Antenna module content

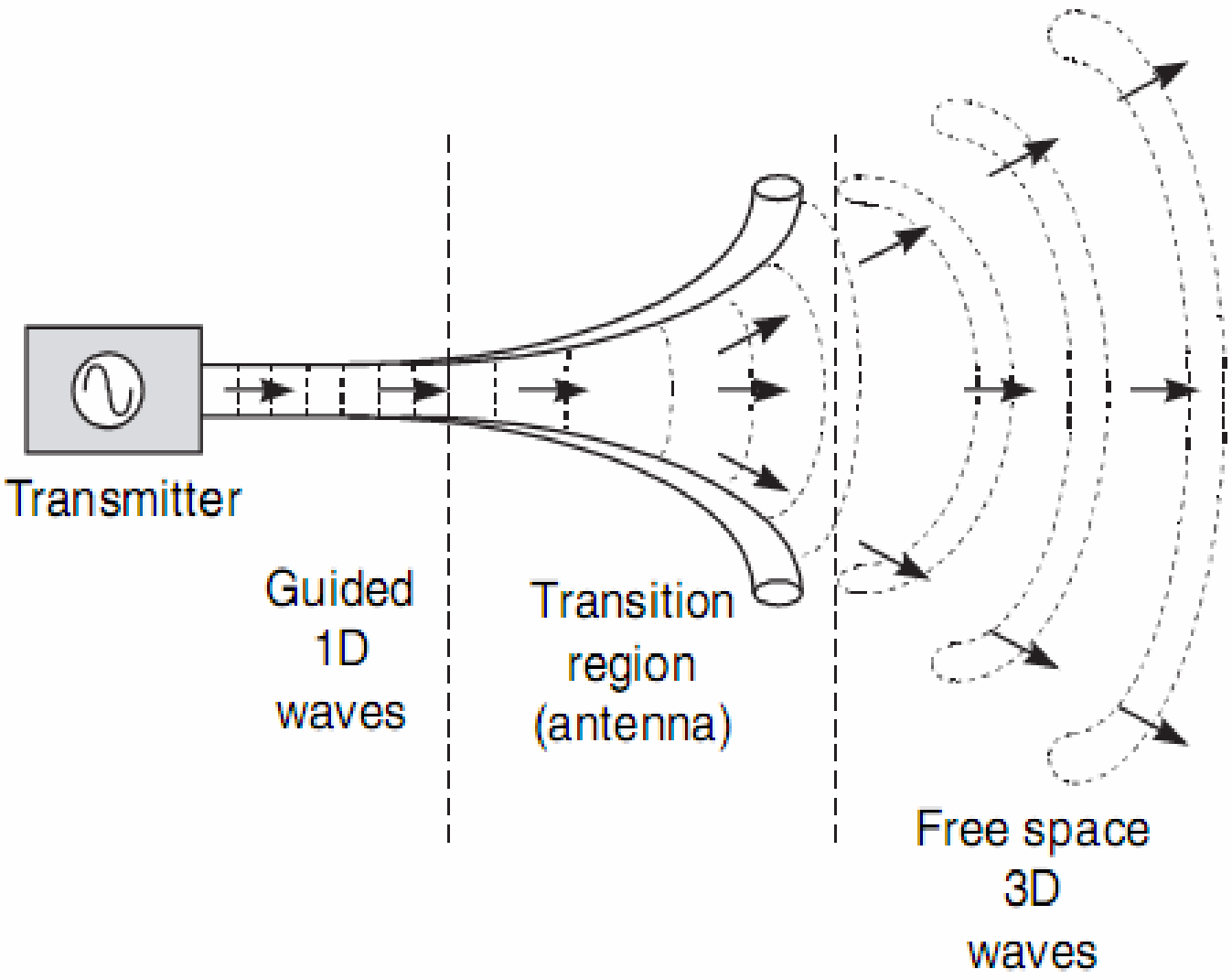
Topics

- Antenna definition.
- Antenna main parameters.
- Types of antennas.
- Antenna examples for each type.

What is the antenna?

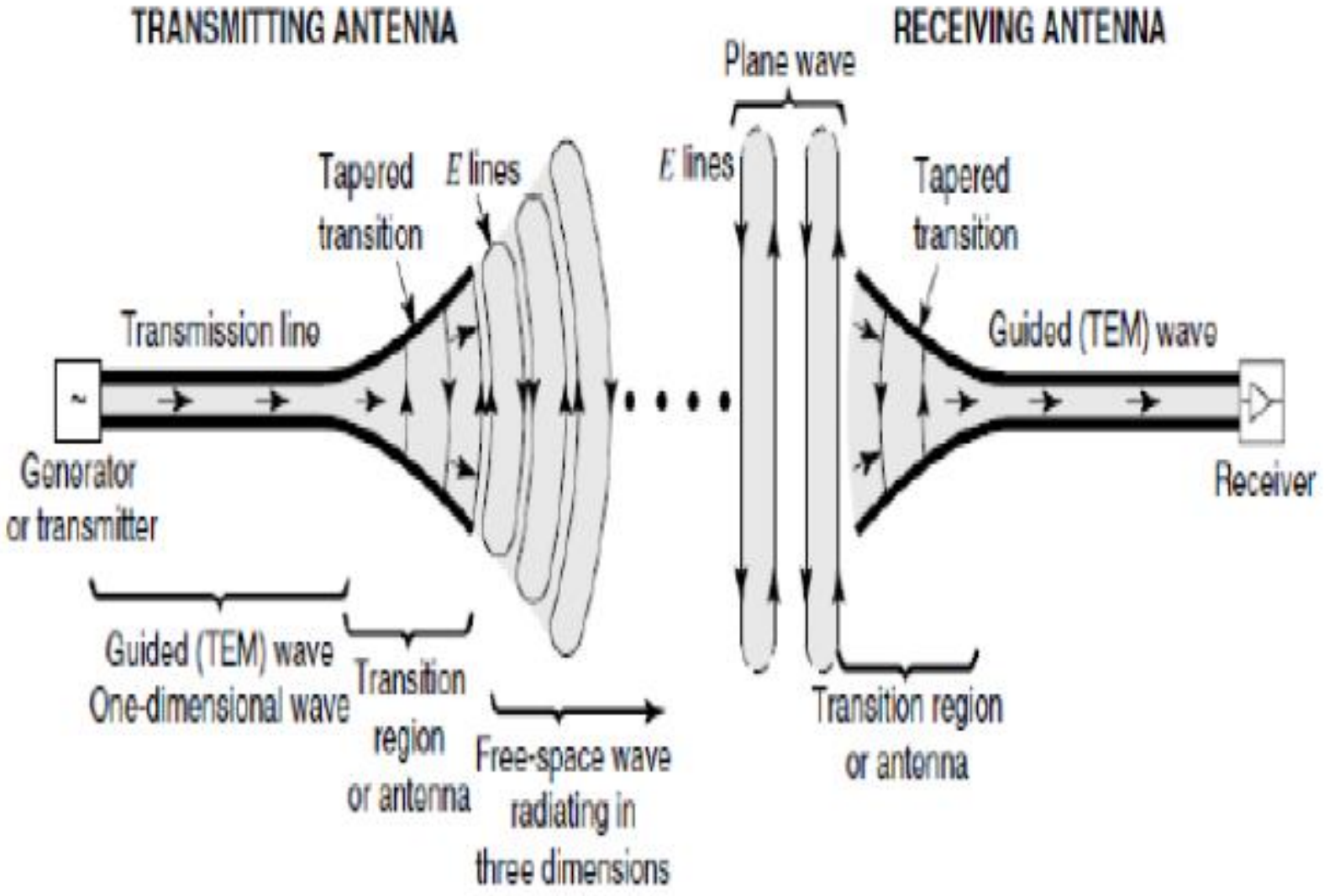
- Antenna is a device used to convert guided electrical energy into radio Waves (i.e. unguided) or vice versa.
- Antenna is a transition structure between feeder (which can be twisted pair, coaxial cable or wave guide) and free space.
- Antenna transfer guided (bounded) wave in the feeder to unguided (unbounded) wave in free space, it either radiates or receives.
- Antenna may intensify radiation in some direction while suppress radiation in the other directions.
- Antenna may be metallic or dielectric.

