ANTENNA EFFICIENCY

Antenna Reference Terminals

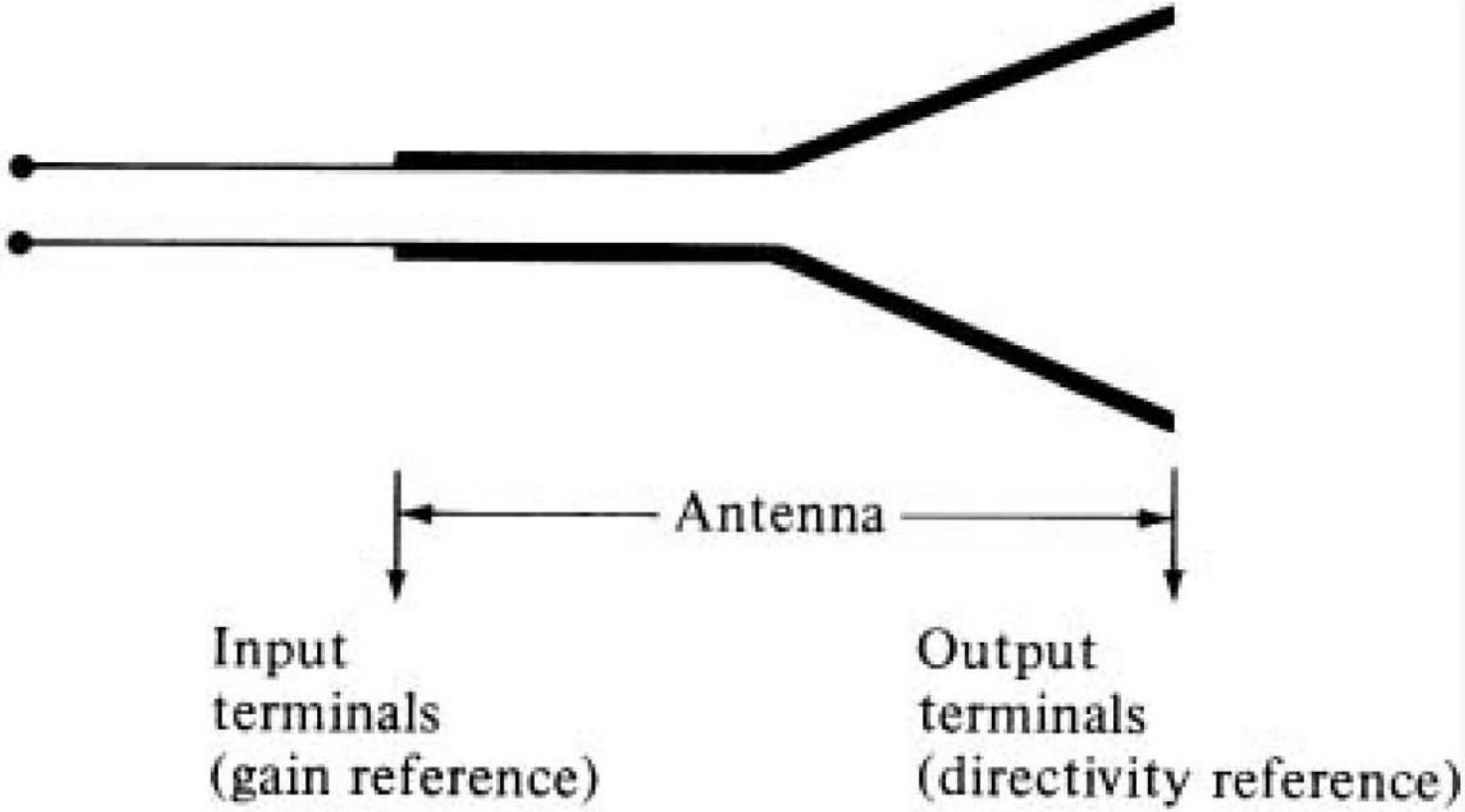


Fig. 2.22(a)

