Propagation and Antenna
Chapter 1.3 - 2.1

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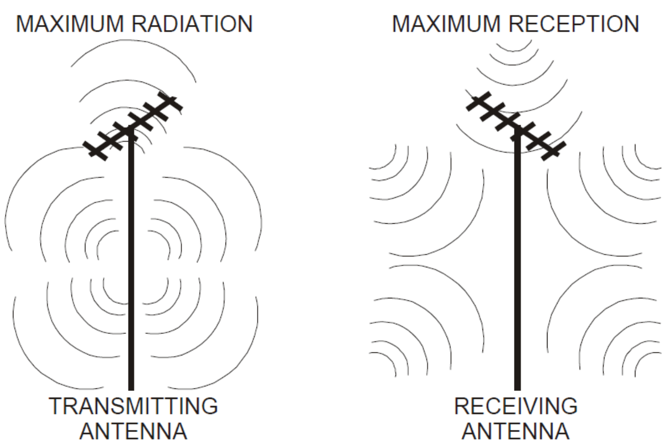
1.3 Antenna Theorems

I. Reciprocity Theorem
II. Superposition Theorem
III. Thevenin Theorem
IV. Maximum Power Transfer Theorem
V. Compensation Theorem
VI. Equality of Directional Patterns
VII. Equivalence of Receiving and Transmitting Impedances

1.3 Antenna Theorems

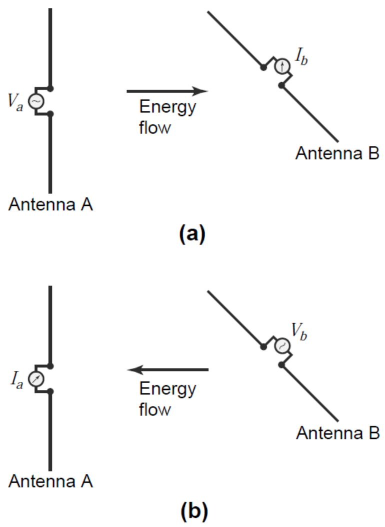
Reciprocity Theorem



Antenna Reciprocity Theorem

- Mostly an Antenna Performs Transmission as well as Reception
- Same Antenna can be Used for both Functions
- $V_a = V_b$ and $I_a = I_b$

Antenna Reciprocity Theorem



Superposition Theorems

- Applicable to only Linear Networks
- Current is Linearly Related to Voltage
- That is as per Ohm's Law
- Current flowing at any Point is Sum of the Currents that would flow if each Generator were Considered Separately
- All other Generators being Replaced at the time by Impedance Equal to their int. Impedances

Superposition Theorems…

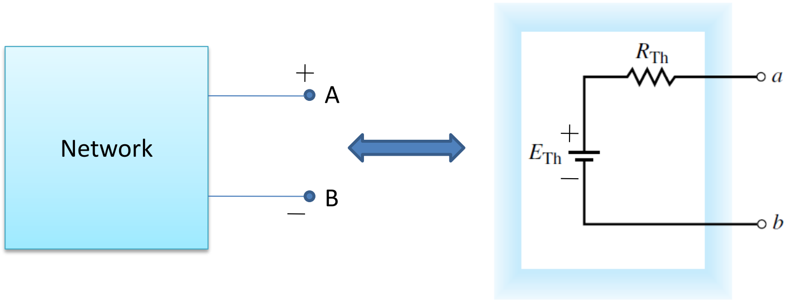
- Field Intensity at a Point due to a number of T_X Antennas Equals the Vector sum of the Field Intensities due to each of Antennas
- One side a R_X antenna and Other side no. of T_X antennas
- Conditions:
  - Use same type of Antennas
  - Same Frequency Bands
  - Directional Antennas
  - R_X Antenna is within the Far Field Regions of T_X Antennas

Thevenin Theorem

- Terminal Voltage A and B (of Generator) can be Replaced by a Single Voltage Source, V_{TH} in Series with a Single Resistance R_{TH}.
- T_X and R_X antennas systems are Equivalent to Generator and Load Equivalent
- So that Thevenin Theorem can be Applied in Both Cases

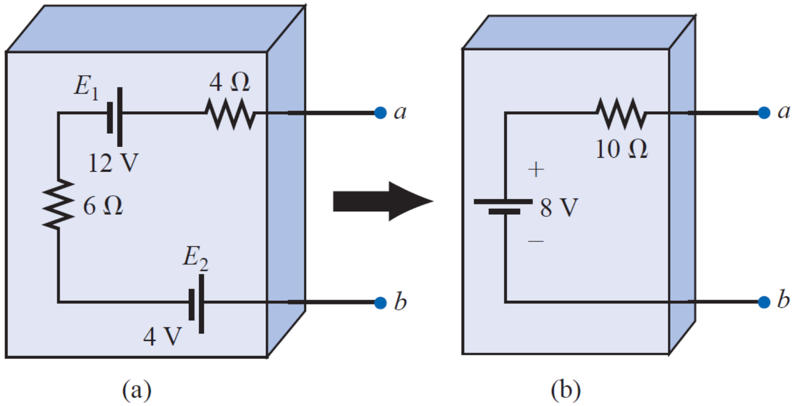
Thevenin Theorem

- Any linear Bilateral Network may be Reduced to a Simplified Two-terminal Circuit consisting of a Single Voltage Source in Series with a Single Resistor as shown in Figure below:



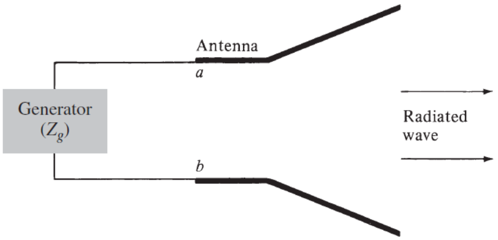
Thévenin Equivalent Circuit

Thevenin Theorem

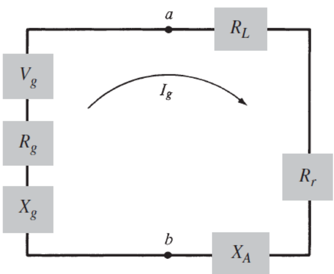


The Effect of Applying Thévenin's Theorem

Antenna Thevenin Theorem



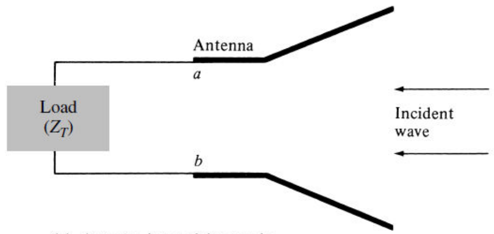
(a) Antenna in transmitting mode



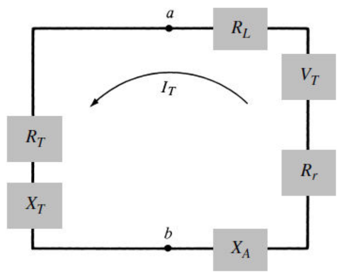
(b) Thevenin equivalent

Thevenin Theorem for Transmitting Antenna

Antenna Thevenin Theorem…



(a) Antenna in receiving mode



(b) Thevenin equivalent

Thevenin Theorem for Receiving Antenna

Maximum Power Transfer Theorem

- Maximum Power Transfer can be Possible.
- Maximum Power can be Transferred when

$$\mathbf{Z_g = Z_0 = Z_a}$$

Where,
Z_g = Generator Impedance, Z_0 =Characteristic Impedance of T_X line and Z_a =Antenna I/p Impedance