Antenna definition



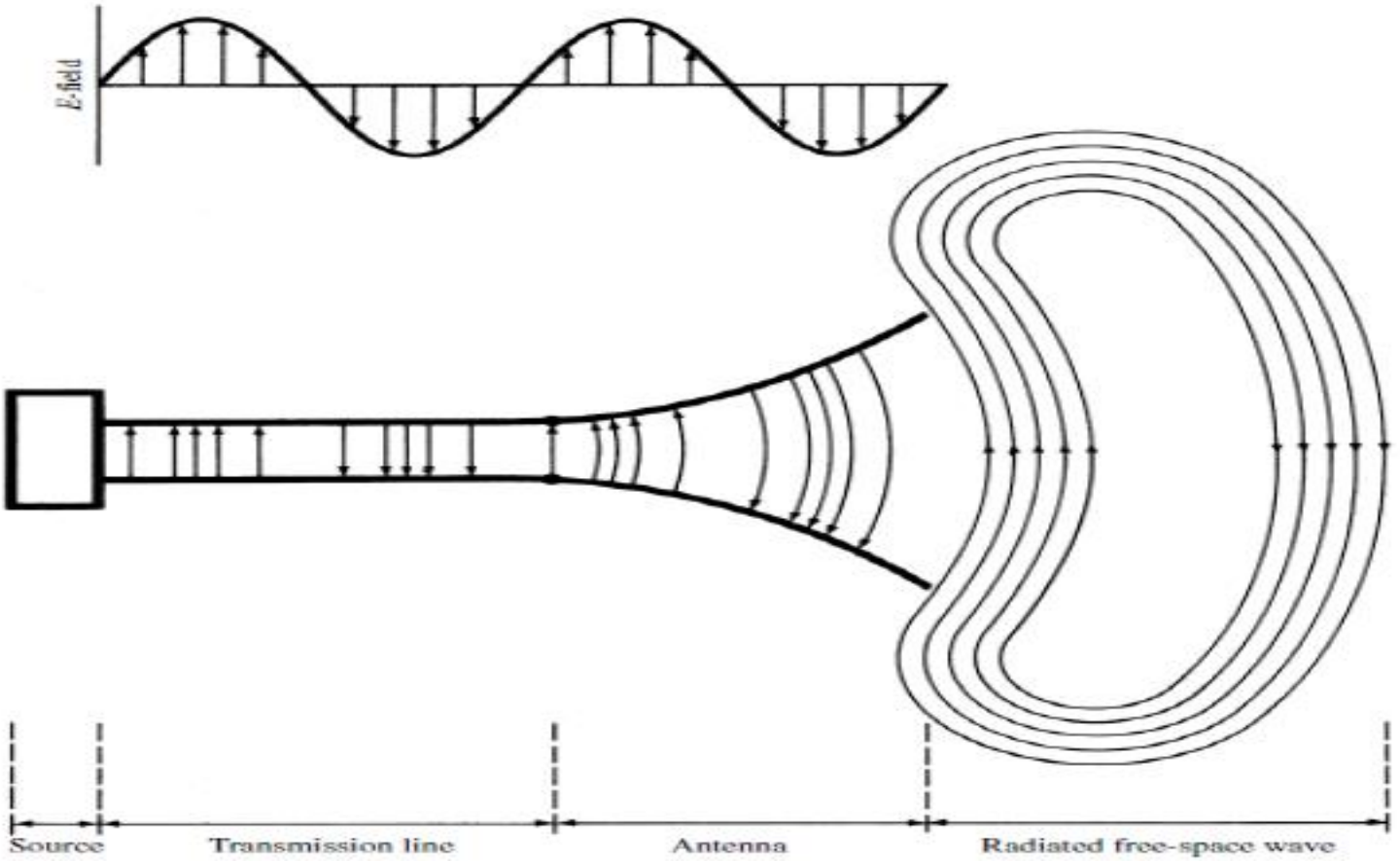
Antenna definition

Transmitting and Receiving Antennas

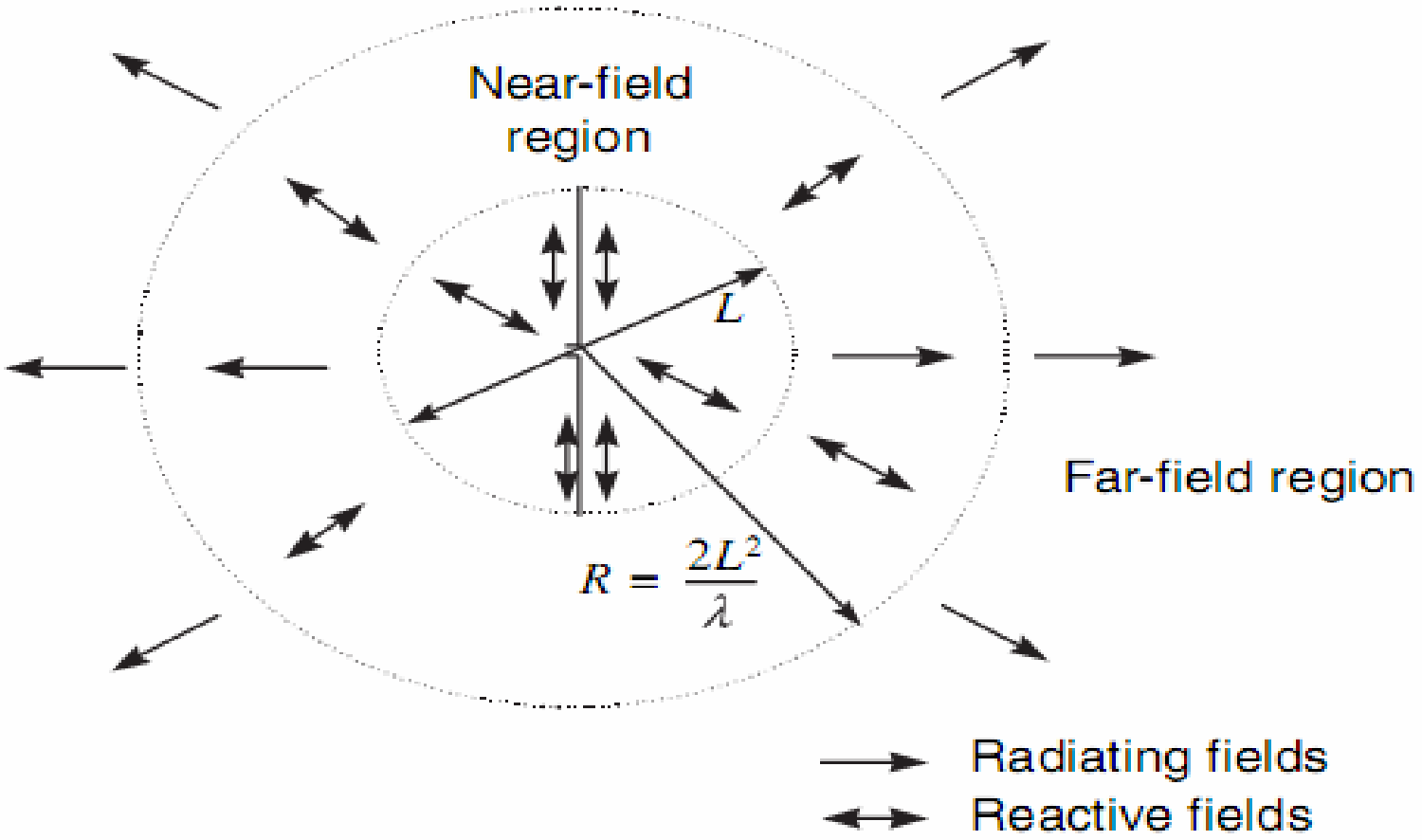


Antenna definition

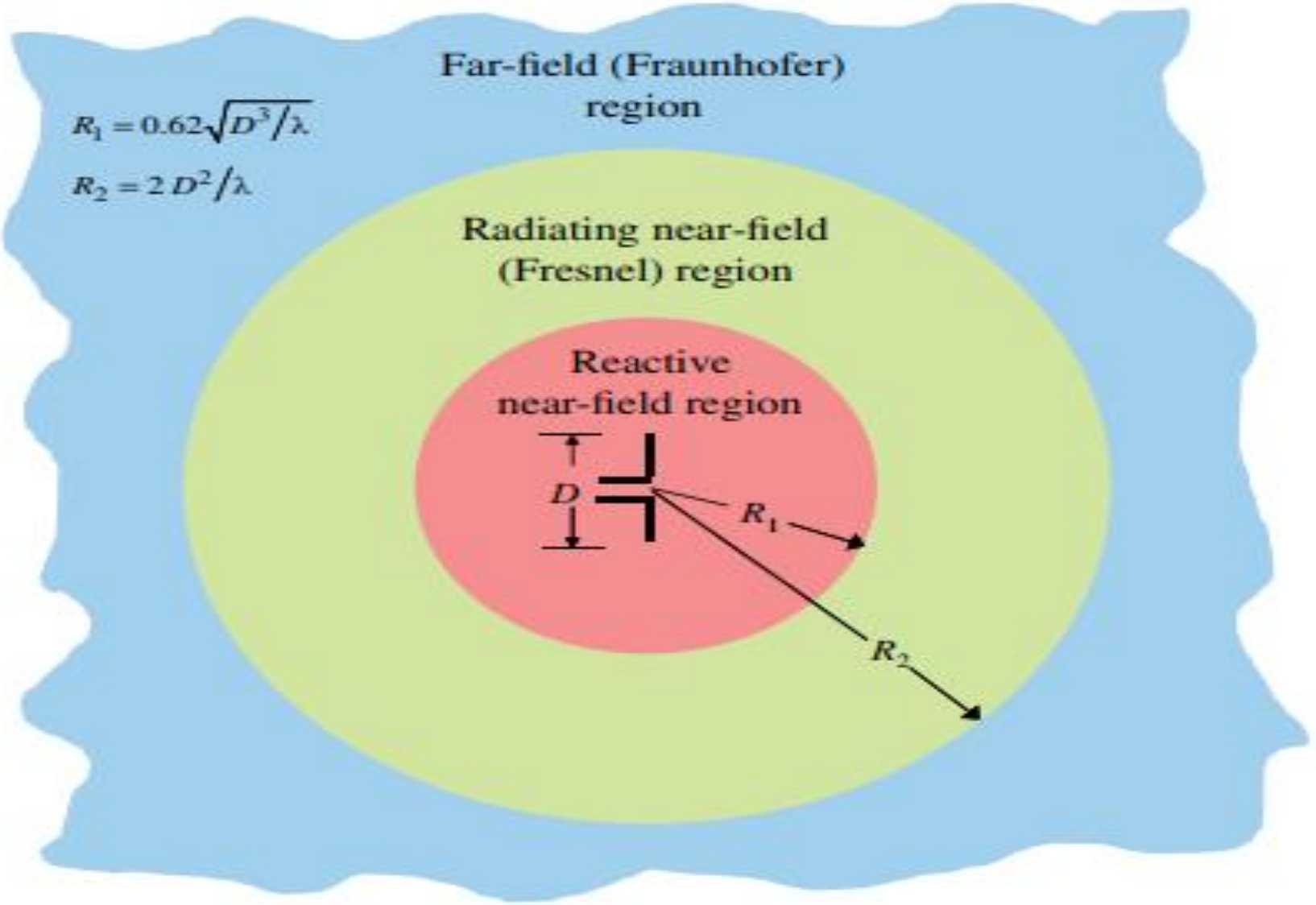
Antenna as a transition device



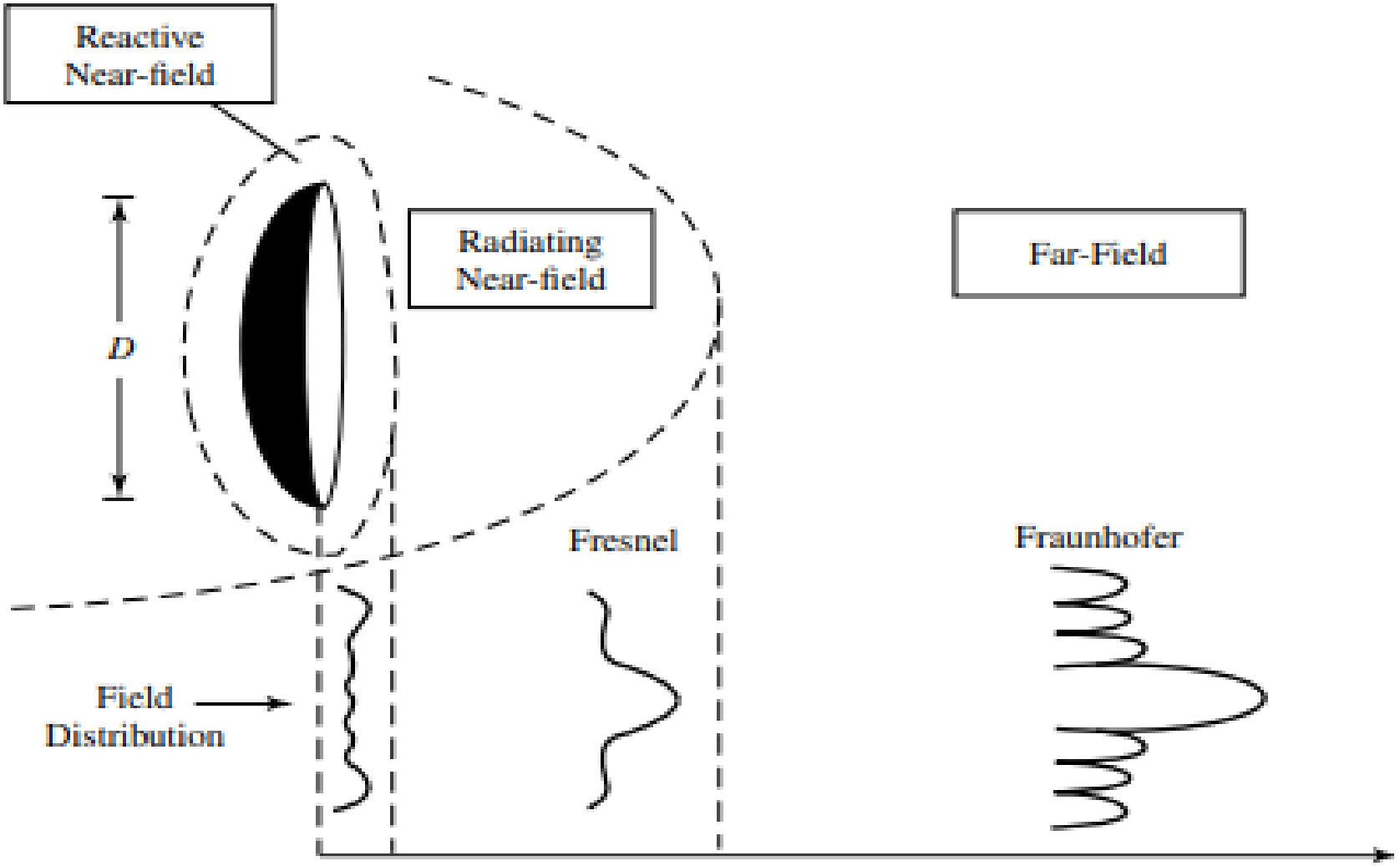
Antenna field regions



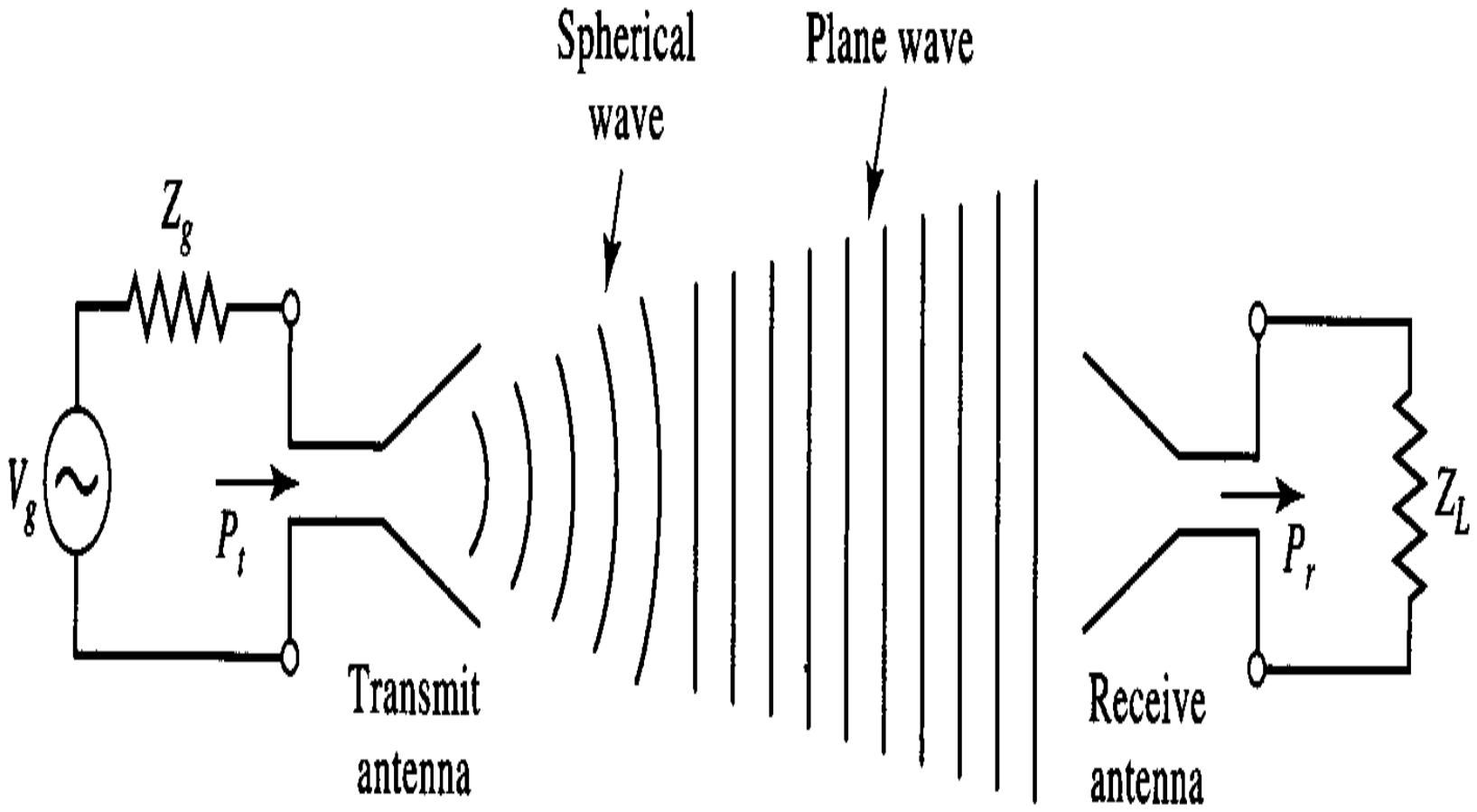
Antenna field regions



Antenna field regions



Plane waves


Spherical
wave
Plane wave
Z_g
V_g
P_t
Transmit
antenna
P_r
Z_L
Receive
antenna

Main parameters of antenna

- Antenna Radiation pattern.
- Antenna Polarization.
- Antenna Directivity.
- Antenna Gain.
- Antenna efficiency.
- Antenna bandwidth
- Input impedance.
- Effective area(in case of aperture antenna)

