

# Subject Name Solutions

4341106 – Summer 2023

Semester 1 Study Material

*Detailed Solutions and Explanations*

## Question 1(a) [3 marks]

Write any three properties of Electromagnetic waves

### Solution

Properties of Electromagnetic Waves

1. EM waves can travel through vacuum or material media
2. EM waves travel at the speed of light in free space ( $3 \times 10^8 \text{ m/s}$ )
3. EM waves exhibit transverse wave characteristics with oscillating electric and magnetic fields

### Mnemonic

“VTS” - Vacuum travel, Transverse nature, Speed of light

## Question 1(b) [4 marks]

Define: (1) Radiation resistance (2) Directivity (3) Gain

### Solution

| Term                 | Definition   |
|----------------------|--|
| Radiation resistance | The equivalent resistance that would dissipate the same amount of power as radiated by an antenna when the current at the feed point is equal to the antenna input current |
| Directivity          | The ratio of maximum radiation intensity in a specific direction to the average radiation intensity in all directions  |
| Gain                 | The product of directivity and radiation efficiency, measuring how efficiently an antenna converts input power into radio waves in a specific direction                    |

### Mnemonic

“RDG” - Resistance dissipates power, Direction concentration, Gain includes efficiency

## Question 1(c) [7 marks]

Explain physical concept of generation of Electromagnetic waves with neat diagram

### Solution

Electromagnetic waves are generated when electric charges accelerate or oscillate, creating coupled oscillating electric and magnetic fields that propagate through space.

#### Mermaid Diagram (Code)

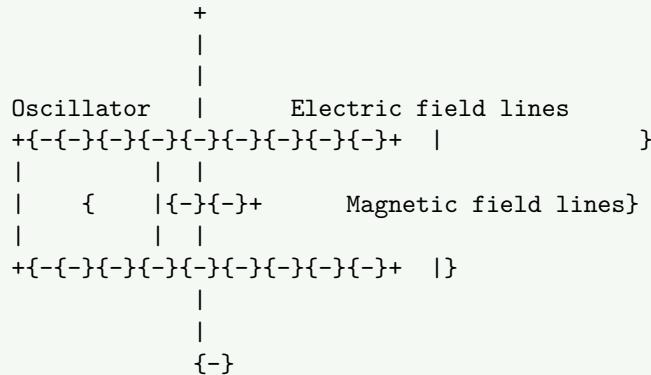
```
{Shaded}  
{Highlighting} []  
graph LR  
A[Electric Current Flow] {-{-}{}}|Oscillation| B[Oscillating Electric Field]
```

- B {-{-}{}|Induces| C[Oscillating Magnetic Field]}
- C {-{-}{}|Induces| D[Oscillating Electric Field]}
- D {-{-}{} E[Self{-}sustaining wave propagation]}

{Highlighting}

{Shaded}

## Diagram: Dipole Antenna EM Wave Generation



- **Basic concept:** When AC current flows in the antenna, electrons accelerate up and down
  - **Electric field:** Created by charge separation in the antenna
  - **Magnetic field:** Produced by the current flow, perpendicular to electric field
  - **Propagation:** Fields detach from antenna and propagate outward at the speed of light
  - **Self-sustaining:** Each field component regenerates the other as wave travels

## Mnemonic

“COMAP” - Current Oscillations Make Alternating Propagations

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

#### **Design 4 Element Yagi Uda antenna for frequency of 435 MHz with necessary equations**

## Solution

For a 4-element Yagi-Uda antenna at 435 MHz:

| Element               | Length Formula    | Spacing Formula      | Calculated Value           |
|-----------------------|-------------------|----------------------|----------------------------|
| <b>Reflector</b>      | $0.5 \times 1.05$ | -                    | 36.2 cm                    |
| <b>Driven element</b> | 0.5               | -                    | 34.5 cm                    |
| <b>Director 1</b>     | 0.45              | 0.2 from driven      | 31.0 cm at 13.8 cm spacing |
| <b>Director 2</b>     | 0.43              | 0.25 from Director 1 | 29.6 cm at 17.2 cm spacing |

