Gain

$$P_{rad} = e_c e_d \, P_{in}$$

$$P_{rad} = e_{cd} \, P_{in}$$

$$\text{Gain} = G = 4\pi \frac{\text{Radiation intensity}}{\text{Total input (accepted) power}}$$

$$G = 4\pi \frac{U(\theta,\phi)}{P_{in}} \qquad (2\text{-}46)$$

$$P_{rad} = e_{cd} P_{in} \Rightarrow P_{in} = \frac{P_{rad}}{e_{cd}} \qquad (2\text{-}47)$$

$$G = 4\pi \frac{U(\theta,\phi)}{P_{rad}/e_{cd}} = e_{cd} \underbrace{\left[4\pi \frac{U(\theta,\phi)}{P_{rad}}\right]}_{D} \qquad (2\text{-}48)$$

$$G = e_{cd} D$$

$$\boxed{G_o = e_{cd} D_o} \quad \text{(2-49a)}$$

$$e_{cd} = e_c e_d = Radiation\ efficiency$$

$$e_c = Conduction\ efficiency$$

$$e_d = Dielectric\ efficiency$$

Absolute Gain G_{abs}

$$G_{abs}(\theta,\phi) = e_o D(\theta,\phi) = e_r e_{cd} D(\theta,\phi)$$

$$= (1-|\Gamma_{in}|^2) e_{cd} D(\theta,\phi) \quad \text{(2-49b)}$$

e_o = antenna total efficiency

$e_r = (1-|\Gamma_{in}|^2)$ = Reflection efficiency

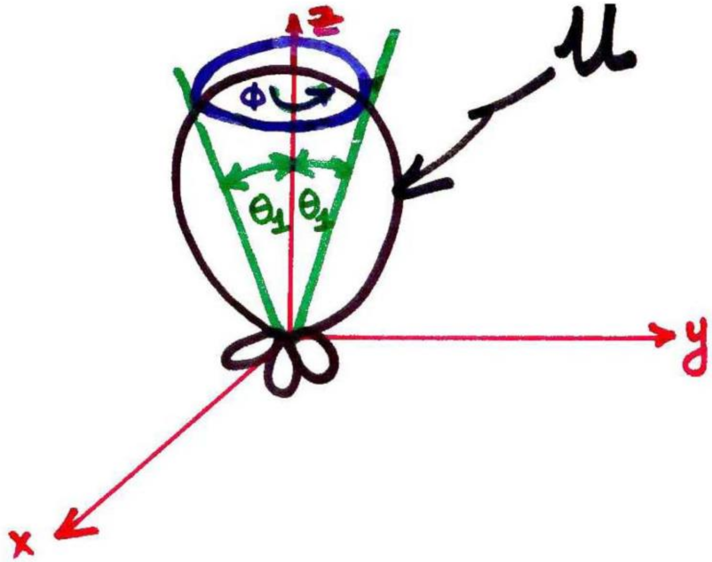
$e_{cd} = e_c e_d$ = Radiation efficiency

e_r = Conduction efficiency

e_d = Dielectric efficiency

Beam Efficiency

$$BE = \frac{\int_0^{2\pi}\int_0^{\theta_1} U(\theta,\phi)\sin\theta d\theta d\phi}{\int_0^{2\pi}\int_0^{\pi} U(\theta,\phi)\sin\theta d\theta d\phi} \qquad (2\text{-}54)$$



