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 ($3 \times 10^8 m/s$)
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

```
             +
             |
             |
    Oscillator   |      Electric field lines
    +{-{-}{-}{-}{-}{-}{-}{-}{-}+  |              }
    |        |  |
    |    {    |{-}{-}+      Magnetic field lines}
    |        |  |
    +{-{-}{-}{-}{-}{-}{-}{-}{-}+  |}
             |
             |
             {-}
```

- **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
Reflector	0.5 ×1.05	-	36.2 cm
Driven element	0.5	-	34.5 cm
Director 1	0.45	0.2 from driven	31.0 cm at 13.8 cm spacing
Director 2	0.43	0.25 from Director 1	29.6 cm at 17.2 cm spacing

Equations used:

- Wavelength:
  $= \text{c/f} = 3{\times}10^8/435 \times 10^6 = 0.69 meters$
- Half-wave dipole:
  L = 0.5 = 34.5 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:\#fbb,stroke:\#333,stroke{-width:2px}
    style D fill:\#fbb,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 < /10, radiation pattern similar to magnetic dipole
- **Large loops**: Circumference $\approx wavelength, bidirectional radiation pattern$
- **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
Definition	Antenna operating at frequencies where its physical length is not a multiple of half-wavelength
Impedance	Complex with both resistive and reactive components
Standing waves	Present along the antenna length
Example	Rhombic antenna, terminated with resistance at the end
Advantage	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:

```
   /2 Dipole              Dipole             /4 Dipole

     0^                     0^                     0^
     |                      |                      |
270^{-{-}+{-}{-}90^   vs.     270^-{-}{-}+{-}{-}{-}90^   vs.    270^-{-}{-}+{-}{-}{-}90^}
     |                      |                      |
    180^                  180^                   180^
   (Figure{-8)         (Multiple lobes)        (Broad pattern)}
```

Dipole Length	Pattern Characteristics
/2 dipole	Figure-8 pattern; maximum radiation perpendicular to antenna axis; HPBW = 78°
dipole	Multi-lobed pattern; four main lobes at angles to antenna axis
/4 dipole	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.

```
             Direction of
               radiation
                  ↓
            A       B
            /            {}
           /              {}
          /                {}
Feed                         Termination
          {                 /}
           {              /}
            {            /}
            D       C
```

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°)	Progressive phase shift
Element spacing	/2 typically	/4 typically

Radiation pattern	Fan-shaped beam	Pencil-shaped beam
Applications	Broadcasting, base stations	Point-to-point links

Diagram comparison:

```
   Broadside Array                    End fire Array

  o   o   o   o         o   o   o   o
       Array Axis                     Array Axis

          ↑ ↑ ↑ ↑
     Main radiation                Main radiation
       direction                     direction
```

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".

```
                    Support


                  / {}
                 /   {}
                /     {}
               /       {}
              /         {}
             /           {}


               Feed point
```

- **Angle**: Arms typically form $90° - 120° angle$
- **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
Parabolic reflector	Collects and focuses incoming signals or directs transmitted signals
Feed element	Located at focal point of parabola to collect/emit signals
Focal length	Distance from vertex to focus, determines beam characteristics
Applications	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
HF (High Frequency)	3 MHz - 30 MHz
VHF (Very High Frequency)	30 MHz - 300 MHz
UHF (Ultra High Frequency)	300 MHz - 3 GHz

Microstrip Antenna:

Radiating Patch

Dielectric Substrate h

Ground Plane

- **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
Turnstile	Two horizontal dipoles at right angles, fed $90^\circ out of phase$
Super Turnstile	Modification with multiple elements forming rectangular loops
Pattern	Omnidirectional in horizontal plane, figure-8 in vertical
Polarization	Horizontal or circular polarization
Applications	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:

```
    /   {   /   }
         { /     }
          X
         / {     }
    {   /      /}




     Ground plane
```

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

Mnemonic

"HASP" - Helical Antenna Supports Polarization

Question 4(a) [3 marks]

Explain Tropospheric scattered propagation

Solution

Aspect	Description
Mechanism	Radio signals scatter from tropospheric irregularities and refractive index variations
Frequency	Typically VHF, UHF (100 MHz - 10 GHz)
Range	100-800 km, beyond line-of-sight
Reliability	Less affected by weather than line-of-sight; more reliable than ionospheric
Applications	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
Virtual Height	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
Maximum Usable Frequency (MUF)	The highest frequency that can be used for reliable communication via ionospheric reflection for a specified path and time
Critical Frequency	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

```
              /|{ Direct wave}
               |
   Transmitter | Receiver
      o        |        o
       {       |       /}
        {      |      /}
         {     |     /}
          {    |    /}
           {   |   /}
            {  |  /}
             { | /}
              {|/}

          Ground
     .............|...........
                  |
                  | Ground reflected wave
                 {|/}
```

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

Wave behavior equation:

- Range (km) $\approx 4.12(_1+_2)whereh_1,h_2areantennaheightsinmeters$

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
D Layer	60-90 km	Absorbs HF waves during daytime, disappears at night
E Layer	90-150 km	Reflects frequencies up to 10 MHz, sporadic E phenomenon
F1 Layer	150-210 km	Present during day, merges with F2 at night
F2 Layer	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
```

```
     o                  o
      {                             /}
       {                           /}
        {                         /}
         {-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}}
              Earth{s surface}
```

- **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:

```
                     /|{}
                      |  Ionosphere

                /     |     {}
               /      |      {}
     TX o   /       |       {   o RX}
              {                /}
               {              /}
                {            /}
                 {-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}}
                 Earth{s surface}
```

- **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
LEO (Low Earth Orbit)	Altitude: 160-2,000 km, Period: 90 min, Applications: Earth observation, communications
MEO (Medium Earth Orbit)	Altitude: 2,000-35,786 km, Period: 2-24 hours, Applications: Navigation (GPS)
GEO (Geostationary Orbit)	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
Types	Switched beam systems, Adaptive array systems
Operation	Uses multiple antenna elements and signal processing to adapt to changing conditions
Benefits	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.

```
                  SAT


               /     {}
              /       {}
       Uplink /        { Downlink}
            /           {}
           /             {}


      TX                    RX
```

Data Communication via Satellite:

Component	Function
Earth Station	Transmits/receives signals to/from satellites
Transponder	Receives, amplifies and retransmits signals at different frequencies
Access methods	FDMA, TDMA, CDMA to allow multiple users to share satellite capacity
Protocols	TCP/IP adaptation for satellite latency, specialized protocols
Applications	Internet backhaul, VSAT networks, IoT, corporate networks
Advantages	Wide coverage area, independence from terrestrial infrastructure
Challenges	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
First Law	Satellites orbit in elliptical paths with the Earth at one focus of the ellipse
Second Law	A line joining the satellite and Earth sweeps out equal areas in equal times (conservation of angular momentum)
Third Law	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.

```
                    {   Satellite}



                      V

                    /////   Dish antenna






      LNB                    Set{-top    }
    (Outdoor)     Cable      Box           TV
                           (Indoor)
```

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

Mnemonic

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