Subject Name Solutions

4341106 – Winter 2024

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

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

Solution

Table 1: Antenna Parameters Definitions

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

"DGH: Direction Gets Higher power with narrow beam"

Question 1(b) [4 marks]

List the properties of electromagnetic waves

Solution

Table 2: Properties of Electromagnetic Waves

Property	Description
Transverse nature	Electric and magnetic fields are perpendicular to each other and to direction of propagation
Velocity	Travel at speed of light $(3\times10^8 m/s) in free space$
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

"TVFERRDP: Travel Very Fast, Energy Reflects Refracts Diffracts Polarizes"

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[Oscillating Electric Charge] {-{-}{} B[Time{-}varying Electric Field]}
    B {-{-}{} C[Time{-}varying Magnetic Field]}
    C {-{-}{} D[Time{-}varying Electric Field]}
    D {-{-}{} E[Self{-}sustaining EM Wave]}
    style A fill:\#f9f,stroke:\#333
    style E fill:\#bbf,stroke:\#333
{Highlighting}
{Shaded}
```

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

"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

Diagram: Radiation from Center-Fed Dipole

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[RF Generator] {-{-}{} B[Center{-}Fed Dipole]}
    B {-{-}{} C\{Current Flow\}}
    C {-{-}{} D[Electric Field]}
    C {-{-}{} E[Magnetic Field]}
    D {-{-}{} F[Radiation Pattern]}
    E {-{-}{} F}
    style A fill:\#f9f,stroke:\#333
    style F fill:\#bbf,stroke:\#333
{Highlighting}
{Shaded}
```

Radiation Process:

Stage	Process
1. Current excitation	RF signal applied at center of dipole creates alternating current

2. Current distribution	Sinusoidal current distribution forms along dipole, maximum at center, zero at ends
3. Electric field	Oscillating charges create time-varying electric field perpendicular to dipole
4. Magnetic field	Current flow creates magnetic field perpendicular to both dipole and electric field
5. Near field	Complex field pattern forms close to antenna (< /2)
6. Far field	At distances > 2 , radiation stabilizes to form distinctive pattern with main and 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

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

Question 2(a) [3 marks]

Differentiate the resonant and non-resonant antennas

Solution

Table 3: Resonant vs Non-Resonant Antennas

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

Mnemonic

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

Question 2(b) [4 marks]

Explain Yagi antenna and discuss its radiation characteristics

Solution

Diagram: Yagi-Uda Antenna

```
      Feed point
          |
          v
   R      D      D1     D2     D3
   |      |      |      |      |
   |      |      |      |      |
  [=]{-{-}{-}[=]{-}{-}{-}[=]{-}{-}{-}[=]{-}{-}{-}[=]}
   |      |      |      |      |
   |      |      |      |      |
 Reflector Driven  Directors
          Element
```

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

"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 /2, 3 /2 and 5 /2 antenna

Solution

Diagram: Current Distribution on Resonant Wire Antennas

```
 /2:     |{{-}{-}{-}{-}{-}{-}{-}  /2 {-}{-}{-}{-}{-}{-}{-}|}
         +{-{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}+}
         |           |           |
         v           \^{           v}
         |           |           |
         |           |           |
Current: *           *           *
        min         max         min

3 /2:    |{{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} 3 /2 {-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}|}
         +{-{-}{-}{-}{-}+{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}+{-}{-}{-}{-}
         |     |     |     |     |     |     |
         v     \^{     v     \^{}     v     \^{}     v}
         |     |     |     |     |     |     |
         |     |     |     |     |     |     |
Current: *     *     *     *     *     *     *
        min   max   min   max   min   max   min

5 /2:    |{{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} 5 /2 {-}{-}{-}{-}{-}{-}{-}{-}{-}{-
         +{-{-}{-}{-}+{-}{-}{-}{-}+{-}{-}{-}{-}+{-}{-}{-}{-}+{-}{-}{-}{-}+{-}{-}{-}{-}+{-}{-}{-}{-}+{-
         |    |    |    |    |    |    |    |    |    |
         v    \^{    v    \^{}    v    \^{}    v    \^{}    v    \^{}}
         |    |    |    |    |    |    |    |    |    |
         |    |    |    |    |    |    |    |    |    |
Current: *    *    *    *    *    *    *    *    *    *
        min  max  min  max  min  max  min  max  min  max
```