Reflection, Conduction, and Dielectric Losses

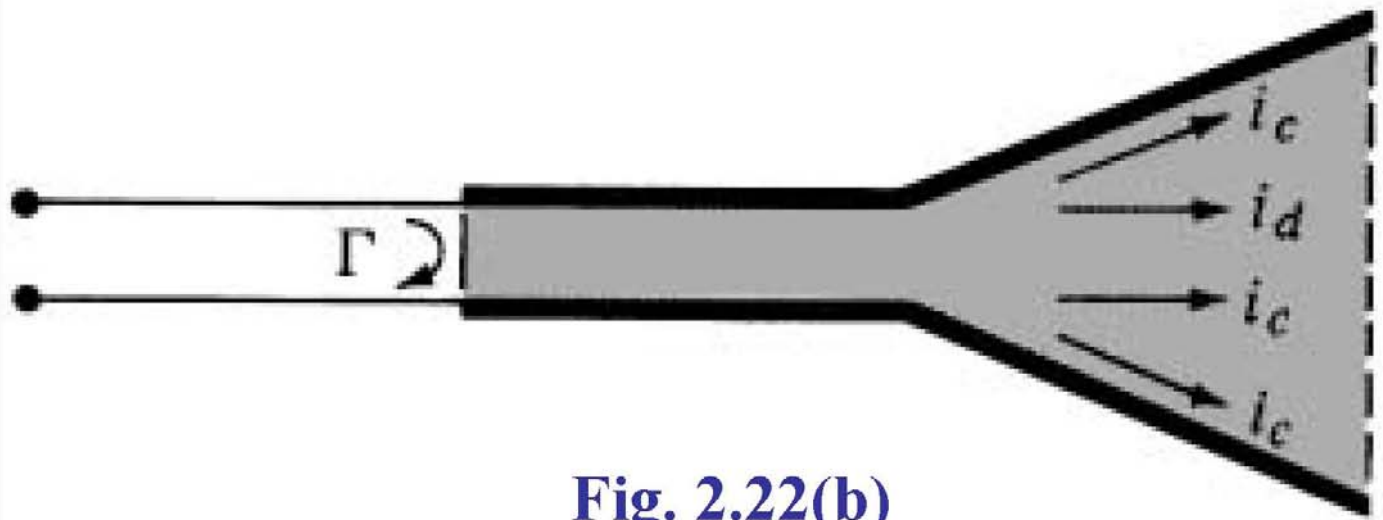


Fig. 2.22(b)

