LINEAR ANTENNAS:
ROLE OF CONDUCTORS

Vertical Electric Dipole above Infinite Perfect Electric Conductor (PEC)

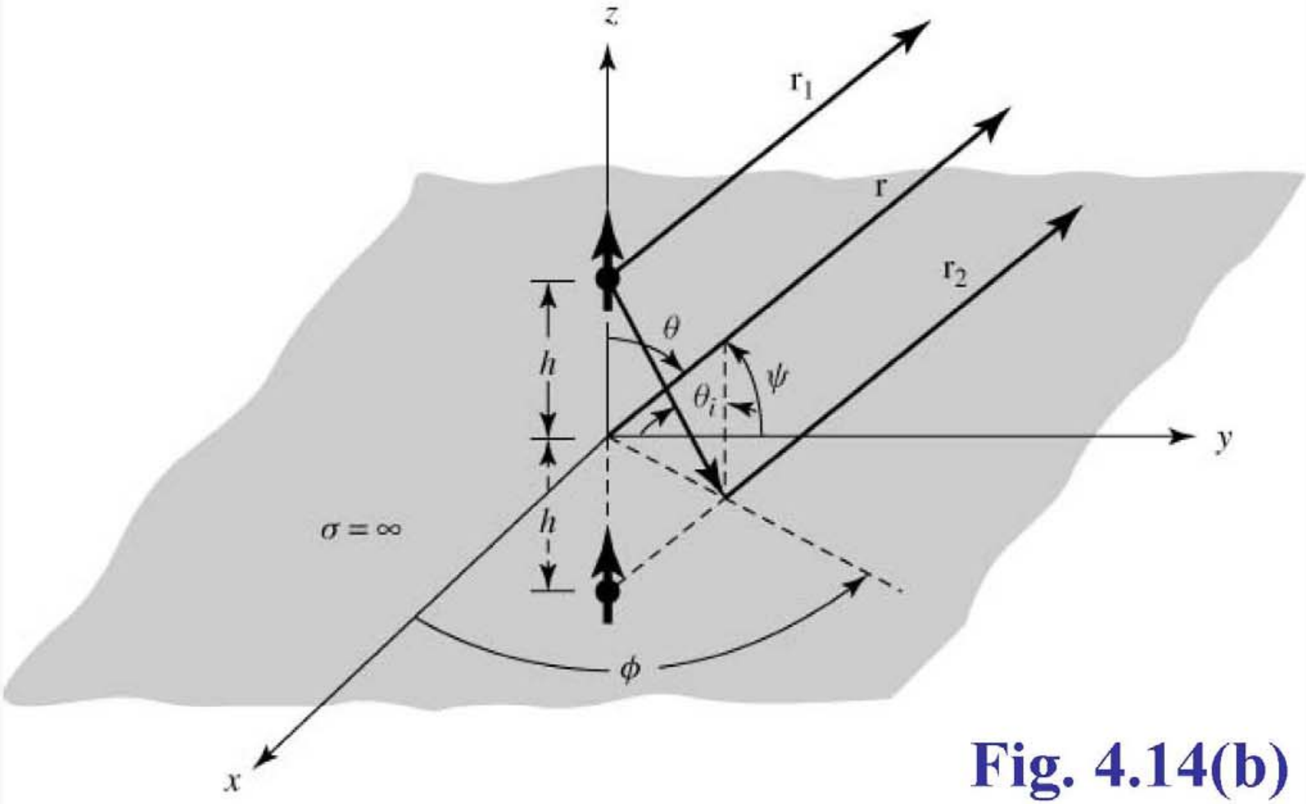

Fig. 4.14(b)

$$E_\theta = \underbrace{j\eta \frac{k I_o \ell e^{-jkr}}{4\pi r} \sin\theta}_{Element \quad Factor} \; \underbrace{\{2\cos(kh\cos\theta)\}}_{Array \quad Factor} \qquad z \geq 0$$

$$E_\theta = 0 \qquad z < 0$$

(4-99)