Radiation Characteristics of Resonant Wire Antennas:

Characteristic	Description
Current distribution	Sinusoidal, with maximum at center for /2, additional maxima for longer antennas
Input impedance	Approximately 73Ω for /2, varies for longer antennas
Radiation pattern	Figure-8 pattern (/2), more complex lobes for longer antennas
Directivity	2.15 dBi for /2, increases with length but with multiple lobes

Polarization	Linear, parallel to wire orientation
Efficiency	High for properly constructed antennas

Key Points:

- /2 antenna has single current maximum at center
- 3 /2 antenna has three half-cycles of current distribution
- 5 /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

"SIMPLE: Sinusoidal In Middle Produces Lobes Efficiently"

Question 2(a) OR [3 marks]

Differentiate the broad side and end fire array antennas

Solution

Table 4: Broadside vs End Fire Array Antennas

Parameter	Broadside Array	End Fire Array
Direction of maximum radiation	Perpendicular to the array axis	Along the array axis
Phase difference	$0°(in-phase)$	$180° or progressive phase$
Element spacing	Typically /2	Typically /4 to /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

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

Question 2(b) OR [4 marks]

Explain loop antenna and discuss its radiation characteristics

Solution

Diagram: Loop Antenna Types

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Loop Antenna] {-{-}{} B[Small Loop{}br /{}Circumference {}  /10]}
    A {-{-}{} C[Large Loop{}br /{}Circumference   ]}
    style A fill:\#f9f,stroke:\#333
    style B fill:\#bbf,stroke:\#333
    style C fill:\#bbf,stroke:\#333
{Highlighting}
{Shaded}
```

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 of loop
Input impedance	Very low ($< 10\Omega$)	Higher (50-200Ω)
Applications	Direction finding, AM receivers	HF communications, RFID

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 /2, 3 /2 and 5 /2 antenna

Solution

Diagram: Radiation Patterns of Wire Antennas

```
 /2 Dipole:
                  * *
               *       *
              *         *
             *           *
            *             *
           *      {-{-}{-}      *}
           *     |   |     *
           *     |   |     *
           *      {-{-}{-}      *}
            *             *
             *           *
              *         *
               *       *
                  * *

3 /2 Dipole:
                 *     *
              *           *
             *       *     *
            *      / {      *}
           *      /   {      *}
          *      |     |      *
          *      |     |      *
          *      |     |      *
          *      {     /      *}
           *      {   /      *}
            *      { /      *}
             *       *     *
              *           *
                 *     *

5 /2 Dipole:
                *   *   *
             *               *
            *    *       *    *
           *   /   {   /      *}
```

```
         *   /     { /        *}
        *   |       |       |   *
        *   |       |       |   *
        *   |       |       |   *
        *   {       |       /   *}
         *   {     /      /   *}
          *   {   /      /   *}
           *    *       *    *
            *              *
               *   *   *
```

Non-Resonant Wire Antenna Characteristics:

Characteristic	Description
Current distribution	Traveling waves with minimal standing waves
Termination	Usually terminated with resistive load to prevent reflections
Bandwidth	Wide bandwidth operation
Input impedance	More constant across frequency range
Radiation pattern	/2: Single main lobe on each side3 /2: Three main lobes on each side5 /2: Five main lobes on each side
Directivity	Increases with length but divided among multiple lobes
Efficiency	Lower than resonant antennas due to resistive termination

Key Points:

- Non-resonant antennas use traveling waves instead of standing waves
- Rhombic antenna is a common non-resonant antenna
- /2 pattern has 2 main lobes (figure-8 pattern)
- 3 /2 pattern has 6 main lobes (3 on each side)
- 5 /2 pattern has 10 main lobes (5 on each side)
- More lobes appear as length increases
- Main beam angle changes with frequency

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

Diagram: Microstrip Patch Antenna

