Antenna

An antenna is defined by ‘Webster’s Dictionary as “ a metallic device (as a rod or wire) for radiating or receiving radio waves.” The IEEE Standard Definitions of Terms for Antennas defines the antenna or aerial as “ a means for radiating or receiving radio waves.”

In other words the antenna is the transitional structure between free space and a guiding device. The guiding device or transmission line may take the form of a coaxial line or hollow pipe (waveguide) and it is used to transport electromagnetic energy from transmitting source to the antenna or from the antenna to the receiver.

Types of Antenna (Physical Structure)

- ❖ Wire Antennas
- ❖ Aperture Antennas
- ❖ Microstrip Antennas
- ❖ Array Antennas
- ❖ Reflector Antennas
- ❖ Lens Antennas

Dipole

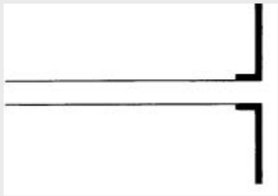

Fig. 1.3(a)

Chapter 1
Antennas

Circular (Square) Loop

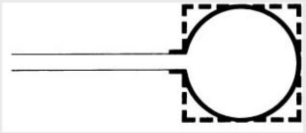

Fig. 1.3(b)

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Helix

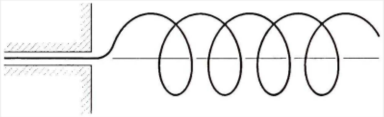

Fig. 1.3(c)

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Pyramidal Horn

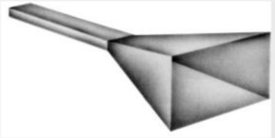

Fig. 1.4(a)

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Conical Horn

Fig. 1.4(b)

Chapter 1
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Rectangular Waveguide

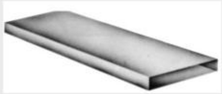

Fig. 1.4(c)

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Rectangular

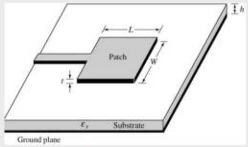

Fig. 1.5(a)

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Circular

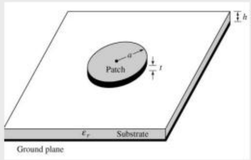

Fig. 1.5(b)

