

# 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
<b>Radiation resistance</b>	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
<b>Directivity</b>	The ratio of maximum radiation intensity in a specific direction to the average radiation intensity in all directions
<b>Gain</b>	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)

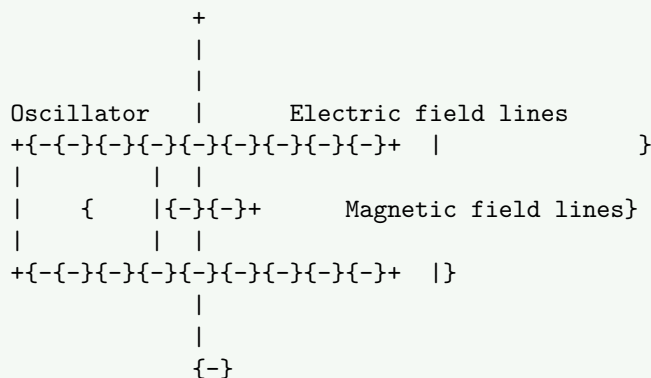
```
{Shaded}
{Highlighting}[]
graph LR
    A[Electric Current Flow] --{-}{-}|Oscillation| B[Oscillating Electric Field]
```

```

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:  
 $L = 0.5 \lambda = 34.5 \text{ cm}$
- Element spacing:  $S = 0.15 \lambda$  to  $0.25 \lambda$

#### 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  $< \lambda/10$ , 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  $\lambda/2$ , and  $\lambda/4$  antenna

### Solution

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

**Radiation patterns:**

$\lambda/2$ Dipole	Dipole	$\lambda/4$ Dipole
<p>0°   270° -{-}{-}{-}{-}90°   180° (Figure-8)</p>	vs.	<p>0°   270° -{-}{-}{-}{-}90°   180° (Broad pattern)}</p>

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

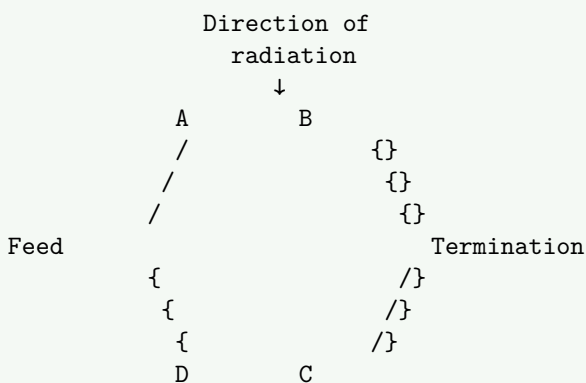
“FIB” - Folded Increases Bandwidth

### 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
<b>Shape</b>	Diamond/rhombus with terminating resistor at far end
<b>Operation</b>	Non-resonant traveling-wave antenna
<b>Directivity</b>	High gain, unidirectional pattern
<b>Bandwidth</b>	Very wide frequency range
<b>Applications</b>	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
<b>Direction of maximum radiation</b>	Perpendicular to array axis	Along array axis
<b>Element phasing</b>	Same phase ( $0^\circ$ )	Progressive phase shift
<b>Element spacing</b>	$\lambda/2$ typically	$\lambda/4$ typically

**Radiation pattern**  
**Applications**

Fan-shaped beam  
Broadcasting, base stations

Pencil-shaped beam  
Point-to-point links

**Diagram comparison:**

Broadside Array

o o o o  
Array Axis

↑ ↑ ↑ ↑  
Main radiation  
direction

End fire Array

o o o o  
Array Axis

Main radiation  
direction

**Mnemonic**

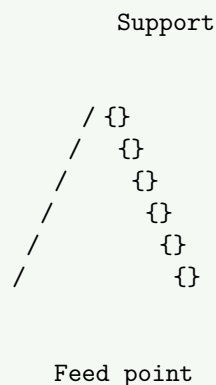
“PAPER” - Perpendicular And Parallel Emission Respectively

### 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”.



- **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:**

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



### Mnemonic

“TOPS” - Turnstile Offers Perpendicular Symmetry

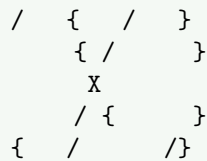
### Question 3(c) OR [7 marks]

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:**



Parameter	Description
<b>Structure</b>	Conductor wound in helical shape above ground plane
<b>Diameter</b>	Typically $\lambda/4$
<b>Pitch</b>	Spacing between turns, usually $\lambda/4$
<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
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	
<div><div>/{ Direct wave}</div><div>Transmitter   Receiver</div><div>o   o</div><div>{   /}</div><div>{   /}</div><div>{   /}</div><div>{   /}</div><div>{   /}</div><div>{   /}</div><div>{   /}</div><div>{   /}</div><div>Ground</div><div>..... .....</div><div>  Ground reflected wave</div><div>{   /}</div></div>	
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:	
<ul style="list-style-type: none"><li>Range (km) <math>\approx 4.12(\sqrt{h_1} + \sqrt{h_2})</math> where <math>h_1, h_2</math> are antenna heights in meters</li></ul>	

### 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]

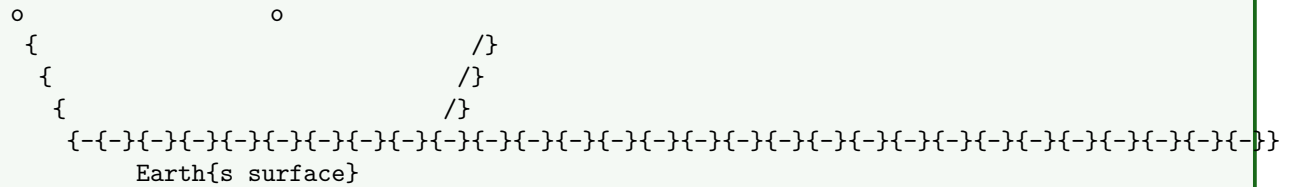
Explain Ground wave and Sky wave propagation

#### Solution

Ground Wave Propagation:

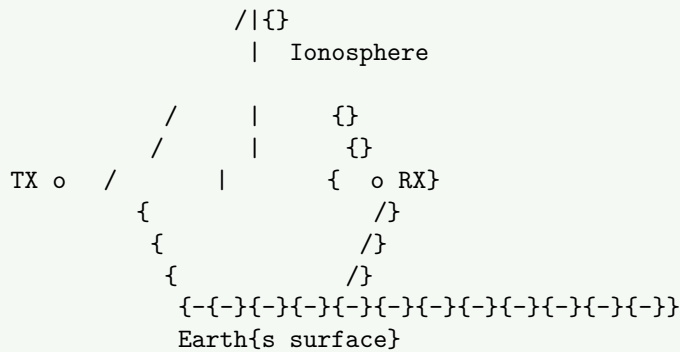
TX

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

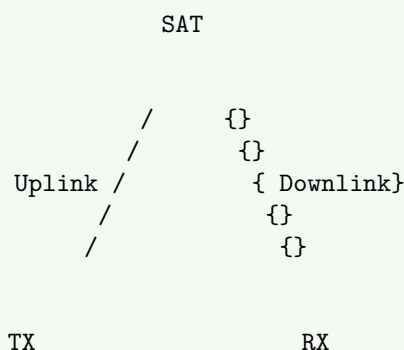
“SMART” - Signal Manipulation And Response Technology

## 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 Transponder</b>	Transmits/receives signals to/from satellites 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.

{ Satellite }

V

///// Dish antenna

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

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 Electronic Program Guide, recording, interactive services

### Mnemonic

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