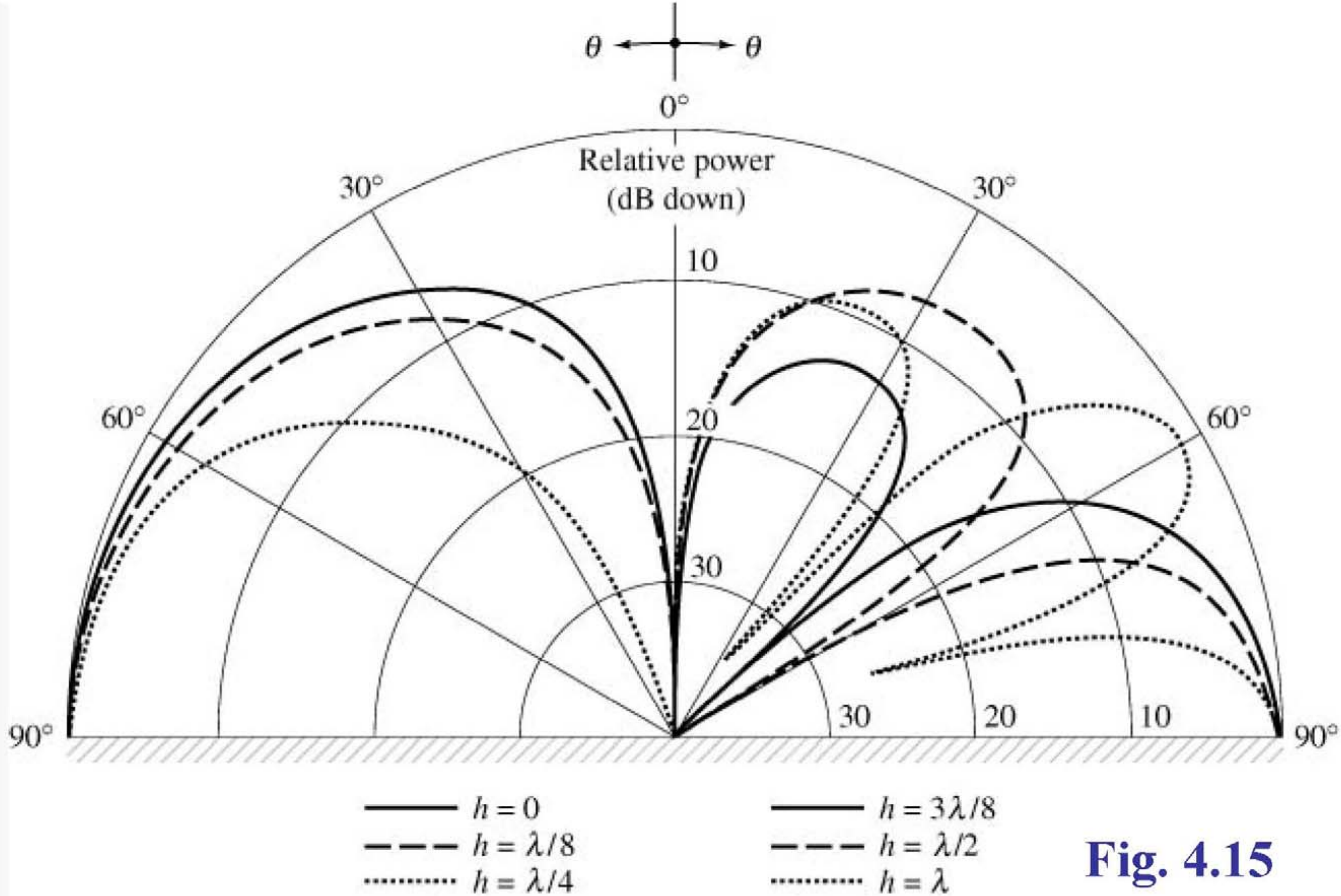
θ
θ
0°
Relative power
(dB down)
30°
30°
10
20
30
60°
60°
90°
90°
30
20
10
h = 0
h = λ/8
h = λ/4
h = 3λ/8
h = λ/2
h = λ

Fig. 4.15

Scalloping of Amplitude Pattern of Vertical Dipole

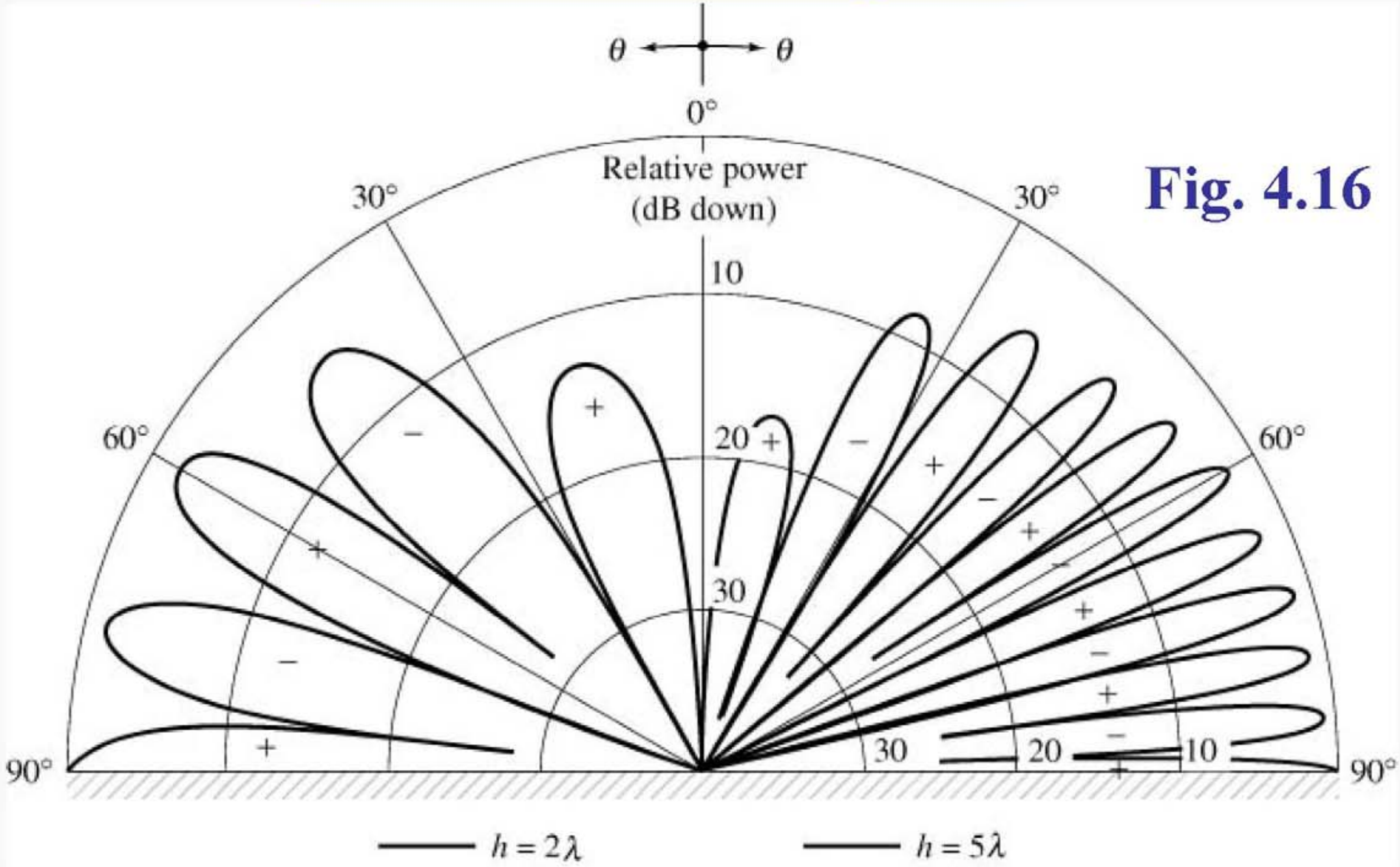

Fig. 4.16

LINEAR ANTENNAS NEAR CONDUCTORS: P_{RAD}, R_R, U,D

$$P_{rad} = \frac{1}{2\eta} \int_0^{2\pi} \int_0^{\pi/2} |E_\theta|^2 r^2 \sin\theta d\theta d\phi \qquad (4\text{-}101)$$