```
      Top View                 Side View
    +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+          +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
    |            |           |////////////| {{-} Patch}
    |            |           +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
    |    Patch   |           |            | {{-} Dielectric}
    |            |           +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
    |            |           |\_\_\_\_\_\_\_\_\_\_\_\_| {{-} Ground plane}
    +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
    |   Feed     |
    +{-{-}{-}+{-}{-}{-}{-}+{-}{-}{-}+}
        |
```

Microstrip Patch Antenna:

- **Structure**: Metal patch on dielectric substrate with ground plane
- **Size**: Typically /2 ×/2or/2 × /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

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

Question 3(b) [4 marks]

Explain helical antenna and discuss its radiation characteristics

Solution

Diagram: Helical Antenna

```
                  \^{}
                 /|{}
                / | {  Direction of maximum radiation}
               /  |  {}
              /   |   {}
             /    |    {}
            /     |     {}
      coil /      |      {}
          /       |       {}
  +{-{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
  |      |        |         |
  |      +{-{-}{-}{-}{-}{-}{-}{-}+         |}
  |      |                  |
  |      |                  |
  |      |                  |
  |      |                  |
  | \_\_\_\_\_+                 |
  |/     |                  |
  +{-{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
         |
      Ground plane
```

Helical Antenna Characteristics:

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

Key Parameters:

- Diameter (D)
- Spacing between turns (S)
- Number of turns (N)
- Pitch angle ( )

Mnemonic

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

Question 3(c) [7 marks]

Explain horn antenna and discuss its radiation characteristics

Solution

Diagram: Types of Horn Antennas

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Horn Antenna] {-{-}{} B[E{-}plane Horn]}
    A {-{-}{} C[H{-}plane Horn]}
    A {-{-}{} D[Pyramidal Horn]}
    A {-{-}{} E[Conical Horn]}
    style A fill:\#f9f,stroke:\#333
    style B fill:\#bbf,stroke:\#333
    style C fill:\#bbf,stroke:\#333
    style D fill:\#bbf,stroke:\#333
    style E fill:\#bbf,stroke:\#333
{Highlighting}
{Shaded}
```

Diagram: Horn Antenna Structure

```
  Waveguide                  Horn
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
|           |            /|
|           |           / |
|           |          /  |
|    RF     |         /   |
|   Feed    |        /    |
|           |       /     |
|           |      /      |
|           |     /       |
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}+}
```

Horn Antenna Characteristics:

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

Types of Horn Antennas:

- **E-plane horn**: Flared in electric field direction
- **H-plane horn**: Flared in magnetic field direction
- **Pyramidal horn**: Flared in both planes
- **Conical horn**: Circular waveguide with conical flare

Mnemonic

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

Question 3(a) OR [3 marks]

Write short note on slot antenna

Solution

Diagram: Slot Antenna

```
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+
|                              |
|                              |
|                              |
|         +{-{-}{-}{-}{-}{-}{-}{-}{-}+          |}
|         |         |          |
|         |  Slot   |          |
|         |         |          |
|         +{-{-}{-}{-}{-}{-}{-}{-}{-}+          |}
|                              |
|                              |
|                              |
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+
        Conductive Sheet
```

Slot Antenna:

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

Key Points:

- Complementary to dipole (Babinet's principle)
- Radiates equally from both sides of plane
- Can be flush-mounted (advantage for aerodynamics)
- Can be covered with dielectric without affecting performance

Mnemonic

"SCRAP: Slot Cut Radiates Alternating Polarization"

Question 3(b) OR [4 marks]

Explain parabolic reflector antenna and discuss its radiation characteristics

Solution

Diagram: Parabolic Reflector Antenna

```
          +
         /|{}
```

```
               / | {}
              /  |  {}
   Incoming  /   |   {  Reflected}
     Waves  /    |    {   Waves}
           /     |     {}
          /      |      {}
         /       |       {}
        /        |        {}
       /         |         {}
      /          |          {}
     /           |           {}
+{-{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}+}
    {            |            /}
     {           |           /}
      {          |          /}
       {         |         /}
        {        |        /}
         {       |       /}
          {      |      /}
           {     |     /}
            {    |    /}
             {   |   /}
              {  |  /}
               { | /}
                {|/}
                 +
                Feed
                Point
```

Parabolic Reflector Antenna Characteristics:

Characteristic	Description
Operating principle	Focuses parallel incoming waves to focal point (receiving) or collimates waves from focal point (transmitting)
Frequency range	From UHF to millimeter waves (300 MHz - 300 GHz)
Directivity	Very high (30-40 dBi for large dishes)
Radiation pattern	Highly directional, narrow main beam
Beamwidth	Inversely proportional to diameter ($\approx 70/D degrees$)
Feed types	Prime focus, Cassegrain, Gregorian, offset
Efficiency	50-70% depending on feed design and blockage
Applications	Satellite communications, radio astronomy, radar, microwave links

Key Parameters:

- Diameter (D)
- Focal length (f)
- f/D ratio (typically 0.3-0.6)

Mnemonic

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

Question 3(c) OR [7 marks]

Describe V and inverted V antenna

Solution

Diagram: V and Inverted V Antennas

```
V Antenna:

            Feed
            Point
              +
             / {}
            /   {}
           /     {}
          /       {}
         /         {}
        /           {}
       /             {}
      /               {}
     /                 {}
    +                   +
   Ground              Ground


Inverted V Antenna:

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

V Antenna Characteristics:

Characteristic	Description
Construction	Two equal length wires arranged in V-shape
Angle between arms	10-90°$(affectsdirectivity)$
Length of each arm	Typically multiple wavelengths (1-6)
Radiation pattern	Bidirectional for larger angles, unidirectional for smaller angles
Directivity	3-15 dBi (increases with arm length and decreases with angle)
Input impedance	300-900Ω (depends on included angle)
Applications	HF long-distance communications, shortwave broadcasting

Inverted V Antenna Characteristics:

Characteristic	Description
Construction	Similar to dipole but bent down in V-shape
Angle between arms	90-120°*typically*
Length of each arm	/4 each (total /2)
Radiation pattern	Omnidirectional (slightly more overhead than dipole)
Input impedance	Lower than dipole (typically 50Ω)
Height requirement	Only center needs to be high
Applications	Amateur radio, general HF communications

Key Differences:

- V antenna is horizontally oriented, Inverted V is vertically oriented with center up
- V antenna usually has longer arms for directivity
- Inverted V requires only one support point (center)
- V antenna has higher directivity, Inverted V is more omnidirectional

Mnemonic

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

Question 4(a) [3 marks]

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

Solution

Table 5: Wave Phenomena Definitions

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

Mnemonic

"RRD: Rays Rebound, Redirect, Disperse"

Question 4(b) [4 marks]

List HAM radio application for communication

Solution

Table 6: HAM Radio Applications for Communication

Application Category	Specific Applications
Emergency communications	Disaster relief, emergency response, weather reporting
Public service	Community events, search and rescue, traffic monitoring
Technical experimentation	Antenna design, propagation studies, digital modes testing

International goodwill	DX communication, contesting, international friendship
Personal recreation	Casual conversations, hobby groups, radio clubs
Educational outreach	School programs, STEM activities, training new operators
Space communication	Satellite operation, ISS contact, EME (moon bounce)
Digital communication	APRS, packet radio, FT8, RTTY, PSK31

Mnemonic

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

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] {-{-}{} B[Ionosphere]}
    B {-{-}{} C[F2 Layer{}br /{}250{-}450 km]}
    B {-{-}{} D[F1 Layer{}br /{}170{-}220 km]}
    B {-{-}{} E[E Layer{}br /{}90{-}120 km]}
    B {-{-}{} F[D Layer{}br /{}60{-}90 km]}
    C {-{-}{} G[Receiver]}
    style A fill:\#f9f,stroke:\#333
    style G fill:\#bbf,stroke:\#333
{Highlighting}
{Shaded}
```

Ionospheric Layers:

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

Sky Wave Propagation Parameters:

Parameter	Definition
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 (below which D-layer absorption is too high)
Optimum Working Frequency (OWF)	Typically 85% of MUF, provides most reliable communication

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

Table 7: Sky Wave Propagation Terms

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

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

Table 8: HAM Radio Digital Modes

Digital Mode	Description	Typical Frequency Bands
FT8	Low power, narrow bandwidth, automated exchange	HF bands (especially 20m, 40m, 80m)
PSK31	Phase Shift Keying, keyboard-to-keyboard	HF bands (especially 20m, 40m)
RTTY	Radio Teletype, oldest digital mode	HF bands