- An Impedance Connected to Two Terminals of a Network will Absorb Maximum Power from the Netwok when the Impedance is Equal to the Conjugate of the Impedance
- I.e. seen Looking back into the Network from the Two Terminals

Maximum Power Transfer Theorem

- The Max. Power can be Absorbed from a Network equals

$$V^2_{oc}/4R,$$

Where,

V_{oc} is the Open Circuit Voltage at the Output Terminals and

R is the Resistive Component of the Impedance Looking back from the Output Terminals

Maximum Power Transfer Theorem

- It Determines the Value of the Load Impedances which Result in Max. Power Transfer across the Terminals of an Active circuit (Network)
- For Max. Power Transfer, the Load Impedance must be Equal to Complex Conjugate of Source Impedance

i.e. $Z_L=Z_S$

$R_L+jx_L= R_S+jx_S$

$R_L= R_S$

$x_L= - x_S$

Compensation Theorem

Compensation or Substitution Theorem:

- Any Impedance in a Network may be Replaced by a Generator with zero Internal Impedance,
- Whose Generated Voltage at Every Instant Equals Instantaneous Potential Difference and
- That Existed across the Impedance because of Current Flowing through it.

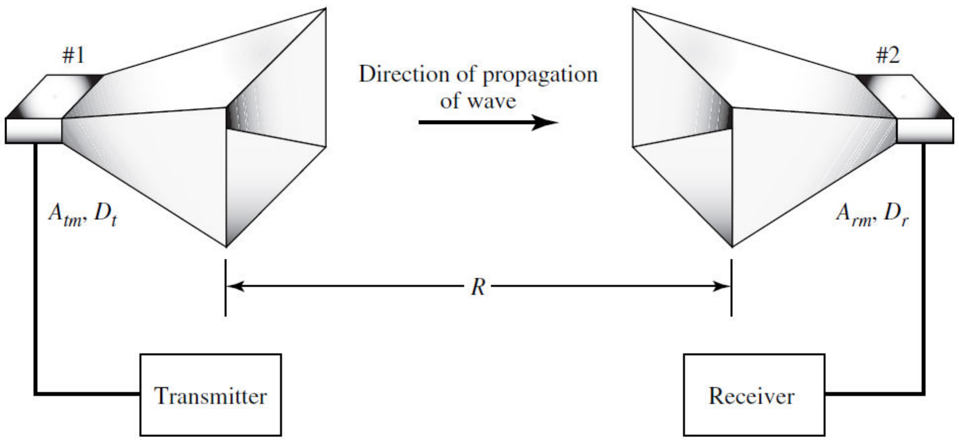
Compensation Theorem…

- The Network Impedance, Z may be Replaced by a Compensating Voltage
- Where the Magnitude and Phase of the Source are equal to I Z.
- Note that Currents and Voltages in all other parts of the Network remains Unchanged after Substituting the Compensation Source
- So that this Theorem is also Known as the <u>Substitution Theorem</u>

Equality of Directional Patterns

- The Directional Pattern of a Receiving Antenna is Identical with its Directional Pattern as a Transmitting Antenna
- Radiation Patterns are similar in Both cases of Transmitting and Receiving Antennas
- This method is used for Designing Antennas
- It is very Effective for Measurement of Antenna Parameters

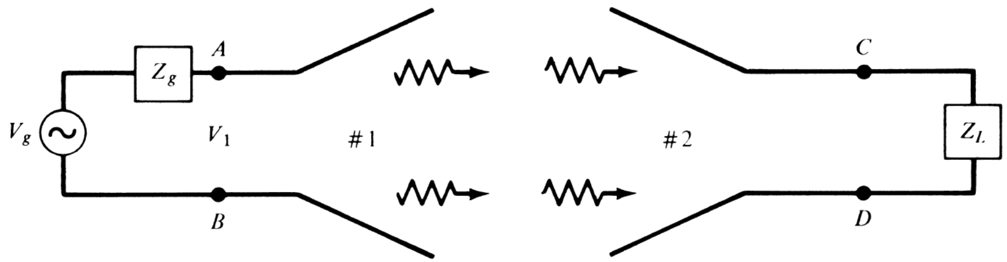
Equality of Directional Patterns



Two (Tx & Rx) Antennas Separated by a Distance *R*

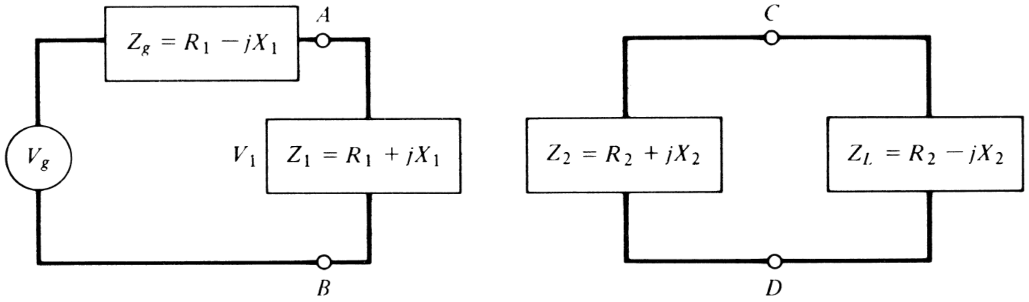
Equivalence of Receiving & Transmitting Impedances

- The Impedance of an Isolated Antenna when use for Receiving is the Same as when used for Transmitting



Transmitting and receiving antenna systems

Equivalence of Receiving & Transmitting Impedances



Two-antenna system with conjugate loads

Chap. 2.0 Basic Antenna Parameters

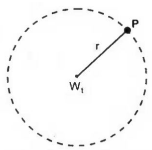
1. Isotropic Radiation
2. Effective Isotropic Radiated Power (EIRP)
3. Power Flux Density (Radiation Power Density)
4. Antenna Gain
5. Antenna Efficiency
6. Receiving Power Intensity
7. Antenna Aperture
8. Free Space Loss
9. Antenna Noise Temperature
10. Receiving Noise Power
11. Carrier-to-Noise Ratio
12. Carrier-to-Noise Density
13. Figure of Merit (G/T)
14. Bandwidths
15. Beamwidths
16. Beam Efficiency
17. Radiation Patterns
18. Directional & Omnidirectional Patterns
19. Radiation Patterns Lobes
20. Radiation Intensity
21. Input Impedance
22. Polarization

17. Front-to-Back Ratio
18. Directivity
19. Antenna Impedance
20 Radiation Resistance
21. Effective Length/Height
22. Gain-to- Noise Ratio
23. Insertion loss
24. Transmission Coefficient t(S)
25. Reflection Coefficient ρ(S)
26. Numerical Efficiency
27. Friis Transmission Equation
28 Radiation Patterns
29. Beam Area (or Beam Solid Angle) Ω_A
30 Signal-to-Noise Ratio (SNR)
31. Antenna Reciprocity
32. Voltage standing wave ratio (vswr)
33. Antenna Factor (AF)

Basic Antenna Parameters (Cont..)

