Antenna and Wave Propagation (4341106) - Summer 2023 Solution

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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 (3×10^8 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

Definitions:

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.

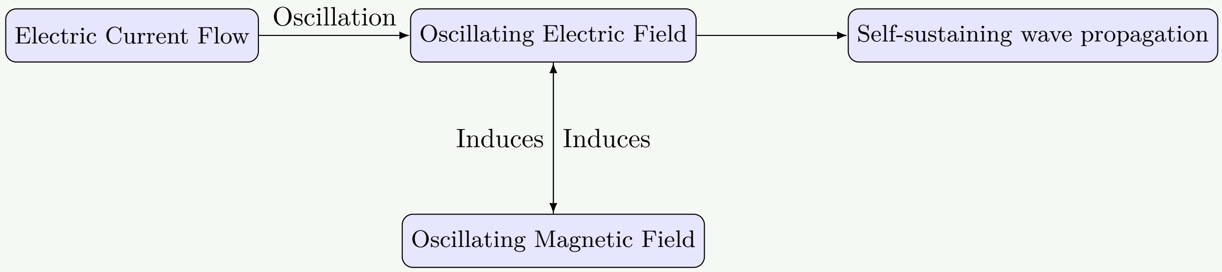
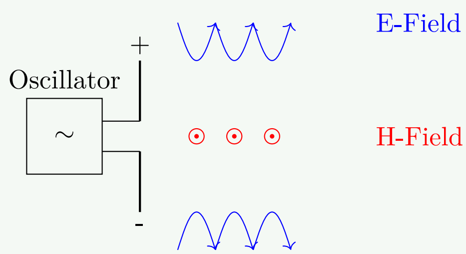


Figure 1. Dipole Antenna EM Wave Generation



- **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”

OR

Question 1(c) [7 marks]

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

Solution

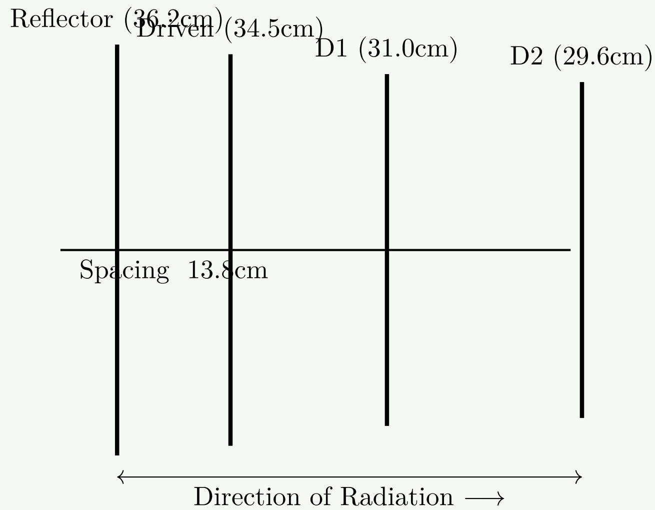
Design for 435 MHz 4-Element Yagi-Uda Antenna:
Equations used:

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

Calculated Values:

Element	**Length Formula**	**Spacing Formula**	**Value**
Reflector	$0.5\lambda \times 1.05$	-	36.2 cm
Driven element	0.5λ	-	34.5 cm
Director 1	0.45λ	0.2λ from driven	31.0 cm (Sp: 13.8 cm)
Director 2	0.43λ	0.25λ from D1	29.6 cm (Sp: 17.2 cm)

Figure 2. 4-Element Yagi-Uda Antenna Layout



Mnemonic

"”RDDS” - Reflector Driven Directors Shrink”

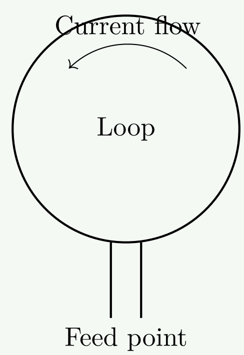
Question 2(a) [3 marks]

Explain Loop antenna with diagram

Solution

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

Figure 3. Loop Antenna



- **Small loops**: Circumference $< \lambda/10$, 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

Non-Resonant Wire Antenna:

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]