#### Equations used:

- Wavelength:  
$$= c/f = 3 \times 10^8 / 435 \times 10^6 = 0.69 \text{ meters}$$
- Half-wave dipole:  
 $L = 0.5 = 34.5 \text{ cm}$
- Element spacing:  $S = 0.15$  to  $0.25$

#### Mermaid Diagram (Code)

```
{Shaded}  
{Highlighting}[]  
graph LR  
    A[Reflector: 36.2cm] --- B[Driven Element: 34.5cm]  
    B --- C[Director 1: 31.0cm]  
    C --- D[Director 2: 29.6cm]  
  
    style A fill:#f9f,stroke:#333,stroke-width:2px  
    style B fill:#bbf,stroke:#333,stroke-width:2px  
    style C fill:#fbf,stroke:#333,stroke-width:2px  
    style D fill:#fbf,stroke:#333,stroke-width:2px  
  
{Highlighting}  
{Shaded}
```

#### Mnemonic

“RDDS” - Reflector Driven Directors Shrink

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

Explain Loop antenna with diagram

#### Solution

Loop antenna is a radiating element formed by shaping a conductor into a loop.

Current flow

Feed point

- **Small loops:** Circumference  $< \lambda/10$ , radiation pattern similar to magnetic dipole
- **Large loops:** Circumference  $\approx \text{wavelength}$ , bidirectional radiation pattern
- **Applications:** Direction finding, AM radio reception, RFID tags

#### Mnemonic

“SLC” - Size affects Loop Characteristics

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

Explain Non Resonant wire antenna

## Solution

| Characteristic        | Description   |
|-----------------------|---|
| <b>Definition</b>     | Antenna operating at frequencies where its physical length is not a multiple of half-wavelength |
| <b>Impedance</b>      | Complex with both resistive and reactive components   |
| <b>Standing waves</b> | Present along the antenna length  |
| <b>Example</b>        | Rhombic antenna, terminated with resistance at the end  |
| <b>Advantage</b>      | Wideband operation, suitable for multiple frequencies   |

## Mnemonic

“NITRO” - Non-resonance Incurs Termination for Resistance and Operation

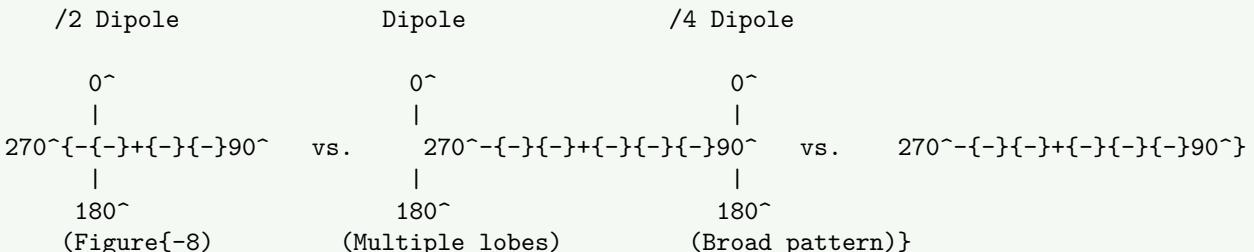
## Question 2(c) [7 marks]

What is Radiation resistance of half wave dipole? Draw radiation patterns of Dipoles of length  $/2$ , and  $/4$  antenna

## Solution

The radiation resistance of a half-wave dipole is approximately 73 ohms.

### Radiation patterns:



| Dipole Length    | Pattern Characteristics  |
|------------------|--|
| <b>/2 dipole</b> | Figure-8 pattern; maximum radiation perpendicular to antenna axis; HPBW = $78^\circ$ |
| <b>dipole</b>    | Multi-lobed pattern; four main lobes at angles to antenna axis                       |
| <b>/4 dipole</b> | Broader pattern than $/2$ ; requires ground plane to complete the equivalent dipole  |

## Mnemonic

“SHORT” - Smaller Half-dipole Offers Rounded-Transmissions

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

Explain Folded dipole antenna with figure

## Solution

Folded dipole is a variation of the half-wave dipole with ends folded back and connected to form a loop.