1. Isotropic Radiation

- Imaginary/Fictitious Radiation Pattern
- Radiation Uniformly in all Directions
- And Equally also all Directions
- Hypothetical Lossless Radiator
- Beam Angle Area (Ω_A) = 4π
- Ideal Source Power, $P = P_t/4\pi r^2$



An Isotropic Antenna

Basic Antenna Parameters (Cont..)

2. Effective Isotropic Radiated Power (EIRP)

- Equivalent Isotropically Radiated Power
- $EIRP = P_tG_t/L_{wg}$ (w) - - - - - - - (1)

  Where,

  P_t is Transmitting Power

  G_t Transmitting Antenna Gain

  L_{wg} is Waveguide (Cable) Loss
- $[EIRP] = [P_t] + [G_t] – [L_{wg}]$ (dBw) - - - - (2)
- It is always Measured in T_X terminal

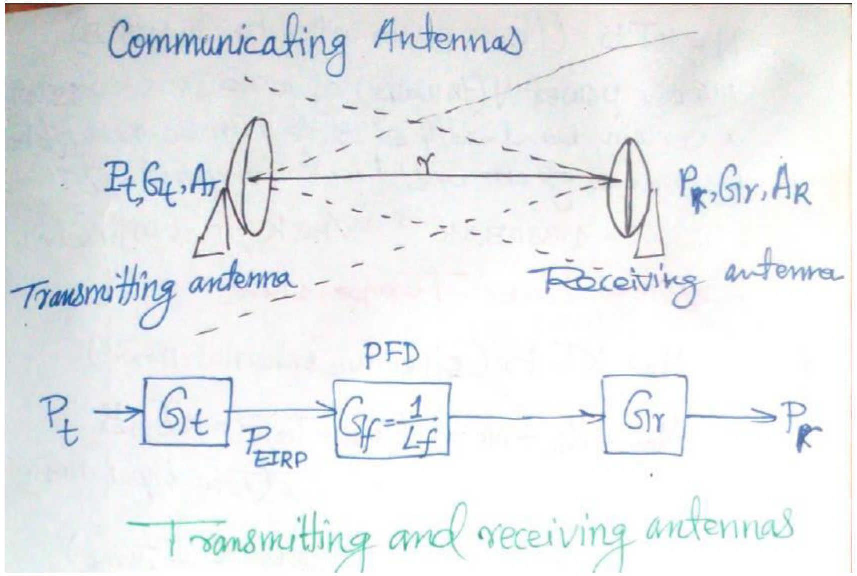
Basic Antenna Parameters (Cont..)

3. Power Flux Density (Radiation Power Density)

- Short Term PFD = EIRP/$4\pi R^2$ (w/m^2) - - - - - - - - - - - (3)
- $[PFD] = [P_t] + [G_t] - [L_{wg}] - [4\pi R^2]$ (dBw/m^2) - - - - - (4)

  Where,

  R is Distance Between T_X and R_X
- PFD is Equal to EIRP Reduced by 4π times Sqr. of R
- It is always Measured in Transmission Side
- It is Function of Radiation of T_X antenna
- So that it is also called Radiation Power Density (RPD)



$$P_r = A_r PFD = \frac{P_t G_t A_e}{4\pi r^2} \quad \text{(Friis formula)}.$$

or,

$$P_r = \frac{P_t A_t A_r}{\lambda^2 r^2} \quad \text{where } G_t = 4\pi A_t/\lambda^2$$

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi r)^2}, \quad \text{where } A_r = \lambda^2 G_r/4\pi$$

$$L_f = \left(\frac{4\pi r}{\lambda}\right)^2, \quad G_f = \frac{1}{L_f} = \left(\frac{\lambda}{4\pi r}\right)^2$$

free space loss and gain

$$[P_r] = [P_t] + [G_t] - [L_f] + [G_r] - [L_{wg}]$$

Basic Antenna Parameters (Cont..)

4. Antenna Gain (G)

- This Antenna Gain is Used for only Aperture Antennas
- Antenna Gain can be for both T_X and T_R antennas
- Only it will be changed λ
- But, usually G is called Receiving Gain
- Here, it will be noted G_r for Receiving Gain
- And, G_t for Transmitting Gain

Basic Antenna Parameters (Cont..)

Antenna Gain (G) ….

- Transmitting and Receiving Antenna Gains
- $G_r = (4\pi/\lambda^2) * A_{eff}$ - - - - - - - - - - - - (5)

  $= (4\pi/\lambda^2) * \eta * (\pi D^2/4)$

  $= \eta\ (\pi D/\lambda)^2$ - - - - - - - - - - - - - - (6)

Where,

$4\pi/\lambda^2$ is Universal Constant

η is Antenna Efficiency which equals

$\eta = G\ (\lambda/\pi D)^2$

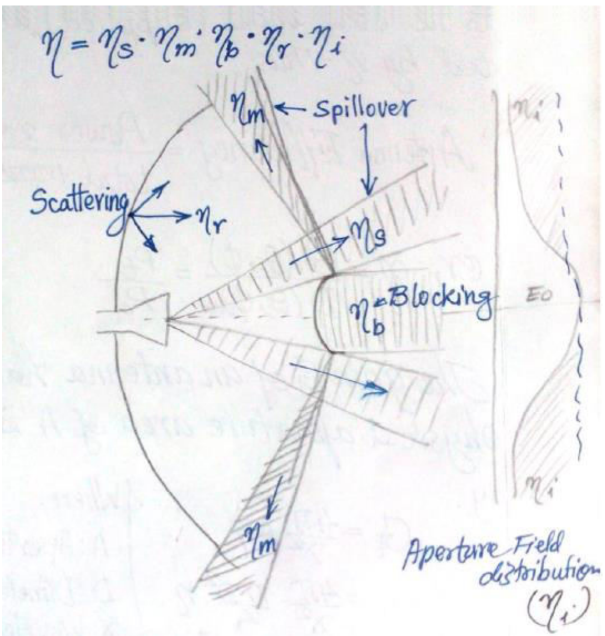
Basic Antenna Parameters (Cont..)

5. Antenna Efficiency, η

- It is Defined as the Ratio of Power Radiated to the Total Power (Supplied) in T_X
- It is Defined as the Ratio of Power Received to the Exposed Total signal Power (EMWs) in R_X
- It is Used to relate the Effective Area and Physical Area
- Similarly, for Relating the Gain and Directivity

$$\eta = G\ (\theta, \phi) / D\ (\theta, \phi) = P_t/P_0$$

Concept of Efficiencies



Basic Antenna Parameters (Cont..)