Antenna Efficiency e_o

$$e_o = e_r e_c e_d = e_r e_{cd} \qquad (2\text{-}44)$$

$$e_o = (1 - |\Gamma_{in}|^2) e_{cd} \qquad (2\text{-}45)$$

$$e_o = Total\ efficiency$$

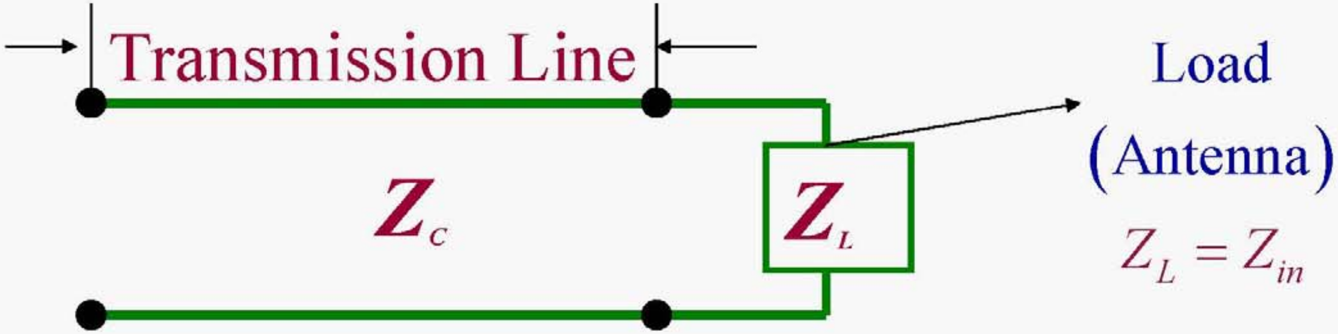
$$e_r = Reflection\ efficiency$$

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

Transmission Line and Load

Z_c = Characteristic Impedance of Line

Z_L = Load Impedance



$$\Gamma_{in} = \frac{Z_L - Z_c}{Z_L + Z_c} = \frac{Z_{in} - Z_c}{Z_{in} + Z_c}$$