Feed point

- **Input impedance:** Approximately 300 ohms (4 times that of simple dipole)
- **Bandwidth:** Wider than simple dipole
- **Applications:** TV reception, FM radio, balanced transmission lines

### Mnemonic

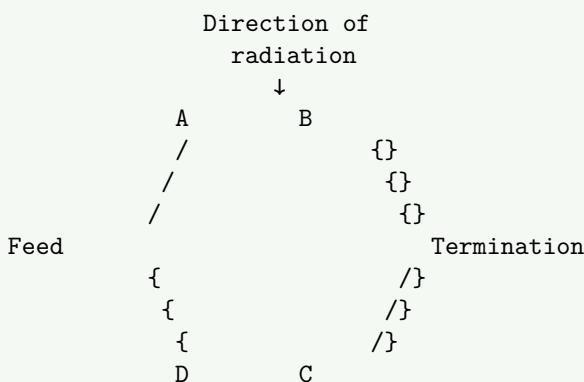
“FIB” - Folded Increases Bandwidth

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

Explain Rhombic antenna with figure

### Solution

Rhombic antenna consists of four wires arranged in a rhombus or diamond shape.



| Characteristic | Description  |
|----------------|--|
| Shape          | Diamond/rhombus with terminating resistor at far end |
| Operation      | Non-resonant traveling-wave antenna                  |
| Directivity    | High gain, unidirectional pattern                    |
| Bandwidth      | Very wide frequency range                            |
| Applications   | HF communications, point-to-point links              |

### Mnemonic

“TREND” - Terminated Rhombic Enables Numerous Directions

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

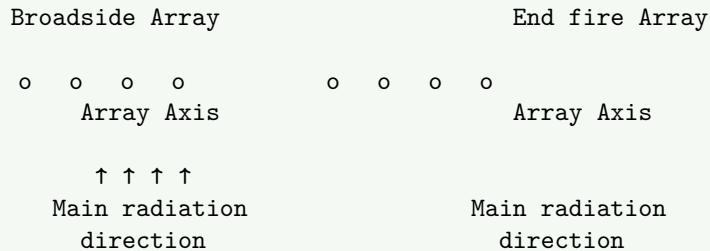
Differentiate between Broadside array and End fire array with suitable diagram

### Solution

| Parameter                      | Broadside Array             | End fire Array          |
|--------------------------------|-----------------------------|-------------------------|
| Direction of maximum radiation | Perpendicular to array axis | Along array axis        |
| Element phasing                | Same phase ( $0^\circ$ )    | Progressive phase shift |
| Element spacing                | /2 typically                | /4 typically            |

|                          |                             |                      |
|--------------------------|-----------------------------|----------------------|
| <b>Radiation pattern</b> | Fan-shaped beam             | Pencil-shaped beam   |
| <b>Applications</b>      | Broadcasting, base stations | Point-to-point links |

#### Diagram comparison:



#### Mnemonic

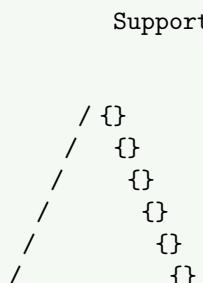
“PAPER” - Perpendicular And Parallel Emission Respectively

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

Draw and Explain Inverted V antenna

#### Solution

Inverted V antenna is a dipole with arms angled downward, resembling an inverted “V”.



Feed point

- **Angle:** Arms typically form  $90^\circ - 120^\circ$  angle
- **Impedance:** Close to 50 ohms, lower than horizontal dipole
- **Pattern:** Omnidirectional, slightly broader than horizontal dipole
- **Applications:** Amateur radio, shortwave communications

#### Mnemonic

“AVS” - Angle Varies Signal

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

Draw and explain parabolic reflector antenna

#### Solution

↓

Feed

Focus

| Component                  | Function   |
|----------------------------|--|
| <b>Parabolic reflector</b> | Collects and focuses incoming signals or directs transmitted signals |
| <b>Feed element</b>        | Located at focal point of parabola to collect/emit signals           |
| <b>Focal length</b>        | Distance from vertex to focus, determines beam characteristics       |
| <b>Applications</b>        | Satellite communications, radar, radio astronomy, microwave links    |

#### Mnemonic

“FOLD” - Focus Of Large Dish

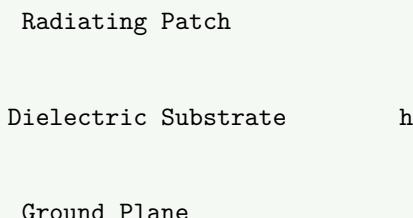
### Question 3(c) [7 marks]

Write down range of frequencies for HF, VHF and UHF. Write short note on Microstrip antenna.