Antenna Efficiency, η ….

$$\eta = G\ (\lambda/\pi D)^2$$

Because,

$$G = \eta\ (\pi D/\lambda)^2$$

- All Signals exposed on the Antenna could not be totally Recovered due to Antenna Efficiency
- The total Efficiency, η_0 is the Product of Various types of Efficiencies
- Efficiency is Unit less or Dimensionless

Basic Antenna Parameters (Cont..)

Antenna Efficiency, η ….

- In general, the overall efficiency can be written as

$\eta_0 = \eta_r \, x \, \eta_c \, x \, \eta_d \, x \, \eta_{Sp} \, x \, \eta_{Sm} \, x \, \eta_b \, x \, \eta_{sc} x \, \eta_i$ - - - *(7)*

Where

η_0 is Total Efficiency

η_r is Reflection(Mismatch) Efficiency = $(1 - |\Gamma|^2)$

η_c is Conduction Efficiency

η_d is Dielectric Efficiency

Basic Antenna Parameters (Cont..)

Antenna Efficiency, η ….

Wherer,

η_0 is Total Efficiency

η_{SP} is Spillover Efficiency from Primary Reflector

η_{sm} is Spillover Efficiency from Main Reflector

η_b is Blockage Efficiency

η_{sc} is Scattering Efficiency

η_i is Illumination Efficiency

Basic Antenna Parameters (Cont..)

Antenna Efficiency, η ….

The *Reflection(Mismatch) Efficiency* , $\eta_r = (1 - |\Gamma|^2)$

Where,

Γ is Voltage Reflection Coefficient at the input Terminals of the Antenna

[$\Gamma = (Z_{in} - Z_0)/(Z_{in} + Z_0)$ where Z_{in} = Antenna input Impedance,

- *Z_0 = Characteristic Impedance of the Transmission Line]*
- Voltage Standing Wave Ratio (VSWR)

VSWR = $(1 + |\Gamma|)/(1 - |\Gamma|)$ - - - - *(8)*

Basic Antenna Parameters (Cont..)

6. Receiving Power Intensity

- Received Power(Pr)
- $P_r = PFD * A_{eff}$ - - - - - - - - - - - - - - - - -(9)

$= [P_t G_t /(L_{wg} * 4\pi R^2)] * \eta * A_{phy}$

$= [P_t G_t /(L_{wg} * 4\pi R^2)] * G_r (\lambda/\pi D)^2 * (\pi D^2/4)$ - - (10)

$= P_t G_t G_r * (\lambda /4\pi R)^2$ - - - - - - - - - - (11)

$P_r/P_t = G_t G_r * (\lambda /4\pi R)^2$ - - - - - - - - - - - - (12)

- Eqn. (11) & (12) are called **Friis Transmission Equation**

Basic Antenna Parameters (Cont..)

Receiving Power Intensity ….

- The Eqn. (11) becomes in dBW

  $[P_r] = [P_t] + [G_t] + [G_r] - [L_{free}]$ - - - - - -(13)

Friis Transmission Equation in Db

The free space loss (L_{free}) = $(4\pi R/\lambda)^2$ - - - - - (14)

Basic Antenna Parameters (Cont..)

7. Antenna Aperture

- Antenna Aperture Area can be Effective or Physical
- Effective Area (A_{eff}) is always η times smaller than Physical Area (A_{phy})
- Then,

  $A_{eff} = \eta A_{phy}$
- Similarly, It is Applied for both in antenna Length as well
- Then, $L_{eff} = \eta L_{phy}$

Basic Antenna Parameters (Cont..)

8. Free Space Loss

$L_{free} = (4\pi R/\lambda)^2$ - - - - - - (14)

- Loss due to signal Spreading over Distance
- Loss is Directly Proportional to Frequency
- And Inversely Proportional to Square of the Frequency
- Free Space Loss in dB

  $[L_{free}] = 10 \log (4\pi R/\lambda)^2$

  $= 20 \log (4\pi R/\lambda)$

  $= 20 \log (4\pi) + 20 \log (R/\lambda)$

  $= 22 + 20 \log (R/\lambda)$ (dB) - - - - - (15)

Basic Antenna Parameters (Cont..)

9. Antenna Noise Temperature, T_0

- It is included with System Noise Temperature

  $T_0 = kT_SB$

  Where,

  k = Boltzmann's Constant=1.381×10^{-23} (J/K)

  T_S = System Noise Temperature

  B = Bandwidth of the Frequency being used
- Antenna Noise Temperature is in always in R_X side

Basic Antenna Parameters (Cont..)

10. Receiving Noise Power, P_n

- It is always Measured in Receiving side
- It is Counted in $C/N = P_r/P_n$
- The Receiving Noise Power, $P_n = kT_SB$
- Receiving Noise Power is Antenna Noise Temp.
- $P_n = kT_SB$

Where,

k = Boltzmann's Constant=1.381×10^{-23} (J/K)

T_S = System Noise Temperature

B = Bandwidth of the Frequency being used

Basic Antenna Parameters (Cont..)

11. Carrier-to-Noise Ratio, C/N

- It is always Measured in Receiving side
- Carrier-to-Noise Ratio, $C/N = P_r/P_n$
- The Receiving Noise Power, $P_n = kT_SB$
- That is Receiving Noise Power is Antenna Noise Temp.
- C/N is Measured in input of Antenna
- Antenna Catches Desired signal including noise power

Basic Antenna Parameters (Cont..)

12. Carrier-to-Noise Density, C/N_0

- It is Measured in after Tuning Circuit with Antenna
- Antenna itself Resonant Circuit Equivalent
- Thus, $C/N_0 = C/N \times B = P_r/P_n \times B = P_r/ kT_SB \times B$

$C/N_0 = P_r/ kT_S$

Where,

$C = P_r = P_t\, G_t\, G_r * (\lambda /4\pi R)^2$ (J/K)

$N_0 = kT_S$

$[C/N_0] = [P_t] + [G_t] + [G_r] – [k] – [T_S] - [L_{free}]$ (dB Hz)

$[C/N_0] = [P_t] + [G_t] + [G/T] – [k] - [L_{free}]$ (dB Hz)

This is a Ling-Design Formula (Equation)

Basic Antenna Parameters (Cont..)

13. Gain-to-Noise Ratio, G/T

- It is also called Figure of Merit
- Ratio of Receiving antenna Gain to Antenna Temp.
- It is Measured in always RX site
- G/T determines the Quality and signal Strength of Earth Station (ES)
- Very important Factor in Link Design
- Link Design can be Up link or Down Link
- Value of G/T Maintains Standard of ES

Basic Antenna Parameters (Cont..)

