ANTENNA PARAMETERS

Gain

Gain takes into account the antenna efficiency.

The absolute gain in a given direction is the ratio of $U(\theta,\phi)$ in a given direction to the average radiation intensity U_0 if the power accepted by the antenna is radiated isotropically.

$$U_0 = \frac{P_{in}}{4\pi} \quad \rightarrow \quad Gain = \frac{4\pi U(\theta,\phi)}{P_{in}}$$

$$P_{rad} = e_a \, P_{in} \quad , \quad e_a = e_r \, e_{cd}$$

Where e_r is the efficiency factor due to reflection mismatch and is given by:

$$e_r = \left(1 - |\Gamma|^2\right)$$

and e_{cd} is the efficiency factor due to the combined dielectric and conduction losses. It can be evaluated from the loss resistance and radiation resistance of the antenna:

$$e_{cd} = \frac{R_r}{R_L + R_r}$$

R_r is the radiation resistance and R_L is the loss resistance.

For a metal rod of length *l* and uniform cross section area *A*, the dc resistance and high frequency resistance are given by:

$$R_{dc} = \frac{1}{\sigma}\frac{l}{A} \text{ ohms}$$

&

$$R_{hf} = \frac{l}{P}R_s = \frac{l}{P}\sqrt{\frac{\omega\mu_0}{2\sigma}} \text{ ohms}$$

where *P* is the perimeter of the cross section of the rod (=$2\pi b$) for a circular rod of radius b. R_s is the surface resistance of the conductor.

Example

A resonant half-wavelength dipole is made of copper (σ=5.7 x 10^7 S/m) wire. Determine ecd of the dipole antenna aat f=100 MHz if the radius of the wire is 3 x 10^{-4} λ, and Rr of the dipole is 73 Ω.

$$f = 10^8 \, Hz, \; \lambda = 3\,m, \; l = 3/2\,m$$

$$C = 2\pi b = 6\pi \times 10^{-4}\,\lambda$$

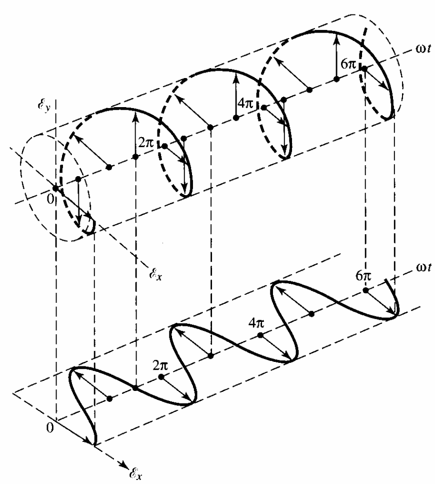
For half-wavelength dipole with a sinusoidal current distribution

$$R_L = 0.5R_{hf} = \frac{0.25}{4\pi \times 10^{-4}}\sqrt{\frac{\pi(10^8)(4\pi \times 10^{-7})}{5.7 \times 10^7}} = 0.349\,\Omega$$

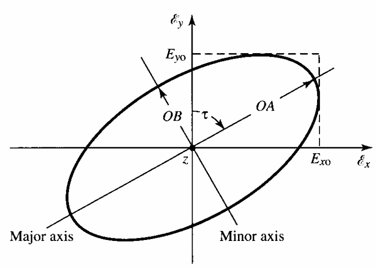
$$e_{cd} = \frac{R_r}{R_r + R_L} = \frac{73}{73 + 0.349} = 99.52\ \%$$

Polarization & Polarization Loss Factor

Polarization of an antenna in a given direction is defined as the polarization of the wave radiated by the antenna



(a) Rotation of wave



(b) Polarization ellipse

This figure shows the rotation of a plane EM wave and its polarization ellipse.

The vector that describes the electric field at a point in space as a function of time determines the type of polarization, which can be classified as:

1. **Linear**
2. **Circular**
3. **Elliptical**

For a plane EM wave travelling along the negative z direction, the instantaneous E field is given by:

$$E(z,t) = \hat{a}_x E_x(z,t) + \hat{a}_y E_y(z,t)$$

Where $E_x(z,t) = E_{xo}\cos(\omega t + kz + \phi_x)$

And $E_y(z,t) = E_{yo}\cos(\omega t + kz + \phi_y)$

If $\Delta\phi = \phi_y - \phi_x = n\pi, \quad n = 0,1,2,3,..$ → **Linear polarization**

Circular polarization:

$$E_{xo} = E_{yo}$$

$$\Delta\phi = \begin{cases} +(\frac{1}{2} + 2n)\pi, \; n = 0,1,2,.. \; for \;\; CW \\ -(\frac{1}{2} + 2n)\pi, \; n = 0,1,2,.. \; for \;\; CCW \end{cases}$$

Elliptical polarization

$$E_{xo} \neq E_{yo}$$

$$\Delta\phi = \begin{cases} +(\frac{1}{2}+2n)\pi, \ n=0,1,2,.. \ for \ \ CW \\ -(\frac{1}{2}+2n)\pi, \ n=0,1,2,.. \ for \ \ CCW \end{cases}$$

or $\Delta\phi \neq \pm \frac{n\pi}{2}$, irrespective of the amplitude relationship.