#### Solution

| Frequency Band                    | Range            |
|-----------------------------------|------------------|
| <b>HF (High Frequency)</b>        | 3 MHz - 30 MHz   |
| <b>VHF (Very High Frequency)</b>  | 30 MHz - 300 MHz |
| <b>UHF (Ultra High Frequency)</b> | 300 MHz - 3 GHz  |

#### Microstrip Antenna:



- **Structure:** Conductive patch on dielectric substrate with ground plane
- **Feeding methods:** Microstrip line, coaxial probe, aperture-coupled
- **Advantages:** Low profile, lightweight, easy fabrication, compatible with PCB
- **Limitations:** Narrow bandwidth, low gain, low power handling
- **Applications:** Mobile devices, RFID, GPS, satellite communications

#### Mnemonic

“PATCH” - Planar Antenna That’s Cheaply Handled

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

Write Morse code for word: “LINE OF SIGHT”

## Solution

| Letter  | Morse Code |
|---------|------------|
| L       | .-..       |
| I       | ..         |
| N       | -.         |
| E       | .          |
| (space) | /          |
| O       | —          |
| F       | ...-       |
| (space) | /          |
| S       | ...        |
| I       | ..         |
| G       | -.         |
| H       | ....       |
| T       | -          |

“LINE OF SIGHT” in Morse code: .-... .. -.. . / — ... / ... .. -.. .... -

## Mnemonic

“Listen In Now, Every Other Frequency Supports Immediate Global Heightened Transmission”

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

Draw and explain Turnstile & Super turnstile antenna

## Solution

**Turnstile Antenna:**

**Super Turnstile Antenna:**

| Type                           | Characteristics   |
|--------------------------------|---|
| <b>Turnstile</b>               | Two horizontal dipoles at right angles, fed $90^\circ$ <i>out of phase</i>                        |
| <b>Super Turnstile Pattern</b> | Modification with multiple elements forming rectangular loops                                     |
| <b>Polarization</b>            | Omnidirectional in horizontal plane, figure-8 in vertical   |
| <b>Applications</b>            | Horizontal or circular polarization<br>TV broadcasting, FM broadcasting, satellite communications |

## Mnemonic

“TOPS” - Turnstile Offers Perpendicular Symmetry

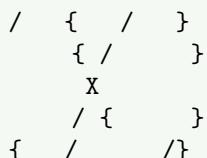
### Question 3(c) OR [7 marks]

What is Polarization? Explain Helical antenna in detail with diagram

#### Solution

**Polarization** is the orientation of the electric field vector of an electromagnetic wave as it propagates through space.

**Helical Antenna:**



Ground plane

| Parameter           | Description   |
|---------------------|---|
| <b>Structure</b>    | Conductor wound in helical shape above ground plane |
| <b>Diameter</b>     | Typically $/$                                       |
| <b>Pitch</b>        | Spacing between turns, usually $/4$                 |
| <b>Turns</b>        | 3-10 turns depending on gain requirements           |
| <b>Modes</b>        | Normal mode (broadside) or Axial mode (end-fire)    |
| <b>Polarization</b> | Circular polarization in axial mode                 |
| <b>Applications</b> | Satellite communications, space telemetry, tracking |