14. Bandwidths

- The range of frequencies within which the performance of the antenna,
- With respect to some Characteristic conforms to a specific standard
- $BW = \Delta f = f_2 - f_1$; $f_c = (f_{max} + f_{min})/2$
- Fractional Bandwidth (FBW) $= (f_{max} - f_{min})/ f_c$
  $= (f_{max} - f_{min})/(f_{max} + f_{min})/2$
- FBW is always measured in Percentage (%) => 0%<FBW<100%

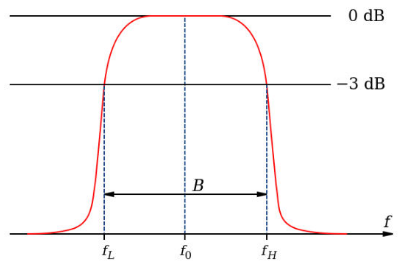
FBW < 1 % => Narrow Banwidth

1%< FBW < 20% => BroadBand

20%< FBW < 50% => WideBroad

50%< FBW => Ultra WideBroad

Bandwidth of Signals



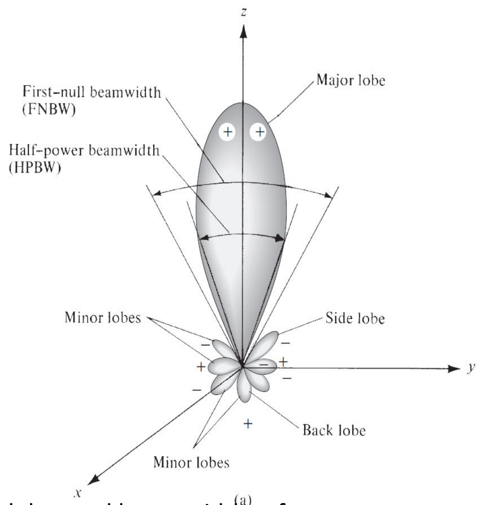
Basic Antenna Parameters (Cont..)

15. Beamwidths

- First-null Beamwidth (FNBW)
- Half-power Beamwidth (HPBW) is in 3dB less from peak of major lobe
- Pencil Beamwidth

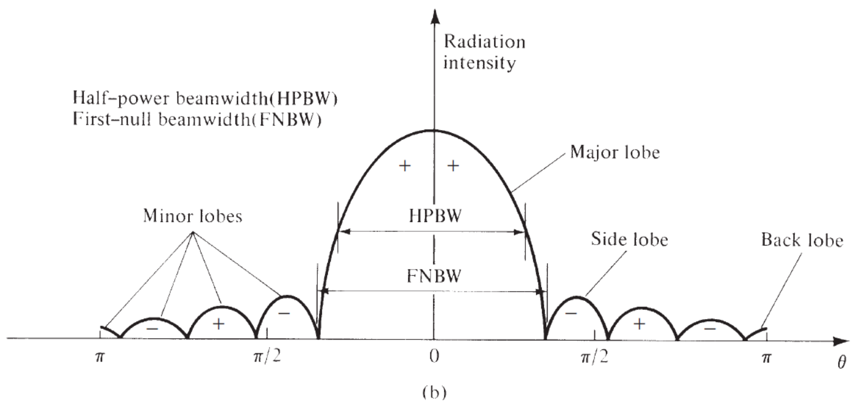
Normally,

HPBW≈FNBW/2



Radiation lobes and beam widths of an antenna pattern

Radiation Patterns with BW



Linear plot of power pattern and its associated lobes and beam widths.

Basic Antenna Parameters (Cont..)

Beamwidth (BW)….

Half-power Beamwidth
(HPBW) = 70 λ/D (Degree)

Or, BW = 21 X 10^9/Fd

- Pencil Beamwidth is used for Space Communication Normally,
  $\theta_{½} \approx$ FNBW/2 = 70 λ/D

Basic Antenna Parameters (Cont..)

16. Beam Efficiency (BE)

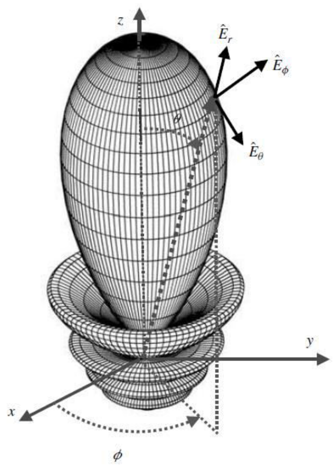
- It is used to Judge the Quality of Transmitting and Receiving antennas
- For an antenna with its major lobe directed along the *z-axis ($\vartheta = 0$)*
- the beam efficiency (BE) is defined by

BE = Power Transmitted (Received) within cone Angle *ϑ1/*
Power Transmitted (Received) by the Antenna

- *BE is dimensionless (Unit less)*

Basic Antenna Parameters (Cont..)

Beam Efficiency (BE) …



Basic Antenna Parameters (Cont..)

Beam Efficiency (BE) ….

- Ratio of Main Beam area to the Total Beam area
  $\varepsilon_M = \Omega_M / \Omega_A$ = Beam Efficiency

Where, $\Omega_A = \Omega_M + \Omega_m$ =

Ω_A is Total Beam Area (or Beam Solid Angle)
Ω_M is Main Beam Area (or Solid Angle)
Ω_m is Minor-lobe area (or Solid Angle)

- Ratio of Minor-lobe area to the Total Beam area
  $\varepsilon_m = \Omega_m / \Omega_A$ = Stray Factor
- It Follows That $\varepsilon_M + \varepsilon_m = 1$

Basic Antenna Parameters (Cont..)

17. Radiation Patterns

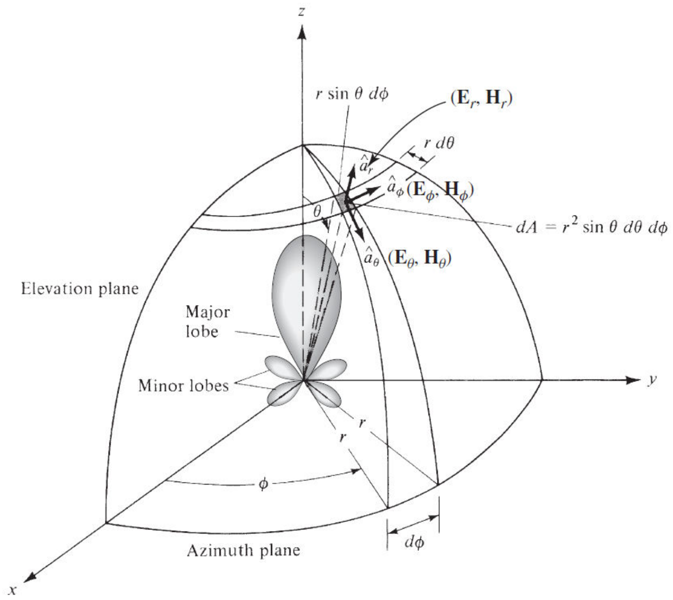
- Mathematical function or a Graphical Representation of the Radiation Properties of the Antenna as a Function of Space Coordinates.
- It is Determined in the Far Field Region
- It is Represented as a Function of the Directional Coordinates.

Basic Antenna Parameters (Cont..)

