Linear Wire Antennas – Continued

EE-4382/5306 - Antenna Engineering

Perfect Ground Effects

Boundary Conditions

Physical Boundary Conditions

APPLIED EM

μ_1 and ε_1

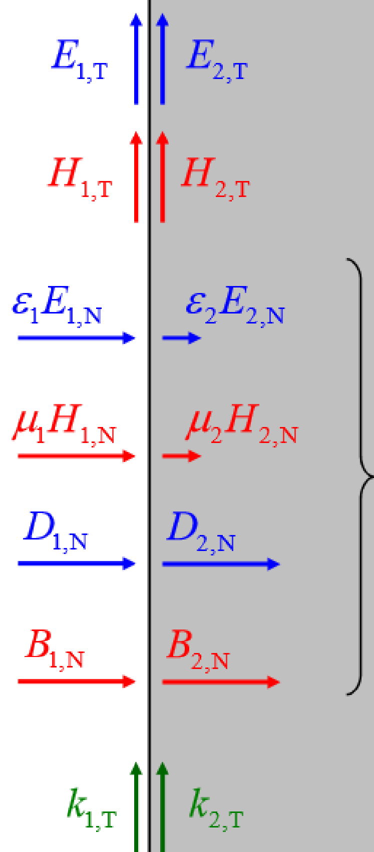
μ_2 and ε_2

Tangential components of E and H are continuous across an interface.

E and H fields normal to the interface are discontinuous across an interface.

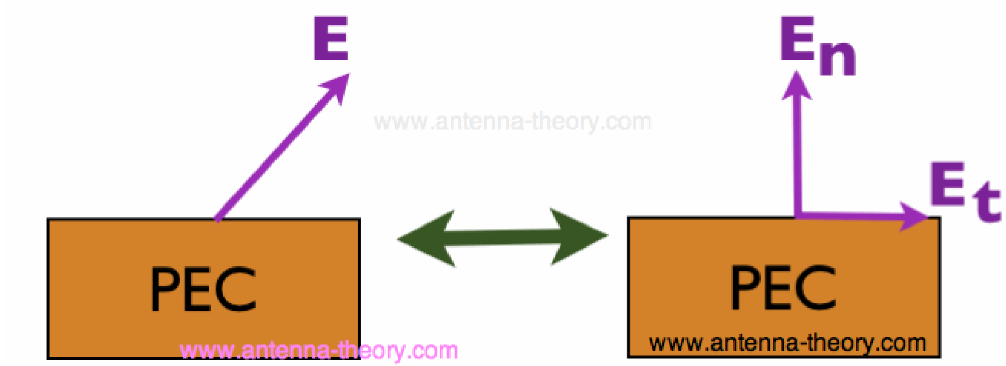
Note: Normal components of D and B are continuous across the interface.

Tangential components of the wave vector are continuous across an interface.



These are more complicated boundary conditions, physically and analytically.