$$P_{rad} = \pi\eta \left|\frac{I_o \ell}{\lambda}\right|^2 \left\{\frac{1}{3} - \frac{\cos(2kh)}{(2kh)^2} + \frac{\sin(2kh)}{(2kh)^3}\right\} \qquad (4\text{-}102)$$

$$U = r^2 W_{av} = r^2 \frac{1}{2\eta} |E_\theta|^2$$

$$= \frac{\eta}{2} \left|\frac{I_o \ell}{\lambda}\right|^2 \sin^2\theta \cos^2(kh\cos\theta) \qquad (4\text{-}103)$$

Directivity and Radiation Resistance of Vertical Element Above a Ground Plane

$$D_0 = \frac{4\pi U_{\max}}{P_{rad}} = \frac{2}{\left[\frac{1}{3} - \frac{\cos(2kh)}{(2kh)^2} + \frac{\sin(2kh)}{(2kh)^3}\right]}$$

$$R_r = \frac{2P_{rad}}{|I_0|^2} = 2\pi\eta\left(\frac{l}{\lambda}\right)^2\left[\frac{1}{3} - \frac{\cos(2kh)}{(2kh)^2} + \frac{\sin(2kh)}{(2kh)^3}\right]$$

Directivity and Radiation Resistance of a Vertical Infinitesimal Electric Pole as a Function of Its Height above an Infinite Perfect Electric Conductor

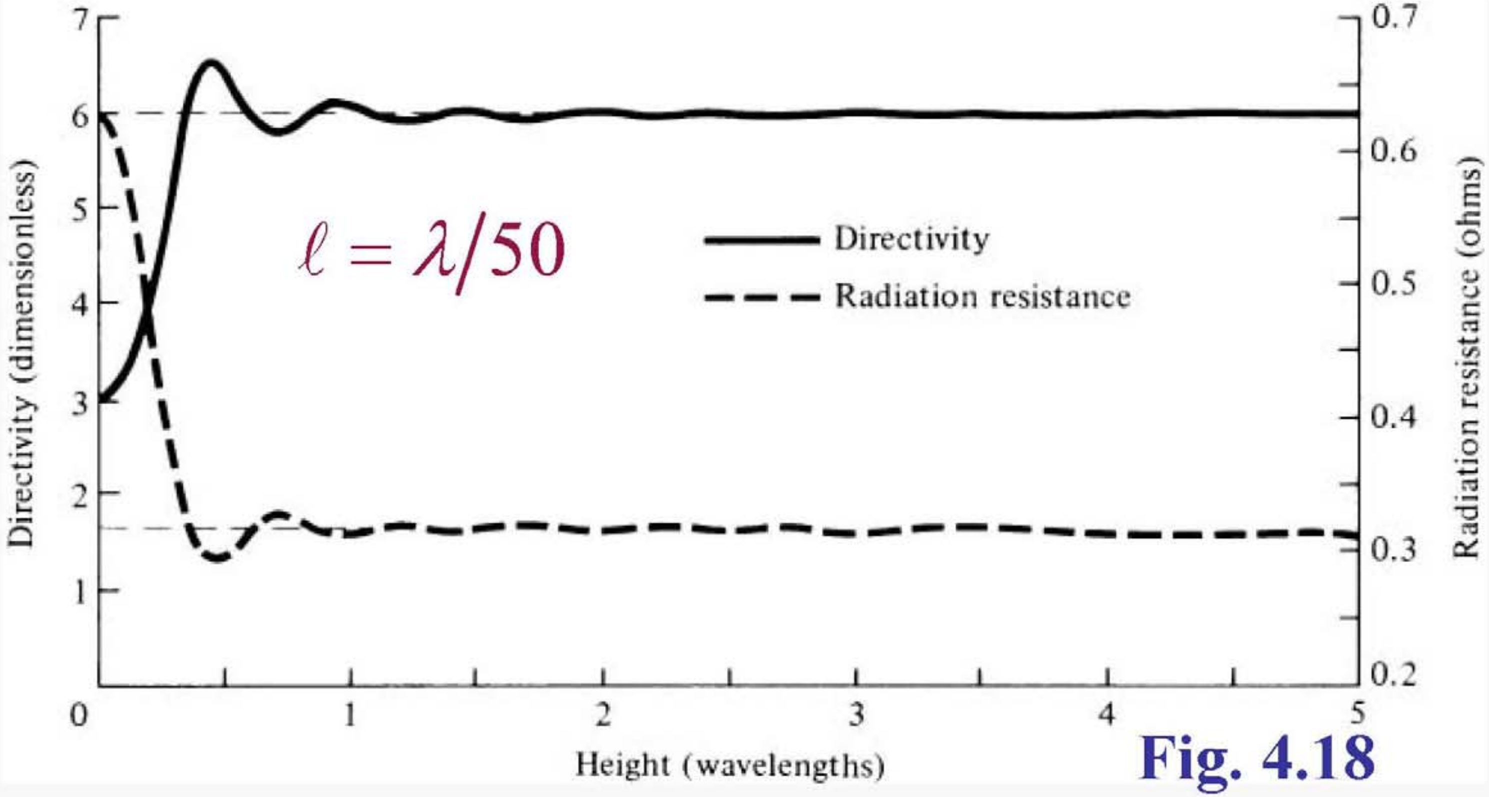

Fig. 4.18

Maximum Directivity Occurs When:

$$kh = 2.881$$

$$h = \frac{2.881}{k} = \frac{2.881}{2\pi / \lambda} = 0.4585\lambda$$

$$D_o = 6.566 = 8.173(dB)$$

Monopoles and Dipoles

- Monopoles and dipoles are widely used antennas in wireless communications systems.
- Monopoles are particularly popular for portable units and on automobiles and other vehicles.
- In practice, wide use is made of the *quarter-wavelength monopole*.