Main parameters of antenna

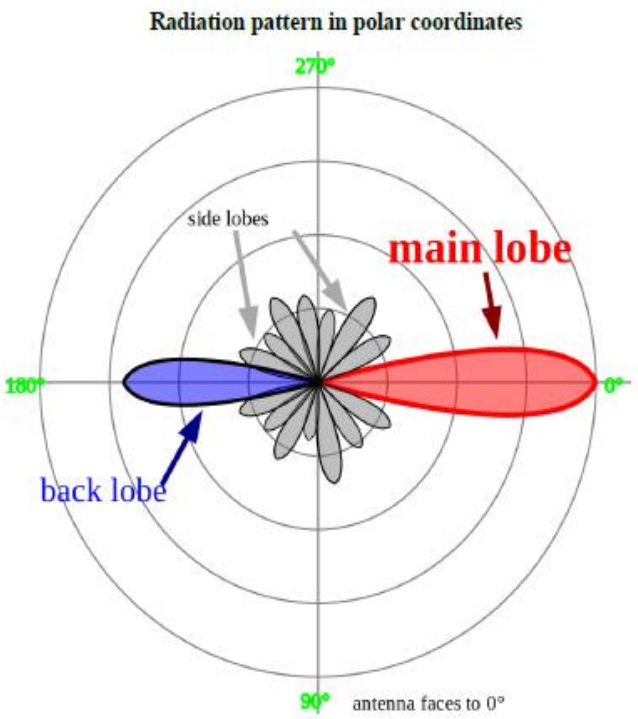
Antenna Radiation Pattern

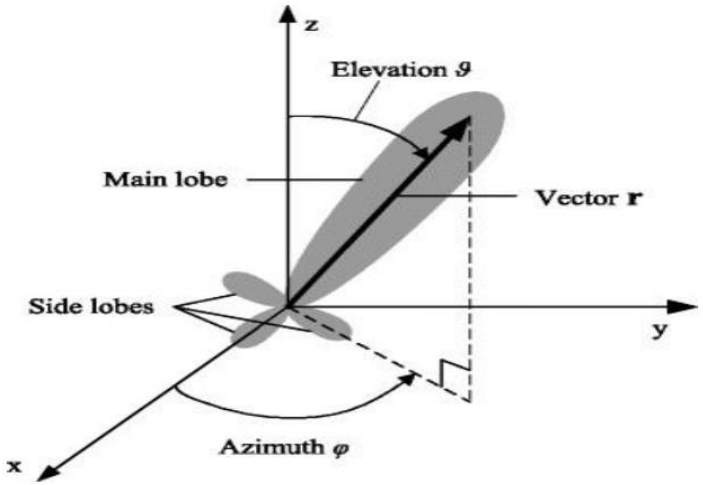
The radiation pattern is defined as a graphical representation of the radiation properties of the antenna (either **power** or **electric field strength**) as a function of space (or spatial) coordinates in all different angular directions".

It is a graphical representation which describes the variation of power radiated from antenna as a function of direction with respect to particular coordinates.

The radiation pattern is **three-dimensional (3D)** graph but it is described in **two dimensional (2D)** cuts or planes either **polar plots** or **rectangular plot (** horizontal and vertical cross sections).

Antenna radiation pattern





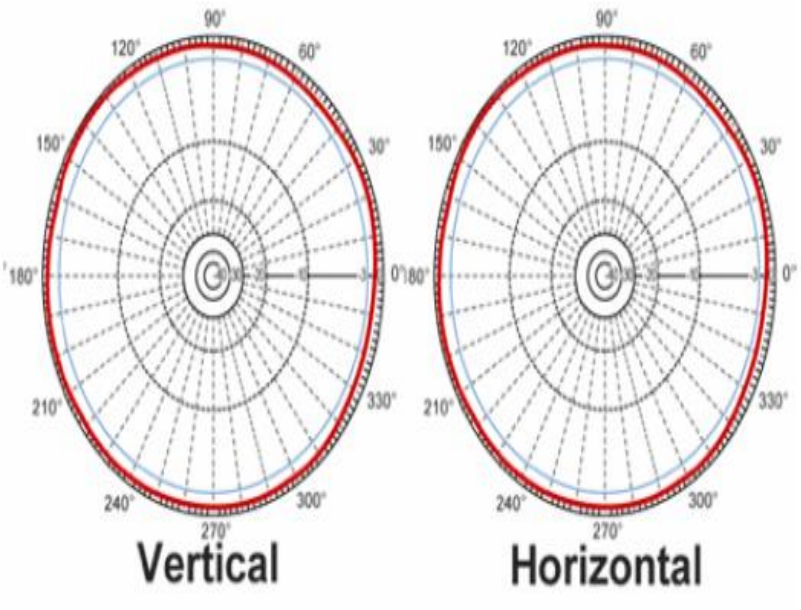
Types of antennas according to radiation pattern

Isotropic antenna

It radiates equally in all directions in all planes such as **point source**. It is hypothetical antenna. It does not exist in reality. But it is taken as a reference. The radiation pattern of isotropic antenna in 3D is a sphere

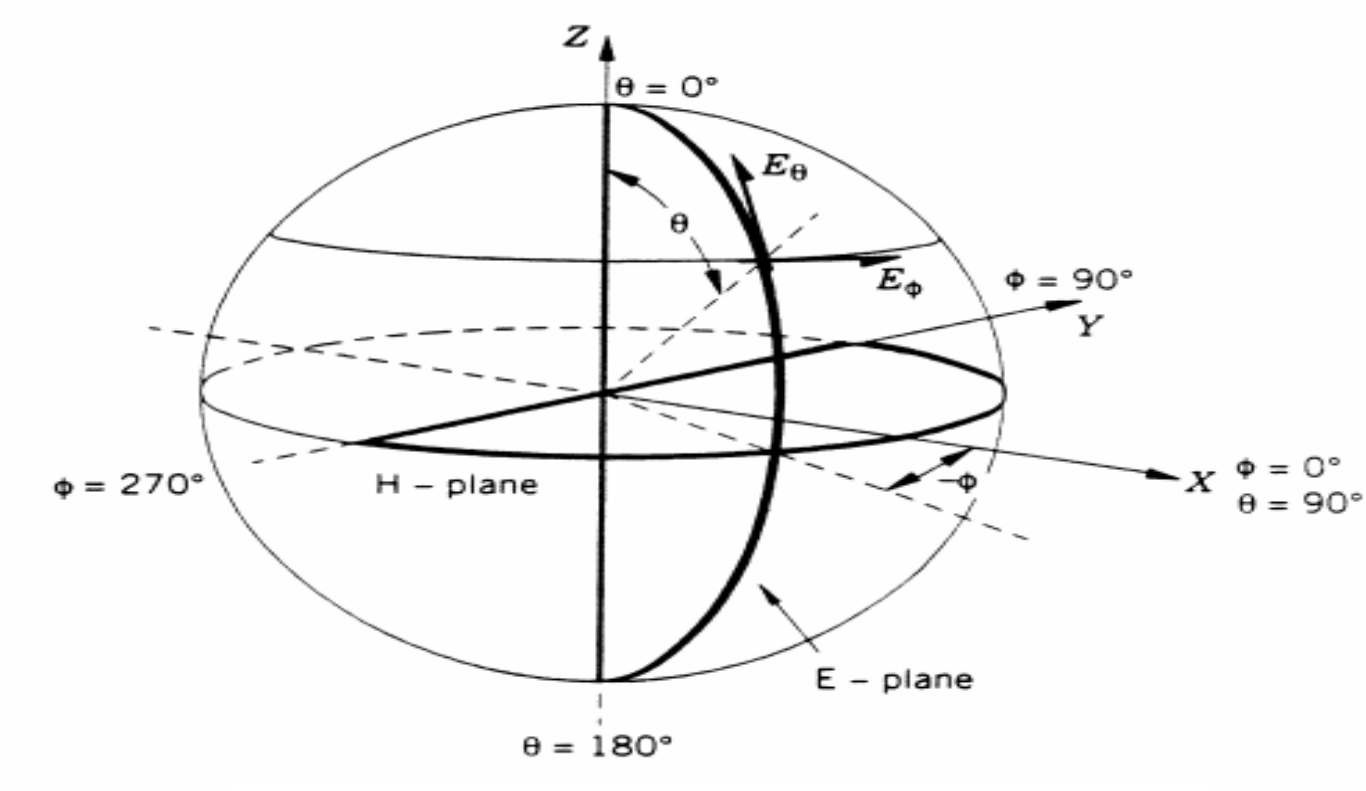
Isotropic antenna

3D radiation pattern of isotropic antenna



2D radiation pattern of isotropic antenna

Azimuth (phi or H plane or horizontal) and elevation (theta or E plane or vertical) angles

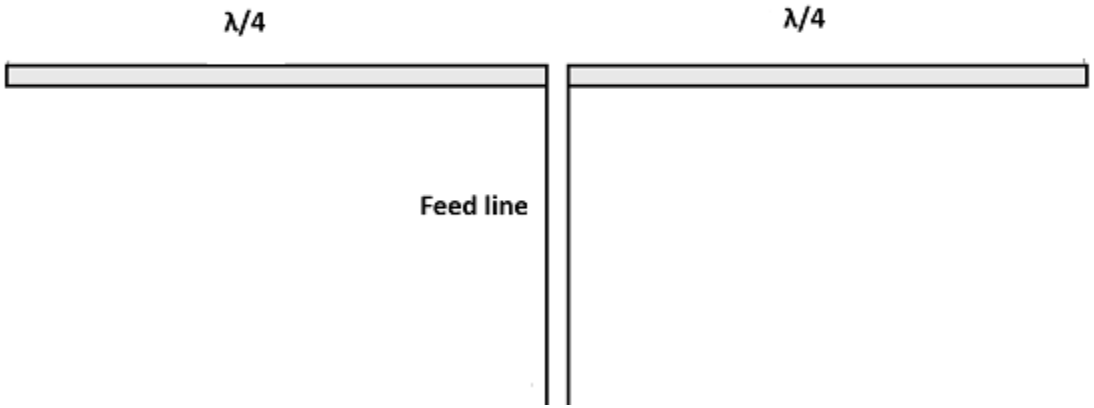


Omnidirectional antenna

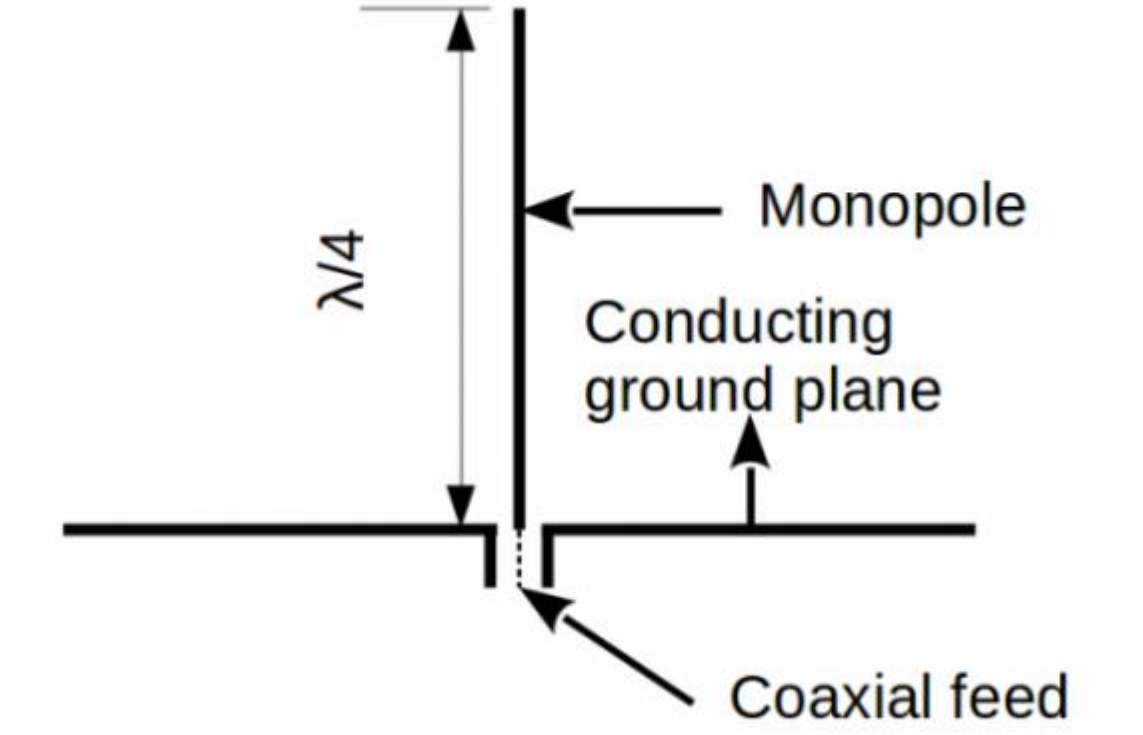
Omni directional antenna has a directional pattern in vertical (elevation) plane and it has non directional pattern in horizontal (azimuth) plane.

