INTRODUCTION TO TL

- Primary constants.
- Secondary constants.
- TL equation.
- Infinite line
- Distortion less line.
- SC & OC lines.
- UHF Lines.
- Any termination.
- Termination by load.

TABLE 11.2 Transmission Line Characteristics

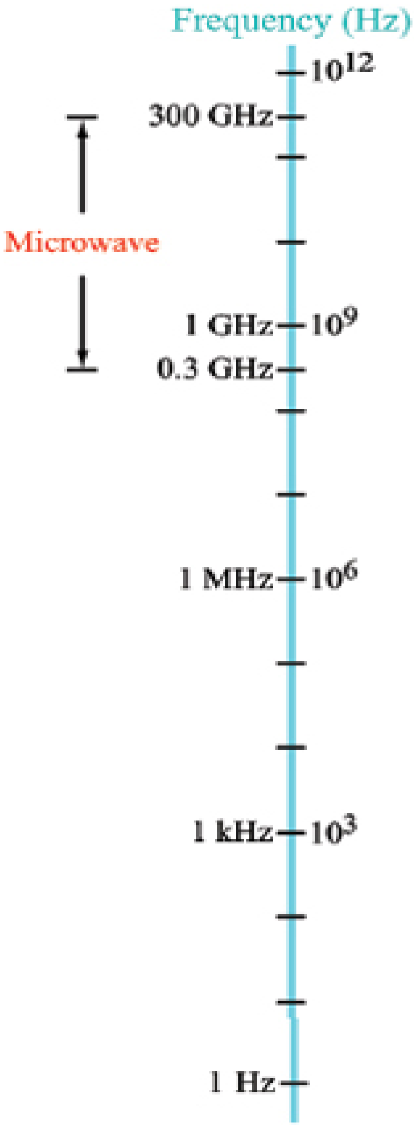
Case	Propagation Constant $\gamma = \alpha + j\beta$	Characteristic Impedance $Z_o = R_o + jX_o$
General	$\sqrt{(R + j\omega L)(G + j\omega C)}$	$\sqrt{\frac{R + j\omega L}{G + j\omega C}}$
Lossless	$0 + j\omega\sqrt{LC}$	$\sqrt{\frac{L}{C}} + j0$
Distortionless	$\sqrt{RG} + j\omega\sqrt{LC}$	$\sqrt{\frac{L}{C}} + j0$

$$Z_o = R_o = \sqrt{\frac{L}{C}}$$

$$\beta = \omega\sqrt{LC} \qquad \frac{R_o}{\beta} = \frac{1}{\omega C} \qquad L = R_o^2 C$$

FREQUENCY SPECTRUM

- ITU-International Telecommunication Union Bands.
- IEEE- Institute of Electrical and Electronics Engineers Association Standard Bands.



Band	Applications
Extremely High Frequency (30–300 GHz)	Radar, advanced communication systems, remote sensing, radio astronomy
Super High Frequency (3–30 GHz)	Radar, satellite communication systems, aircraft navigation, radio astronomy, remote sensing
Ultra High Frequency (300 MHz – 3 GHz)	TV broadcasting, radar, radio astronomy, microwave ovens, cellular telephone
Very High Frequency (30–300 MHz)	TV and FM broadcasting, mobile radio communication, air traffic control
High Frequency (3–30 MHz)	Shortwave broadcasting
Medium Frequency (300 kHz – 3 MHz)	AM broadcasting
Low Frequency (30–300 kHz)	Radio beacons, weather broadcast stations for air navigation
Very Low Frequency (3–30 kHz)	Navigation and position location
Ultra Low Frequency (300 Hz – 3 kHz)	Audio signals on telephone
Super Low Frequency (30–300 Hz)	Ionospheric sensing, electric power distribution, submarine communication
Extremely Low Frequency (3–30 Hz)	Detection of buried metal objects
	Magnetotelluric sensing of the Earth's structure