APRS	Automatic Packet Reporting System, position reporting	VHF (typically 144.39 MHz in US)
SSTV	Slow Scan Television, image transmission	HF bands (especially 20m)
JT65/JT9	Weak signal modes for EME and DX	HF and VHF bands
WINLINK	Email over radio	HF and VHF bands
DMR	Digital Mobile Radio, voice digital mode	VHF and UHF bands

Mnemonic

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

Question 4(c) OR [7 marks]

Explain space wave propagation

Solution

Diagram: Space Wave Propagation

```
                          /{/////////  Troposphere}
     Tx                  /                  {             Rx}
  +{-{-}{-}+{-}{-}{-}+             /                          +{-}{-}{-}{-}+{-}{-}{-}{-}{-}+}
  |       |  Direct Wave  /                    {       |         |}
  |       |{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}|{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-
  |       |             |                |       |         |
  +{-{-}{-}{-}{-}{-}{-}+            |                     |      +{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
     |                 |                |            \^{}
     |                 |                |             |
     |                 |                |             |
     |                 |                |             |
     |                 v                v             |
     |              +{-{-}{-}{-}{-}{-}+              +{-}{-}{-}{-}{-}{-}+        |}
     |              |      |                |      |        |
     |              |      |                |      |        |
     |              |      |                |      |        |
     |              |      |                |      |        |
     |              +{-{-}{-}{-}{-}{-}+              +{-}{-}{-}{-}{-}{-}+        |}
     |                |                     |             |
     |                |                     |             |
     v                |        Earth        |             |
  Reflected Wave {-{-}{-}{-}{-}{-}{-}|{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-
```

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

Component	Description
Direct wave	Travels in straight line from transmitter to receiver (line-of-sight)
Ground-reflected wave	Reflects off Earth's surface before reaching receiver
Surface wave	Follows Earth's curvature due to diffraction

Types of Space Wave Propagation:

1. **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)
   - **Characteristics**: High power required, fading common, reliable
   - **Applications**: Military communications, backup links
2. **Duct Propagation:**
   - **Mechanism**: Trapping of waves in atmospheric ducts (layers with abnormal refractive index)
   - **Frequency range**: VHF, UHF, microwave
   - **Distance**: Up to 2000 km (far beyond horizon)
   - **Characteristics**: Seasonal/weather dependent, mainly over water
   - **Applications**: Maritime communications, coastal radar

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

"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

Table 9: Antenna Beam Parameters

Parameter	Definition
Beam Area	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
Beam Efficiency	The ratio of power radiated in the main beam to the total power radiated by the antenna
Effective Aperture	The ratio of power received by the antenna to the power density of the incident wave

Mnemonic

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

Question 5(b) [4 marks]

Describe need of smart antenna

Solution

Diagram: Smart Antenna System

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Antenna Array] {-{-}{} B[Signal Processing]}
    B {-{-}{} C[Adaptive Algorithm]}
    C {-{-}{} D[Beamforming]}
```

```
    D {-{-}{} E[Interference Reduction]}
    D {-{-}{} F[Coverage Enhancement]}
    D {-{-}{} G[Capacity Increase]}
    style A fill:\#f9f,stroke:\#333
    style G fill:\#bbf,stroke:\#333
{Highlighting}
{Shaded}
```

Need for Smart Antennas:

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

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 black diagram and discuss its functions

Solution

Diagram: DTH Receiver System Block Diagram

```
      OUTDOOR UNIT                           INDOOR UNIT
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+            +{-}{-}{-}{-}{-}{-}{-}{-}
|                     |             |                         |
|  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+    |             |   +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}
|  |             |    |             |   |              |      |
|  |  Satellite  |    |  Coaxial    |   |    Tuner/    |      |
|  |   Dish      |{-{-}{-}{-}+{-}{-}{-}Cable{-}{-}{-}{-}{-}+{-}{-}| Demodulator  |      |}
|  |             |    |             |   |              |      |
|  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+    |             |   +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}
|        |            |             |          |             |
|  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+    |             |   +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}
|  |    LNB      |    |             |   |  MPEG{-2/4    |      |}
|  | (Low Noise  |    |             |   |  Decoder     |      |   +{-{-}{-}{-}{-}{-}{-}+}
|  |  Block)     |    |             |   |              |{-{-}{-}{-}{-}{-}|{-}{-}|  TV   |}
|  +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+    |             |   +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}
|                     |             |          |             |   +{-{-}{-}{-}{-}{-}{-}+}
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+            |   +{-}{-}{-}{-}{-}{-}
                                    |   | Conditional  |      |
                                    |   |   Access     |      |
                                    |   |   Module     |      |
                                    |   +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+      |}
                                    |          |             |
                                    |   +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+      |}
                                    |   |   System     |      |
                                    |   | Controller/  |      |
                                    |   |     CPU      |      |
                                    |   +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+      |}
                                    |          |             |
```

