MASINDE MULIRO UNIVERSITY OF SCIENCE & TECHNOLOGY

ECE 516E – ANTENNA & RADIOWAVE PROPAGATION

ANTENNA FUNDAMENTALS STUDY GUIDE

1. OBJECTIVES

By the end of this guide, you should be able to:

1. Define an antenna and state its fundamental purpose.
2. Explain the basic principles of antenna operation (transmission and reception).
3. Define and calculate key antenna parameters (e.g., gain, directivity, impedance, VSWR, bandwidth, polarization).
4. Identify and describe the operating principles of common antenna types.
5. Interpret 2D and 3D radiation patterns, including lobes, beamwidth, and nulls.
6. Understand the relationship between antenna size, frequency, and performance.

2. DEFINITION OF ANTENNA

An antenna is a transducer that converts guided electromagnetic waves (traveling in a transmission line like a coaxial cable) into free-space electromagnetic waves (radio waves), and vice versa. An antenna can operate in transmit and receive modes.

1.1Transmit Mode

AC electrical energy from a transmitter → Oscillating electrons in the antenna → Radiated EM wave.

1.2Receive Mode

Incident EM wave → Oscillating electrons in the antenna → AC electrical energy to the receiver.

1.3Reciprocity

Reciprocity is a fundamental property which states that an antenna's characteristics (pattern, impedance, etc.) are identical whether it is transmitting or receiving.

3. KEY ANTENNA PARAMETERS & METRICS

Key antenna parameters are frequency/bandwidth, radiation pattern, directivity and gain. Understanding these parameters is crucial for comparing and selecting antennas.

3.1 Frequency & Bandwidth

Antenna performance in the frequency domain is stated in terms of the resonant frequency and bandwidth.

Resonant Frequency: The frequency at which the antenna's impedance is purely resistive (no reactance). This is where it is most efficient.

Bandwidth: The range of frequencies over which the antenna can operate effectively, typically defined by a metric like VSWR < 2:1 or impedance matching within a certain limit.

3.2 Radiation Pattern

A graphical representation of the antenna's radiation properties as a function of space. The radiation pattern is a 3D graph, but we often analyse 2D cross-sections.

3D Pattern: Shows the full radiation sphere.

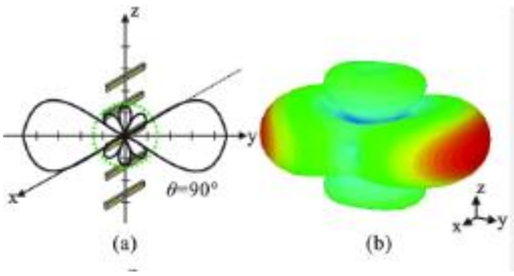

Figure 1. 2D and 3D radiation pattern

2D Pattern Slices which can be in E-plane or H-plane. E-Plane: The plane containing the electric field vector and the direction of maximum radiation. H-Plane: The plane containing the magnetic field vector and the direction of maximum radiation.

Key parameters of a radiation pattern are:

Main Lobe (Major Lobe): The lobe in the direction of maximum radiation. This is the desired lobe for communication.

Sidelobes: Smaller lobes radiating in unwanted directions. Energy in sidelobes is wasted and can cause interference.

Back Lobe: A lobe directed exactly opposite (180°) to the main lobe.

Half-Power Beamwidth (HPBW) or 3-dB Beamwidth: The angular width between the two points on the main lobe where the power is half (-3 dB) its maximum value. It is a measure of the antenna's directivity.

Beamwidth: The angular width of the main radiation lobe, measured between the half-power (-3 dB) points. A smaller beamwidth indicates higher directivity and gain.