Frequency Band	Designation	Example uses
3–30 Hz	Extremely low frequency (ELF)	Submarine communication
30–300 Hz	Super low frequency (SLF)	Submarine communication
300–3000 Hz	Ultra low frequency (ULF)	Submarine communication
3–30 kHz	Very low frequency (VLF)	Submarine communication
30–300 kHz	Low frequency (LF)	AM longwave broadcasting, RFID
300–3000 kHz	Medium frequency (MF)	AM (medium-wave) broadcasts
3–30 MHz	High frequency (HF)	Shortwave broadcasts, aviation communications, RFID,
30–300 MHz	Very high frequency (VHF)	FM, television broadcasts
300–3000 MHz	Ultra high frequency (UHF)	TV broadcasts, mobile phones, wireless LAN, Bluetooth
3–30 GHz	Super high frequency (SHF)	microwave devices/communications, wireless LAN
30–300 GHz	Extremely high frequency (EHF)	microwave remote sensing

S.No	Band No.	Abbreviation	Frequency Range	Wavelength
1	4	VLF	3-30KHz	10 to 100Km
2	5	LF	30-300 KHz	1 to 10Km
3	6	MF	300-3000KHz	100 to 1000m
4	7	HF	3-30 MHz	10 to 100m
5	8	VHF	30-300 MHz	1 to 10m
6	9	UHF	300-3000 MHz	10 to 100cm
7	10	SHF	3-30 GHz	1 to 10cm
8	11	EHF	30-300 GHz	1 to 10 mm
9	12	THF	300-3000 GHz	0.1 to 1mm

ITU BANDS

S.No	Band Description	Frequency range (GHz)	Abbreviation
1	HF	0.003-0.03	High frequency
2	VHF	0.03-0.3	Very High frequency
3	UHF	0.3-1	Ultra High Frequency
4	L	1-2	Long wave
5	S	2-4	Short wave
6	C	4-8	Compromise between S and L
7	X	8-12	X for cross
8	K_u	12-18	Kurz under
9	K	18-27	Kurz
10	K_a	27-40	Kurz above
11	V	40-75	
12	W	75-110	
13	millimeter	110-300	millimeter

IEEE BANDS

WAVEGUIDES

- Micro- indicates that microwaves are "**small**" compared to waves used in typical radio broadcasting, in that they have shorter wavelengths.
- waveguide may assume any arbitrary but **uniform cross section, common waveguides are either rectangular or circular i.e perfect conductor**.
- Frequency > 300MHz.

Need for Waveguides

- During the case of high frequencies; it seen that there is loss of electromagnetic waves in transmission lines. This is mainly because of the factors like radiation leakage and conduction resistance. To solve this problem waveguides are widely used.
- Waveguides can direct the power where it is required.
- It can at the same time handle large amount of the power.

- The fundamental characteristics of waveguide and transmission line waves (*modes*) are **quite different**.
- transmission line may operate from dc (f= 0Hz) to a very high frequency.
- a **waveguide can operate only above a certain frequency** called the ***cutoff frequency*** and therefore **acts as a high-pass filter**.

- For a rectangular waveguide, cut off frequency is given by;

$$f_c = \frac{1}{2a\sqrt{\mu\varepsilon}} = \frac{c}{2a}$$

Here **fc** represents the cut off frequency,
a represents the rectangular cross section,
c is the speed of light,
µ represents the permeability and
£ is the permittivity

Comparison of Waveguide and Transmission Line Characteristics

Comparison of Waveguide and Transmission Line Characteristics:

Transmission line	Waveguide
Two or more conductors separated by some insulating medium (two-wire, coaxial, microstrip, etc.).	Metal waveguides are typically one enclosed conductor filled with an insulating medium (rectangular, circular) while a dielectric waveguide consists of multiple dielectrics.
Normal operating mode is the TEM or quasi-TEM mode (can support TE and TM modes but these modes are typically undesirable).	Operating modes are TE or TM modes (cannot support a TEM mode).
No cutoff frequency for the TEM mode. Transmission lines can transmit signals from DC up to high frequency.	Must operate the waveguide at a frequency above the respective TE or TM mode cutoff frequency for that mode to propagate.
Significant signal attenuation at high frequencies due to conductor and dielectric losses.	Lower signal attenuation at high frequencies than transmission lines.
Small cross-section transmission lines (like coaxial cables) can only transmit low power levels due to the relatively high fields concentrated at specific locations within the device (field levels are limited by dielectric breakdown).	Metal waveguides can transmit high power levels. The fields of the propagating wave are spread more uniformly over a larger cross-sectional area than the small cross-section transmission line.
Large cross-section transmission lines (like power transmission lines) can transmit high power levels.	Large cross-section (low frequency) waveguides are impractical due to large size and high cost.