Omni directional antenna radiates energy equally in horizontal plane but has directionality in vertical plane such as **horizontal half wave dipole.**

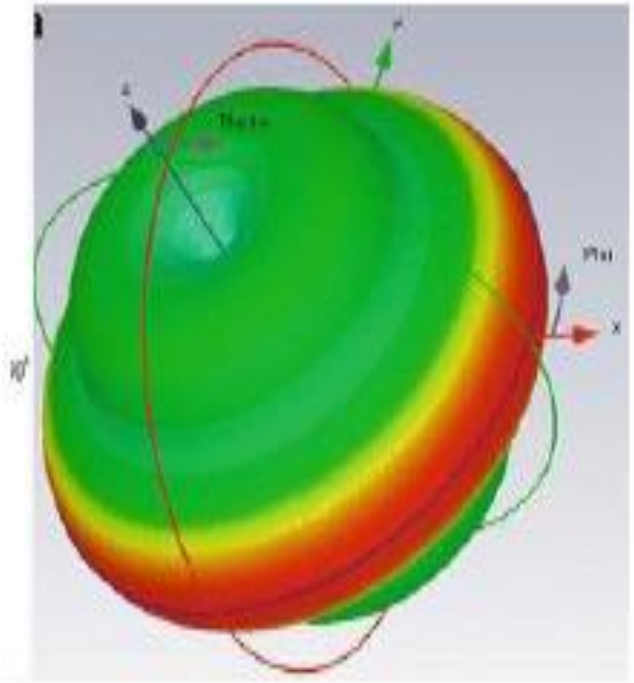
Horizontal half dipole



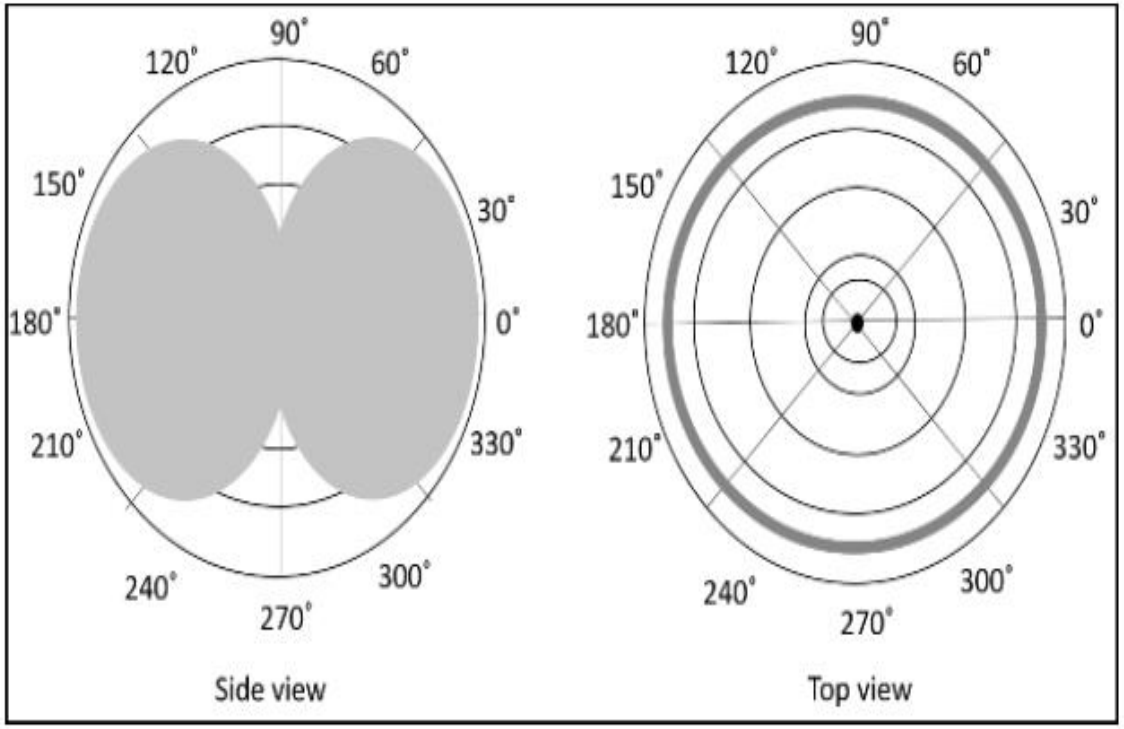
Vertical monopole antenna



Omnidirectional antenna

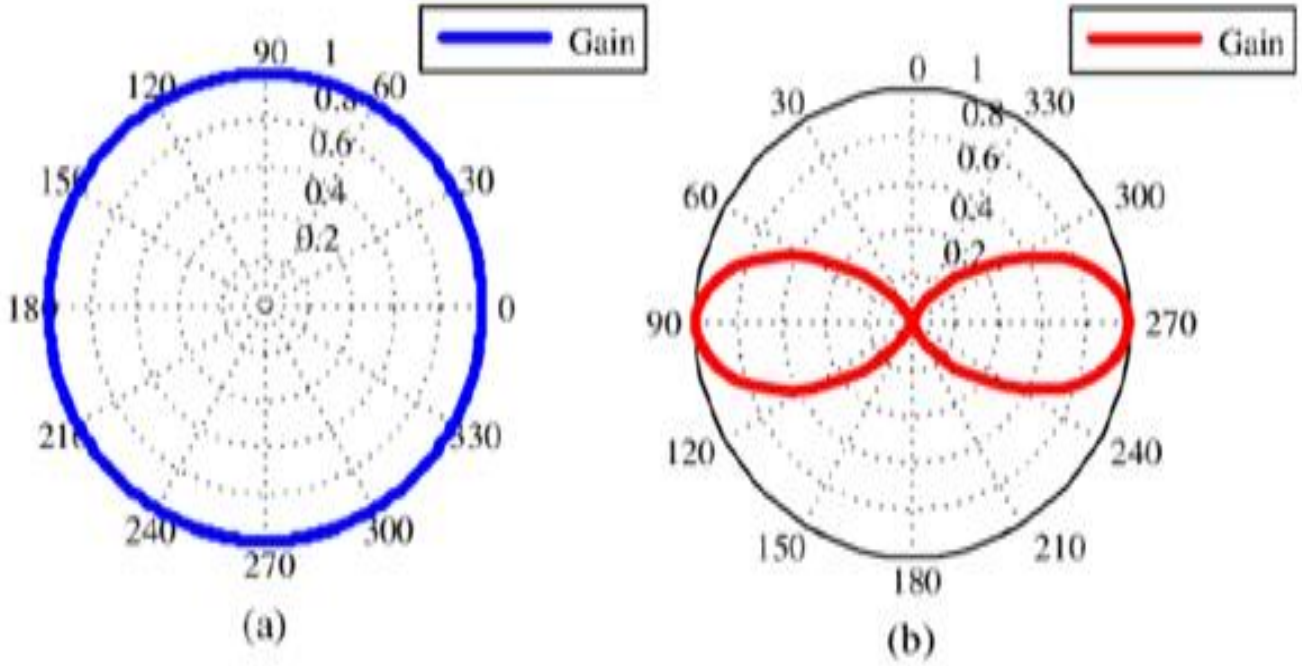


3D radiation pattern of omnidirectional antenna



2D radiation pattern of omnidirectional antenna

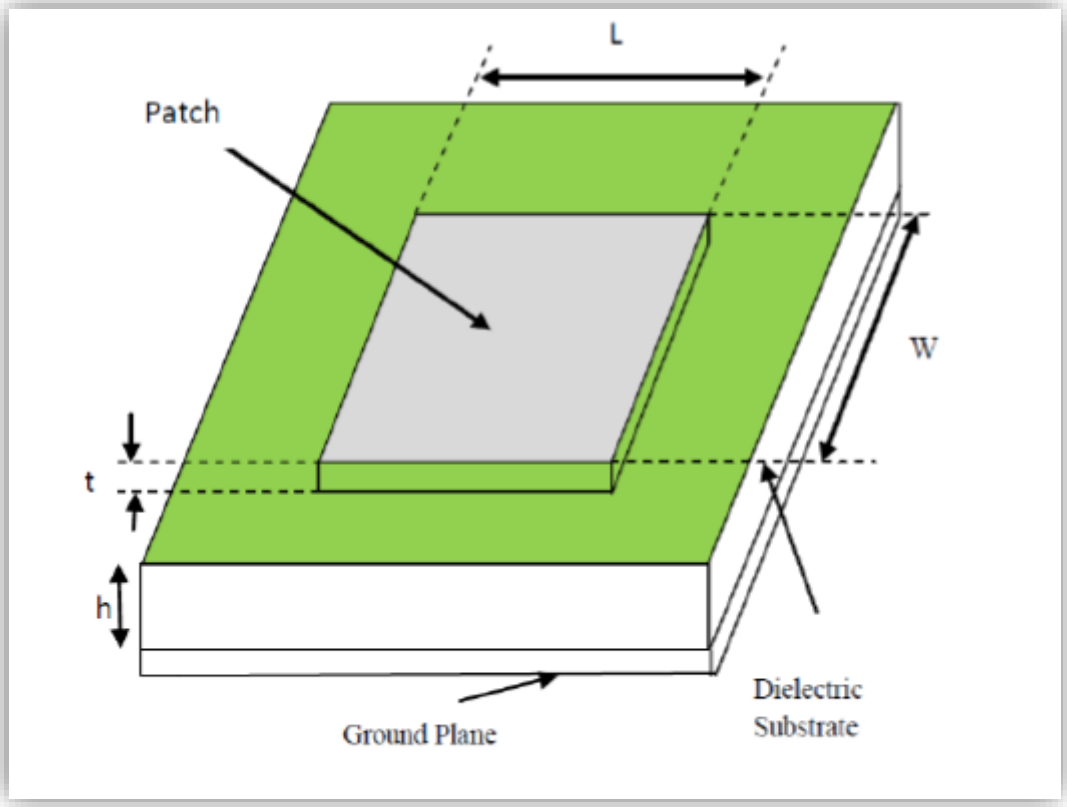
Omnidirectional antenna



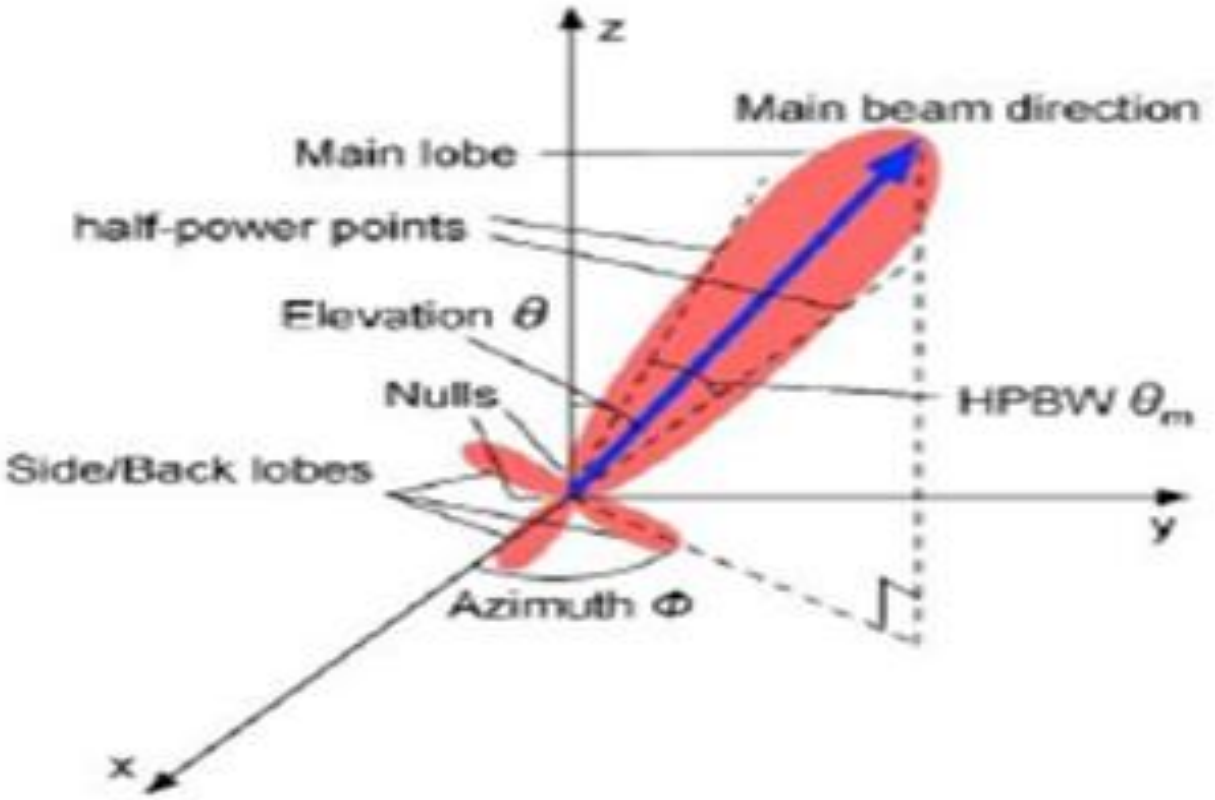
Directional antenna

A directional antenna or beam antenna is an antenna that radiates or receives greater power in specific directions than the other, which increases performance and reduces the interference from unwanted sources. A directional antenna intensify energy in some direction and suppress it in the other directions, it radiates or receives most of its power in one direction. Examples are **Yagi-Uda antenna array**, **helical antenna** and **microstrip antenna array.**