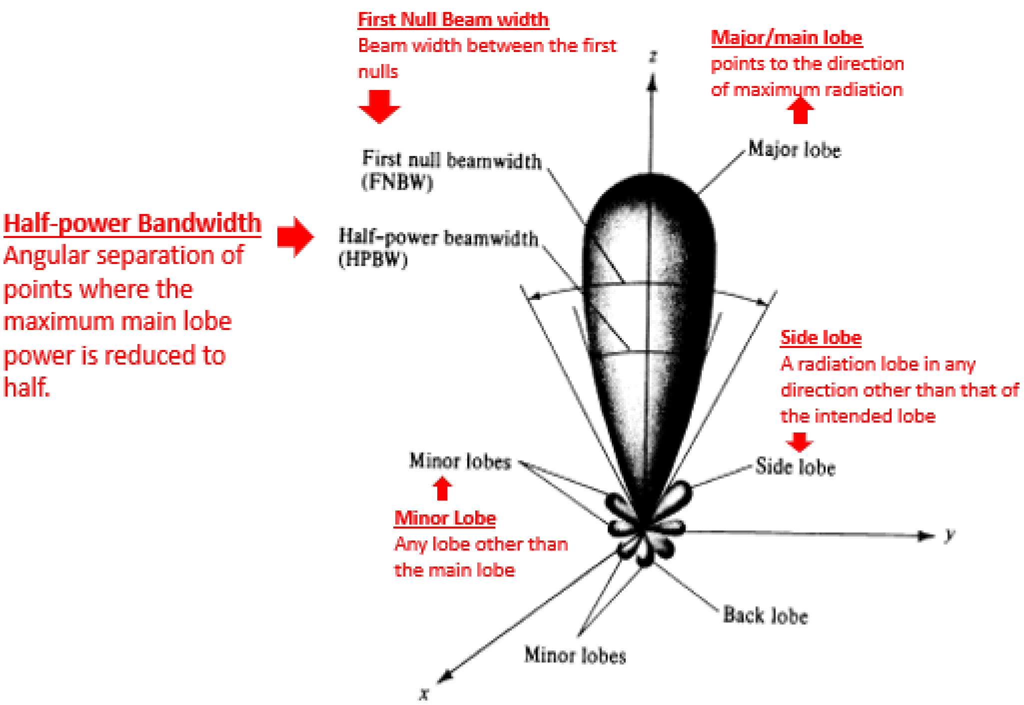

Figure 2. Radiation pattern parameters

3.3. Directivity

A measure of how "focused" the radiated power is in a particular direction. It is a ratio of power densities and is independent of efficiency.

Isotropic radiator (a theoretical point source that radiates equally in all directions) has a directivity of 1 (or 0 dBi).

3.4 Gain (G)

Gain is directivity less efficiency losses. Gain tells us how much power is actually radiated in the maximum direction compared to an isotropic radiator.

Gain can be stated in dBi (gain over an isotropic radiator) or dBd (gain over a dipole, where 0 dBd = 2.15 dBi).

4. COMMON ANTENNA TYPES

Common antenna types are dipole, monopole (Marconi), Loop, Yagi-Uda, Patch (Microstrip) and Parabolic reflector.

4.1 Dipole

Construction: Straight wire, fed at centre

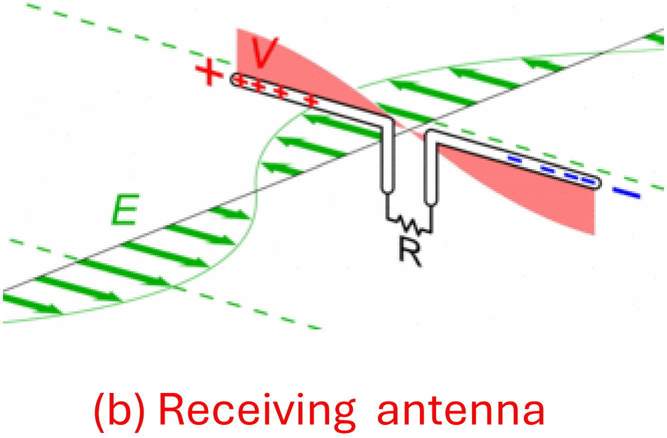

Figure 3. Dipole Antenna

Principle / How it Works: A centre-fed straight conductor of length ~λ/2. Current is maximum at the centre, zero at the ends.

Key characteristics: Omnidirectional in H-plane, figure-8 in E-plane. Z_a ~73 Ω. Simple, fundamental.

Applications: FM radio, TV reception, reference antenna.

4.2 Monopole/Marconi

Construction: Single vertical element over ground plane

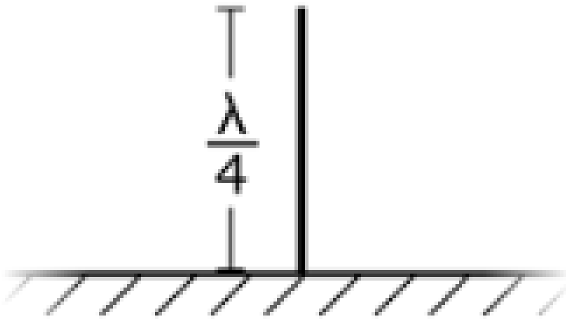

Figure 4. Monopole/Marconi Antenna

Principle / How it Works: A λ/4 vertical element working against a ground plane (e.g., car roof).