## Mnemonic

“HASP” - Helical Antenna Supports Polarization

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

Explain Tropospheric scattered propagation

#### Solution

| Aspect              | Description  |
|---------------------|--|
| <b>Mechanism</b>    | Radio signals scatter from tropospheric irregularities and refractive index variations |
| <b>Frequency</b>    | Typically VHF, UHF (100 MHz - 10 GHz)  |
| <b>Range</b>        | 100-800 km, beyond line-of-sight   |
| <b>Reliability</b>  | Less affected by weather than line-of-sight; more reliable than ionospheric            |
| <b>Applications</b> | Military communications, remote areas where other systems aren't practical             |

## Mnemonic

“STRIP” - Scatter Through Refractive Index Patterns

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

Define: (1) Virtual Height (2) Maximum Usable Frequency - MUF (3) Critical Frequency

## Solution

| Term                                  | Definition  |
|---------------------------------------|---|
| <b>Virtual Height</b>                 | The apparent height of the ionosphere calculated from the time delay of a radio signal reflected back to Earth, as if reflection occurred at a single point |
| <b>Maximum Usable Frequency (MUF)</b> | The highest frequency that can be used for reliable communication via ionospheric reflection for a specified path and time                                  |
| <b>Critical Frequency</b>             | The highest frequency that can be reflected back when transmitted vertically to the ionosphere (when angle of incidence is 90°)                             |

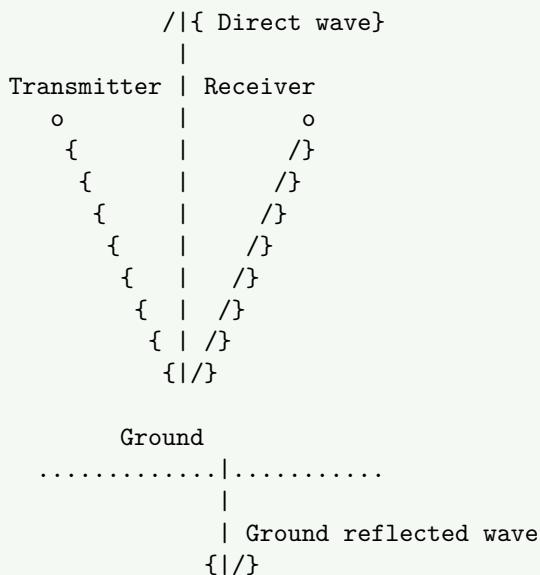
## Mnemonic

“VMC” - Virtual height Measures Critical reflection

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

Explain effect of ground on electromagnetic wave propagation

## Solution



| Effect                     | Description   |
|----------------------------|---|
| <b>Ground reflection</b>   | Signal reflects off ground, causing multipath reception   |
| <b>Ground absorption</b>   | Part of signal energy absorbed by ground, reducing signal strength  |
| <b>Ground diffraction</b>  | Waves bend around obstacles, extending coverage beyond line-of-sight                                      |
| <b>Earth curvature</b>     | Limits line-of-sight distance based on antenna height   |
| <b>Ground conductivity</b> | Higher conductivity (water, wet soil) allows better propagation than poor conductors (dry, rocky terrain) |

### Wave behavior equation:

- Range (km)  $\approx 4.12(1+2)$  where  $h_1, h_2$  are antenna heights in meters

## Mnemonic

## “RADAR” - Reflection Absorption Diffraction Affect Range

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

## Explain Duct Propagation

## Solution

Duct propagation occurs when radio waves become trapped in atmospheric layers with special refractive properties.

### Normal atmosphere

## Temperature inversion layer

- o TX
- o RX

## Normal atmosphere

- **Formation:** Temperature inversions or moisture gradients create atmospheric ducts
  - **Effect:** Signals trapped within duct, allowing propagation far beyond normal range
  - **Frequencies:** Most common in UHF and microwave bands
  - **Applications:** Extended over-water communications, radar anomalies

## Mnemonic

## “TIDE” - Trapped In Ducting Environment

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

**Explain different layers of Ionosphere**

### Solution

| Layer           | Altitude    | Characteristics  |
|-----------------|-------------|--|
| <b>D Layer</b>  | 60-90 km    | Absorbs HF waves during daytime, disappears at night                   |
| <b>E Layer</b>  | 90-150 km   | Reflects frequencies up to 10 MHz, sporadic E phenomenon               |
| <b>F1 Layer</b> | 150-210 km  | Present during day, merges with F2 at night                            |
| <b>F2 Layer</b> | 210-400+ km | Main reflecting layer, highest electron density, present day and night |