ANTENNA GAIN

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

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

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

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

$$G = e_{cd} D$$

$$G = e_{cd} D$$

$$G_o = e_{cd} D_o$$

$$G_o(dB) = 10\log_{10}\left[e_{cd} D_o\right]$$

$$G_o(dB) = 10\log_{10}(e_{cd}) + 10\log_{10}(D_o)$$

Absolute Gain G_{abs}

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

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

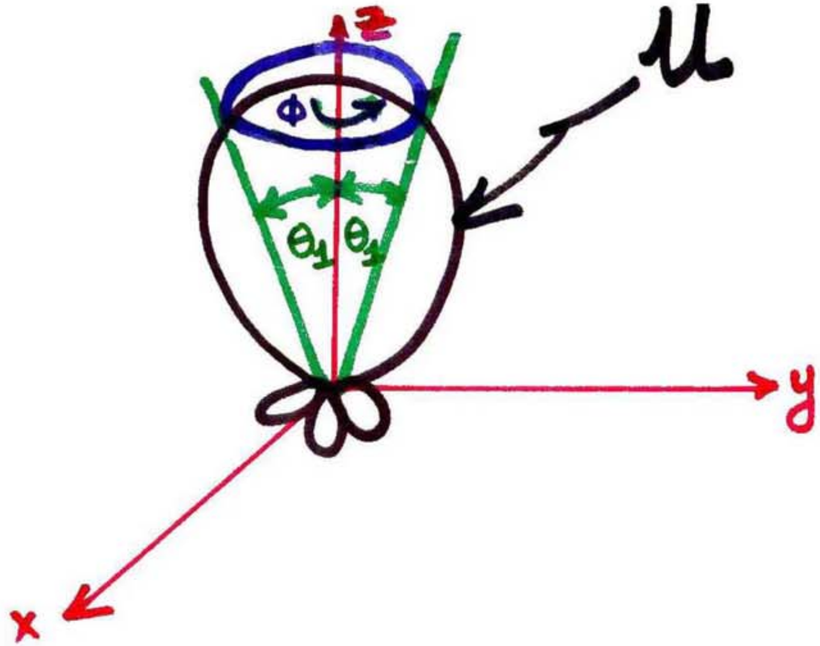
e_o = antenna total efficiency

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

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

BEAM EFFICIENCY

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



POLARIZATION

Rotation of Wave

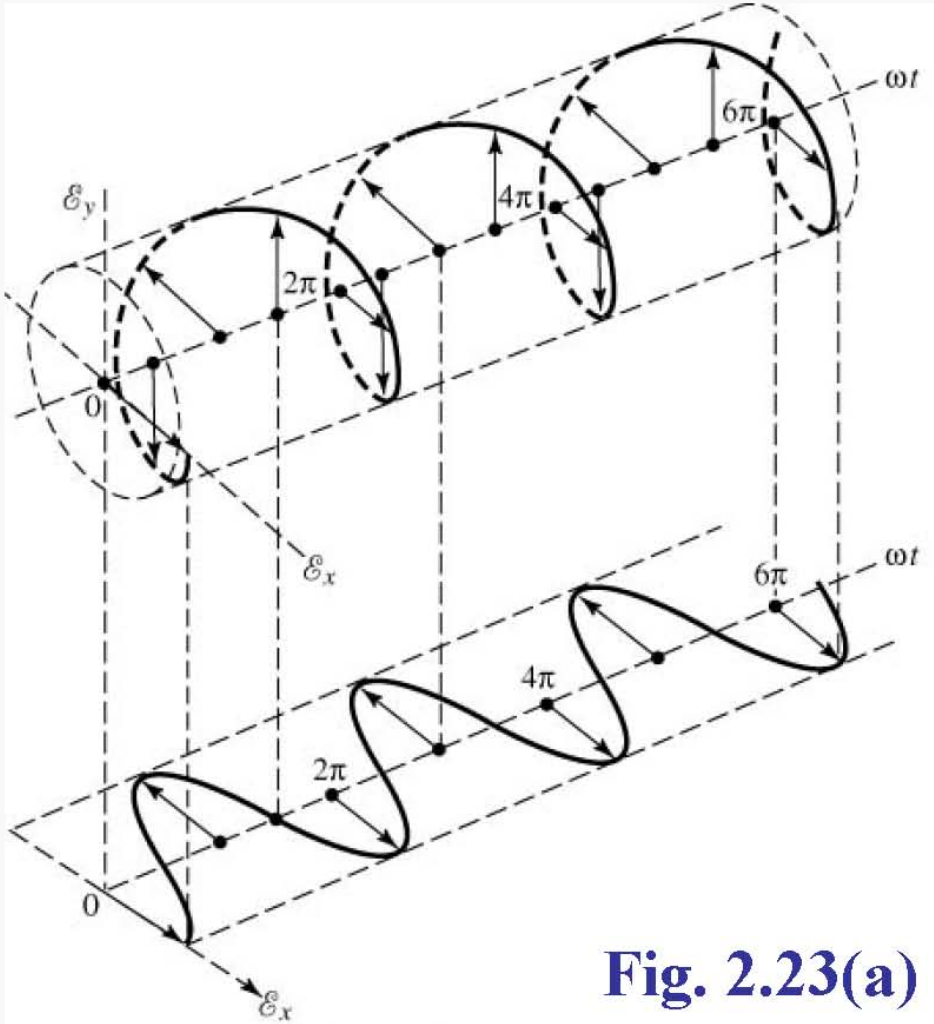


Fig. 2.23(a)