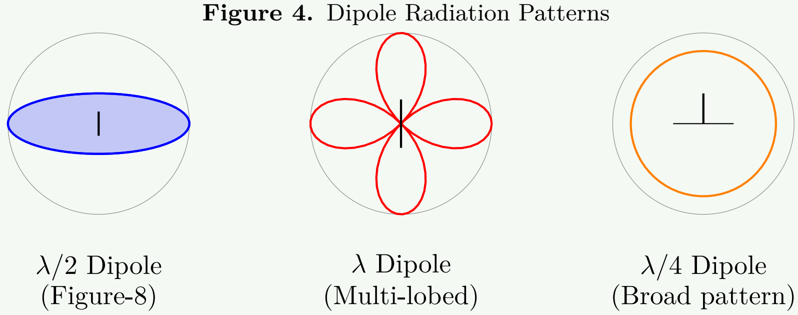
What is Radiation resistance of half wave dipole? Draw radiation patterns of Dipoles of length $\lambda/2$, λ and $\lambda/4$ antenna

Solution

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

Radiation Patterns:

Figure 4. Dipole Radiation Patterns



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

Mnemonic

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

OR

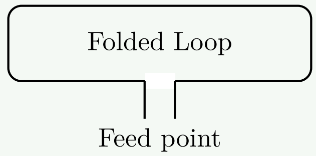
Question 2(a) [3 marks]

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.

Figure 5. Folded Dipole



- **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”

OR

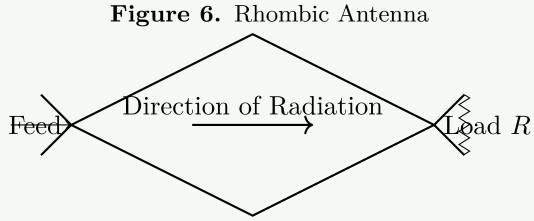
Question 2(b) [4 marks]

Explain Rhombic antenna with figure

Solution

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

Figure 6. Rhombic Antenna



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”

OR

Question 2(c) [7 marks]

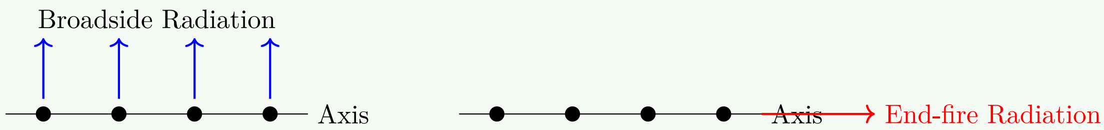
Differentiate between Broadside array and End fire array with suitable diagram

Solution

Comparison:

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	$\lambda/2$ typically	$\lambda/4$ typically
Radiation pattern	Fan-shaped beam	Pencil-shaped beam
Applications	Broadcasting, base stations	Point-to-point links

Figure 7. Array Comparison



Mnemonic

“”PAPER” - Perpendicular And Parallel Emission Respectively”

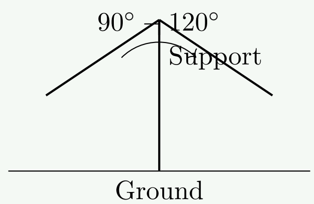
Question 3(a) [3 marks]

Draw and Explain Inverted V antenna

Solution

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

Figure 8. Inverted V Antenna



- **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

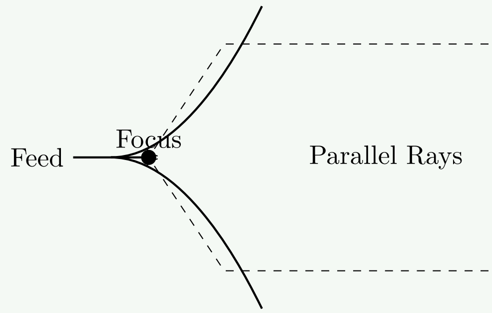
“”AVS” - Angle Varies Signal”

Question 3(b) [4 marks]

Draw and explain parabolic reflector antenna

Solution

Figure 9. Parabolic Reflector Antenna



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.

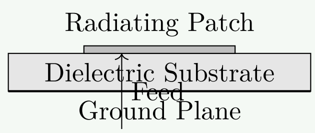
Solution

Frequency Ranges:

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:

Figure 10. Microstrip Antenna Structure



- **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”

OR

Question 3(a) [3 marks]

Write Morse code for word: ”LINE OF SIGHT”

Solution

Morse Code Translation:

Letter	Code	Letter	Code
L	.-..	F	..-.
I	..	S	...
N	-.	G	–.
E	.	H	....
O	—	T	-

”LINE OF SIGHT”: `.-.. .. -. . / --- ..-. / ... .. --. .... -`

Mnemonic

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

OR

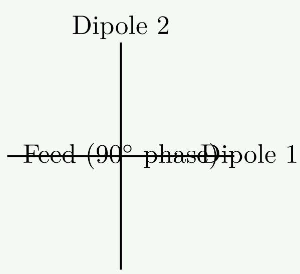
Question 3(b) [4 marks]

Draw and explain Turnstile & Super turnstile antenna

Solution

Turnstile Antenna:

Figure 11. Turnstile Antenna



Super Turnstile Antenna:

- Modification with multiple elements forming rectangular loops (Batwing shape).
- Provides broader bandwidth.