Boundary Conditions on PEC



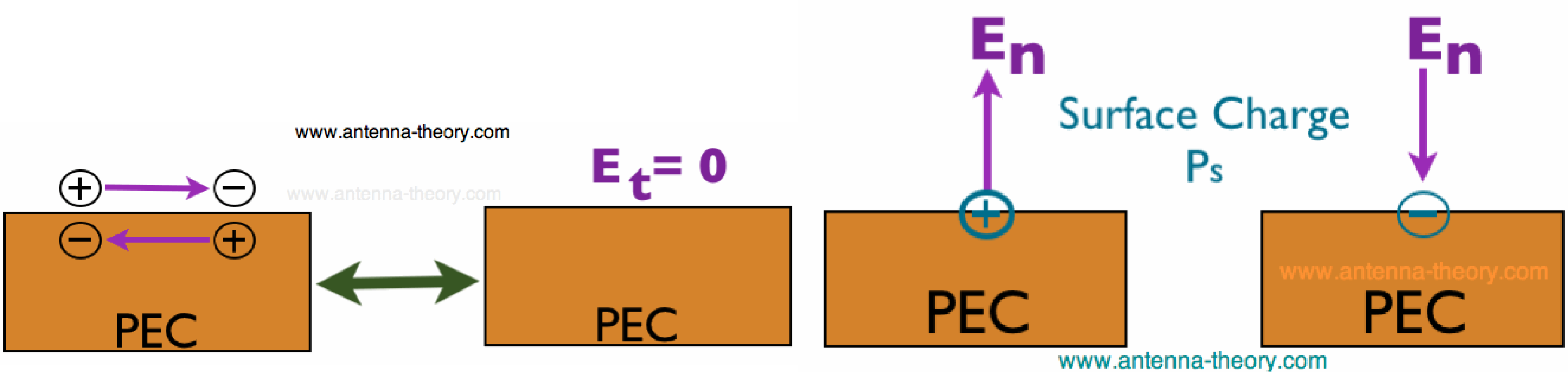


Image Theory

Virtual sources (images) are introduced to account for reflections. They also need to satisfy boundary conditions. We will assume infinitesimal dipoles for infinite ground plane.

Electric Conductor

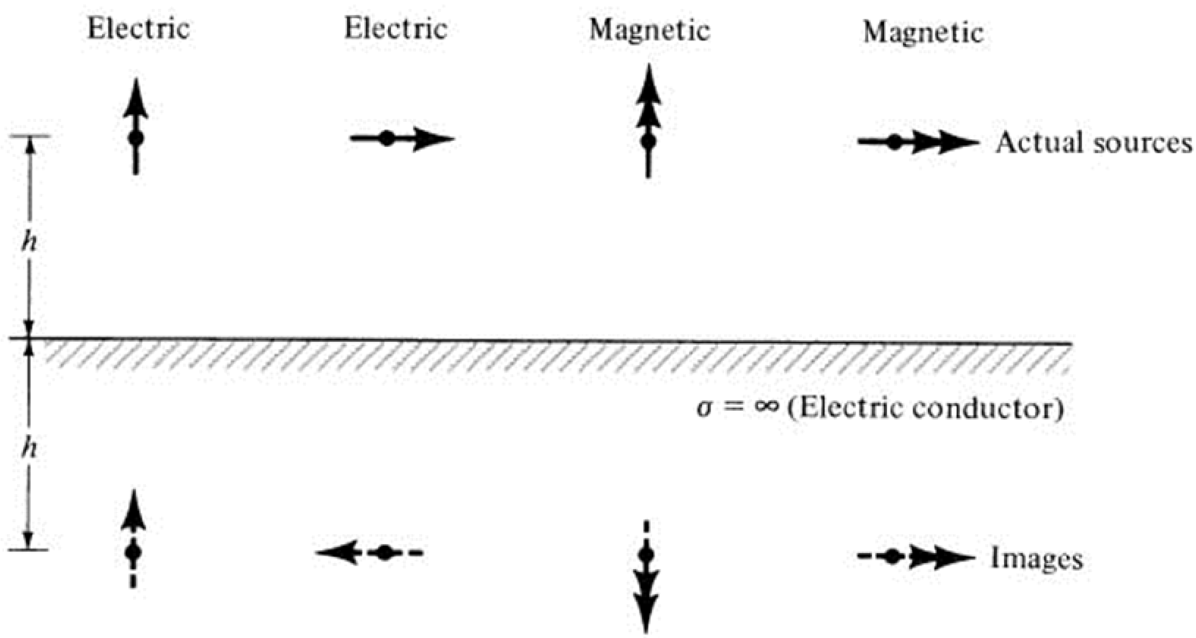


Fig. 4.16(a)

