ANTENNA AND WAVE PROPAGATION

ANTENNA EFFICIENCY

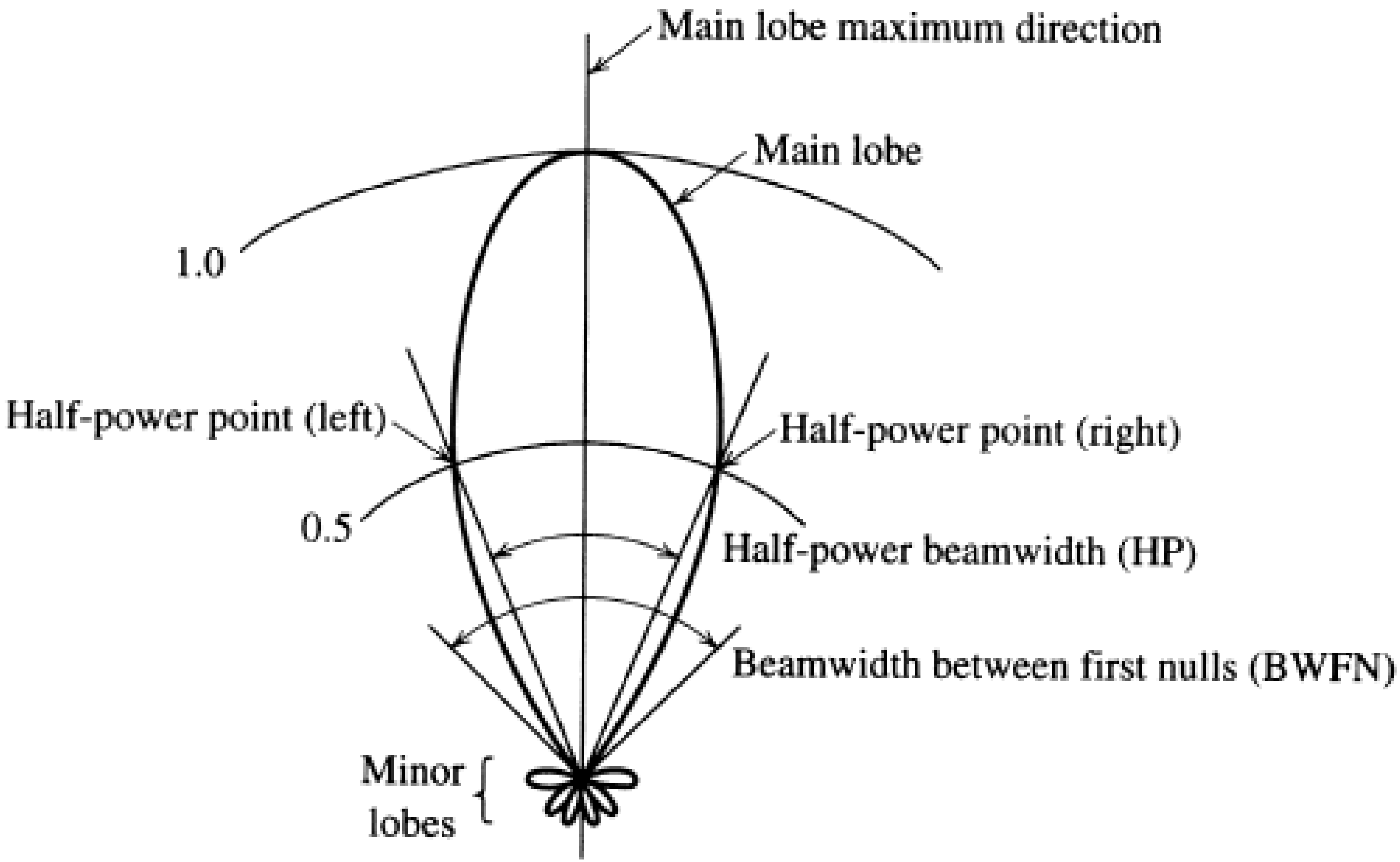
- Efficiency of a transmitting antenna is the ratio of power actually radiated (in all directions) to the power absorbed by the antenna terminals.
- The power supplied to the antenna terminals which is not radiated is converted into heat. This is usually through loss resistance in the antenna's conductors, but can also be due to dielectric or magnetic core losses in antennas (or antenna systems) using such components.