Advantages of Microwaves

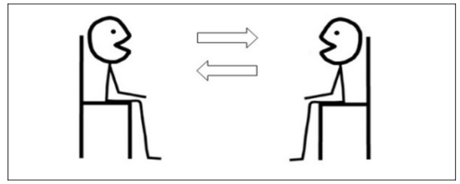
- Supports larger bandwidth and hence more information is transmitted. For this reason, microwaves are used for point-to-point communications.
- More antenna gain is possible.
- Higher data rates are transmitted as the bandwidth is more.
- Antenna size gets reduced, as the frequencies are higher.
- Low power consumption as the signals are of higher frequencies.
- Effect of fading gets reduced by using line of sight propagation.
- Provides effective reflection area in the radar systems.
- Satellite and terrestrial communications with high capacities are possible.
- Low-cost miniature microwave components can be developed.
- Effective spectrum usage with wide variety of applications in all available frequency ranges of operation.

- Completely shielded; provides good isolation.
- Transmits high powers
- Low loss.
- Waveguides can bend if required in a desired application.

Disadvantages of Microwaves

- Cost of equipment or installation cost is high.
- They are hefty and occupy more space.
- Electromagnetic interference may occur.
- Variations in dielectric properties with temperatures may occur.
- Inherent inefficiency of electric power.
- High cost.
- Large size and mass, particularly at lower frequencies.
- Can't pass DC currents along with your RF signal.