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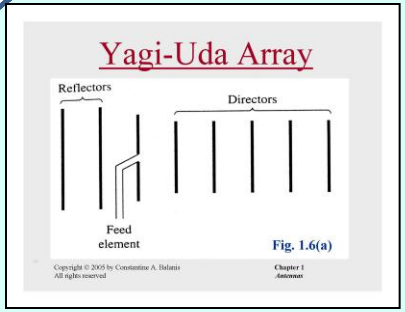
Yagi-Uda Array
Reflectors
Directors
Feed
element
Fig. 1.6(a)
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Chapter 1
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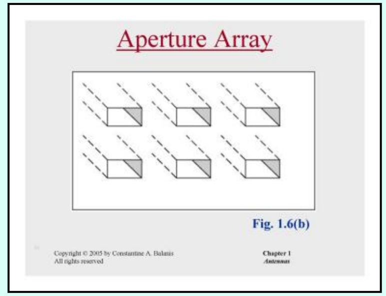
Aperture Array
Fig. 1.6(b)
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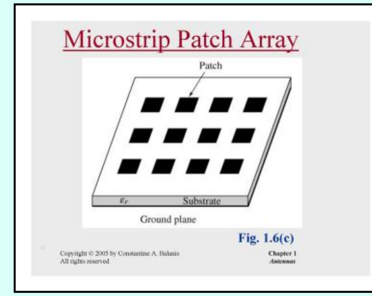
Microstrip Patch Array
Patch
Substrate
Ground plane
Fig. 1.6(c)
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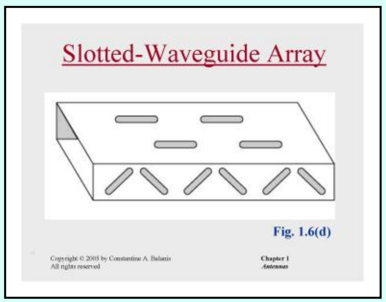
Slotted-Waveguide Array
Fig. 1.6(d)
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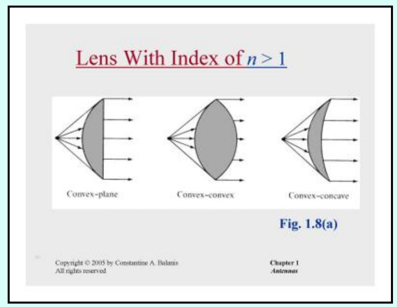
Lens With Index of n > 1
Convex-plane
Convex-convex
Convex-concave
Fig. 1.8(a)
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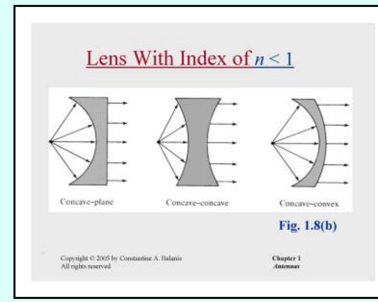
Lens With Index of n < 1
Concave-plane
Concave-concave
Concave-convex
Fig. 1.8(b)
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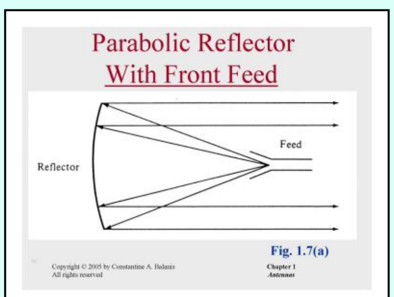
Parabolic Reflector
With Front Feed
Feed
Reflector
Fig. 1.7(a)
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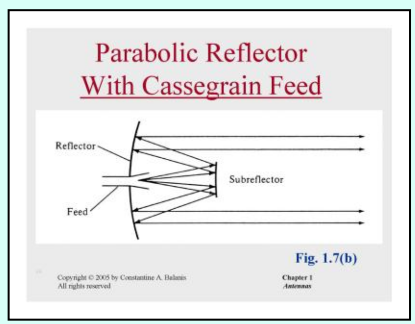
Parabolic Reflector
With Cassegrain Feed
Reflector
Subreflector
Feed
Fig. 1.7(b)
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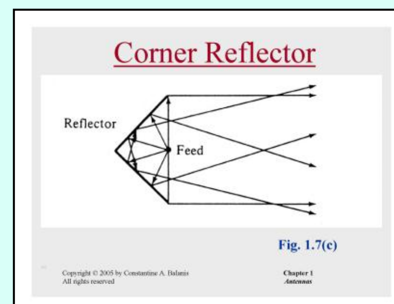
Chapter 1
Antennas


Corner Reflector
Reflector
Feed
Fig. 1.7(c)
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Chapter 1
Antennas

Types of Antenna (Frequencies)

- ❖ **High Frequency Antennas**
  - V, Inverted V, Rhombic, Travelling wave
- ❖ **Medium Frequency Antennas**
  - Tower antenna
- ❖ **VHF/UHF Antennas**
  - Folded Dipole, Yagi-Uda, Ground Plane, Helical
- ❖ **Microwave Antennas**
  - Parabolic Reflector, Horn, Lens
- ❖ **Broadband Antenna**
  - Helical, Log-periodic, Bi-Conical, Slot, Turnstile

Parameters (Properties) of Antenna

- Radiation Pattern
- Radiation Intensity
- Polarization Gain
- Directive Gain or Directivity
- Power Gain
- Efficiency
- Effective Aperture or Area
- Self Impedance and Mutual Impedance
- Radiation Resistance
- Beam Width
- Band Width

Radiation Pattern & Isotropic Radiator

It is a mathematical function or a graphical representation of radiation properties (Amplitude, Phase, Polarization) of the antenna as a function of space coordinates.

It is a graph which shows the variation in actual field strength of electromagnetic field at all points which are equal distance from the antenna.

Types of Pattern

- Omnidirectional or Broadcast type Pattern
- Pencil Beam pattern
- Fan Beam Pattern
- Shaped Beam patter

An Isotropic radiator is a fictitious radiator and is defined as a radiator which radiates uniformly in all directions. It is also called as isotropic source or omnidirectional radiator or simply unipole.