POLARIZATION

- The polarization of an antenna is the orientation of the electric field (E-plane) of the radio wave with respect to the Earth's surface and is determined by the physical structure of the antenna and by its orientation.
- A simple straight wire antenna will have one polarization when mounted vertically, and a different polarization when mounted horizontally.
- Reflections generally affect polarization. For radio waves the most important reflector is the ionosphere - signals which reflect from it will have their polarization changed
- LF,VLF and MF antennas are vertically polarized

BEAM-WIDTH

- Beam-width of an antenna is defined as angular separation between the two half power points on power density radiation pattern OR
- Angular separation between two 3dB down points on the field strength of radiation pattern
- It is expressed in degrees



Main lobe maximum direction
Main lobe
1.0
Half-power point (left)
Half-power point (right)
0.5
Half-power beamwidth (HP)
Beamwidth between first nulls (BWFN)
Minor lobes

Beam Efficiency

Antenna Efficiency (η)

- Antenna Efficiency= $\frac{\text{Power Radiated}}{\text{Total Input Power}}$

- Antenna Efficiency represents the fraction of total energy supplied to the antenna which is converted into electromagnetic waves.

If W_T => Total Input Power
W_r => Power radiated
W_l =>Ohmic Losses then

$$\mathbf{W_T = W_r + W_l}$$

$$\eta = \frac{W_r}{W_T} = \frac{W_r}{W_r + W_l}$$

$$= \frac{W_r}{W_T} \times \frac{4\pi\Phi(\theta,\phi)}{4\pi\Phi(\theta,\phi)}$$

$$= \frac{4\pi\Phi(\theta,\phi)}{W_T} \times \frac{W_r}{4\pi\Phi(\theta,\phi)} = Gp.\frac{1}{Gd} = \frac{Gp}{Gd}$$

$$\eta = \frac{W_r}{W_T} = \frac{W_r}{W_r + W_l} = \frac{Gp}{Gd}$$

- If current flowing in an antenna is I then

$$\eta = \frac{I^2 R_r}{I^2 (R_r + R_l)}$$

$$\eta(\%) = \frac{R_r}{(R_r + R_l)} \times 100$$

Where,

R_r =Radiation Resistance

R_l =Ohmic Loss Resistance of antenna conductor

R_r + R_l =Total Effective Resistance

Effective Area or Antenna Aperture or Capture Area

- A Tx-ing antenna transmits electromagnetic waves and a rx-ing antenna receives the same.
- An antenna is considered to have an effective area or aperture over which it extracts electromagnetic energy from em waves.
- It is defined as the ratio of power received at the antenna load terminal to the poynting vector(or power density)in Watts/meter^2 of the incident wave. Thus

$$\text{Effective Area} = \frac{\text{Power Received}}{\text{Poynting Vector of incident wave}}$$

$$A_e = W/P$$

Let a rx-ing antenna is placed in the field of plane polarised travelling waves having an effective area A and the rxing antenna is terminated at a load impedance $Z_L = R_L + X_L$