Monopoles and Dipoles

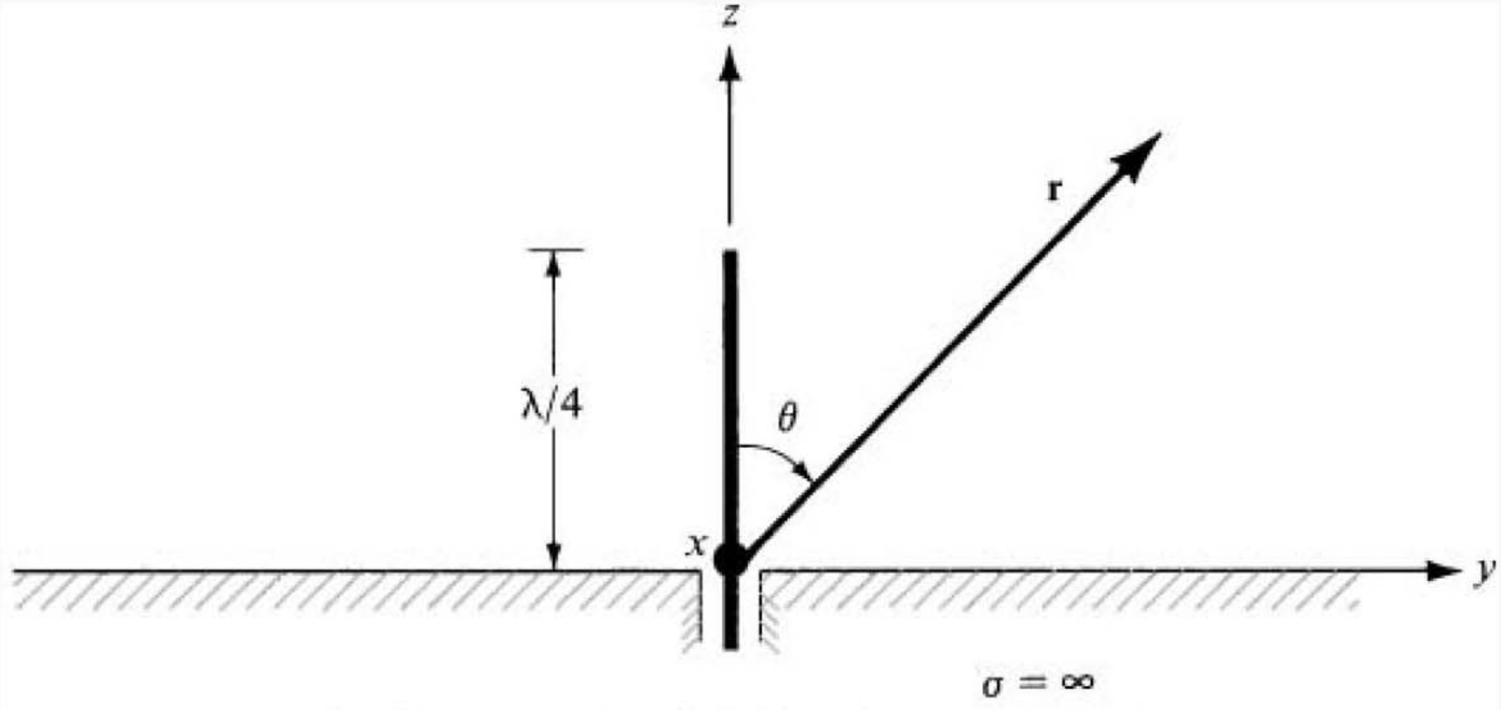

Fig. 4.19(a)

Equivalent of a λ/4 Monopole on a PEC

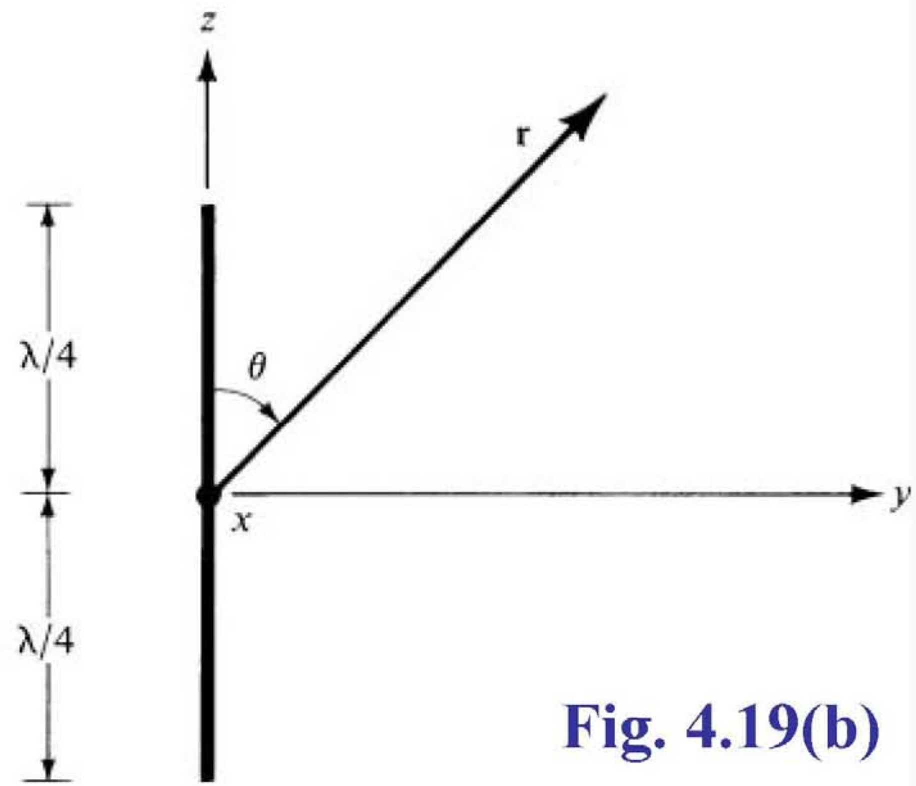

Fig. 4.19(b)