Radiation Patterns:

- A trace of the received electric (magnetic) field at a constant radius is called the amplitude field *pattern.*
- *On the other hand, a graph of the spatial* variation of the power density along a constant radius is called an amplitude *power pattern.*
- Often the *field and power patterns are normalized with respect to their maximum* value, yielding *normalized field and power patterns.*
- *Also, the power pattern is usually* plotted on a logarithmic scale or more commonly in decibels (dB).

Coordinate system for antenna analysis



Radiation Patterns & Input Impedance

Radiation Patterns…

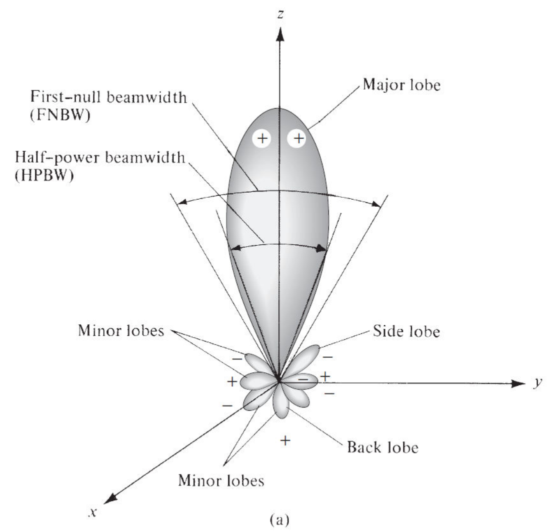
- Mathematical function or a Graphical Representation of the Radiation Properties of the Antenna as a Function of Space Coordinates.
- It is Determined in the Far Field Region
- It is Represented as a Function of the Directional Coordinates.

Radiation Patterns & Input Impedance

Radiation Properties Include

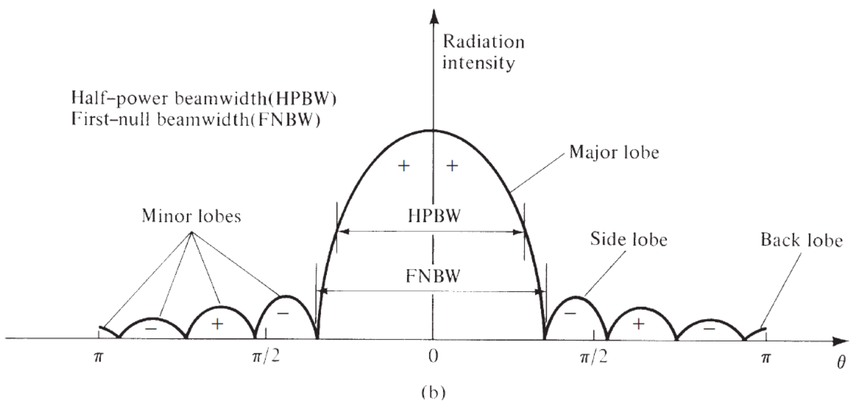
- –Power Flux Density (PFD),
- –Radiation Intensity,
- –Field Strength,
- –Directivity,
- –Phase, or
- –Polarization.

Radiation Pattern



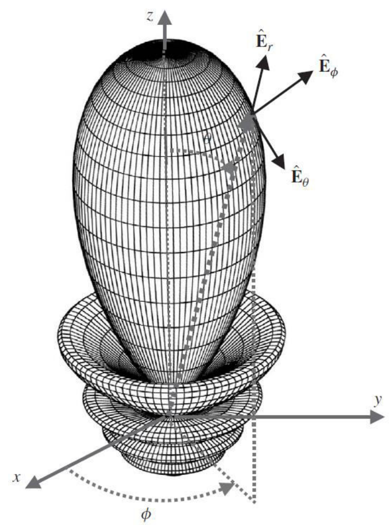
Radiation lobes and beam widths of an antenna pattern

Radiation Patterns



Linear plot of power pattern and its associated lobes and beam widths.