Key characteristics: Omnidirectional. Z_a ~36 Ω. Requires a ground plane.

Applications: Car antennas, portable radios, WiFi routers.

4.3 Loop Antenna

Construction: Circular or square loop of wire

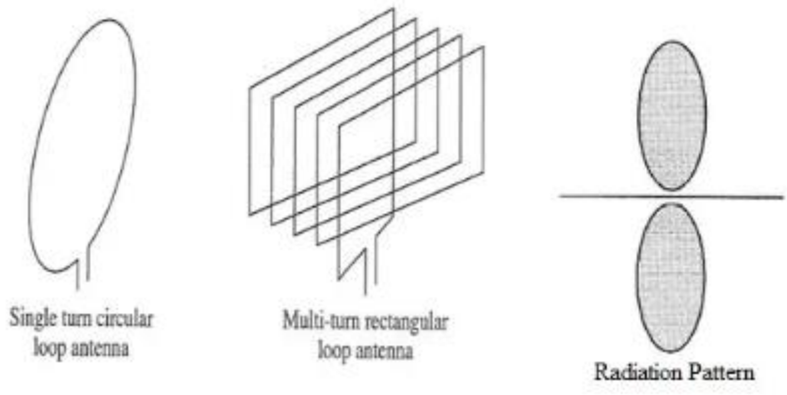

Figure 5. Monopole/Marconi Antenna

Principle / How it Works: Can be small (magnetic dipole) or resonant (~1λ circumference).

Key characteristics: For small loops: omnidirectional null broadside to loop. Low radiation resistance.

Applications: RFID tags, AM radio receivers, magnetic communications.

4.4 Yagi-Uda Antenna

Construction: A driven element, reflector, and directors

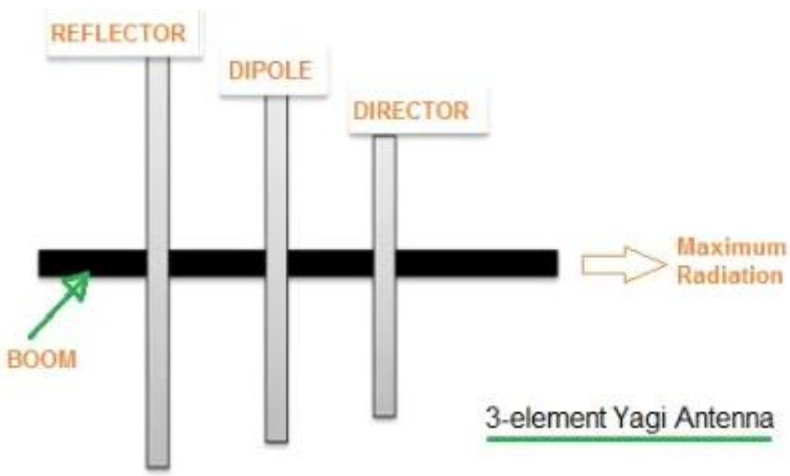

Figure 6. Yagi-Uda Antenna

Principle / How it Works: A driven element (dipole) is coupled with passive reflector and director elements to focus the beam.

Key characteristics: Directional, high gain. Relatively narrow bandwidth.

Applications: TV reception, amateur radio (HF/VHF/UHF), point-to-point links.

4.5 Patch / Microstrip Antenna:

Construction: Square metal patch on a grounded substrate.