```
|   +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+      |}
|   |    User      |      |
|   |  Interface   |      |
|   +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+      |}
|                         |
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{
```

DTH Receiver System Components and Functions:
Outdoor Unit Components:

Component	Function
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:

Component	Function
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
6. MPEG decoder converts digital stream to audio/video
7. Output sent to television for viewing

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

Table 10: Antenna Definitions

Term	Definition
Antenna	A device that converts electrical signals into electromagnetic waves for transmission or electromagnetic waves into electrical signals for reception

Folded Dipole	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
Antenna Array	A system of multiple antenna elements arranged in a specific geometric pattern to achieve desired radiation characteristics

Mnemonic

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

Question 5(b) OR [4 marks]

Describe application of smart antenna

Solution

Table 11: Smart Antenna Applications

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

Key Smart Antenna Technologies:

- **Switched Beam**: Predetermined fixed beam patterns
- **Adaptive Array**: Dynamic beam adjustment based on signal environment
- **MIMO (Multiple Input Multiple Output)**: Multiple antennas for spatial multiplexing

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

Diagram: Terrestrial Mobile Communication System

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Base Station] {-{-}{-} B[Mobile Station]}
    A {-{-}{-} C[Mobile Station]}
```

```
    A {-{-}{-} D[Mobile Station]}
    E[Base Station Antennas] {-{-}{-} F[High Gain{}br /{}Sectorized]}
    E {-{-}{-} G[Omnidirectional]}
    E {-{-}{-} H[Smart Antennas]}
    I[Mobile Antennas] {-{-}{-} J[Whip/Monopole]}
    I {-{-}{-} K[Helical]}
    I {-{-}{-} L[PIFA/Patch]}
    style A fill:\#f9f,stroke:\#333
    style I fill:\#bbf,stroke:\#333
{Highlighting}
{Shaded}
```

Base Station Antennas:

Antenna Type	Characteristics	Applications
Omnidirectional	- $360^\circ horizontalcoverage - 6 - 12dBigain - Verticalpolarization - Collineararrays$	- Rural areas- Low traffic density- Small cells
Sectorized	- 65-$120^\circ sectorcoverage - 12 - 20dBigain - Vertical/slantpolarization - Paneldesign$	- Urban/suburban areas- Frequency reuse- High capacity networks
Diversity Antennas	- Multiple elements- Space/polarization diversity- Reduced fading	- Multipath environments- High reliability links
Smart Antennas	- Adaptive beamforming- Multiple elements- 15-25 dBi gain	- High capacity areas- Interference reduction- 4G/5G systems

Mobile Station Antennas:

Antenna Type	Characteristics	Applications
Whip/Monopole	- External antenna- /4 length- Omnidirectional- 2-3 dBi gain	- Vehicle-mounted phones- Older handsets- Rural area devices
Helical	- Compact size- Good bandwidth- Flexible design- 0-2 dBi gain	- Portable radios- Early mobile phones
PIFA (Planar Inverted-F)	- Internal antenna- Compact size- Multiband operation- 0-2 dBi gain	- Modern smartphones- Tablets- IoT devices
Patch/Microstrip	- Low profile- Directional pattern- Dual polarization- 5-8 dBi gain	- Data cards- Fixed wireless terminals- High-speed data devices

Key Considerations for Mobile Communication Antennas:

1. **Base Station Requirements:**
   - High gain for coverage
   - Focused beams for capacity
   - Downtilt to control interference
   - Diversity for multipath mitigation
   - Weather resistance
2. **Mobile Station Requirements:**
   - Small size and low profile
   - Multiband operation
   - Omnidirectional pattern
   - SAR (Specific Absorption Rate) compliance
   - Integration with device design

Mnemonic

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