Polarization Ellipse & Sense of Rotation for Antenna Coordinate System

Sense Of Rotation

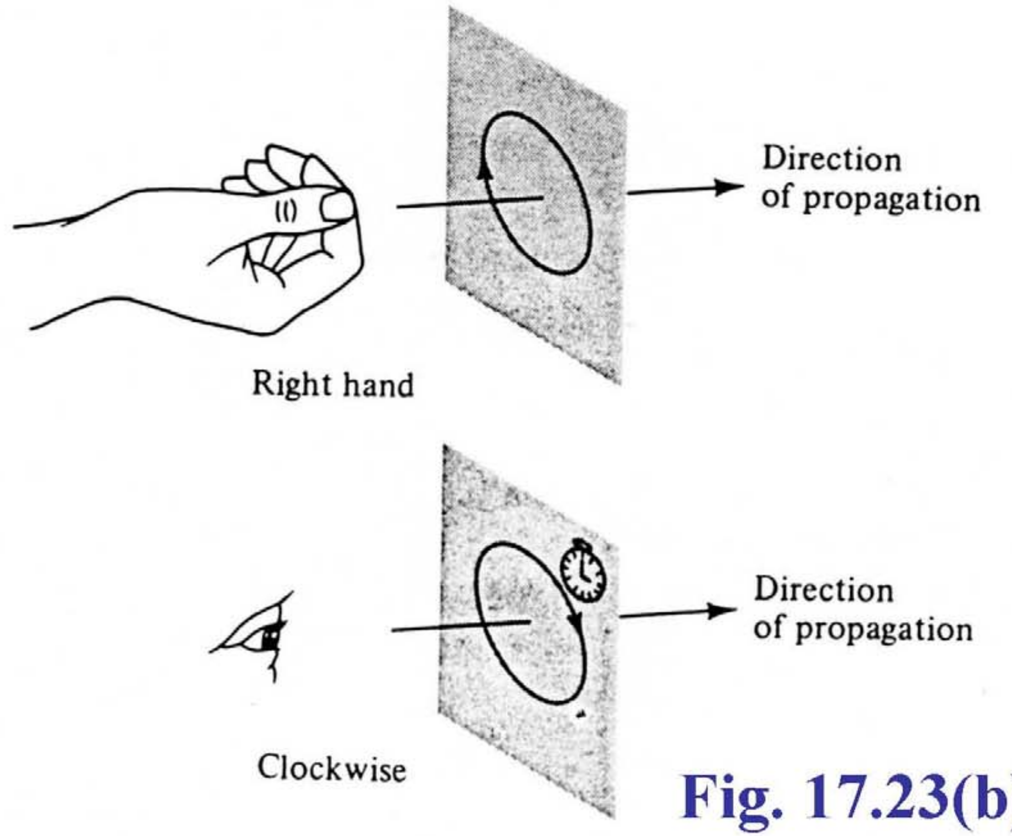


Fig. 17.23(b)

Polarization

A. Linear

B. Circular

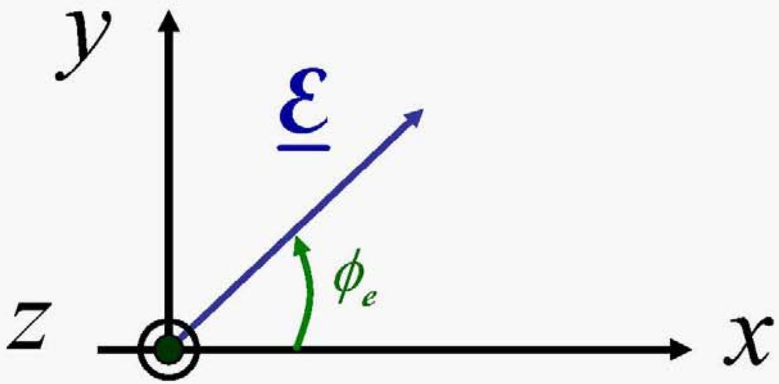
   1. CW (RH)
   2. CCW (LH)

C. Elliptical (Axial Ratio)

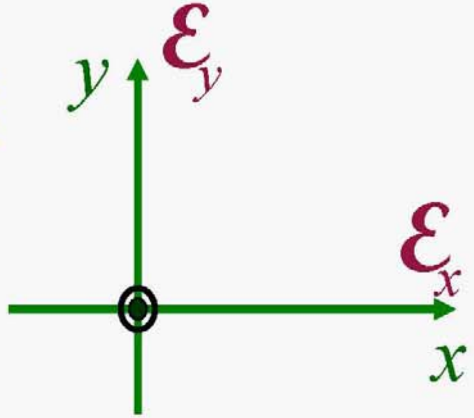
   1. CW (RH)
   2. CCW (LH)

$$\underline{\mathcal{E}}(x, y, z\ ; t) = \mathrm{Re}\left[\underline{E}(x, y, z)\, e^{j\omega t}\right]$$

$$\underline{\mathcal{E}}(x, y, z\ ; t) = \left|\underline{\mathcal{E}}(x, y, z\ ; t)\right| \underline{\angle \phi_e}$$



$\underline{e^{j\omega t}}$:



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

$$\underline{\mathcal{E}}(x, y, z\ ;t) = \mathrm{Re}\left| \underline{E}(x, y, z\ ) e^{j\omega t} \right|$$

$$\underline{\mathcal{E}}(x, y, z\ ;t) = \mathrm{Re}\left\{ \left[\left(\hat{a}_x E_{x_0} + \hat{a}_y E_{y_0} e^{j\Delta\phi} \right) e^{+jkz} \right] e^{j\omega t} \right\}$$