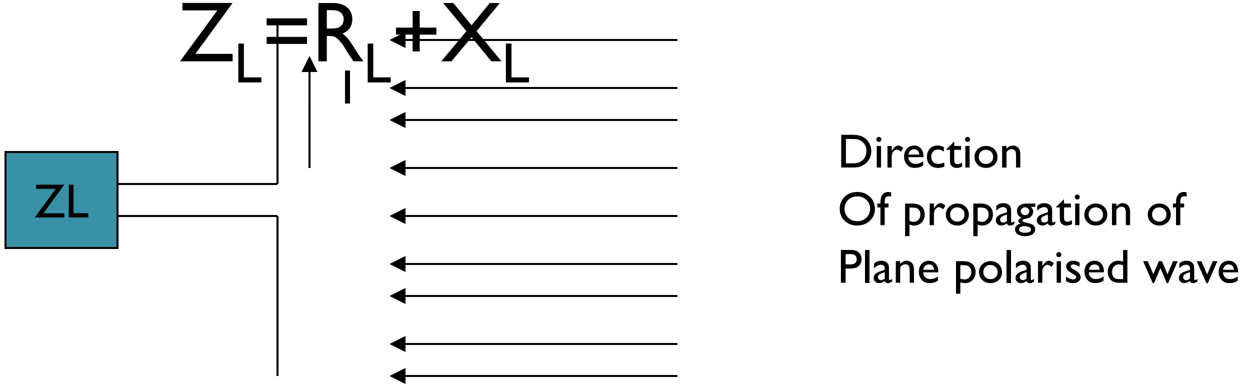


Fig 1

- If I be the terminal current then Rx-ed Power is

$$W = I_{rms}^2 R_L$$

Where R_L =>Load Resistance

I_{rms} =>Terminal rms current

$$\text{Therefore } A = \frac{W}{P} = \frac{I_{rms}^2 R_L}{P}$$

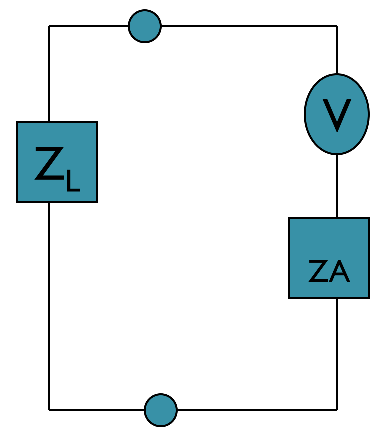


Fig 2

The entire system can be replaced by an equivalent thevenin circuit as shown in Fig 2

V=>Equivalent Thevenin Voltage

ZA =>Equivalent Thevenin Impedance

- $I_{rms} = \dfrac{\text{Equivalent Voltage}}{\text{Equivalent Impedance}}$

$$I_{rms} = \frac{V}{Z_L + Z_A} \qquad \text{Eq 1}$$

Where $Z_A = R_A + jX_A$ =>Complex Antenna Impedance

$R_A = R_r + R_l = R_r$ if R_l is assumed to be 0

Where R_r =Radiation Resistance

R_l =Loss Resistance

Putting the values of Z_A and Z_L in Eq 1 we get

$$I_{rms} = \frac{V}{(R_L + jX_L) + (R_A + jX_A)}$$

$$|I_{rms}| = \frac{|V|}{\sqrt{(R_L + R_A)^2 + (X_L + X_A)^2}}$$

$$|I_{rms}| = \frac{|V|}{\sqrt{(R_L + R_r + R_l)^2 + (X_L + X_A)^2}}$$

Where,

X_L=Load Reactance

X_A=Antenna Reactance

$W = I_{rms}^2 R_L$

$$W = \frac{V^2 R_L}{(R_L + R_A)^2 + (X_L + X_A)^2} \qquad \text{———— Eq 2}$$

$$A_e = \frac{V^2 R_L}{[(R_L + R_A)^2 + (X_L + X_A)^2]P}$$

$$A_e = \frac{V^2 R_L}{[(R_L + R_r + R_l)^2 + (X_L + X_A)^2]P}$$

According to maximum power transfer theorem, maximum power will be transferred from antenna to the antenna terminating load if

$$X_L = -X_A$$

$$R_L = R_A = R_l + R_r$$

$$R_L = R_r \quad \text{If } R_l = 0$$

Eq-3

Maximum Power received in antenna terminating load impedance ZL can be Obtained by putting eq 3 in eq 2

$$W_{\max} = \frac{V^2 R_L}{4{R_L}^2} = \frac{V^2}{4R_L} = \frac{V^2}{4R_r}$$

$$W_{\max} = \frac{V^2}{4R_r}$$

- Maximum Effective Aperture

$$(A_e)_{\max} = \frac{V^2}{4PR_r}$$

Eq 4

The ratio of effective area and max effective area is known as effectiveness Ratio and is denoted by α

$$\alpha = \frac{A_e}{(A_e)_{\max}}$$

The value of α lies between o and 1