Polarization

Rotation of Wave

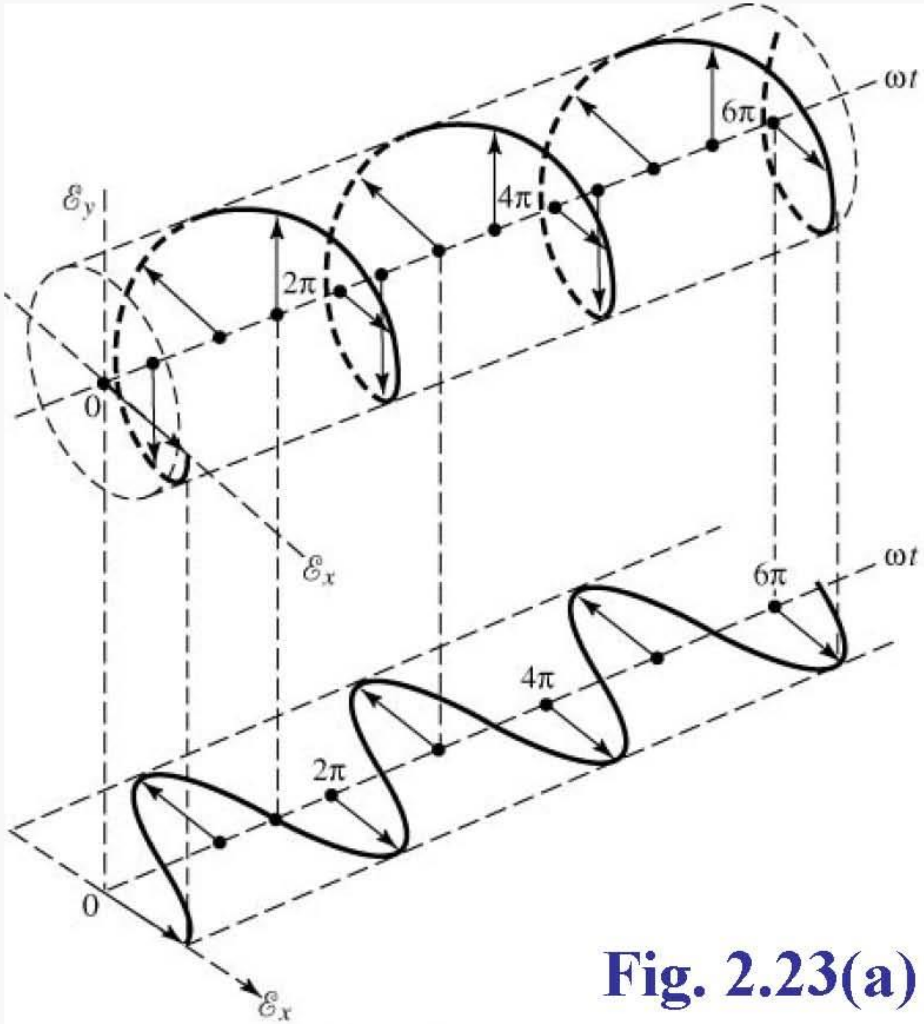


Fig. 2.23(a)