I. Linear

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

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

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

$$\Delta\phi = \pm n\pi, \quad n = 0, 1, 2, \ldots \tag{2-58}$$

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)

Polarization Ellipse

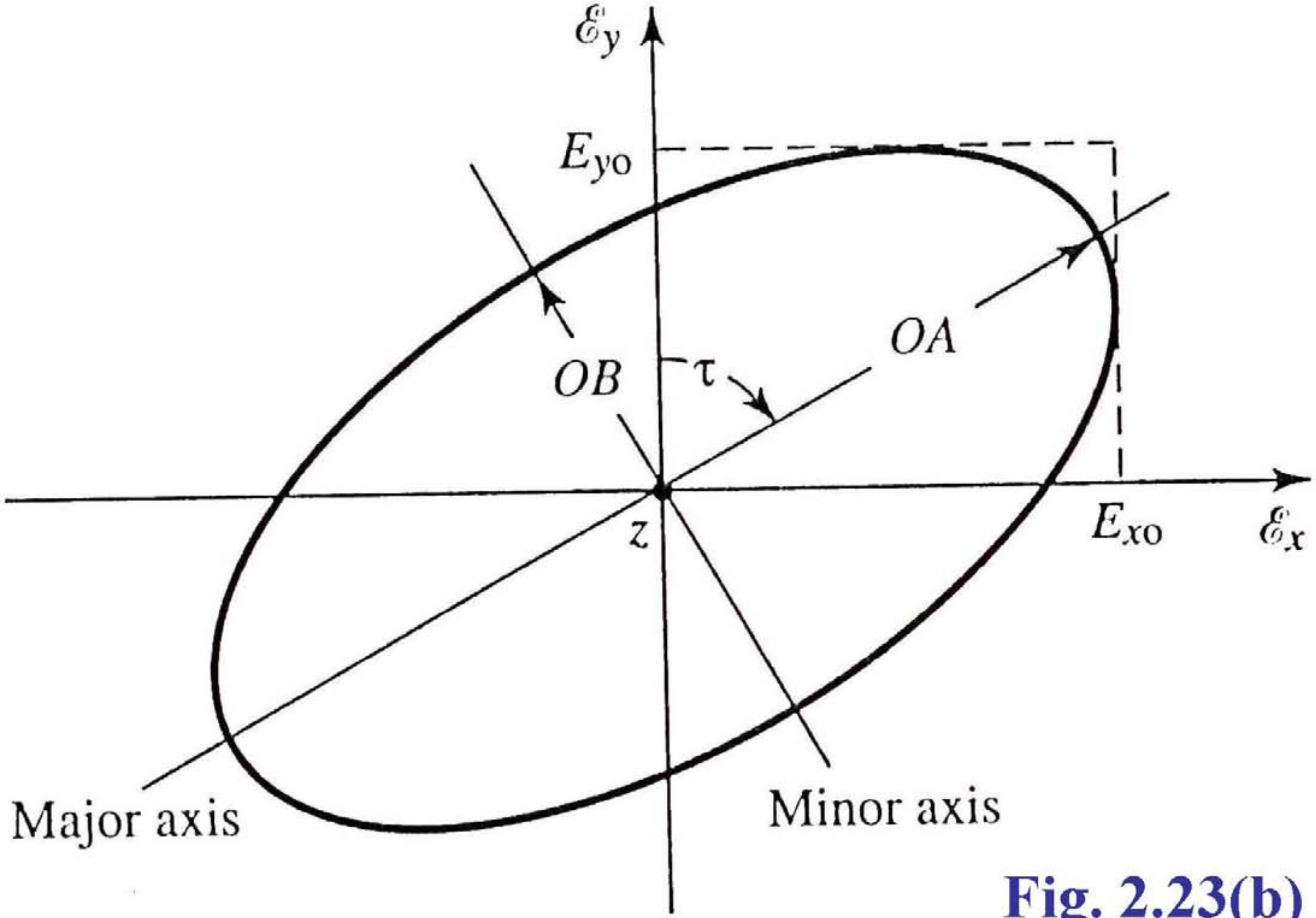


Fig. 2.23(b)