INTRODUCTIO TO ANTENNA

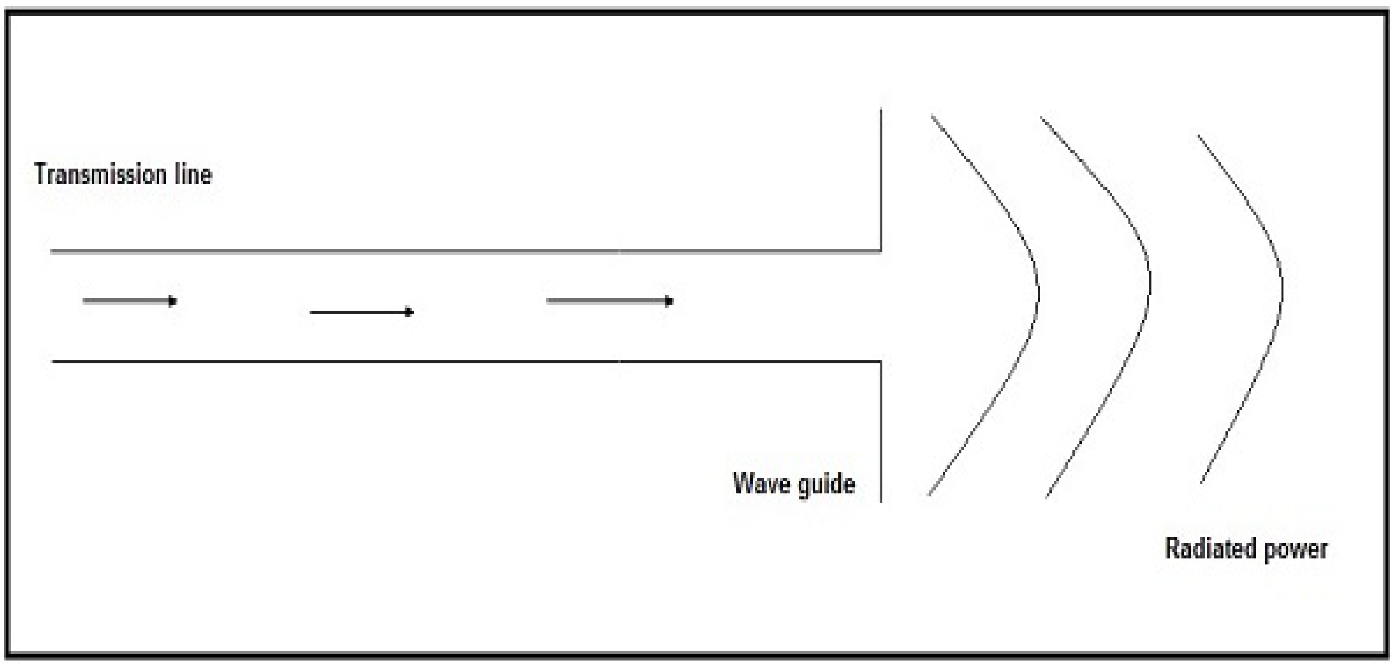


- **voice communication**.
- two individuals communicating with each other. Here, communication takes place through **sound waves**.
- if two people want to communicate who are at longer distances, then we have to convert these sound waves into **electromagnetic waves**.
- The device, which converts the required information signal into electromagnetic waves, is known as an **Antenna**.

ANTENNA BASICS

- An Antenna is a transducer, which converts electrical power into electromagnetic waves and vice versa.
- An Antenna can be used either as a **transmitting antenna** or a **receiving antenna**.

- The power from the transmission line travels through the **waveguide** which has an aperture, to radiate the energy.