## Mnemonic

“DEAF” - D absorbs, E reflects, All merge, F2 persists

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

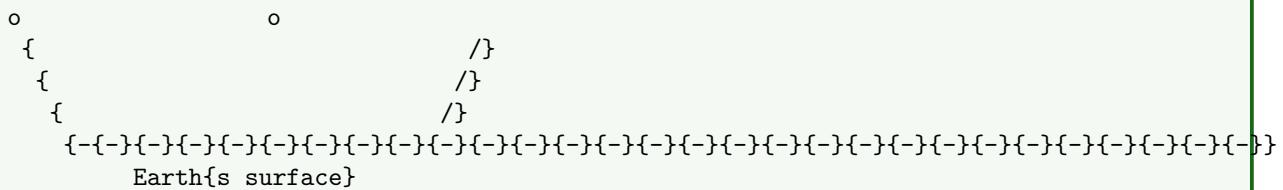
**Explain Ground wave and Sky wave propagation**

### Solution

## Ground Wave Propagation:

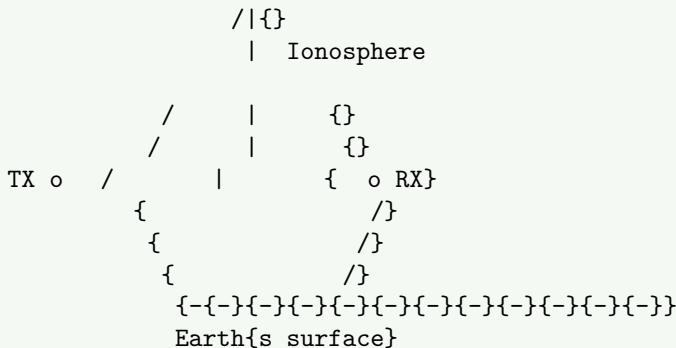
TX

RX



- **Frequency range:** LF, MF (30 kHz - 3 MHz)
  - **Components:** Direct, ground-reflected, surface waves
  - **Range:** Depends on frequency, ground conductivity, transmitter power
  - **Applications:** AM broadcasting, navigation systems, maritime communications

## Sky Wave Propagation:



- **Mechanism:** Waves refracted by ionosphere back to Earth
  - **Frequency:** Mainly HF (3-30 MHz)
  - **Range:** 100-10,000+ km, multiple hops possible
  - **Variability:** Time of day, season, solar activity, frequency
  - **Applications:** International broadcasting, amateur radio, military

## Mnemonic

“GIST” - Ground-Interface Surface Transmission vs Ionospheric Sky Transmission

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

**Explain three different types of Satellites**

## Solution

| Satellite Type                   | Characteristics  |
|----------------------------------|--|
| <b>LEO (Low Earth Orbit)</b>     | Altitude: 160-2,000 km, Period: 90 min, Applications: Earth observation, communications  |
| <b>MEO (Medium Earth Orbit)</b>  | Altitude: 2,000-35,786 km, Period: 2-24 hours, Applications: Navigation (GPS)            |
| <b>GEO (Geostationary Orbit)</b> | Altitude: 35,786 km, Period: 24 hours, Applications: TV broadcasting, weather monitoring |

## Mnemonic

## “LMG” - Low Medium Geostationary

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

What are smart antennas? Write two applications of it

## Solution

Smart antennas are antenna systems that use digital signal processing algorithms to identify spatial signatures and dynamically adjust radiation patterns.

| Feature          | Description  |
|------------------|--|
| <b>Types</b>     | Switched beam systems, Adaptive array systems  |
| <b>Operation</b> | Uses multiple antenna elements and signal processing to adapt to changing conditions |
| <b>Benefits</b>  | Increased capacity, improved coverage, reduced interference                          |

### Applications:

1. Mobile cellular networks (4G, 5G) for increased capacity and coverage
2. Wireless LANs for improved throughput and reduced interference