Half-Wavelength Dipole ($l = \lambda/2$)

$$E_\theta \simeq j\eta \frac{I_0 e^{-jkr}}{2\pi r}\left[\underbrace{\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}}_{Field\ Pattern}\right] \qquad (4\text{-}84)$$

$$H_\phi \simeq j \frac{I_0 e^{-jkr}}{2\pi r}\left[\underbrace{\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}}_{Field\ Pattern}\right] = \frac{E_\theta}{\eta} \qquad (4\text{-}85)$$

Directivity?

- Dipole in free space, and a monopole of half the length above a perfect ground plane will have the same radiation intensity in the top-half plane (since fields are identical).
- If the dipole emits power P, then the monopole emits power P/2, since the fields are zero in bottom hemisphere.
- Thus, $D_d = \frac{4\pi U_m}{P}$, whereas for the monopole, $D_m = \frac{4\pi U_m}{\frac{P}{2}} = 2D_d$

Radiation resistance?

- If the dipole emits power P, then the monopole emits power P/2, since the fields are zero in bottom hemisphere.

- Thus, $R_{rd} = 2P/I_0^2$, whereas for the monopole, $R_{rm} = 2(\frac{P}{2})/I_0^2 = R_{rd}/2$

Monopoles and Dipoles

$$Z_{in}\ \text{(monopole)} = \frac{1}{2} Z_{in}\ \text{(dipole)}$$
$$D_0\ \text{(monopole)} = 2 D_0\ \text{(dipole)} \qquad (4\text{-}106)$$

Use Of Linear Monopole

Linear monopoles, especially $\lambda/4$, are used as transmitting/receiving elements for wireless mobile/cellular telephones.

Examples:

A. Civilian Band (CB) Radio
B. Cellular Telephone
C. Rooftop Automobile Antenna
D. Amateur Radio Antenna

Examples of Antennas on Cellular and Cordless Telephones, Walkie-Talkies, and CB Radios

Fig. 4.22

Triangular Array Of Linear Dipoles For Wireless Mobile Communication Base Stations