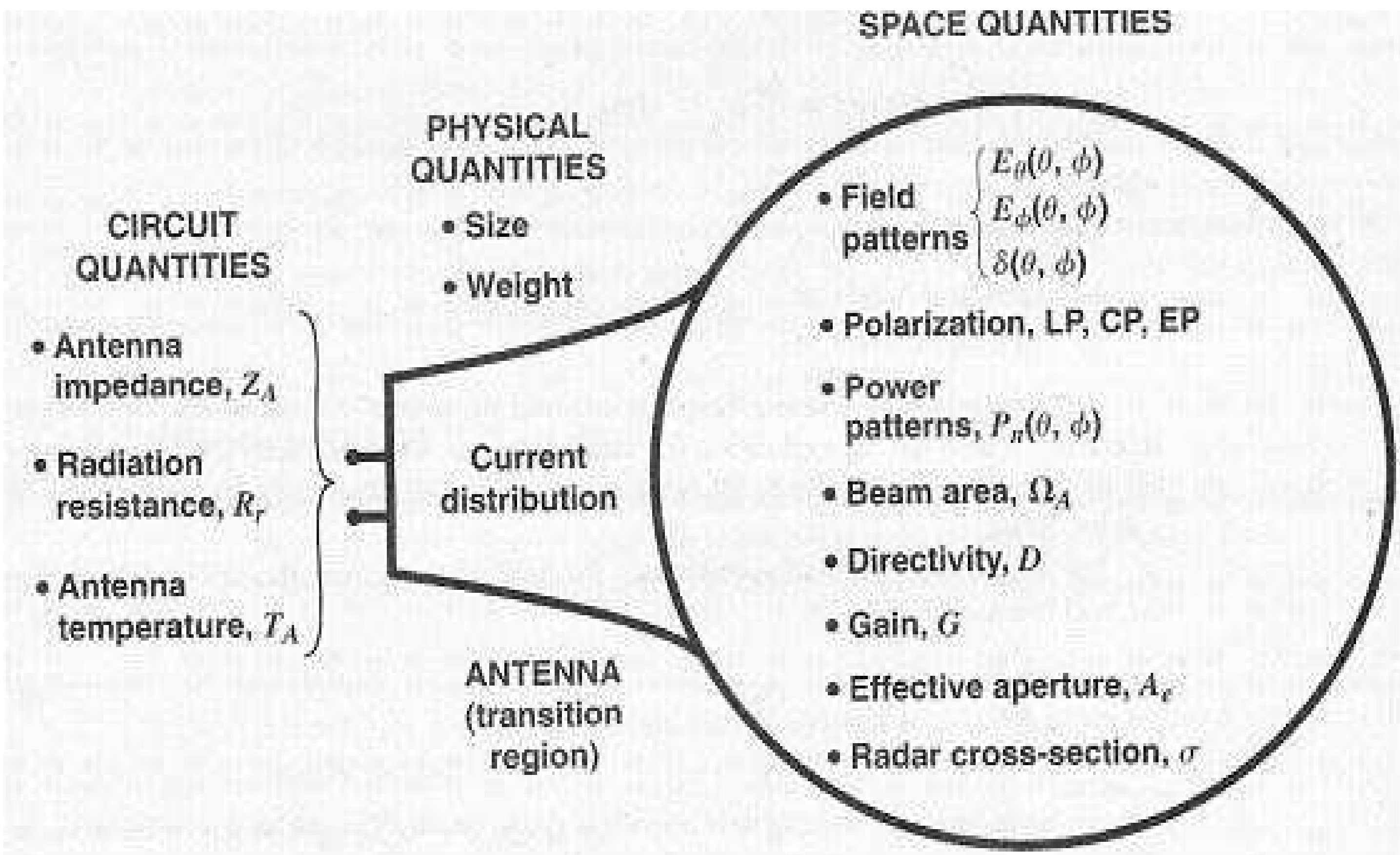


Basic Types of Antennas

- Depending upon –
  - The physical structure of the antenna.
  - The frequency ranges of operation.
  - The mode of applications etc.
  - Physical structure
- Antennas according to the physical structure.
  - Wire antennas
  - Aperture antennas
  - Reflector antennas
  - Lens antennas
  - Micro strip antennas
  - Array antennas

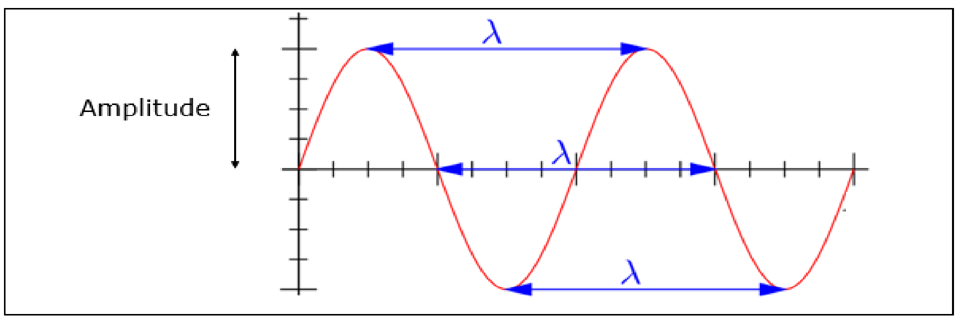
- Frequency of operation
  – Very Low Frequency (VLF)
  – Low Frequency (LF)
  – Medium Frequency (MF)
  – High Frequency (HF)
  – Very High Frequency (VHF)
  – Ultra High Frequency (UHF)
  – Super High Frequency (SHF)
  – Micro wave
  – Radio wave
- Mode of Applications
  – Point-to-point communications
  – Broadcasting applications
  – Radar communications
  – Satellite communications

Antenna Parameters



- Frequency
- Wavelength
- Impedance matching
- VSWR & reflected power
- Bandwidth
- Percentage bandwidth
- Radiation intensity
- Radiation Pattern
- Field Regions
- Directivity
- Antenna Efficiency
- Antenna Gain
- Effective Aperture
- Friis Transmission Equation
- Antenna Temperature

- Frequency - The rate of repetition of a wave over a particular period of time, is called as **frequency**.
- Wavelength - The distance between two consecutive maximum points (crests) or between two consecutive minimum points (troughs) is known as the **wavelength**.
  - The higher the frequency, the lesser will be the wavelength and vice versa.



$$\lambda = \frac{c}{f}$$

- Impedance Matching - The approximate value of impedance of a transmitter, when equals the approximate value of the impedance of a receiver, or vice versa, it is termed as **Impedance matching**.
- Necessity of Matching:
  - The power radiated by an antenna, will be effectively radiated, if the **antenna impedance** matches the free space impedance.
  - For a **receiver antenna**, antenna's output impedance should match with the input impedance of the receiver amplifier circuit.
  - For a **transmitter antenna**, antenna's input impedance should match with transmitter amplifier's output impedance, along with the transmission line impedance.