Polarization Ellipse & Sense of Rotation for Antenna Coordinate System

Sense Of Rotation

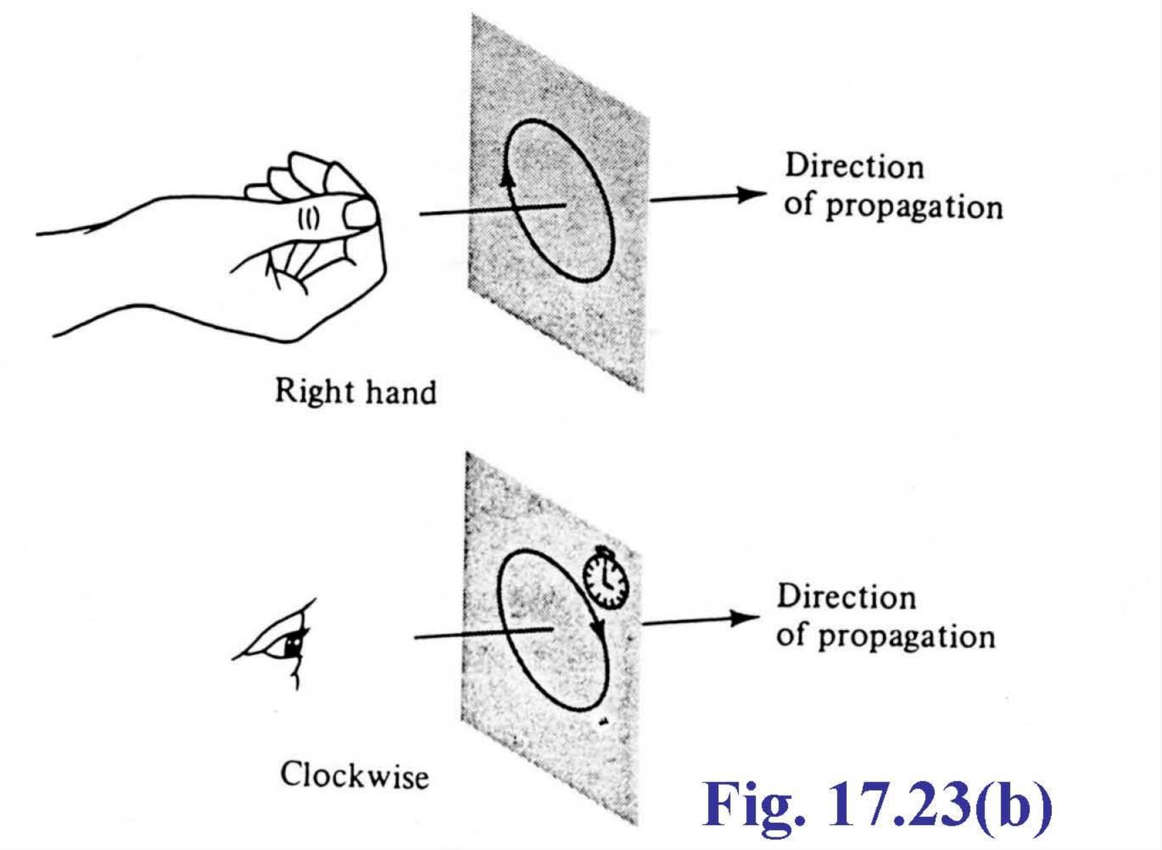
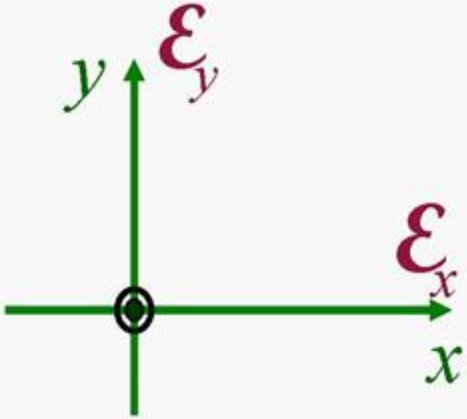


Fig. 17.23(b)

Polarization

A. Linear
B. Circular
   1. CW (RH)
   2. CCW (LH)
C. Elliptical (Axial Ratio)
   1. CW (RH)
   2. CCW (LH)



$$\underline{E} = \left[\hat{a}_x E_{x_0} + \hat{a}_y E_{y_0} e^{j\Delta\phi}\right] e^{+jkz}$$

I. Linear

A. $E_{xo} \neq 0, \quad E_{yo} = 0$

B. $E_{xo} = 0, \quad E_{yo} \neq 0$

C. $E_{xo} \neq 0, \quad E_{yo} \neq 0$

$\Delta\phi = \pm n\pi, \quad n = 0,1,2,\ldots$

II. Circular

$$E_{xo} = E_{yo} \qquad (2\text{-}59)$$

$$\Delta\phi = \pm\left(\frac{1}{2} + n\right)\pi, \quad n = 0,1,2,\ldots \qquad (2\text{-}60, \text{-}61)$$

\+ : clockwise (RH)

\- : counterclockwise (LH)