Fig. 4.23

Electric Conductor

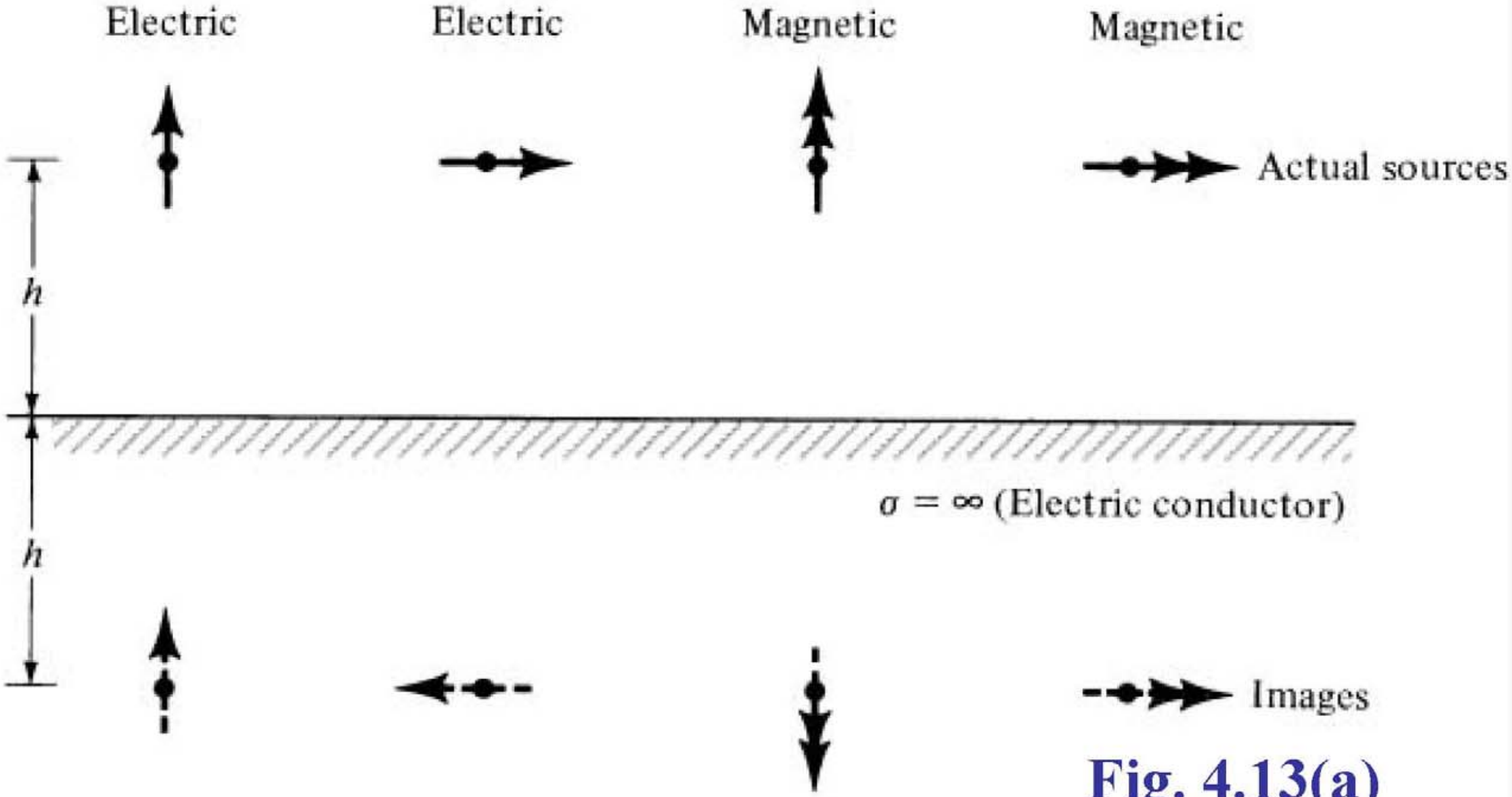

Fig. 4.13(a)

Horizontal Electric Dipole Above an Infinite Perfect Electric Conductor

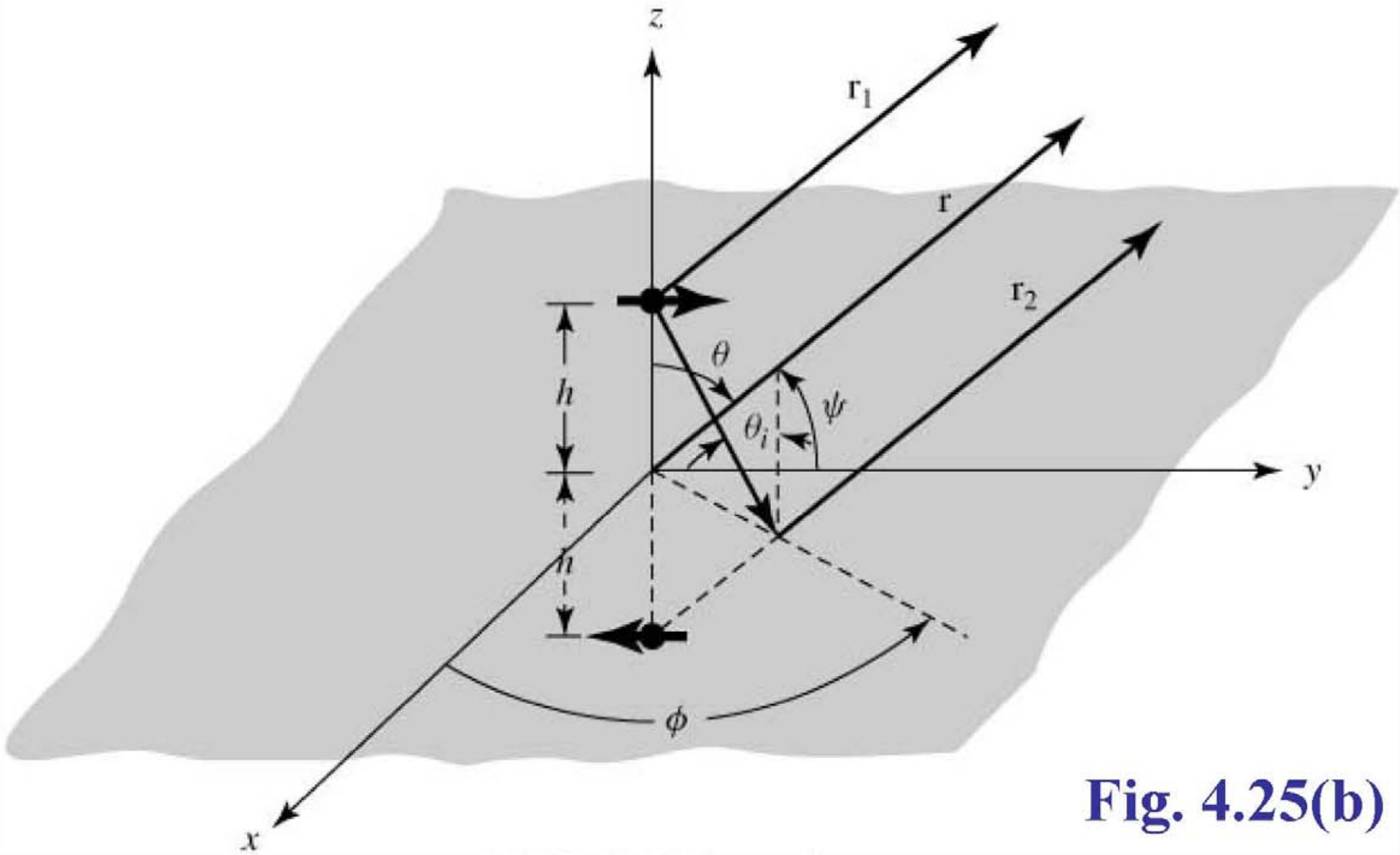

Fig. 4.25(b)

$$E_\psi^d = j\eta \frac{kI_o \ell e^{-jkr_1}}{4\pi r_1} \sin\psi \qquad (4\text{-}111)$$

$$E_\psi^r = jR_h \eta \frac{kI_o \ell e^{-jkr_2}}{4\pi r_2} \sin\psi \qquad (4\text{-}112)$$

$$= -j\eta \frac{kI_o \ell e^{-jkr_2}}{4\pi r_2} \sin\psi \qquad (4\text{-}112a)$$