- VSWR & Reflected Power - The ratio of the maximum voltage to the minimum voltage in a standing wave is known as **Voltage Standing Wave Ratio**.

The key features are :

- – which indicates the impedance mismatch is **VSWR**.
- – The higher the impedance mismatch, the higher will be the value of **VSWR**.
- – The ideal value of VSWR should be 1:1 for effective radiation.
- – Reflected power is the power wasted out of the forward power. Both reflected power and VSWR indicate the same thing.

- Bandwidth - A band of frequencies in a wavelength, specified for the particular communication, is known as **bandwidth**.
  - Bandwidth is the band of frequencies between the higher and lower frequencies over which a signal is transmitted.
  - The bandwidth once allotted, cannot be used by others.
  - The whole spectrum is divided into bandwidths to allot to different transmitters.

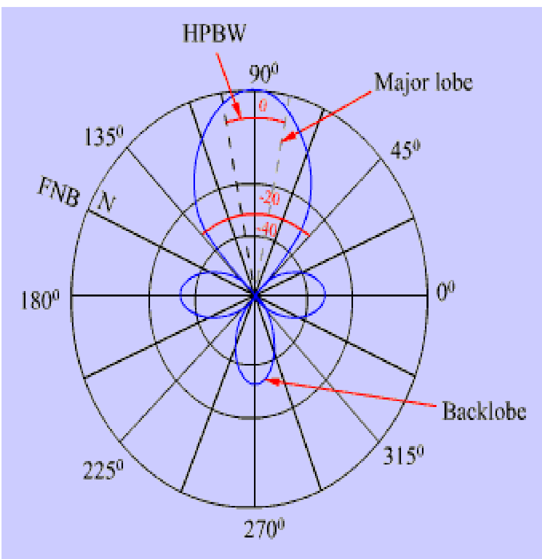
- Percentage Bandwidth - The ratio of absolute bandwidth to the center frequency of that bandwidth can be termed as **percentage bandwidth**.
  - The particular frequency within a frequency band, at which the signal strength is maximum, is called as **resonant frequency**. It is also called as **center frequency** **(f_C)** of the band.
  - The higher and lower frequencies are denoted as **f_H and f_L** respectively.
  - The absolute bandwidth is given by- **f_H - f_L**.
  - To know how wider the bandwidth is, either **fractional bandwidth** or **percentage bandwidth** has to be calculated.

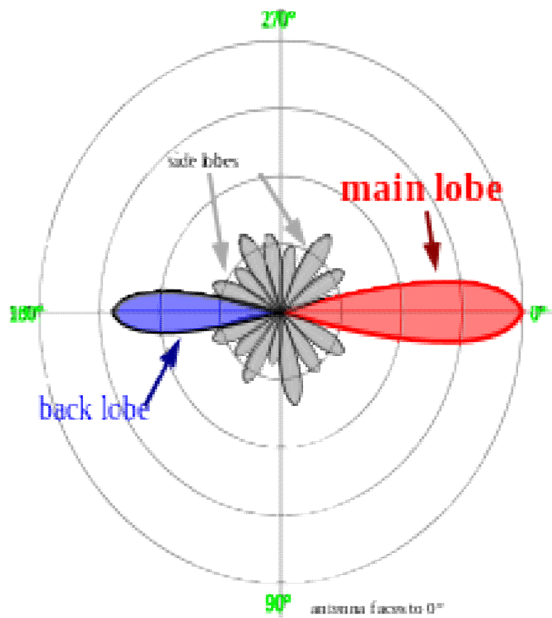
$$Percentage\ bandwidth = \frac{absolute\ bandwidth}{center\, frequency} = \frac{f_H - f_L}{f_c}$$