III. Elliptical

A. $E_{xo} \neq E_{yo}, \quad \Delta\phi \neq \pm n\pi, \quad n = 0,1,2,\ldots$

B. $E_{xo} = E_{yo}, \quad \Delta\phi \neq \pm\left(\frac{1}{2} + n\right)\pi, \quad n = 0,1,2,\ldots$

(2-62a,b)

$$\text{AR} = \frac{\text{major axis}}{\text{minor axis}} = \frac{OA}{OB} \qquad 1 \leq \text{AR} \leq \infty \qquad (2\text{-}65)$$

Polarization Loss Factor (PLF)

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

$$0 \le PLF \le 1$$

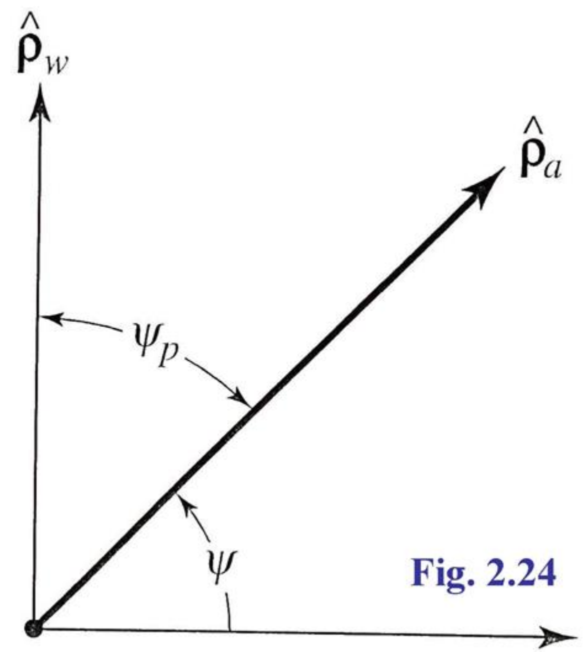


Fig. 2.24

Effective Aperture (Area) A_e