Amplitude Radiation Pattern

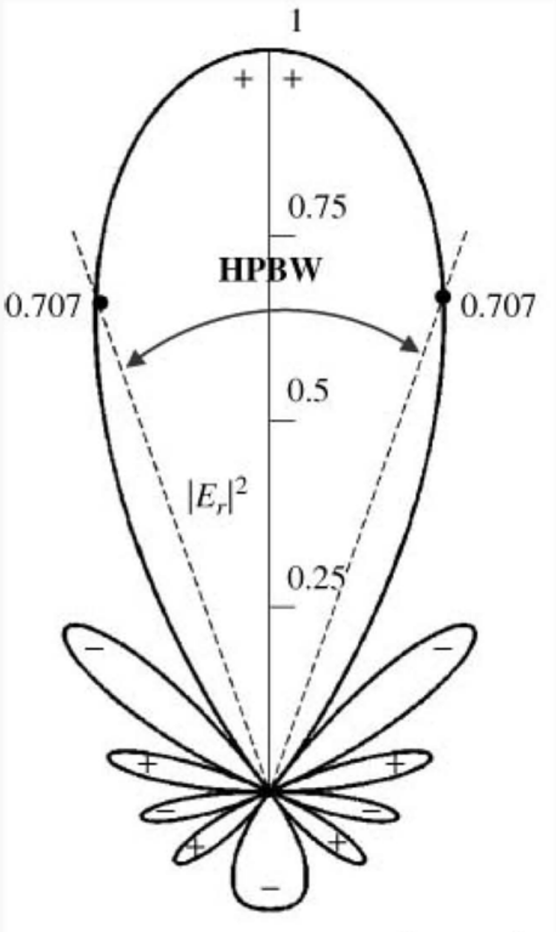
- Field Pattern:

  A plot of the field (either electric $|\underline{E}|$ or magnetic $|\underline{H}|$) on a *linear* scale

- Power Pattern:

  A plot of the power (proportional to either the electric $|\underline{E}|^2$ or magnetic $|\underline{H}|^2$ fields) on a *linear* or *decibel (dB)* scale.

2-D Normalized *Field* $|\underline{E}_n|$ Pattern of a Linear Array



Linear Scale

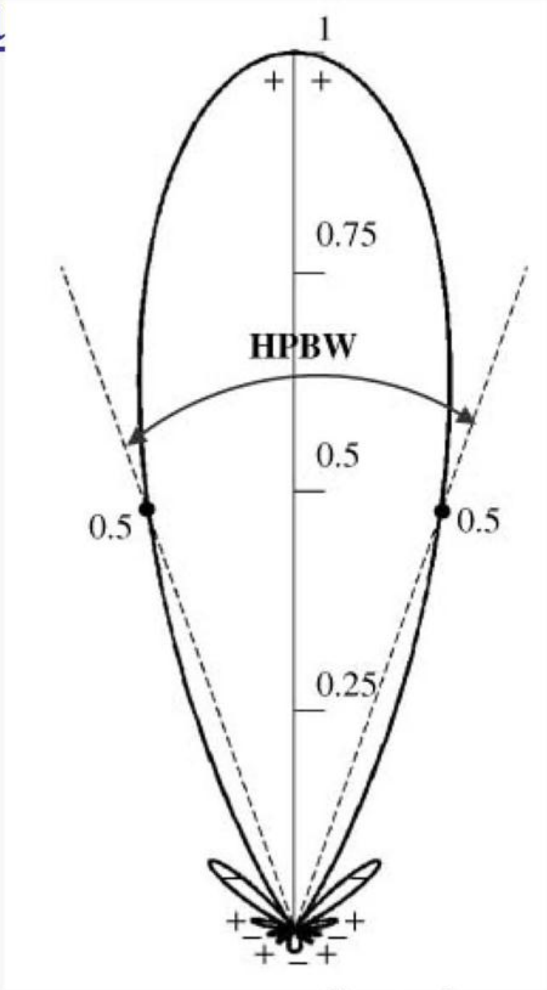
N = 10 elements

$d = \lambda/4$ spacing

HPBW = 38.64°

Fig. 2.2(a)