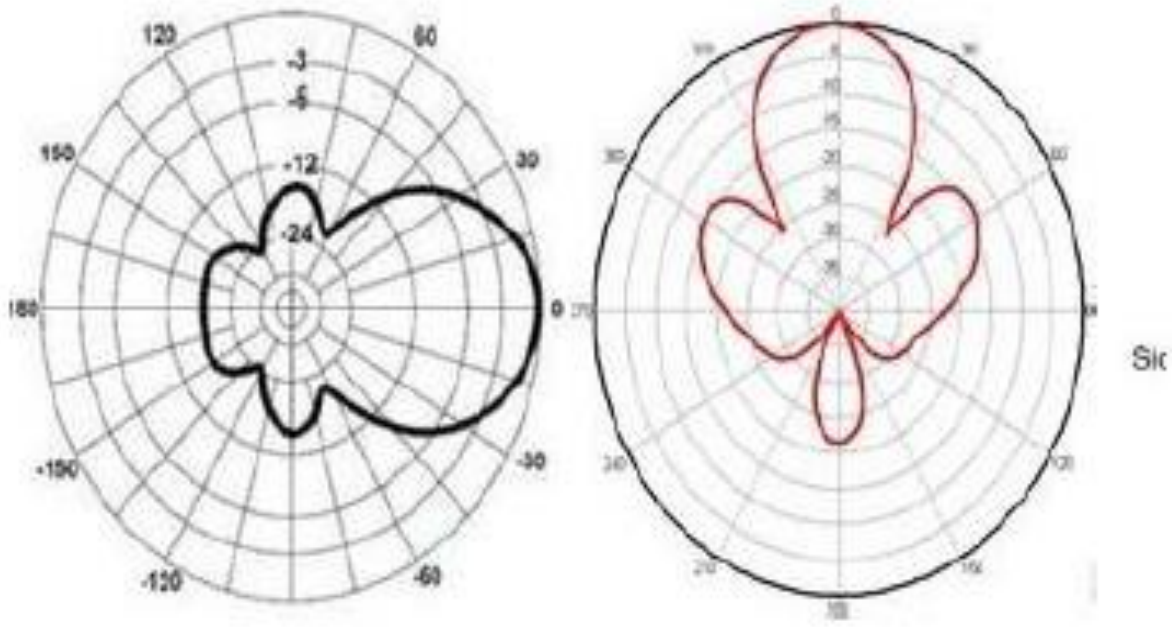
Micro strip antenna



Directional antenna



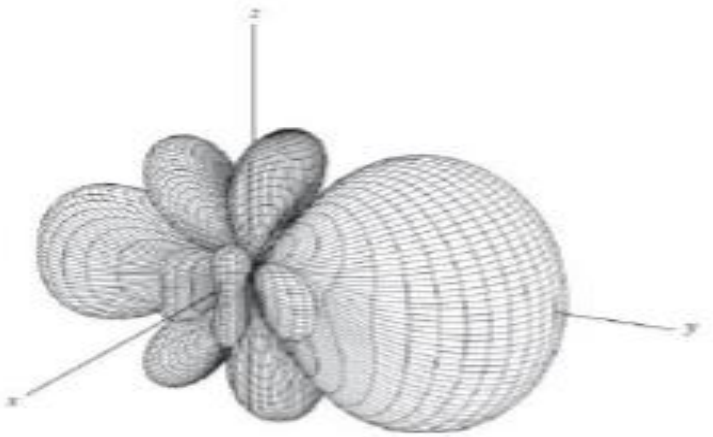
Directional antenna

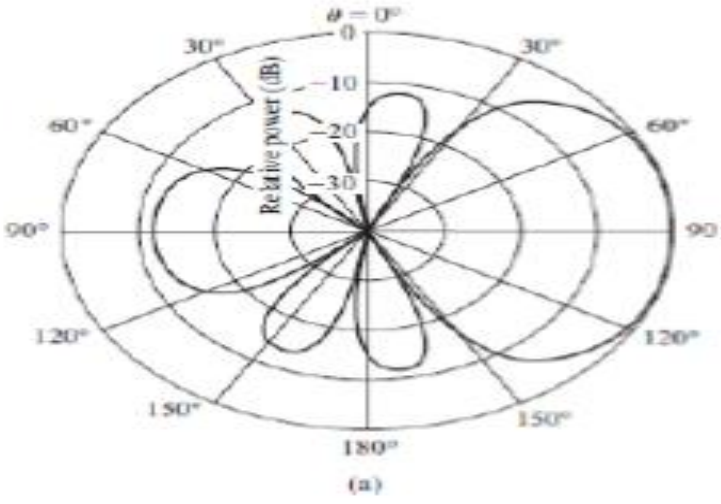


Radiation pattern of directional antenna in horizontal (azimuth) and vertical (elevation) planes

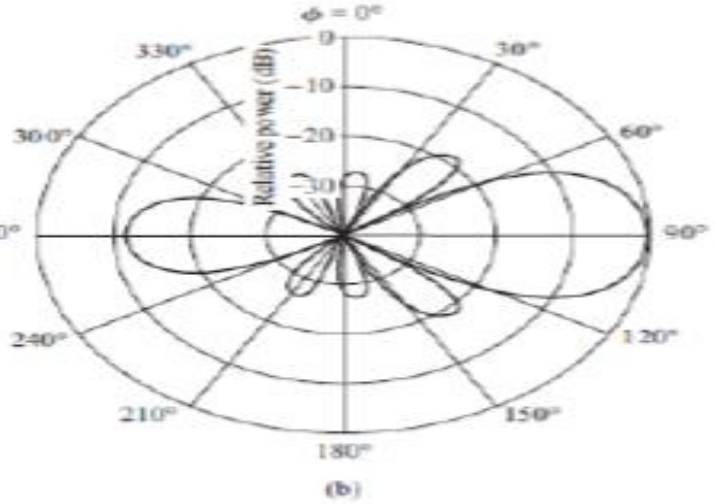
Antenna radiation pattern

3D and 2D Power Patterns





E-plane cut (Ø = 90°)



H-plane cut ($\theta = 90°$)

Antenna radiation pattern

Components of radiation pattern: main (major) lobe, side lobes(or minor lobes) and back lobe.

Main (major) lobe is the main part of the radiated field, which covers a larger area, where maximum radiated energy occurs.

Side lobes(or minor lobes) are the other parts of the pattern where the radiation is distributed side wards. They are the areas where the power is wasted.

Back lobe which is also **a minor lobe**. It is exactly the opposite to the direction of main lobe, where a considerable amount of energy is lost even there.

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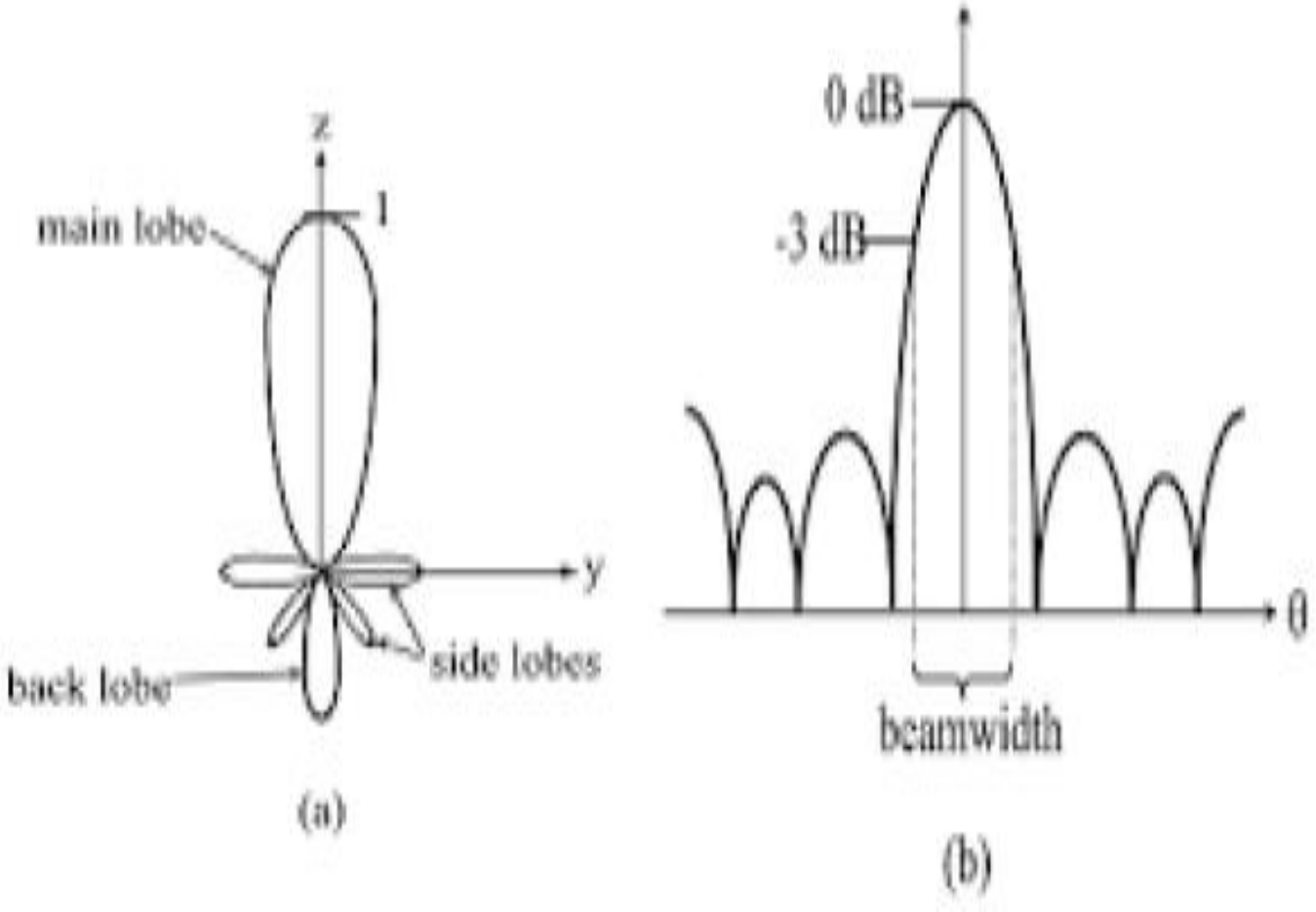
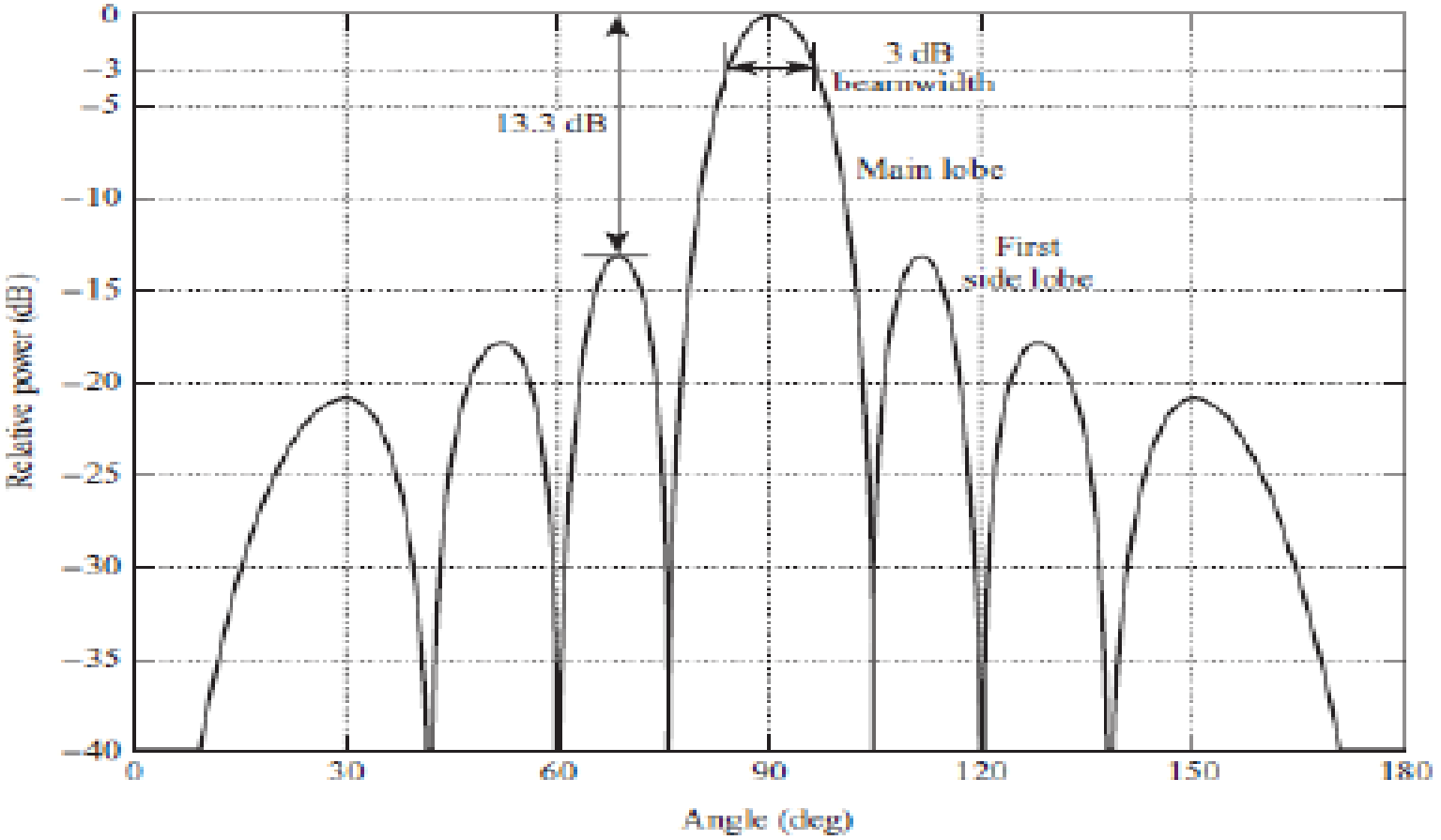
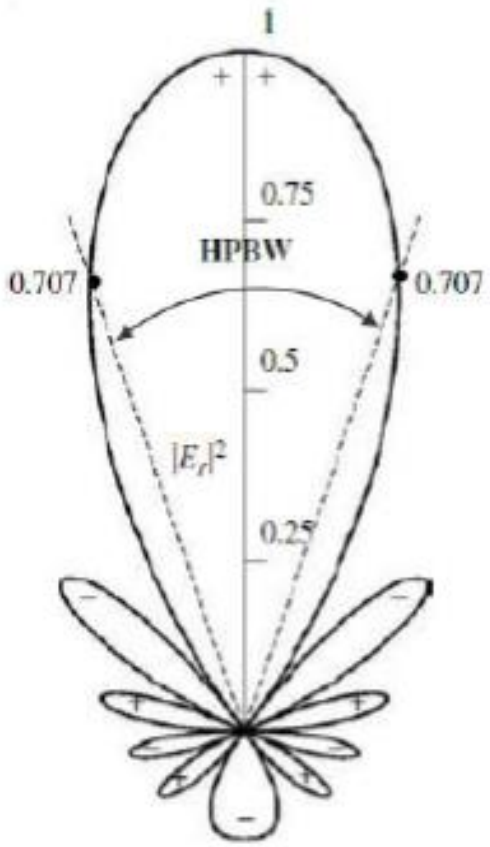
Antenna radiation pattern