Aperture Antenna in Receiving Mode

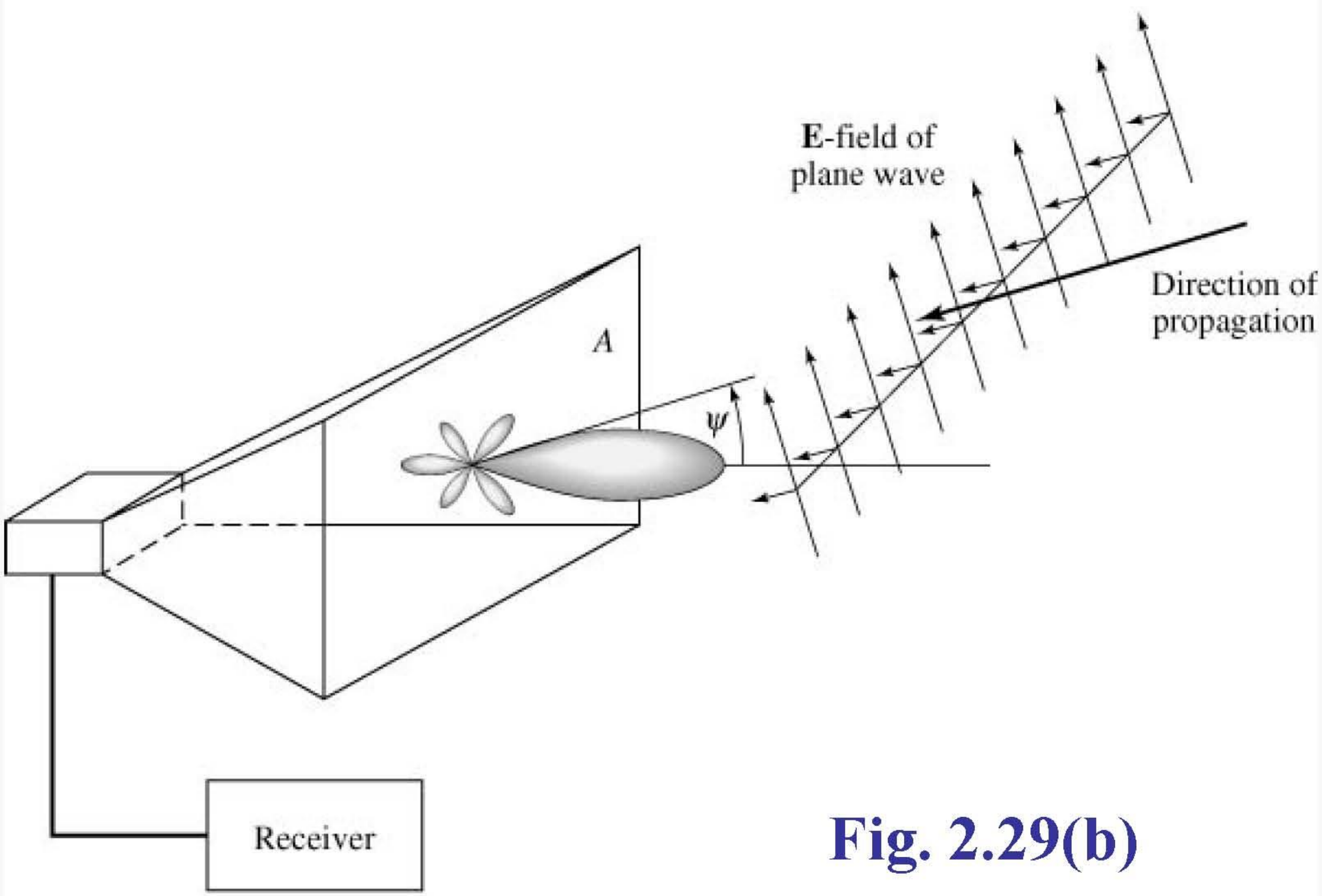


Fig. 2.29(b)

$$A_e = \frac{\lambda^2}{4\pi} \underbrace{e_o D(\theta,\phi)}_{G_{abs}(\theta,\phi)} \left|\hat{\rho}_w \cdot \hat{\rho}_a\right|^2$$

$$A_{em} = \frac{\lambda^2}{4\pi} \underbrace{e_o D_0}_{G_{0\,abs}} \left|\hat{\rho}_w \cdot \hat{\rho}_a\right|^2$$

$$A_{em} = \frac{\lambda^2}{4\pi} D_0 \underbrace{e_{cd}\left(1-\left|\Gamma\right|^2\right)}_{e_o} \underbrace{\left|\hat{\rho}_w \cdot \hat{\rho}_a\right|^2}_{e_p = PLF} \qquad (2\text{-}112)$$