2-D Normalized *Power* $|\underline{E}_n|^2$ Pattern of a Linear Arra



Linear Scale

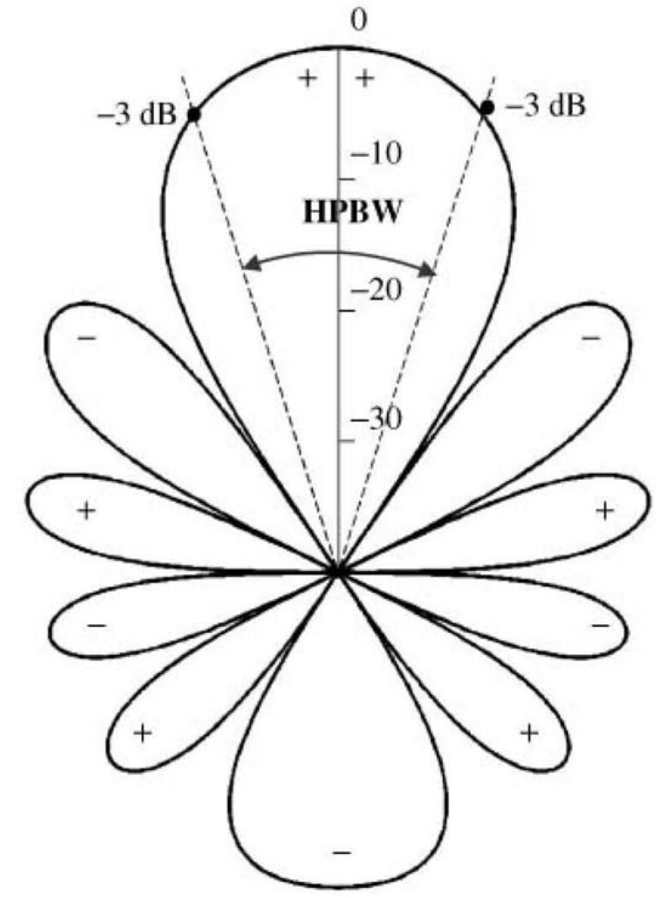
$N = 10$ elements

$d = \lambda/4$ spacing

HPBW = 38.64°

Fig. 2.2(b)

2-D Normalized *Power* $|\underline{E}_n|^2$ Pattern of a Linear Array



dB Scale

N = 10 element

$d = \lambda/4$ spacing

HPBW = 38.64°

Fig. 2.2(c)