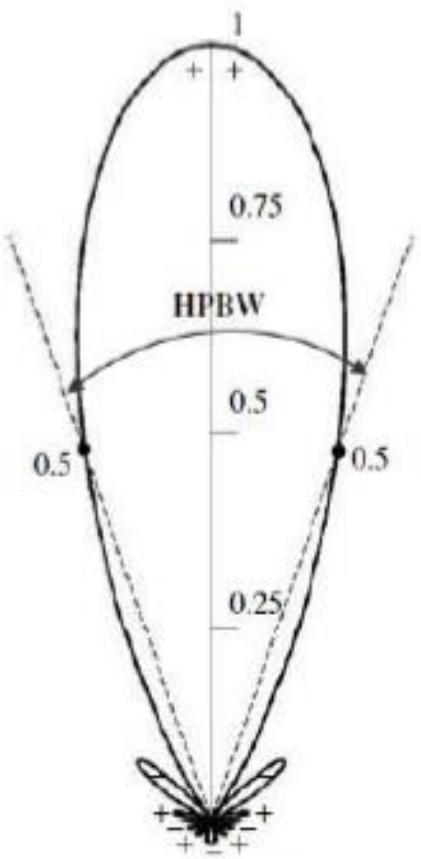
Antenna radiation pattern



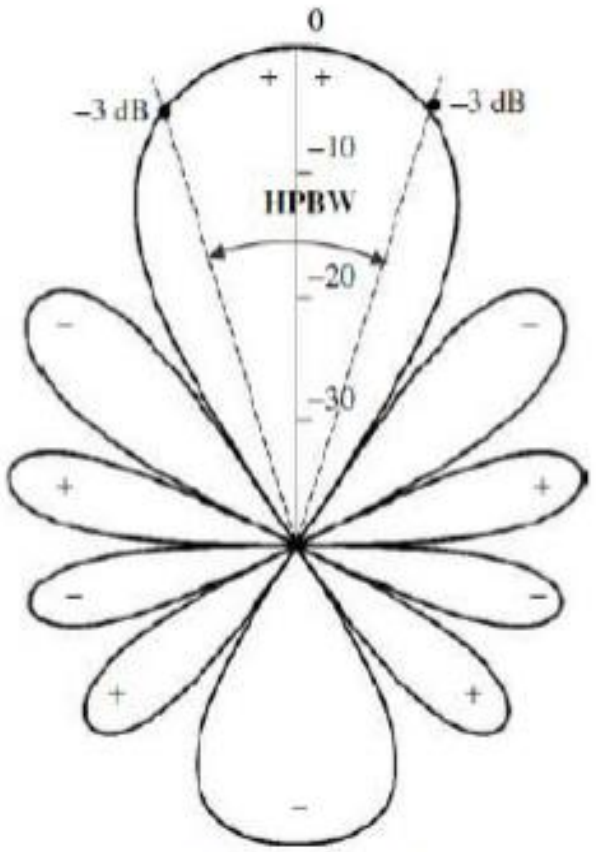
Antenna radiation pattern



(a) Field pattern (in linear scale)

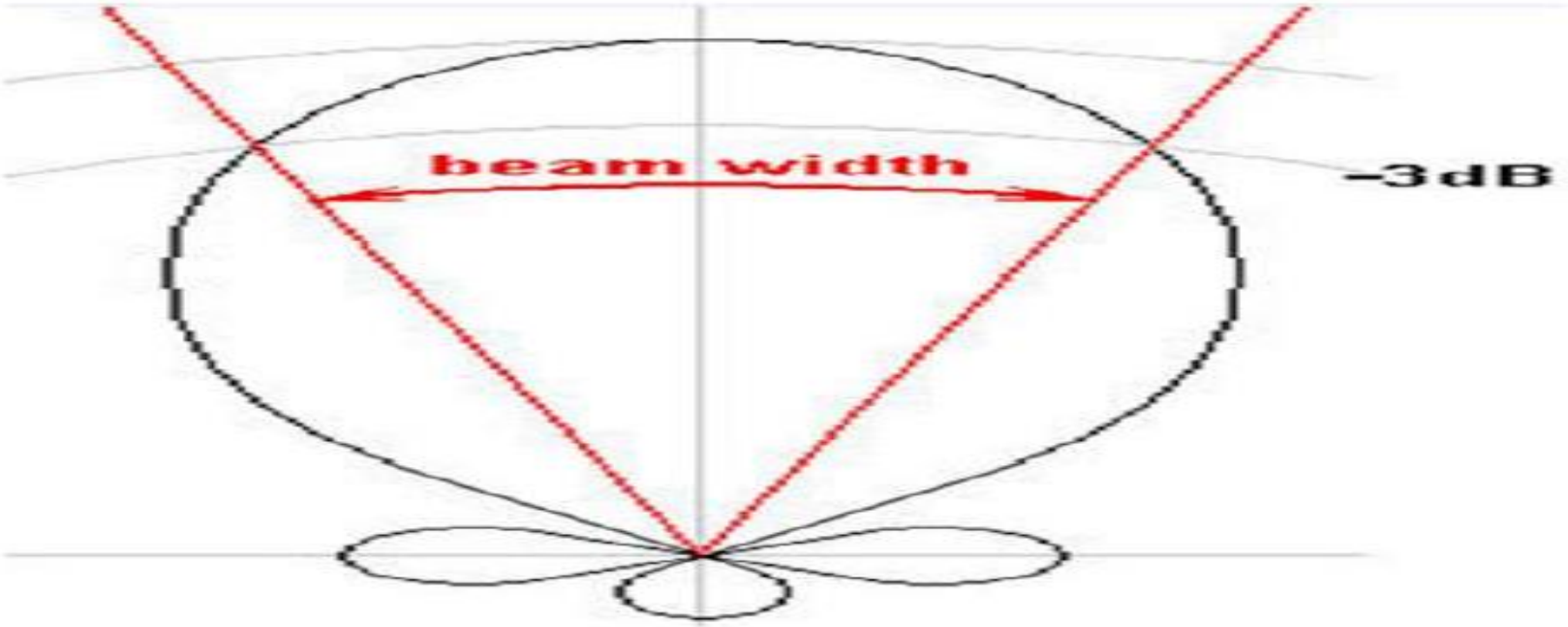


(b) Power pattern (in linear scale)



(c) Power pattern (in dB)

Half Power Beam Width (HPBW): it is the angle of half power which is subtended by points of half power P1/2 or 1/√2E0 =0.707E0 or -3 dB



Half Power Beam Width (HPBW):

It is the angular width between the two points in the antenna radiation pattern which are 3dB below the main beam peak

HPBW = $N\lambda/D$ (degrees)

Where λ is operating wavelength

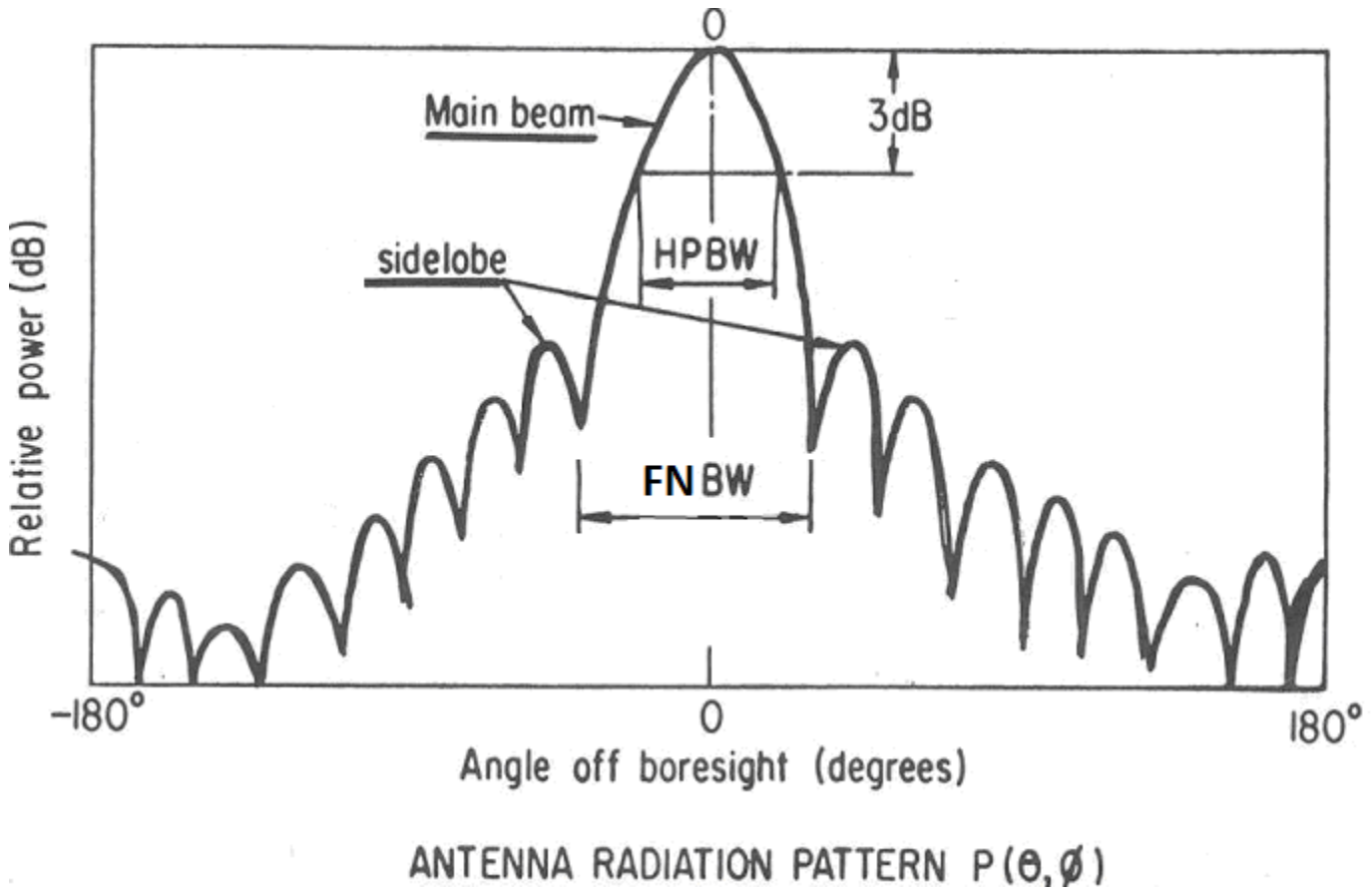
D is **circular aperture** diameter

N is beam width factor dependent on the aperture illumination distribution. In general $58 \leq N \leq 75$

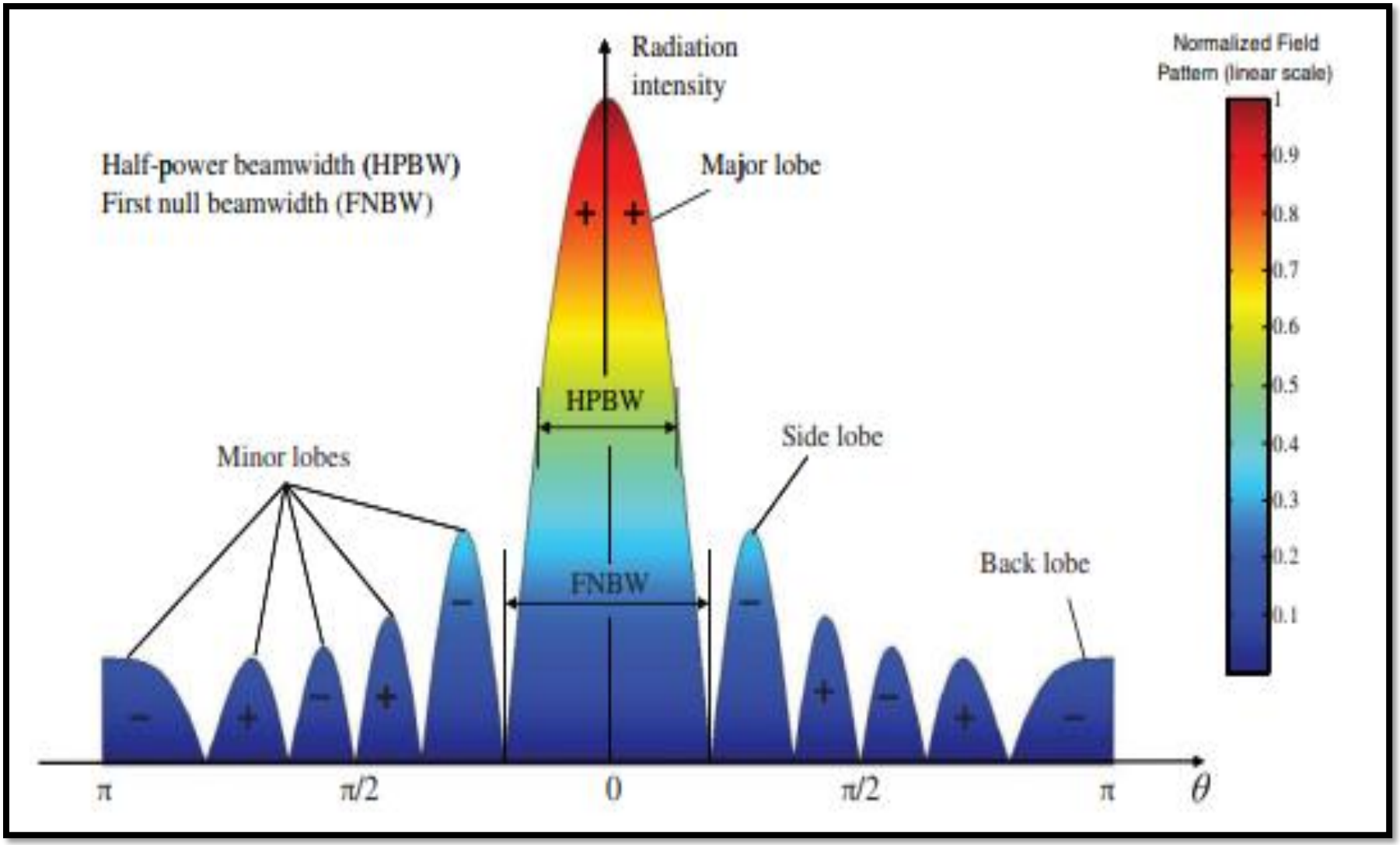
Then, the 3dB beam width in degrees of the antenna is given by:

HPBW = $\theta 3\ dB = 70\ \lambda / D$

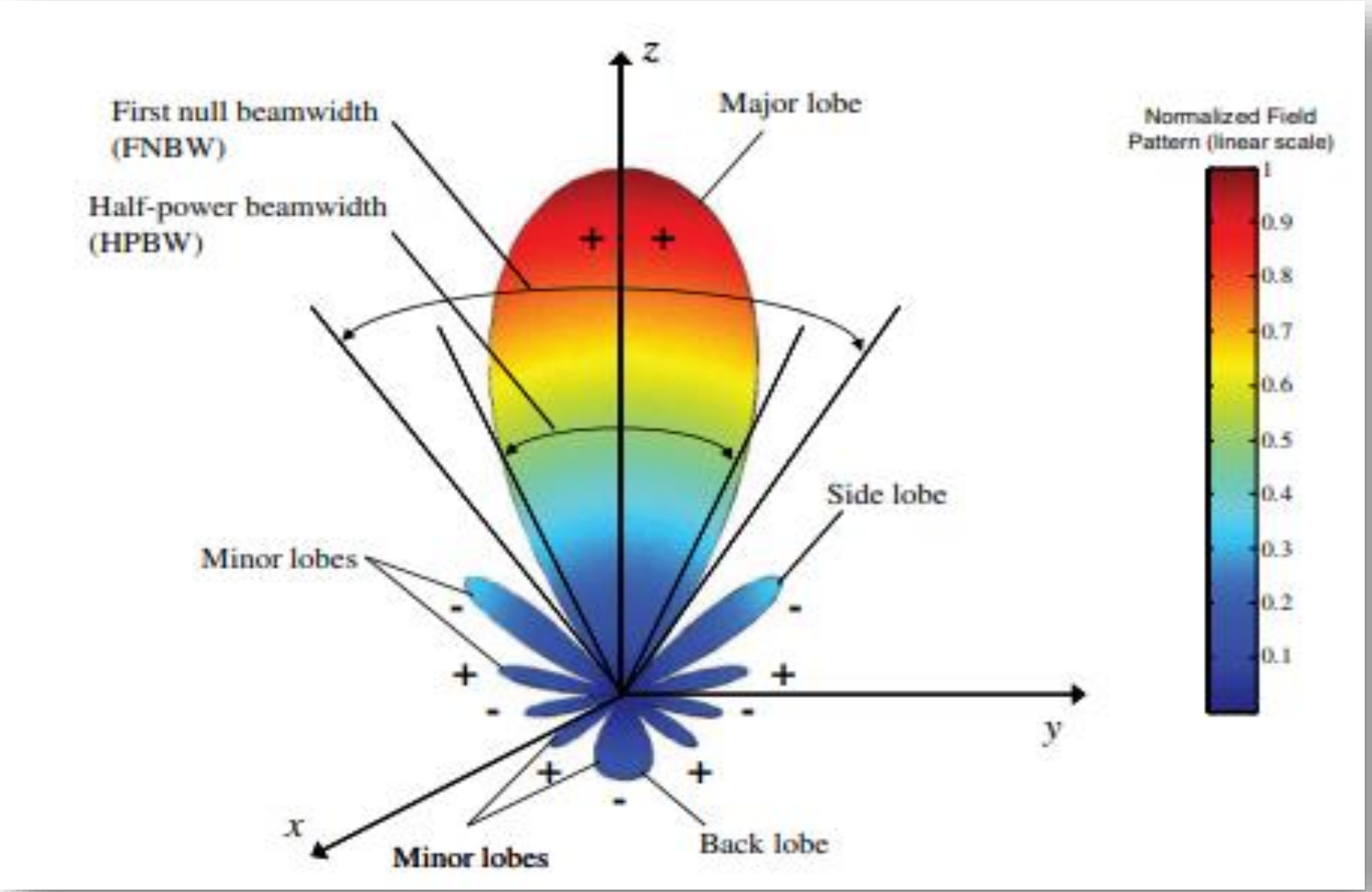
Half Power Beam Width (HPBW):



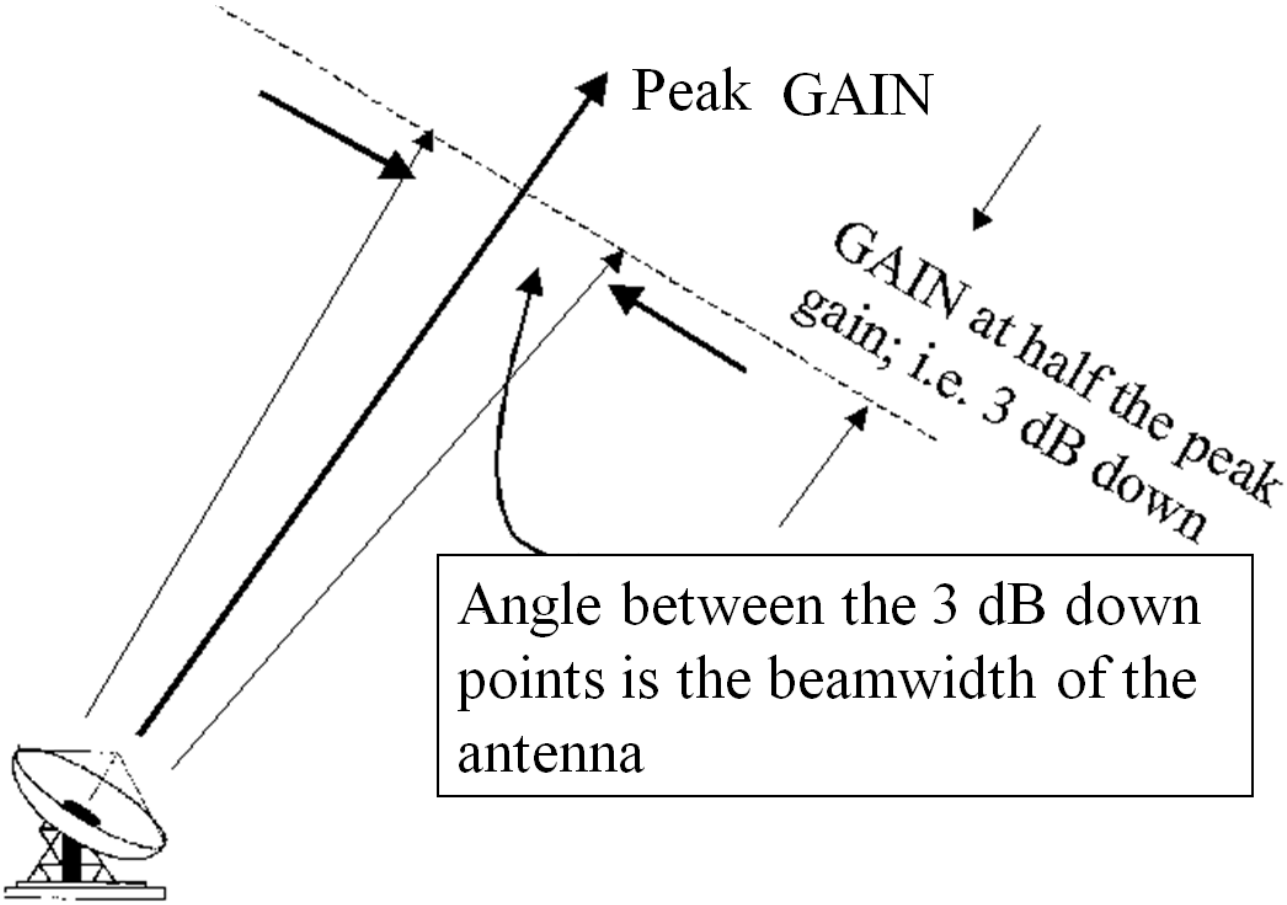
Antenna radiation pattern



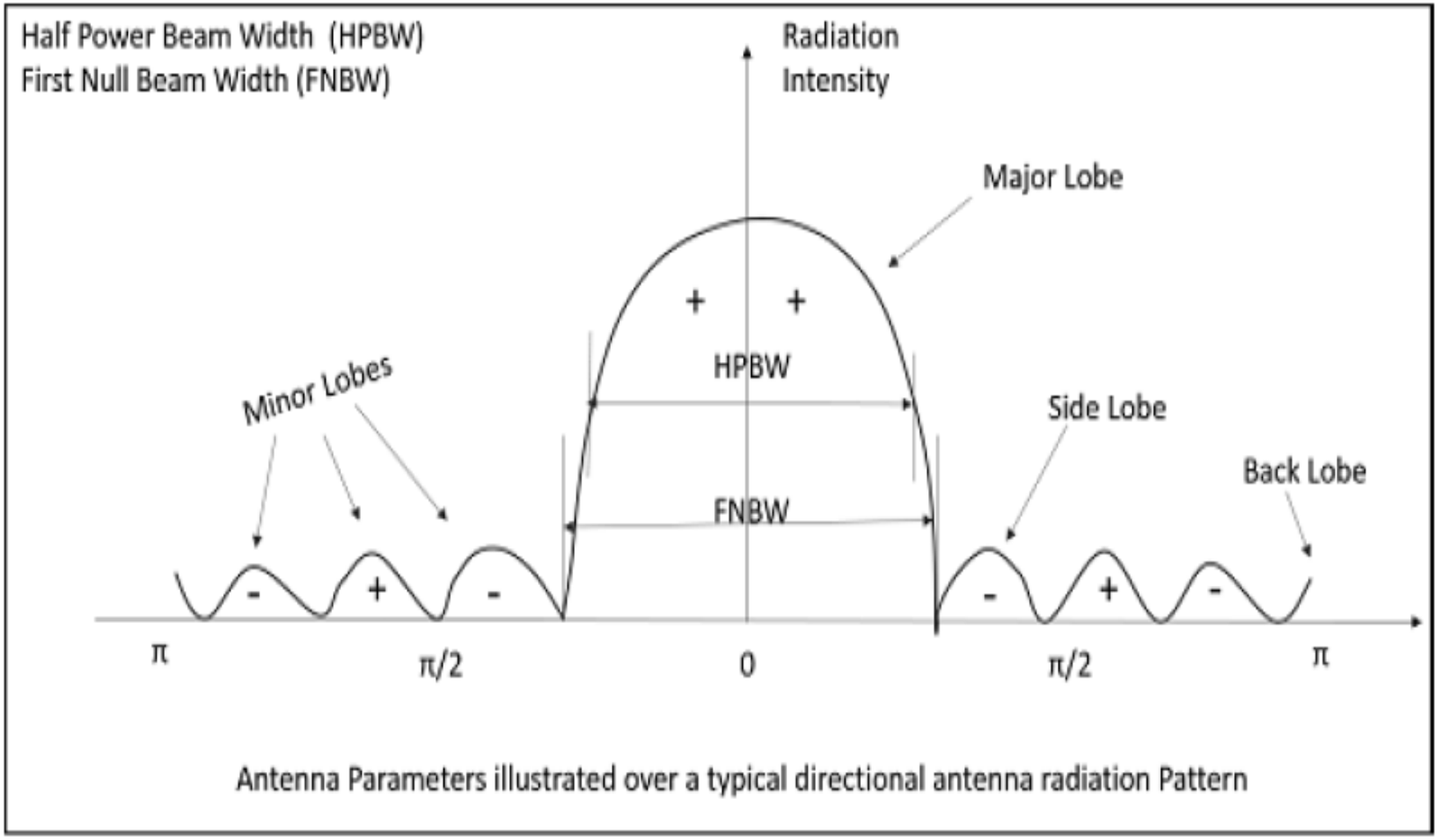
Antenna radiation pattern



Half Power Beam Width (HPBW):