Very Maximum (no losses) A_{em}

$$A_{em} = \frac{\lambda^2}{4\pi} D_o \qquad (2\text{-}110)$$

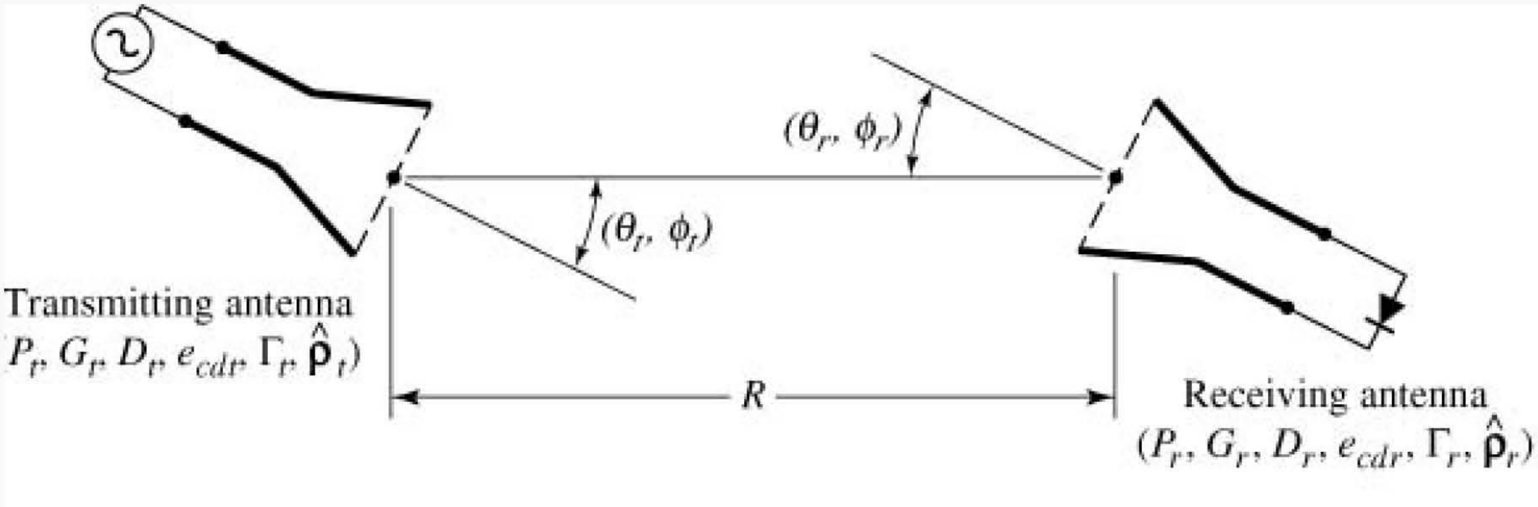
Aperture Efficiency (ε_{ap})

$$\varepsilon_{ap} = \frac{A_{em}}{A_p} \qquad (2\text{-}100)$$

For aperture Antennas:

$$A_{em} \leq A_p \Rightarrow \varepsilon_{ap} \leq 1$$

Friis Transmission Equation



(θ_r, φ_r)
(θ_t, φ_t)
Transmitting antenna
(P_t, G_t, D_t, e_cdt, Γ_t, ρ̂_t)
R
Receiving antenna
(P_r, G_r, D_r, e_cdr, Γ_r, ρ̂_r)

Fig. 2.31

$$\frac{P_r}{P_t} = e_t e_r \frac{\lambda^2 D_t(\theta_t, \phi_t) D_r(\theta_r, \phi_r)}{(4\pi R)^2} \qquad (2\text{-}217)$$

$$\frac{P_r}{P_t} = e_{cdt} e_{cdr} \left(1 - |\Gamma_t|^2\right)\left(1 - |\Gamma_r|^2\right)\left(\frac{\lambda}{4\pi R}\right)^2 D_t D_r$$

$$\frac{P_r}{P_t} = e_{cdt} e_{cdr} \left(1 - |\Gamma_t|^2\right)\left(1 - |\Gamma_r|^2\right)\left(\frac{\lambda}{4\pi R}\right)^2 D_t D_r \left|\hat{\rho}_t \cdot \hat{\rho}_r\right|^2$$

$$\boxed{\frac{P_r}{P_t} = \left(1 - |\Gamma_t|^2\right)\left(1 - |\Gamma_r|^2\right)\left(\frac{\lambda}{4\pi R}\right)^2 G_t G_r \left|\hat{\rho}_t \cdot \hat{\rho}_r\right|^2}$$

Assuming No Losses:

$$\frac{P_r}{P_t} = D_{ot} D_{or} \left(\frac{\lambda}{4\pi R} \right)^2$$

More General: Includes Losses:

$$\frac{P_r}{P_t} = G_{ot} G_{or} \underbrace{\left(\frac{\lambda}{4\pi R} \right)^2}_{\text{Free space loss factor}} \left| \hat{\rho}_t \cdot \hat{\rho}_r \right|^2 \qquad (2\text{-}119)$$