Polar Pattern

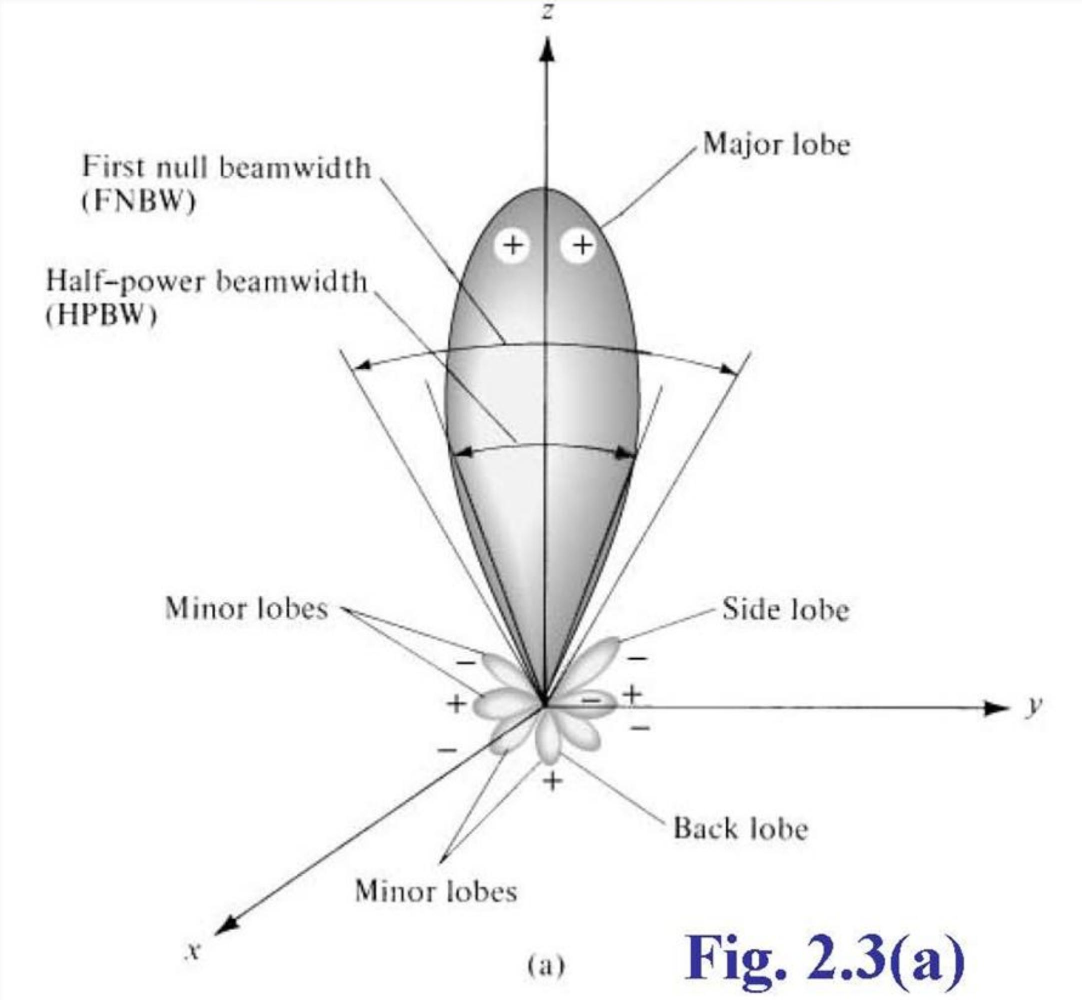
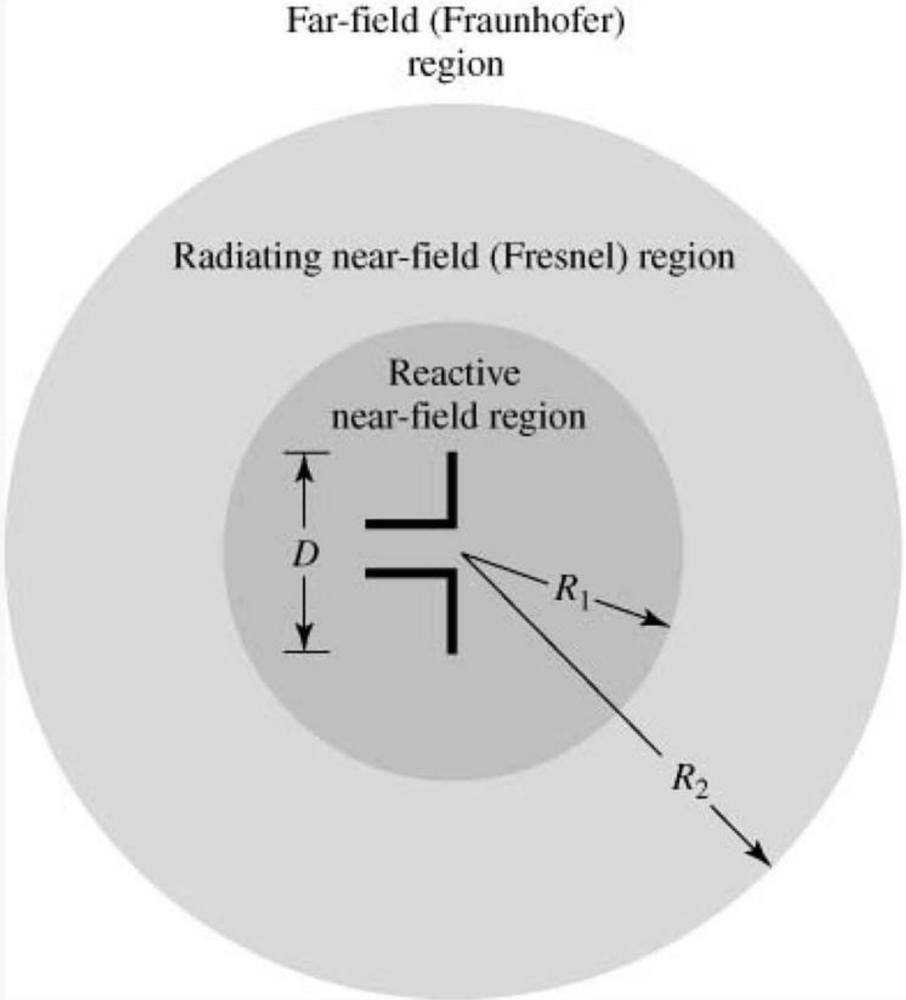


Fig. 2.3(a)

Field Regions



$R_1 = 0.62\sqrt{D^3/\lambda}$

$R_2 = 2D^2/\lambda$

Fig. 2.7

Field Regions

1. Reactive Near-field
2. Radiating Near-field: Fresnel
3. Far-field: Fraunhofer

Parameters of an Antenna

Gain (G) : It is the ratio of Maximum Radiation Intensity from the Test antenna to the Radiation Intensity from Isotropic antenna (Lossless) with same power input.