Elevation Plane ($\phi = 90°$) Amplitude Patterns

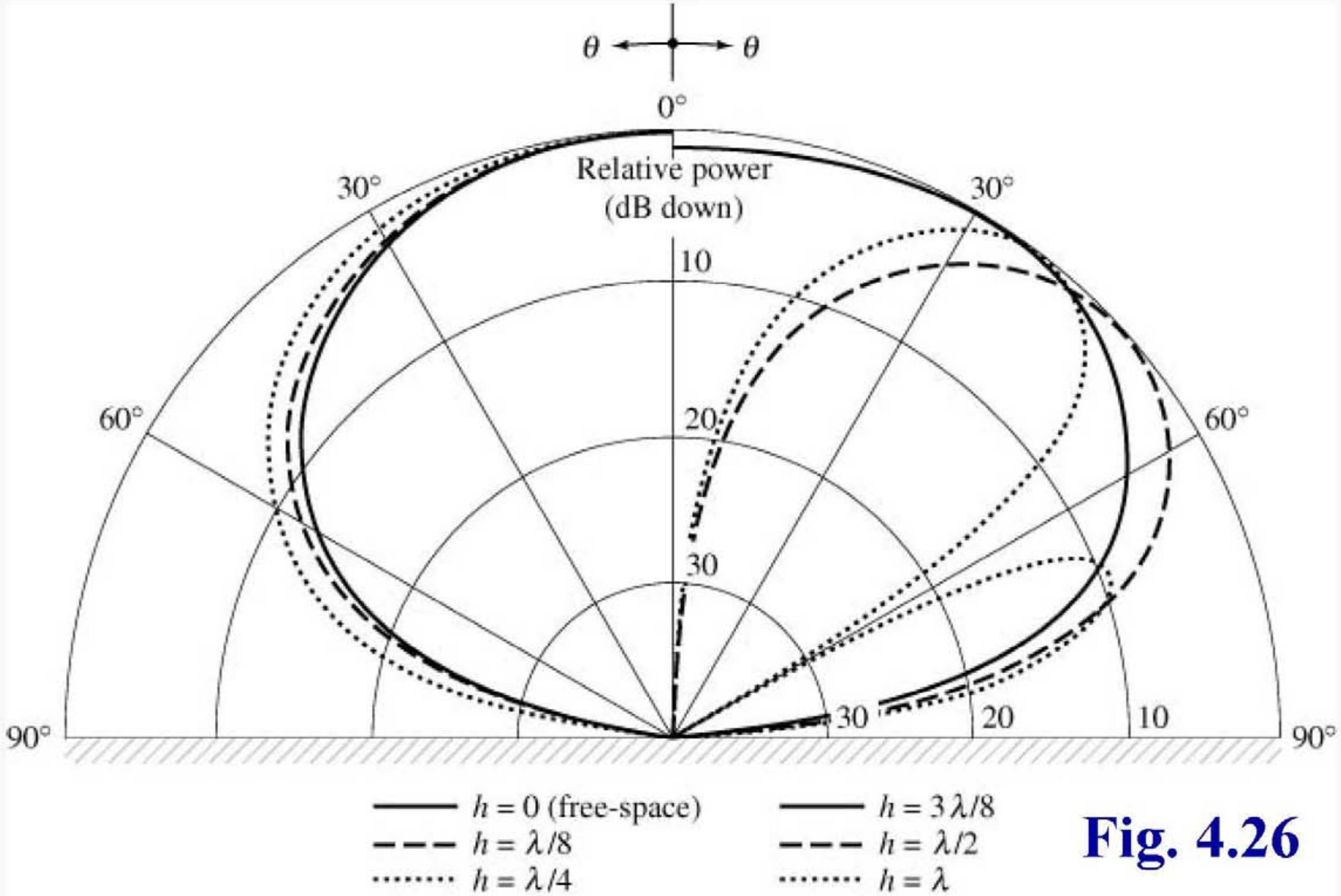

Fig. 4.26

3-D Amplitude Pattern of a Horizontal Dipole

$h = \lambda$

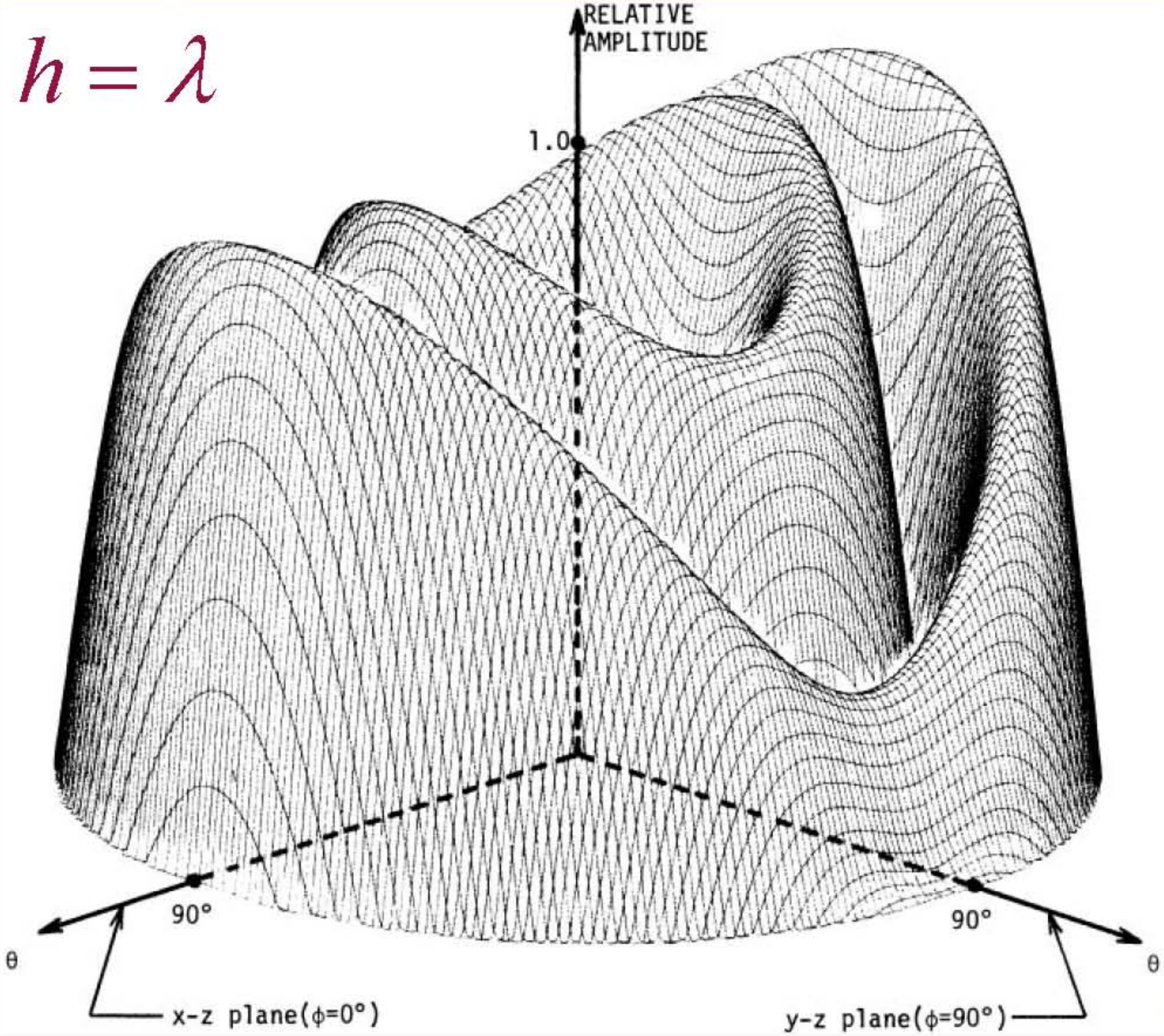

Fig. 4.27