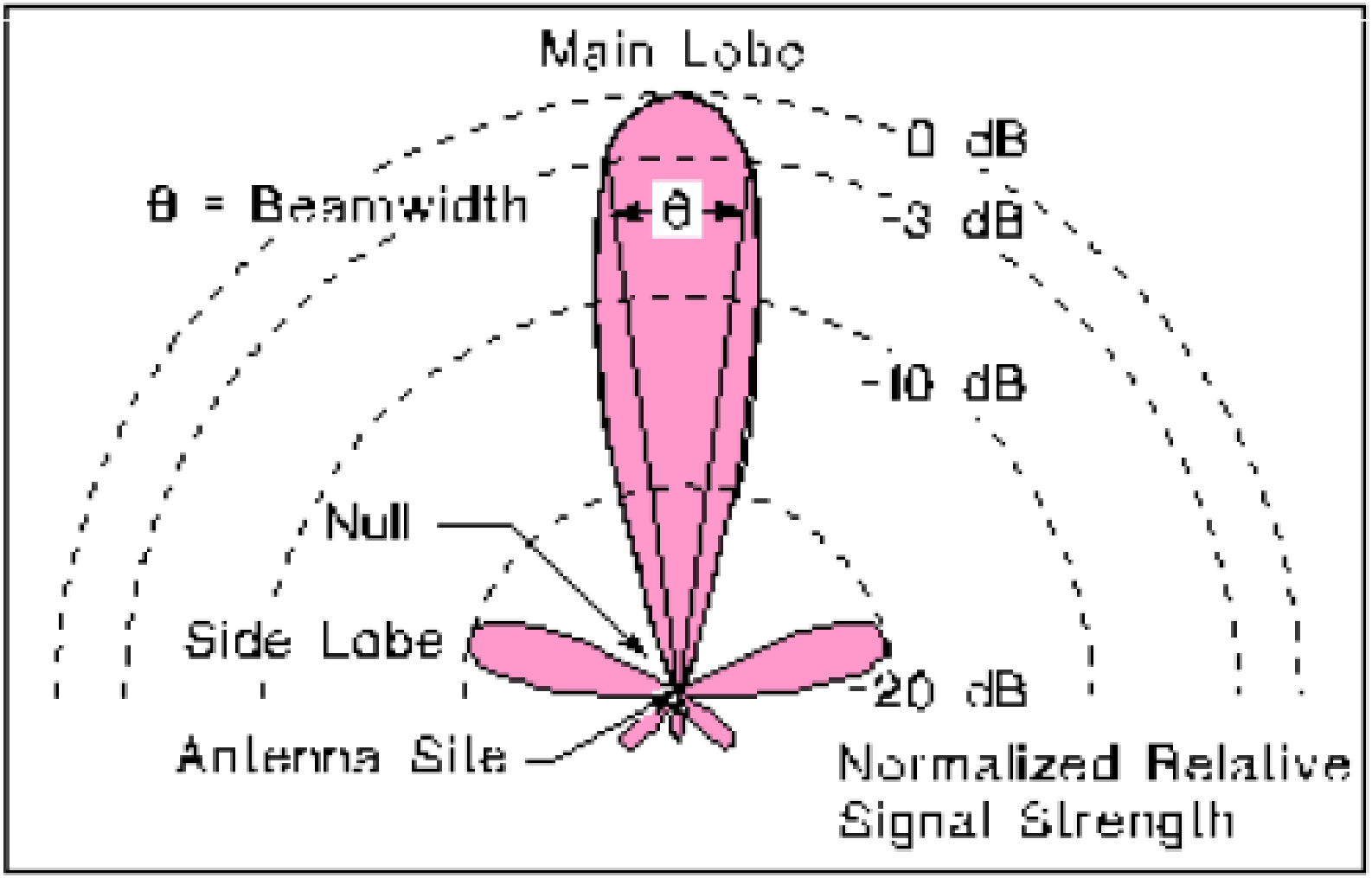


Antenna radiation pattern

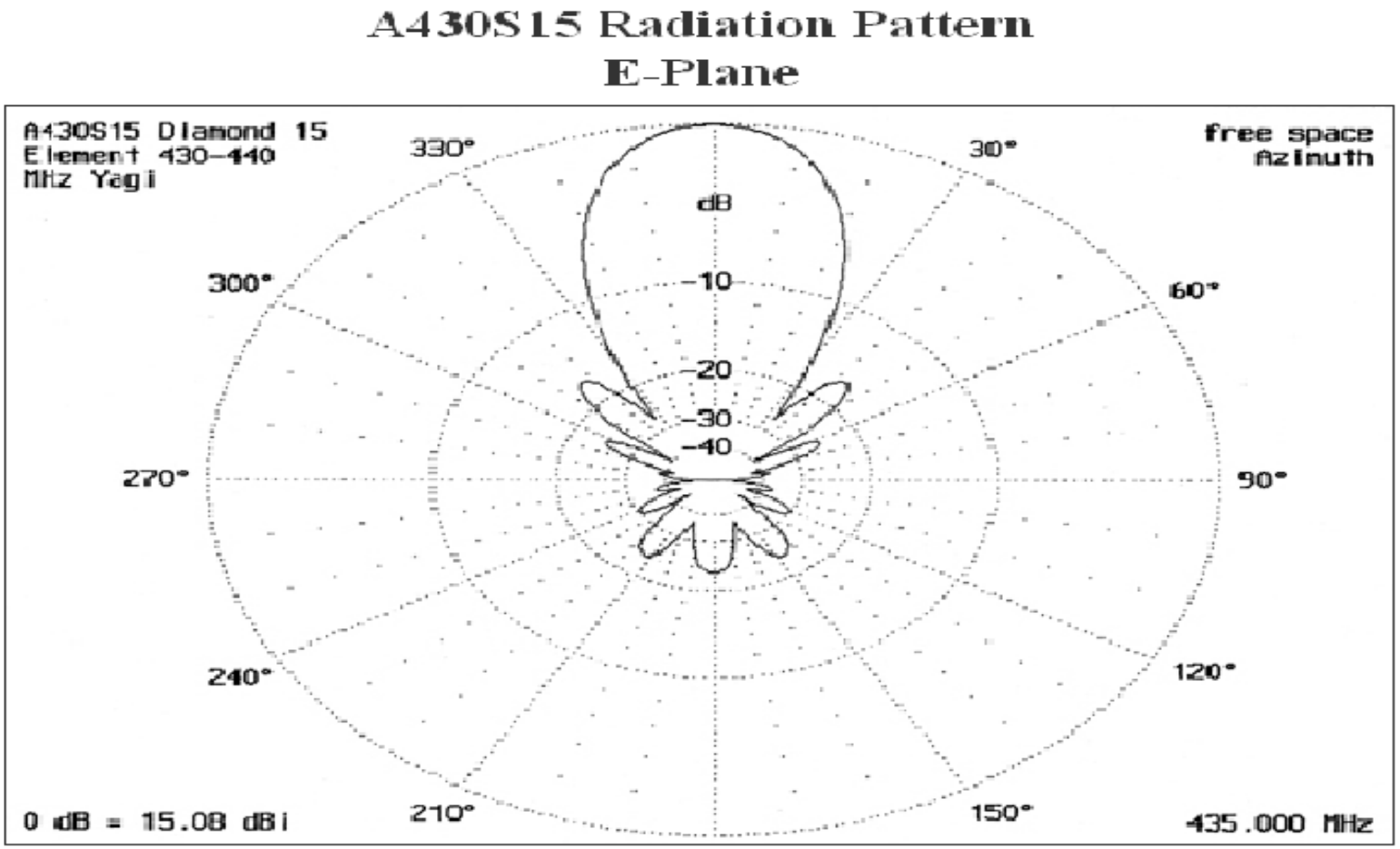


Antenna Parameters illustrated over a typical directional antenna radiation Pattern

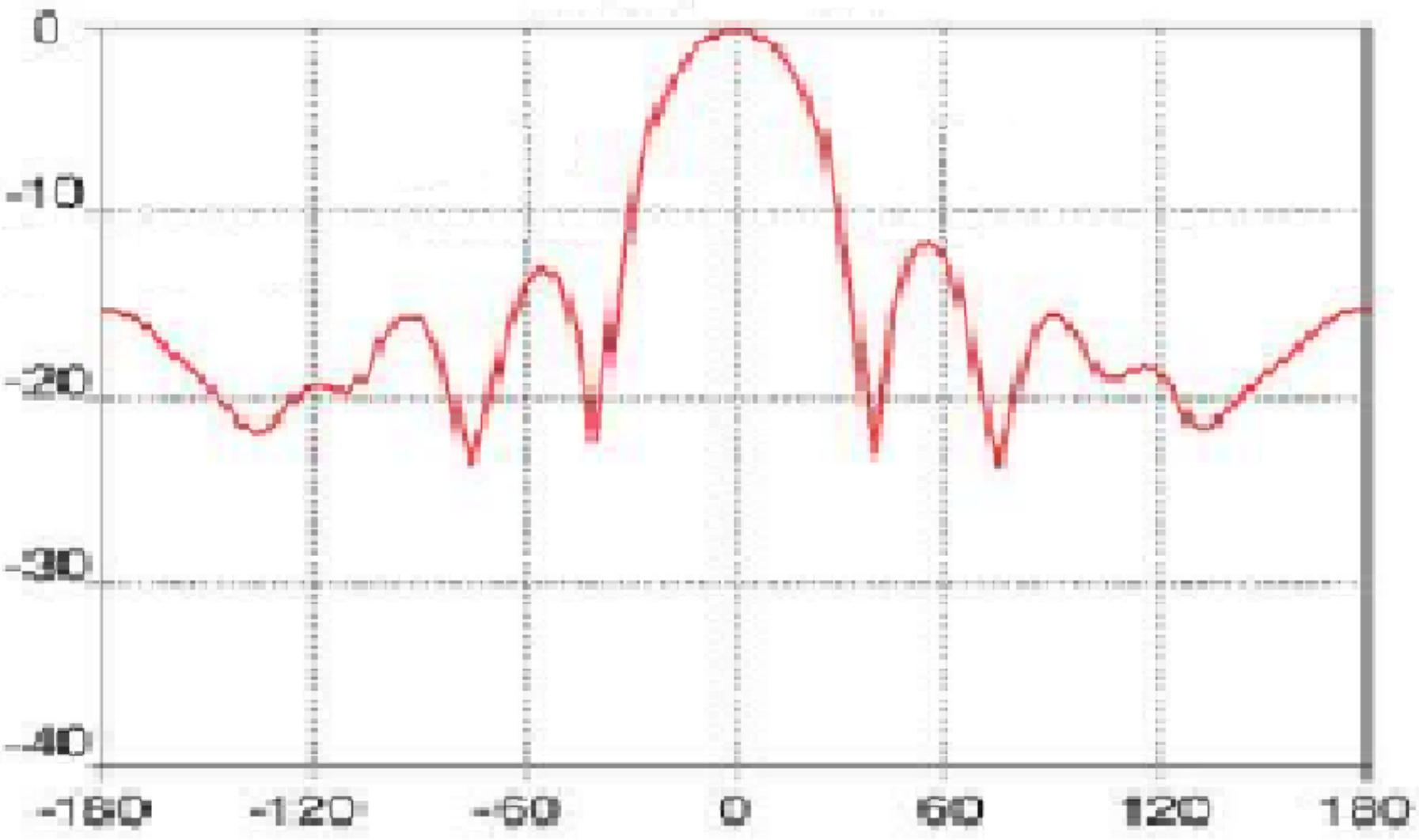
Antenna radiation pattern in polar coordinates



Antenna radiation pattern in polar coordinates



Antenna radiation pattern in Cartesian coordinates



Antenna radiation pattern

First Null Beam Width (FNBW): the angular separation (or span) in degrees between first pattern null points from the main lobe. It is the angle in degrees subtended by the first nulls adjacent to the main lobe.

Second null beam width: it is the angle subtended by second nulls or it is the angular separation from which the magnitude of the radiation pattern decreases to zero away from the main beam.

Antenna radiation pattern

Main lobe level and direction:

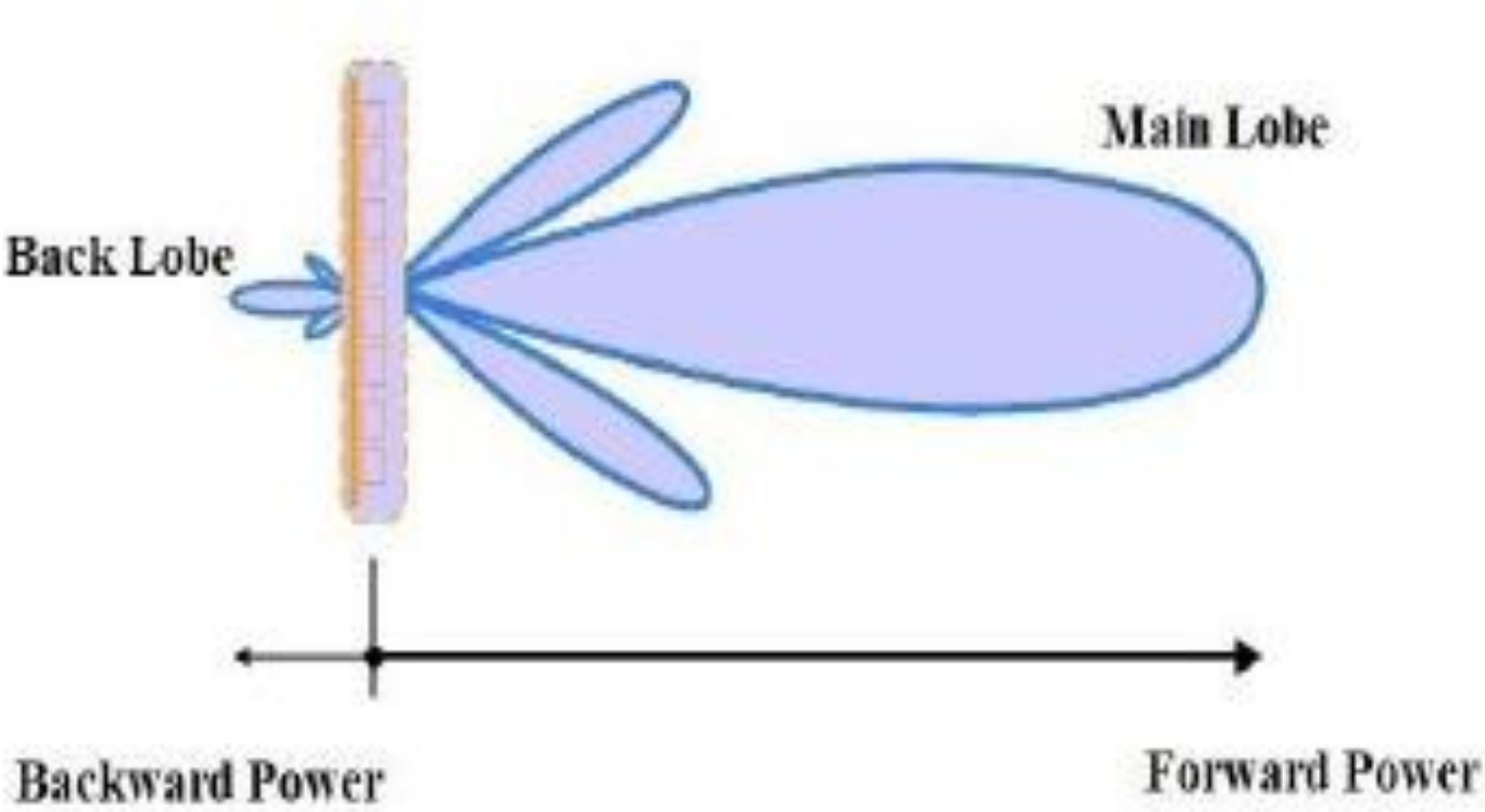
Radiation pattern is a pattern of **"lobes"** at different angles, **directions** where the radiated signal strength reaches a maximum, separated by "**nulls**" angles at which the radiation falls to zero. Directional antenna emits the radio waves in one direction, the lobe in that direction has greater field strength than the others, so on the radiation pattern it appears biggest and is called the “**main lobe”.**

Antenna radiation pattern

Front to back ratio: it is the ratio between the power radiated in the direction of the main lobe and the power in the opposite direction i.e. the power radiated within the other way (180 degrees from the main beam).

This ratio describes the extent of backward radiation and is expressed in dB. This parameter is vital since interference or coverage within the reverse direction must be minimized.

Front to Back Ratio



Antenna radiation pattern

First side lobe level (*SLL*) and directions:

The first side lobe level is the maximum value of the first side lobes away from the main beam.

Second side lobe level (*SLL*) and directions.

The second side lobe level is the maximum value of the second side lobes away from the main beam.

Report

- What is the radiation pattern type?
- What is the type of radiation pattern plot?
- Mark the main components of the radiation pattern.
- Determine the half power beam width (HPBW).
- Determine the first side lobe levels (SLLs)and directions (the angles at both sides).

Report

- Determine the second side lobe levels(SLLs) and direction (the angles at both sides).
- Calculate the first null beam width (FNBW).
- Determine the level and direction of main lobe.
- Determine the types and angles of the nulls on each side.
- Determine the front to back ratio.