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)

$$\text{AR} = \frac{\text{major axis}}{\text{minor axis}} = \frac{OA}{OB} \qquad 1 \leq \text{AR} \leq \infty$$

(2-65)

Cont'd.

$$OA = \left[\frac{1}{2} \left\{ E_{xo}^2 + E_{yo}^2 + \left[E_{xo}^4 + E_{y_0}^4 + 2E_{xo}^2 E_{yo}^2 \cos(2\Delta\phi) \right]^{1/2} \right\} \right]^{1/2}$$

(2-66)

$$OB = \left[\frac{1}{2} \left\{ E_{xo}^2 + E_{yo}^2 - \left[E_{xo}^4 + E_{yo}^4 + 2E_{xo}^2 E_{yo}^2 \cos(2\Delta\phi) \right]^{1/2} \right\} \right]^{1/2}$$

(2-67)

$$\tau = \frac{\pi}{2} - \frac{1}{2} \tan^{-1} \left[\frac{2E_{xo}E_{yo}}{E_{xo}^2 - E_{yo}^2} \cos(\Delta\phi) \right]$$ (2-68)

To Determine Polarization of:

$$\underline{\mathcal{E}}(x, y, z; t) = \mathrm{Re}\left[\underline{E}(x, y, z)e^{j\omega t}\right]$$

1. Form $\underline{\mathcal{E}}(x, y, z; t)$
2. Plot $|\underline{\mathcal{E}}(x, y, z; t)|$ as a function of time
3. Plot Phase of $\underline{\mathcal{E}}(x, y, z; t)$ as a function of time

Example:

$$\underline{E} = \left(2\hat{a}_x + j2\hat{a}_y\right)e^{jkz} = \left(2\hat{a}_x + 2\hat{a}_y e^{j\pi/2}\right)e^{+jkz}$$

$$E_x = 2e^{+jkz}$$

$$E_y = 2e^{j\pi/2}e^{-jkz} = 2e^{j\left(\frac{\pi}{2} + kz\right)}$$

Solution:

1. $$\mathcal{E}_x = \text{Re}\left[E_x e^{j\omega t}\right] = \text{Re}\left[2e^{j(\omega t + kz)}\right]$$

$$= 2\cos(\omega t + kz)$$

$$\mathcal{E}_y = \text{Re}\left[E_y e^{j\omega t}\right] = \text{Re}\left[2e^{j\left(\omega t + \frac{\pi}{2} + kz\right)}\right]$$

