embedded”