Polarization loss factor

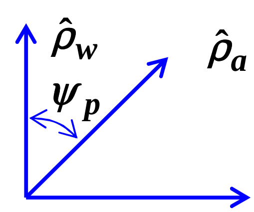
If the electric field of the incoming wave is given by:

$$E_i = \hat{\rho}_w |E_i|$$

and the polarization of the electric field of the receiving antenna is given by:

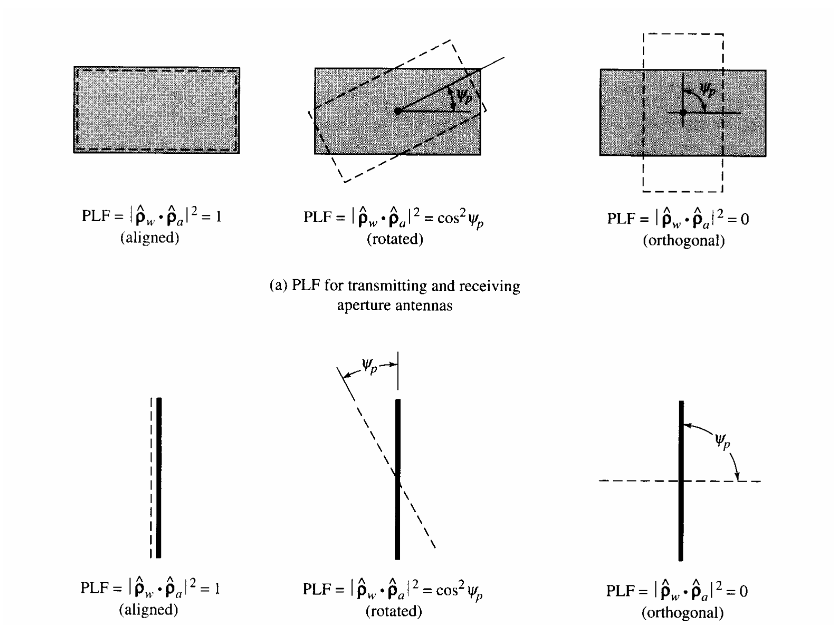
$$E_a = \hat{\rho}_a |E_a|$$

The polarization loss factor is defined by:



$$PLF = |\hat{\rho}_w . \hat{\rho}_a|^2 = |\cos\psi_p|^2$$

where ψ_p is the angle between the two unit vectors.



(a) PLF for transmitting and receiving aperture antennas

(b) PLF for transmitting and receiving linear wire antennas

The polarization loss factor for both aperture and wire antennas is illustrated in the previous Figure.

Antenna Input Impedance

Antenna input impedance is defined as the impedance presented by the antenna at its terminals.

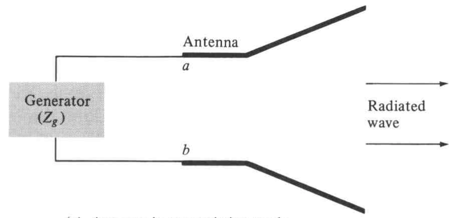
$$Z_A = R_A + jX_A$$

Where $R_A = R_r + R_L$

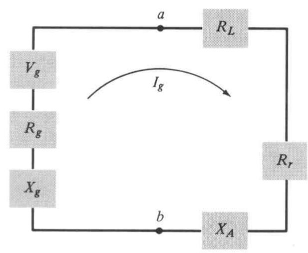
R_r → **Radiation resistance,**

R_L → **Loss resistance.**

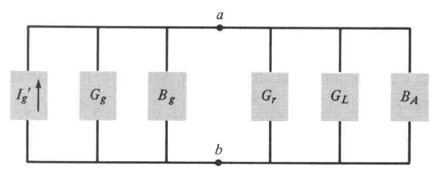
The generator impedance is $Z_g = R_g + jX_g$



(a) Antenna in transmitting mode



(b) Thévenin equivalent



(c) Norton equivalent

$$I_g = \frac{V_g}{Z_t} = \frac{V_g}{(R_r + R_L + R_g) + j(X_A + X_g)}$$

$$P_r = \frac{1}{2}|I_g|^2 R_r = \frac{|V_g|^2}{2}\left[\frac{R_r}{(R_r + R_L + R_g)^2 + (X_A + X_g)^2}\right]$$

Similar expressions can be

obtained for P_L and P_g