$$= 2\cos\left(\omega t + \frac{\pi}{2} + kz\right) = -2\sin(\omega t + kz)$$

$$2.\quad |\mathcal{E}| = \sqrt{\mathcal{E}_x^2 + \mathcal{E}_y^2}$$

$$= \sqrt{4\cos^2(\omega t + kz) + 4\sin^2(\omega t + kz)}$$

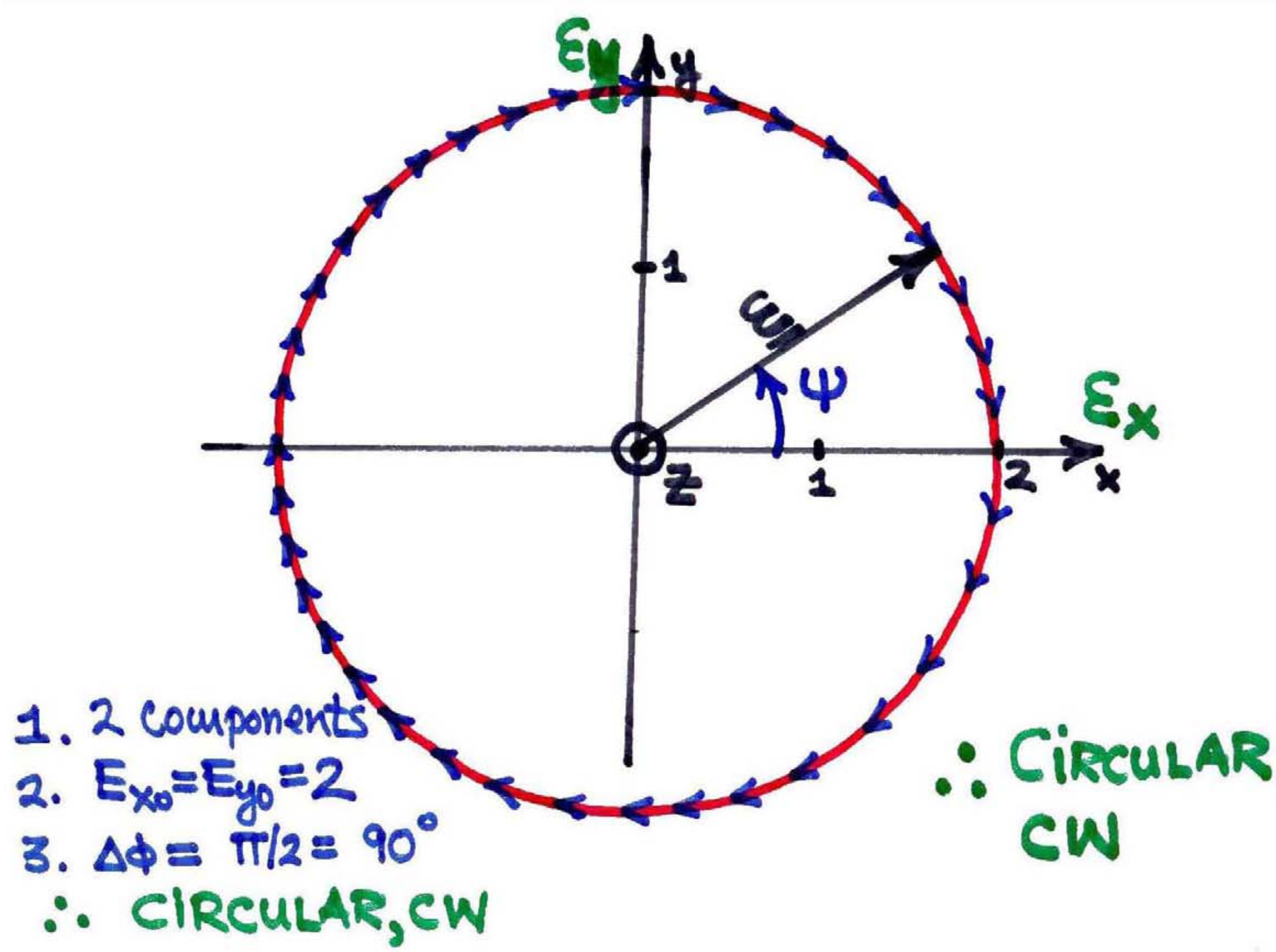
$$= 2\sqrt{\cos^2(\omega t + kz) + \sin^2(\omega t + kz)}$$

$$|\mathcal{E}| = 2$$

$$3.\quad \psi = \tan^{-1}\left(\frac{\mathcal{E}_y}{\mathcal{E}_x}\right) = \tan^{-1}\left(-\frac{\sin(\omega t + kz)}{\cos(\omega t + kz)}\right)$$

$$= \tan^{-1}\left[-\tan(\omega t + kz)\right] = -(\omega t + kz)$$

$$\psi = -(\omega t + kz)\Big|_{z=0} = -\omega t$$



Ey
y
1
E
ψ
Ex
1
2
x
z
1. 2 components
2. Exo=Eyo=2
3. ΔΦ= π/2= 90°
∴ CIRCULAR, CW
∴ CIRCULAR
CW