Directive Gain : It is the ratio of Power density/Intensity Radiated in a particular direction by test antenna to Power density/Intensity Radiated in that particular direction by an isotropic antenna (Average radiated Power)

Power gain and Directive Gain is almost same in VHF and UHF. And this can be called the antenna Gain.

Directivity : The maximum directive gain is called as directivity of an antenna and is denoted by D. In particular direction D is constant.

That is directivity is the ratio of maximum radiation Intensity from a Test/Subject antenna to Radiation Intensity of an Isotropic antenna.

Parameters of an Antenna (Continue)

Antenna Efficiency :

The efficiency of an antenna is defined as the ratio of power radiated to the total input power supplied to the antenna and is denoted by η.

Effective area/Effective aperture or Capture area :

It is the ratio of power received at the antenna load terminal to the pointing vector (or Power density) in Watts/m^2 of the incident wave.

Effective Length :

The term "effective length" of an antenna represents the effectiveness of an antenna as radiator or collector of electromagnetic wave energy. In other words, effective length indicates how for an antenna is effective in transmitting or receiving the electromagnetic wave energy.

Effective Length (l_e) = Open circuited voltage (V)/Incident field strength (E)

Beam width of Antenna

Half Power Beam Width (HPBW) of antenna

The main beam is the angular region where primarily the radiation goes. The effective width of the antenna main beam called the HPBW is defined as the angular separation between directions where the field reduces to $1/\sqrt{2}$ of its maximum value. Since the power density of a wave is proportional to the square of the electric field, when the electric field reduces to $1/\sqrt{2}$ of its maximum value, the power density reduces to 1/2 of its maximum value. That is, the power density reduces by 3-dB. The HPBW therefore is also referred to as the 3-dB Beam width. There two HPBWs, one for the E-plane pattern and other for the H-plane pattern. For the Hertz dipole, the E-plane HPBW is 900 and the H-plane HPBW is not defined since the radiation pattern is constant in the H-plane.

The HPBW is a better measure of the effective width of the main beam of the antenna compared to BWFN because there are situations when the effective width of the antenna beam changes but the BWFN remains same.

Band width of an Antenna

The bandwidth of an antenna refers to the range of frequencies over which the antenna can operate correctly. The antenna's bandwidth is the number of Hz for which the antenna will exhibit an SWR less than 2:1. The bandwidth can also be described in terms of percentage of the center frequency of the band.

$$BW = 100 \times (FH - FL) / FC$$

where, FH is the highest frequency in the band, FL is the lowest frequency in the band, and FC is the center frequency in the band. In this way, bandwidth is constant relative to frequency. If bandwidth was expressed in absolute units of frequency, it would be different depending upon the center frequency. Different types of antennas have different bandwidth limitations.

Radiation Resistance of Antenna

In general, an antenna radiates power into free space in the form of electromagnetic waves. So the power dissipated is given by, Assuming all the power dissipated in the form of electromagnetic waves, then we can write,

The resistance which relates power radiated by radiating antenna and the current flowing through the antenna is a fictitious resistance. Such resistance is called radiation resistance of antenna and it is denoted by

R_{rad} or R_r, or R_o.

Note: The radiation resistance is a fictitious resistance such that when it is connected in series with antenna dissipates same power as the antenna actually radiates. But practically the energy supplied to the antenna is not completely radiated in the form of electromagnetic waves, but there are certain radiation losses due to the loss resistance denoted by $R_{loss.}$. Thus the total power is given by,

$W = W' + W'' =$ Ohmic loss + Radiation loss

$W = I^2 R_{rad} + I^2 R_{loss}$

$\mathbf{W = I2(R_{rad} + R_{loss})}$

Note: The radiation resistance of antenna depends on antenna configuration, ratio of length and diameter of conductor used, location of the antenna with respect to ground and other objects.