Scalloping of Amplitude Pattern of Horizontal Dipole

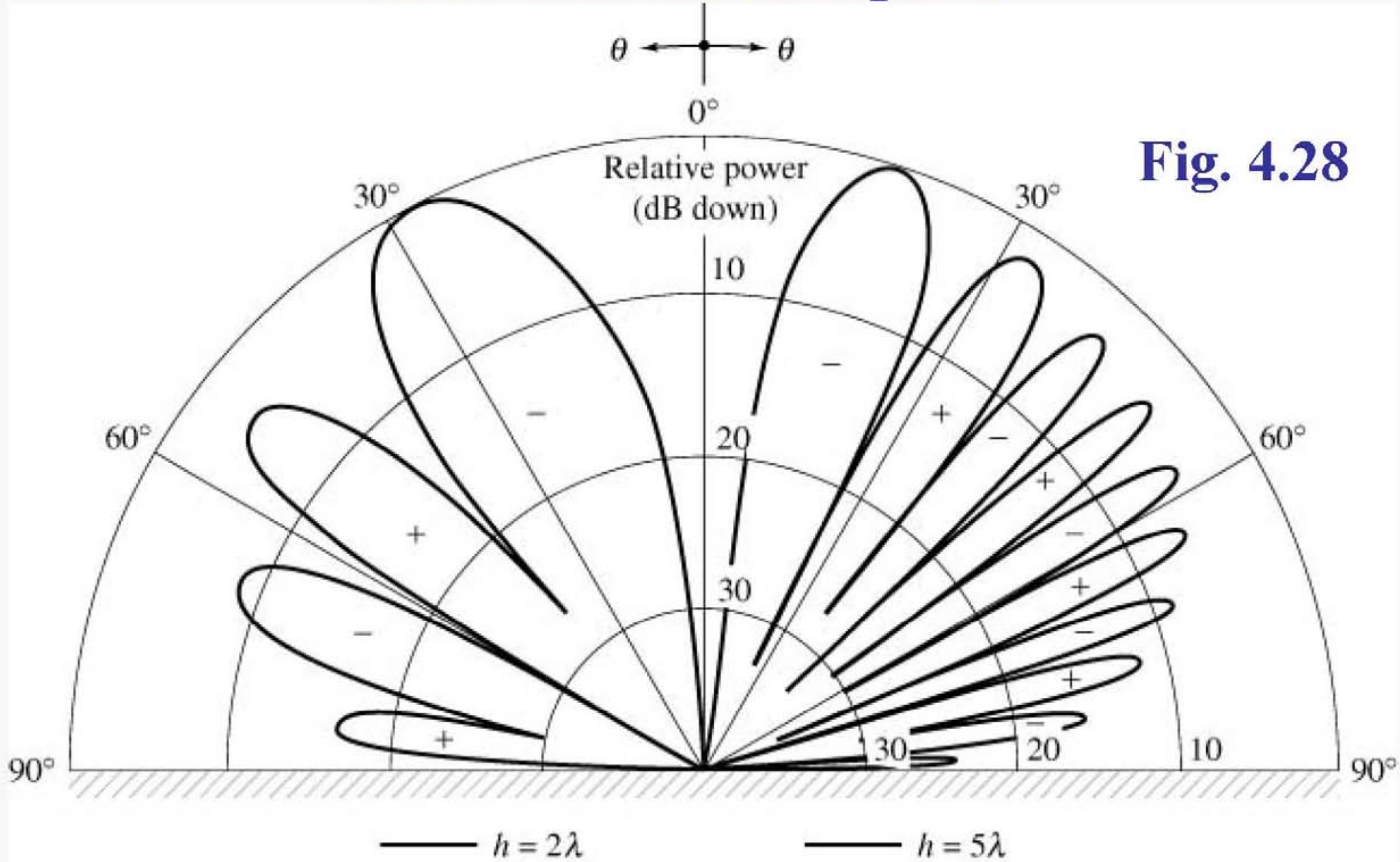

Fig. 4.28

Horizontal Dipole

$$\text{Number of Lobes} \cong 2\left(\frac{h}{\lambda}\right) \tag{4-117}$$

$$h >> \lambda$$