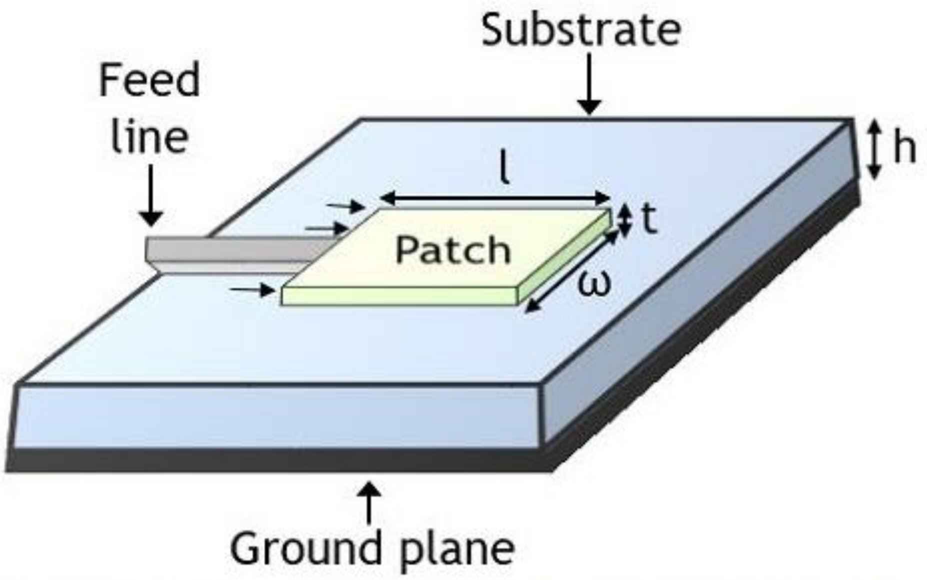

Figure 7. Patch/Microstrip Antenna

Principle / How it Works: A resonant patch of metal on a dielectric substrate above a ground plane. Length is ~λ/2.

Key characteristics: Low profile, lightweight, cheap to manufacture. Medium gain. Limited bandwidth.

Applications: GPS, mobile phones, WiFi access points, satellite comms.

4.6 Parabolic Reflector

Construction: A feed antenna illuminating a parabolic reflector.

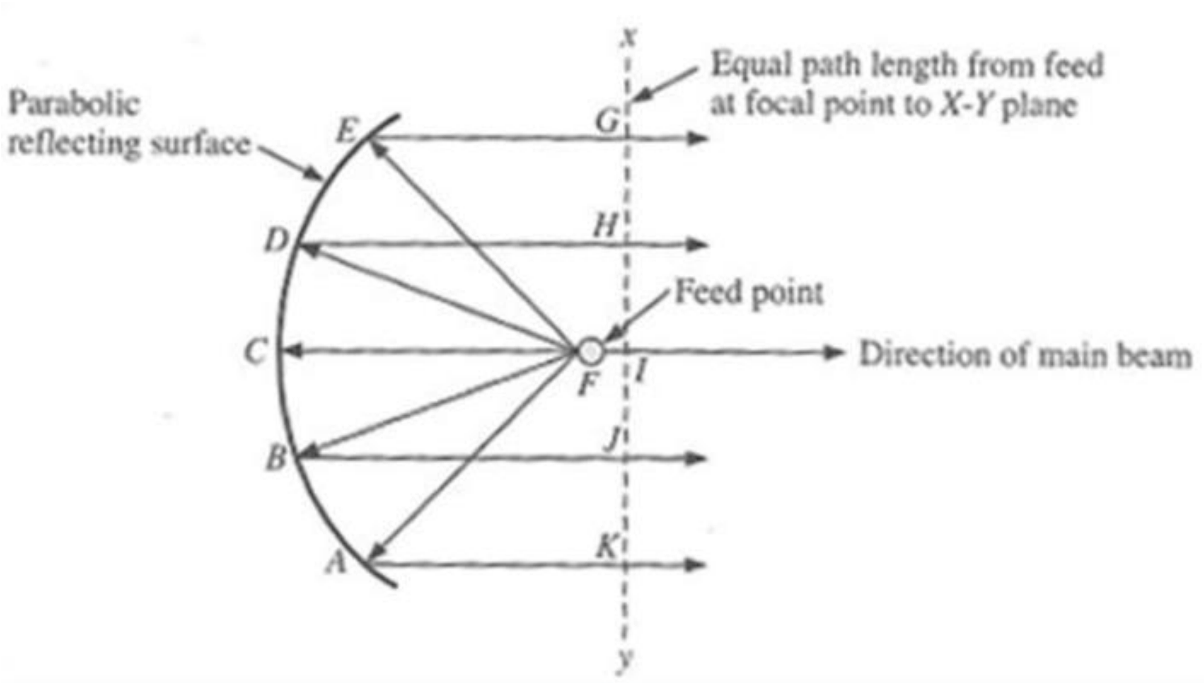

Figure 8. Parabolic Reflector Antenna

Principle / How it Works: The parabolic shape reflects incoming waves to a single focal point (the feed antenna), and vice versa.

Key characteristics: Extremely high gain and directivity. Gain proportional to $(D/\lambda)^2$.

Applications: Satellite communications, radio astronomy, radar, deep space networks.

5. PRACTICE PROBLEMS

1 Calculate the ideal length for a half-wave dipole antenna designed to operate at 100 MHz.
2 An antenna has a directivity of 10 and a radiation efficiency of 80%. What is its gain in dBi?
3 A parabolic dish antenna has a diameter of 1 meter and is operating at 12 GHz. Estimate its gain in dBi
4 Sketch the approximate E-plane and H-plane radiation patterns for a half-wave dipole.