3D Radiation Patterns

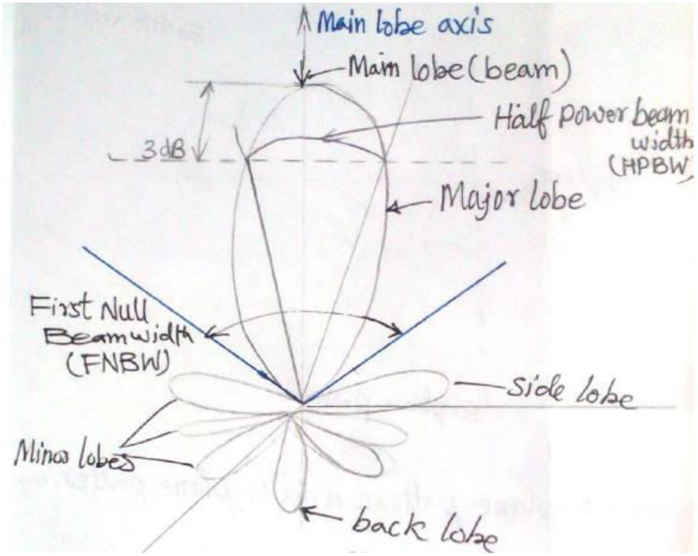


Normalized three-dimensional amplitude *field pattern (in linear scale)*

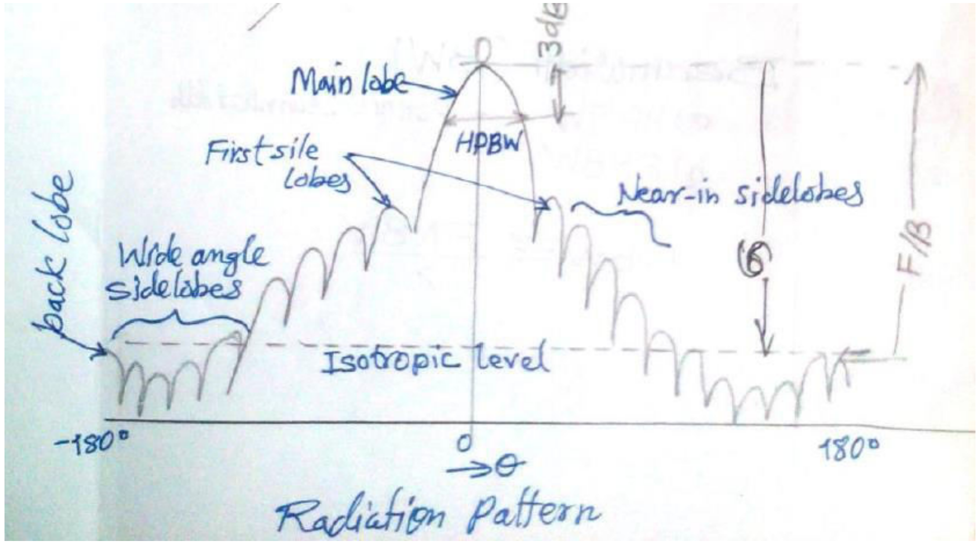
Radiation Patterns & Input Impedance

Radiation Patterns can be

1. Isotropic Radiation Pattern
2. Omni-directional Radiation Pattern
3. Directional Radiation Pattern



Radiation Patterns in 2D

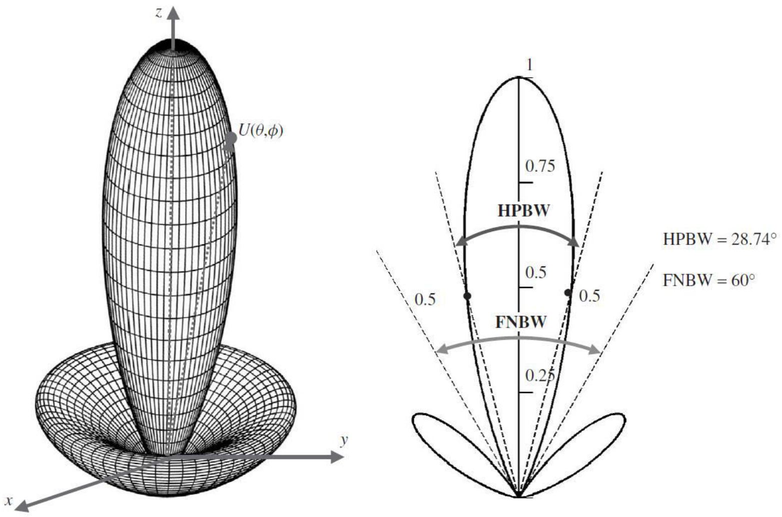


Basic Antenna Parameters (Cont..)

18. Directional and Omni-Directional Patterns

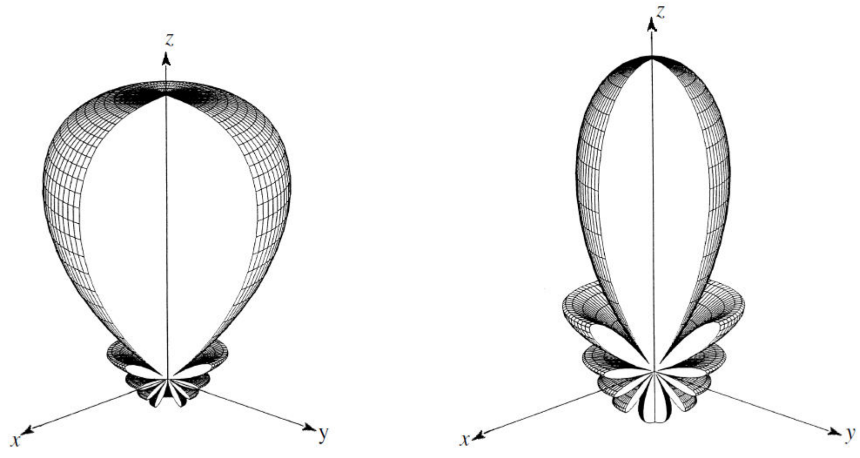
- Directional Antenna is Antenna having Radiation Pattern (s) directed Desired Direction (s) rather than other Directions
- Directional antennas can be Unidirectional, Bidirectional and Quad directional
- Omni directional Antenna has Radiation uniformly and equally in all direction except upwards
- Vertical antennas have such types of Radiations

Three- and two-dimensional power patterns



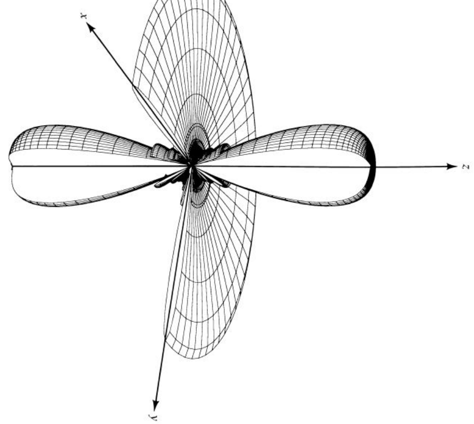
(a) Three dimensional (b) Two dimensional