## Mnemonic

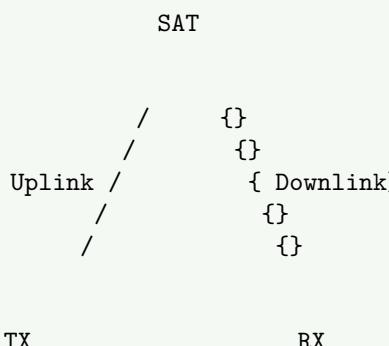
“SMART” - Signal Manipulation And Response Technology

## Question 5(c) [7 marks]

What is Satellite communication? Explain Data Communication

## Solution

**Satellite Communication** is the use of artificial satellites to provide communication links between various points on Earth.



### Data Communication via Satellite:

| Component             | Function   |
|-----------------------|--|
| <b>Earth Station</b>  | Transmits/receives signals to/from satellites                        |
| <b>Transponder</b>    | Receives, amplifies and retransmits signals at different frequencies |
| <b>Access methods</b> | FDMA, TDMA, CDMA to allow multiple users to share satellite capacity |
| <b>Protocols</b>      | TCP/IP adaptation for satellite latency, specialized protocols       |
| <b>Applications</b>   | Internet backhaul, VSAT networks, IoT, corporate networks            |
| <b>Advantages</b>     | Wide coverage area, independence from terrestrial infrastructure     |
| <b>Challenges</b>     | Signal delay (latency), power limitations, weather effects           |

## Mnemonic

“UPDATA” - Uplink Provides Data Access To All

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

Write laws of Kepler for satellite

### Solution

| Kepler's Laws     | Description   |
|-------------------|---|
| <b>First Law</b>  | Satellites orbit in elliptical paths with the Earth at one focus of the ellipse                                 |
| <b>Second Law</b> | A line joining the satellite and Earth sweeps out equal areas in equal times (conservation of angular momentum) |
| <b>Third Law</b>  | The square of the orbital period is proportional to the cube of the semi-major axis of the orbit                |

## Mnemonic

“ESP” - Elliptical orbits, Sweep equal areas, Period-distance relation

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

Explain Base station and Mobile station antennas

### Solution

**Base Station Antennas:**

Vertical collinear

- **Types:** Omnidirectional, sector, panel antennas
- **Gain:** Typically 10-18 dBi
- **Mounting:** Tower or rooftop installation
- **Features:** Downtilt capability, multiple frequency bands

**Mobile Station Antennas:**

Internal antenna

Smartphone

- **Types:** Internal PIFA, patch, monopole antennas
- **Gain:** Low gain (0-3 dBi)
- **Size:** Compact, often integrated inside device
- **Characteristics:** Omnidirectional pattern, multiple bands

## Mnemonic

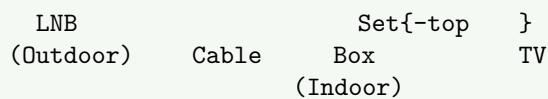
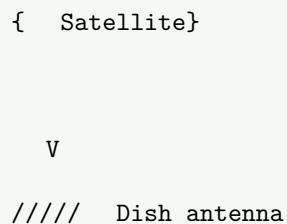
“BIMS” - Base stations Install Multiple Sectors, Mobile stations Stay small

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

Explain DTH receiver system in detail

### Solution

DTH (Direct-to-Home) receiver system delivers television signals directly to users via satellite.



| Component                                 | Function   |
|---|--|
| <b>Dish Antenna</b>                       | Parabolic reflector to collect satellite signals (45-90 cm typical diameter)                               |
| <b>LNB (Low Noise Block)</b>              | Converts high-frequency satellite signals to lower frequencies for transmission through coaxial cable      |
| <b>Coaxial Cable</b>                      | Carries signals from LNB to set-top box  |
| <b>Set-top Box</b>                        | Decodes/demodulates signals, provides user interface, conditional access                                   |
| <b>Conditional Access Module Features</b> | Provides security and subscription management<br>Electronic Program Guide, recording, interactive services |

## Mnemonic

“DISCS” - Dish Intercepts Signals, Converter Sends to Set-top box