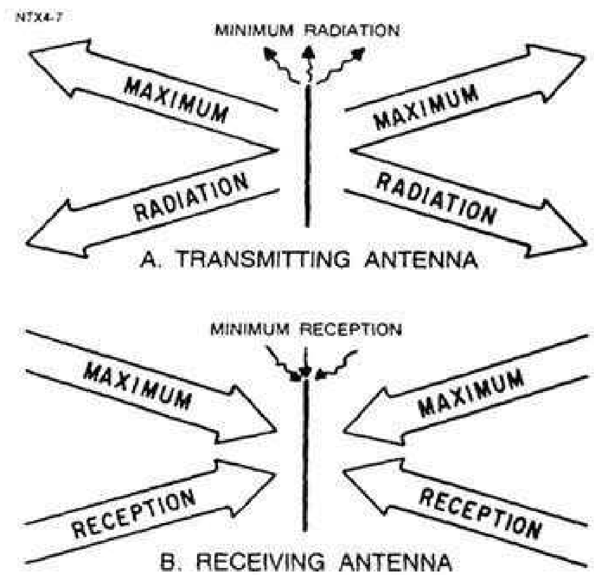
- Radiation Intensity - the power per unit solid angle.
  - Radiation emitted from an antenna which is more intense in a particular direction, indicates the maximum intensity of that antenna.
  - The emission of radiation to a maximum possible extent is nothing but the radiation intensity.

$$U = r^2 \times W_{rad}$$

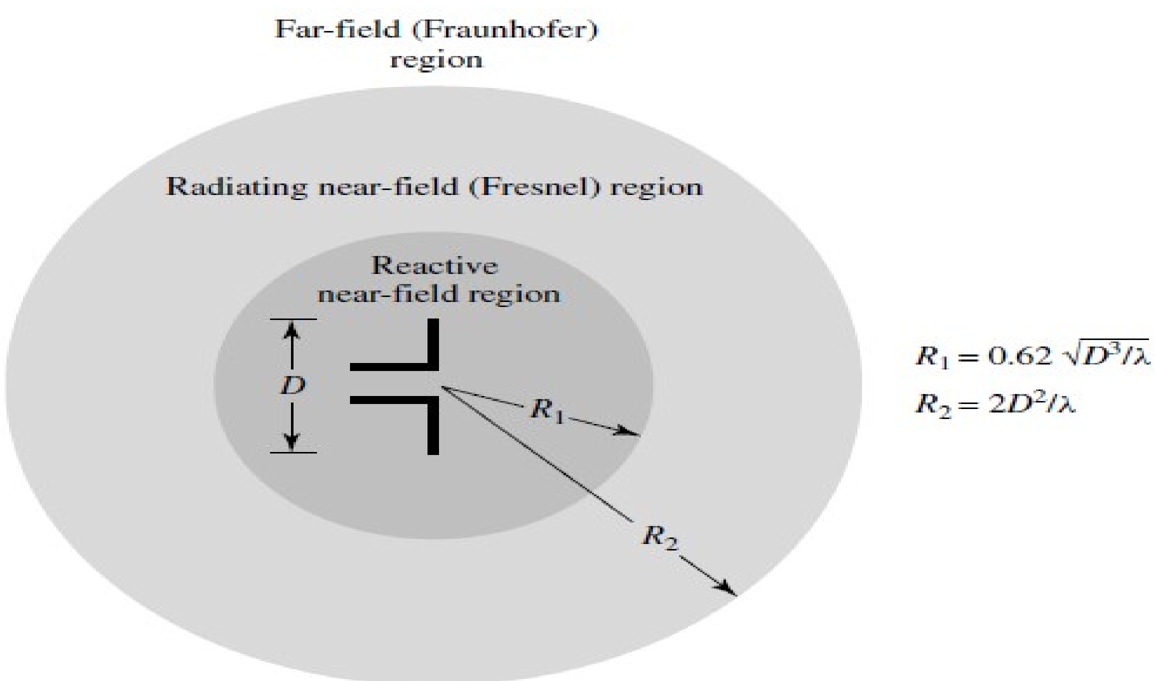
- **Radiation Pattern** - the variation of the power radiated by an antenna as a function of the direction away from the antenna.
  - This power variation as a function of the arrival angle is observed in the antenna's far field.
  - An antenna's normalized radiation pattern can be written as a function in spherical coordinates F(θ,ø).