Type	Characteristics
Turnstile	Two horizontal dipoles at right angles, fed 90° out of phase
Super Turnstile	Uses batwing/sheet elements for wider bandwidth
Pattern	Omnidirectional in horizontal plane, figure-8 in vertical
Polarization	Horizontal or circular polarization
Applications	TV broadcasting, FM broadcasting

Mnemonic

“”TOPS” - Turnstile Offers Perpendicular Symmetry”

OR

Question 3(c) [7 marks]

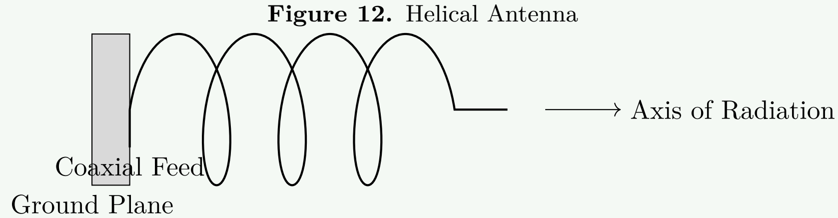
What is Polarization? Explain Helical antenna in detail with diagram

Solution

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

Helical Antenna:

Figure 12. Helical Antenna



Parameter	Description
Structure	Conductor wound in helical shape above ground plane
Diameter	Typically λ/π
Pitch	Spacing between turns, usually $\lambda/4$
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

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
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

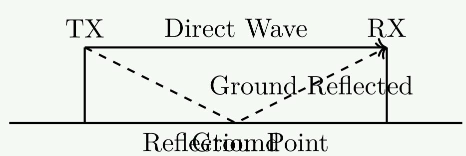
“”VMC” - Virtual height Measures Critical reflection”

Question 4(c) [7 marks]

Explain effect of ground on electromagnetic wave propagation

Solution

Figure 13. Ground Wave Propagation Effects



Effect	Description
Ground reflection	Signal reflects off ground, causing multipath reception (constructive/destructive interference)
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) allows better propagation than poor conductors (dry soil)

Range Equation: $d \approx 4.12(\sqrt{h_t} + \sqrt{h_r})$ km.

Mnemonic

“”RADAR” - Reflection Absorption Diffraction Affect Range”

OR

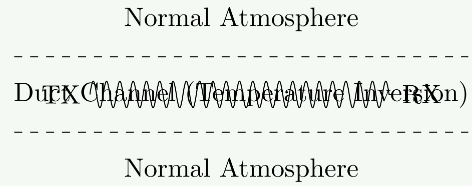
Question 4(a) [3 marks]

Explain Duct Propagation

Solution

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

Figure 14. Atmospheric Duct



- **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.

Mnemonic

“”TIDE” - Trapped In Ducting Environment”

OR

Question 4(b) [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”

OR

Question 4(c) [7 marks]

Explain Ground wave and Sky wave propagation

Solution

Ground Wave Propagation:

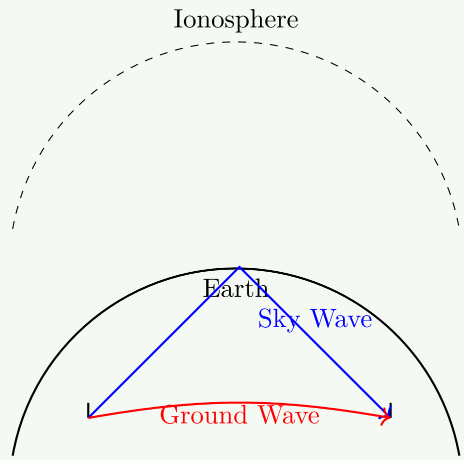
- **Frequency range**: LF, MF (30 kHz - 3 MHz).
- **Mechanism**: Waves follow curvature of the earth.

- **Applications**: AM broadcasting, maritime communications.

Sky Wave Propagation:

- **Frequency range**: HF (3-30 MHz).
- **Mechanism**: Waves refracted by ionosphere back to Earth.
- **Applications**: International broadcasting, long-distance communication.