Unidirectional End-Fire Radiations

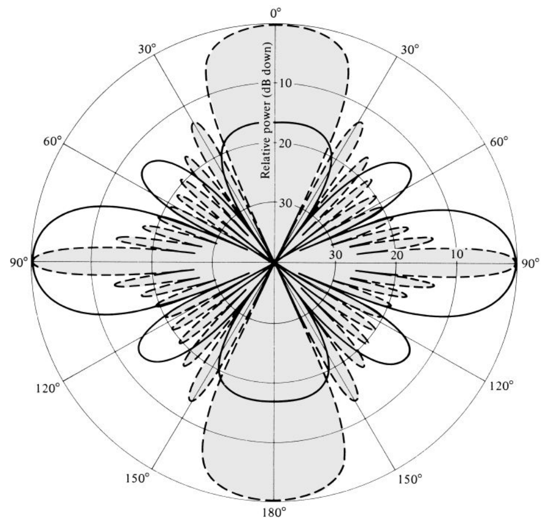


(a) Ordinary (b) Hansen-Woodyard

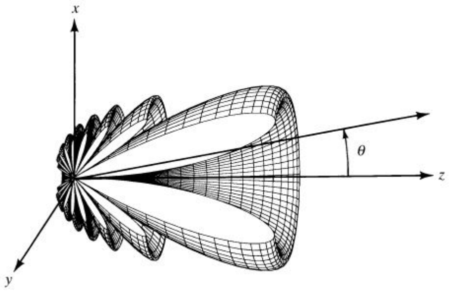
Bidirectional Pattern



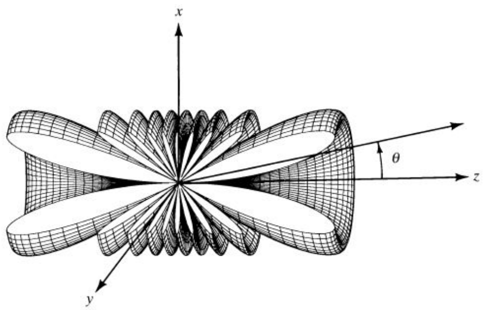
Quad-directional Pattern



Travelling & Standing Radiations

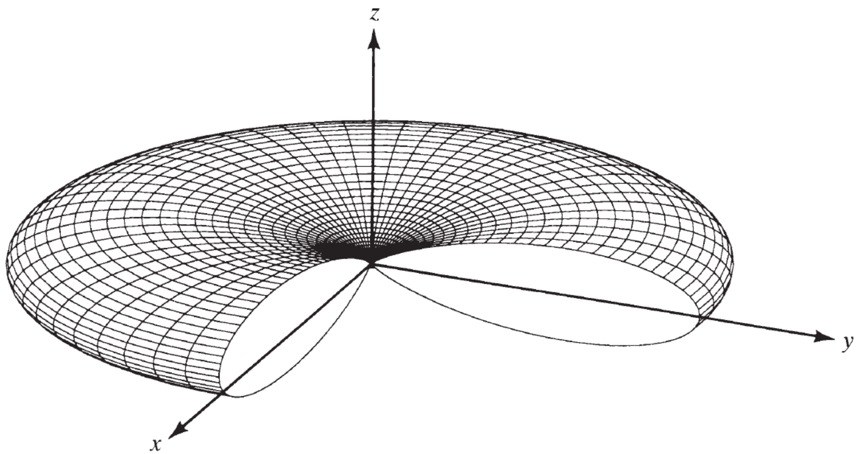


(a) Traveling wave



(b) Standing wave

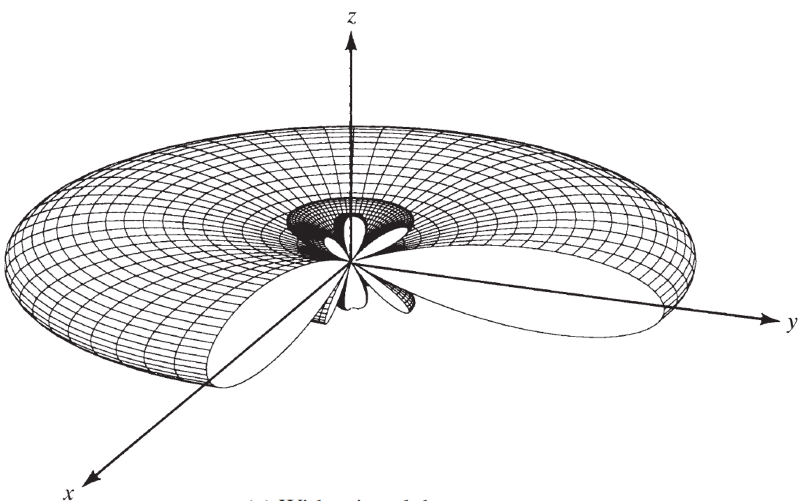
Omnidirectional Patterns



(b) Without minor lobes

Omnidirectional patterns with and without minor lobes.

Omnidirectional Patterns

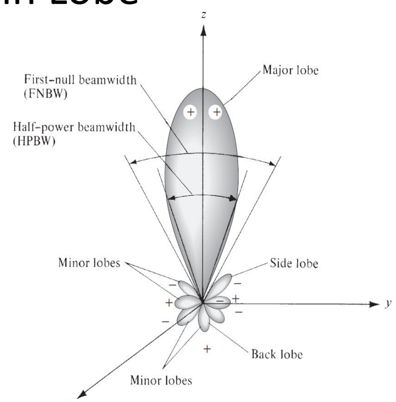


(a) With minor lobes

Basic Antenna Parameters (Cont..)

19. Radiation Pattern Lobes

- Radiation Pattern Lobes are Sub-classified into
    1. Major or Main Lobe
    2. Minor Lobe
    3. Side Lobes
    4. Back Lobes

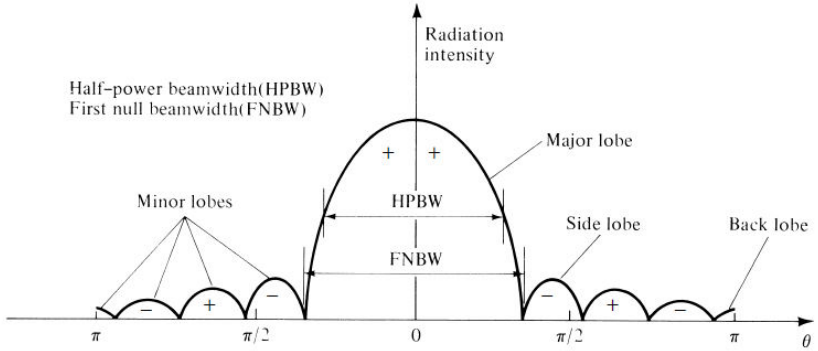


(a)

Basic Antenna Parameters (Cont..)

Radiation Pattern Lobes …

- Radiation Pattern Lobe is a “Portion of the Radiation Pattern bounded by regions of Relatively Weak Radiation Intensity.”



Basic Antenna Parameters (Cont..)

Radiation Pattern Lobes …

- Radiation Pattern Lobes are Sub-classified into
  Major Lobe (Main Beam) and Minor Lobes
- It is defined as “the Radiation lobe containing the direction of Maximum Radiation.”
- Minor Lobe is any Lobe except a Major Lobe.
- Side Lobes and Back Lobes are Minor Lobes
- A *side lobe is “a radiation lobe in any direction other than the intended lobe.”*

Basic Antenna Parameters (Cont..)

Radiation Pattern Lobes …

- Usually a Side Lobe is Adjacent to the Main Lobe and occupies the Hemisphere in the Direction of the Main Beam
- A Back Lobe is a Radiation lobe whose axis makes an angle of Approximately 180° with respect to the Main Beam of an Antenna.
- Minor Lobes usually represent Radiation in Undesired Directions
- They should be Minimized
- Side Lobes are Normally the Largest of the Minor Lobes

Basic Antenna Parameters (Cont..)

20. Radiation Intensity

- Power Radiated from an Antenna per Unit Solid Angle
- It is Measured in Watts per Steradian or per Square Degree
- The Ratio of the Radiation Intensity $U(\theta,\phi)$, as a Function of angle, to its Maximum value. Thus,

$$P_n(\theta,\phi) = U(\theta,\phi)/U(\theta,\phi)_{max} = S(\theta,\phi)/S(\theta,\phi)_{max}$$

Basic Antenna Parameters (Cont..)

Radiation Intensity ….

- Where as the Poynting vector S depends on the Distance from the Antenna
- That is Varying Inversely as the Square of Distance
- Radiation Intensity is Independent of the Distance
- Assuming in Both Cases, Far Field of Antenna is Applied

$P_n(\theta,\phi) = [U(\theta,\phi)/U(\theta,\phi)_{max}] = [S(\theta,\phi)/S(\theta,\phi)_{max}]$

Basic Antenna Parameters (Cont..)

21. Input Impedance (Z_{in})

- Impedance Presented by Antenna at itsTerminals
- The Ratio of the Voltage to Current at a Terminals
- Ratio of the Appropriate Components of
- The Electric to Magnetic Fields at a Point Impedance
- Input Impedance is Measured at a pair of Terminals
- That is Input Terminals of the Antenna
- It is Measured as:

$$Z_{in} = R_A + jX_A$$

Input Impedance (Z_{in})

Input Impedance:

$$Z_A = R_A + jX_A$$

Where,

Z_A is Antenna Imepedance at Terminals a-b

R_A is Antenna Resistance at Terminals a-b

X_A is Antenna Reactance at Terminals a-b

And, $R_A = R_r + R_L$

R_r = Radiation Resistance of the Antenna

R_L = Loss Resistance of the Antenna

Input Impedance (Cont…)

Radiation Resistance

- Fictitious Resistance
- Equivalent to Same Amount of Power When actually Radiating
- Not actually Measured the Resistance from Antenna
- R_r is Subject to the power that it converts into EMW
- Ratio of power radiated to the square of current at the feed point

Loss Resistance

- Ohmic or Load Resistance
- For Efficient Radiation, R_r must be very Higher than R_L
- Loss Resistance gives Rise to Power Loss

Thank You
for Your Present!

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