- Field Regions - this determines the antenna's radiation pattern.
  - Since antennas are used to communicate wirelessly from long distances, this is the region of operation for most antennas.



- Directivity: fundamental antenna parameter.
- “The ratio of maximum radiation intensity of the subject antenna to the radiation intensity of an isotropic or reference antenna, radiating the same total power is called the **directivity**.”
- It is a measure of how 'directional' an antenna's radiation pattern is. An antenna that radiates equally in all directions would have effectively zero directionality, and the directivity of this type of antenna would be 1 (or 0 dB).

$$Directivity = \frac{Maximum\ radiation\ intensity\ of\ subject\ antenna}{Radiation\ intensity\ of\ an\ isotropic\ antenna}$$

$$D = \frac{\phi(\theta, \phi)_{max}\,(from\ subject\ antenna)}{\phi_0\,(from\ an\ isotropic\ antenna)}$$

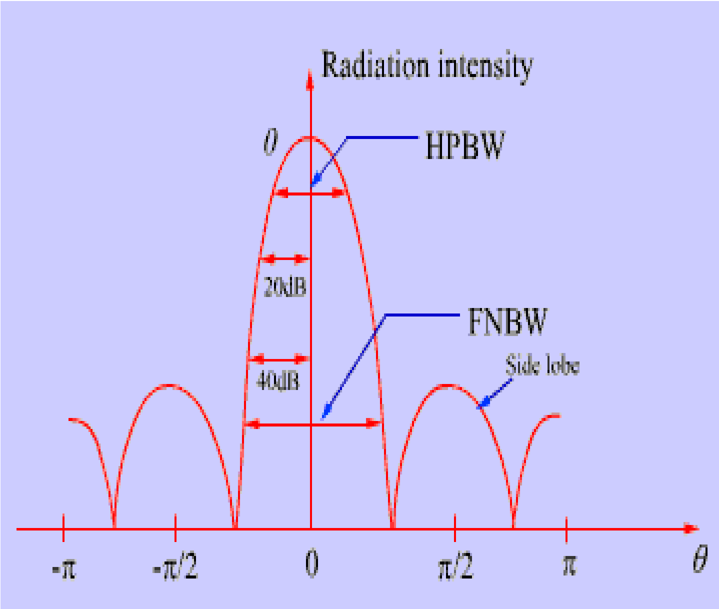
Where

- $\phi(\theta,\phi)_{max}\phi$- is the maximum radiation intensity of subject antenna.
- Φ_{0}- is the radiation intensity of an isotropic antenna (antenna with zero losses).

- **Effective Area** or **Effective Aperture**:
- useful parameter calculating the receive power of an antenna.
- Assume that a plane wave with the same polarization as the receive antenna is incident upon the antenna.
- Further assume that the wave is travelling towards the antenna in the antenna's direction of maximum radiation.

- *effective aperture* parameter describes how much power is captured from a given plane wave.
  - Let *p* be the power density of the plane wave (in W/m^2).
  - If *P_t* represents the power (in Watts) at the antennas terminals available to the antenna's receiver,
    - $P_t = p A_e$
- the effective area simply represents how much power is captured from the plane wave and delivered by the antenna. This area factors in the losses intrinsic to the antenna (ohmic losses, dielectric losses, etc.).
- A general relation for the effective aperture in terms of the peak **antenna gain** (**G**) of any antenna is given by:

$$A_e = \frac{\lambda^2}{4\pi} G$$


Radiation intensity
0
HPBW
20dB
FNBW
Side lobe
40dB
-π
-π/2
0
π/2
π
θ