Figure 15. Ground vs Sky Wave



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. Uses: Earth observation, comms.
MEO (Medium Earth Orbit)	Altitude: 2,000-35,786 km, Period: 2-24 hrs. Uses: Navigation (GPS).
GEO (Geostationary Orbit)	Altitude: 35,786 km, Period: 24 hrs. Uses: TV, Weather.

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
Benefits	Increased capacity, improved coverage, reduced interference

Applications: 1. Mobile cellular networks (4G, 5G). 2. Wireless LANs (Wi-Fi).

Mnemonic

“”SMART” - Signal Manipulation And Response Technology”

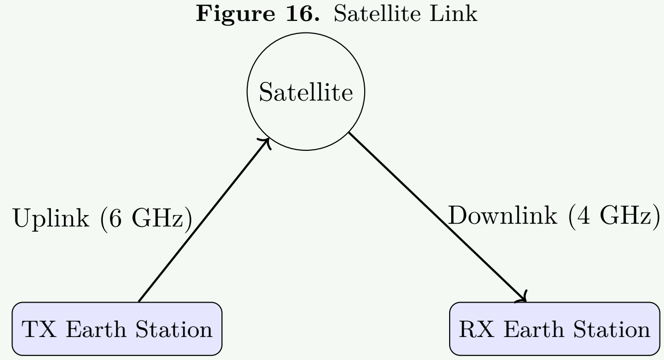
Question 5(c) [7 marks]

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.

Figure 16. Satellite Link



Data Communication via Satellite:

Component	Function
Earth Station	Transmits/receives signals to/from satellites
Transponder	Receives, amplifies and retransmits signals at different frequenci
Access methods	FDMA, TDMA, CDMA to allow multiple users to share capacit
Applications	Internet backhaul, VSAT networks, IoT
Advantages	Wide coverage area, independence from terrestrial infrastructure

Mnemonic

“”UPDATA” - Uplink Provides Data Access To All”

OR

Question 5(a) [3 marks]

Write laws of Kepler for satellite

Solution

Law	Description
First Law	Satellites orbit in elliptical paths with the Earth at one focus
Second Law	A line joining the satellite and Earth sweeps out equal areas in equal times
Third Law	The square of the orbital period is proportional to the cube of the semi-major axis ($T^2 \propto a^3$)

Mnemonic

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

OR

Question 5(b) [4 marks]

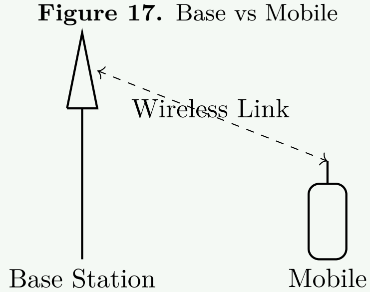
Explain Base station and Mobile station antennas

Solution

Base Station Antennas:
- **Types**: Omnidirectional, sector, panel antennas.
- **Gain**: Typically 10-18 dBi.
- **Mounting**: Tower or rooftop installation.

Mobile Station Antennas:
- **Types**: Internal PIFA, patch, monopole.
- **Gain**: Low gain (0-3 dBi).
- **Size**: Compact, integrated inside device.

Figure 17. Base vs Mobile



Mnemonic

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

OR

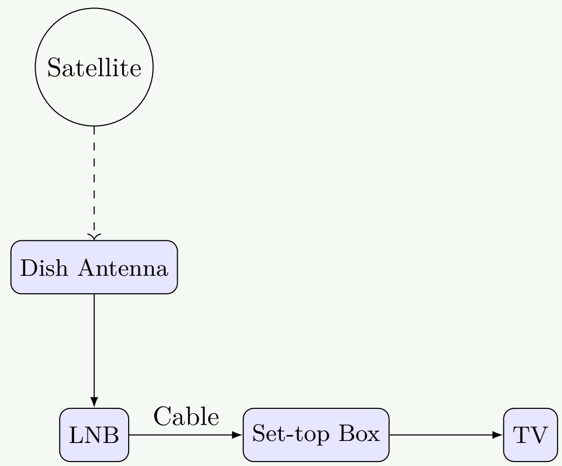
Question 5(c) [7 marks]

Explain DTH receiver system in detail

Solution

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

Figure 18. DTH System



Component	Function
Dish Antenna	Parabolic reflector to collect satellite signals (45-90 cm)
LNB	Low Noise Block downconverter; amplifies signal and converts to lower frequency
Set-top Box	Decodes digital signals and converts to audio/video for TV
TV	Display unit