Chapter 4
Linear Wire Antennas

Image Theory – Vertical Dipole

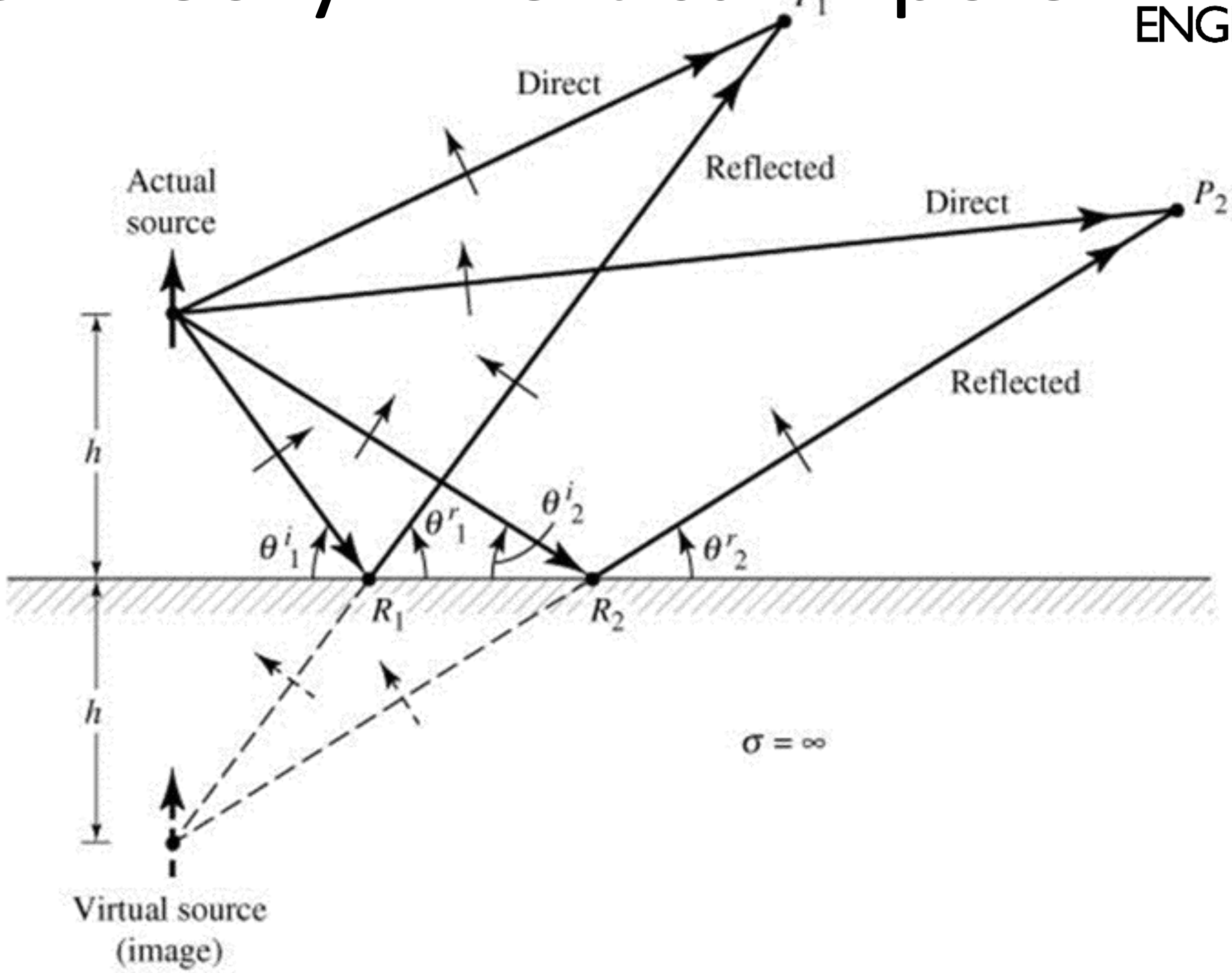


Fig. 4.15(a)

Chapter 4
Linear Wire Antennas

Image Theory – Vertical Dipole

For electric field direct component (radiated),

$$E_\theta^d = j\eta \frac{kI_0 l e^{-jkr_1}}{4\pi r_1} \sin(\theta_1)$$

For electric field reflected component,

$$E_\theta^r = jR_v \eta \frac{kI_0 l e^{-jkr_2}}{4\pi r_2} \sin(\theta_2)$$

R_v is reflection coefficient. For PEC, $R_v = 1$

$$E_\theta^r = j\eta \frac{kI_0 l e^{-jkr_2}}{4\pi r_2} \sin(\theta_2)$$

$$E_\theta^t = E_\theta^d + E_\theta^r$$

Image Theory – Vertical Dipole

Vertical Electric Dipole Above Infinite Perfect Electric Conductor (PEC)

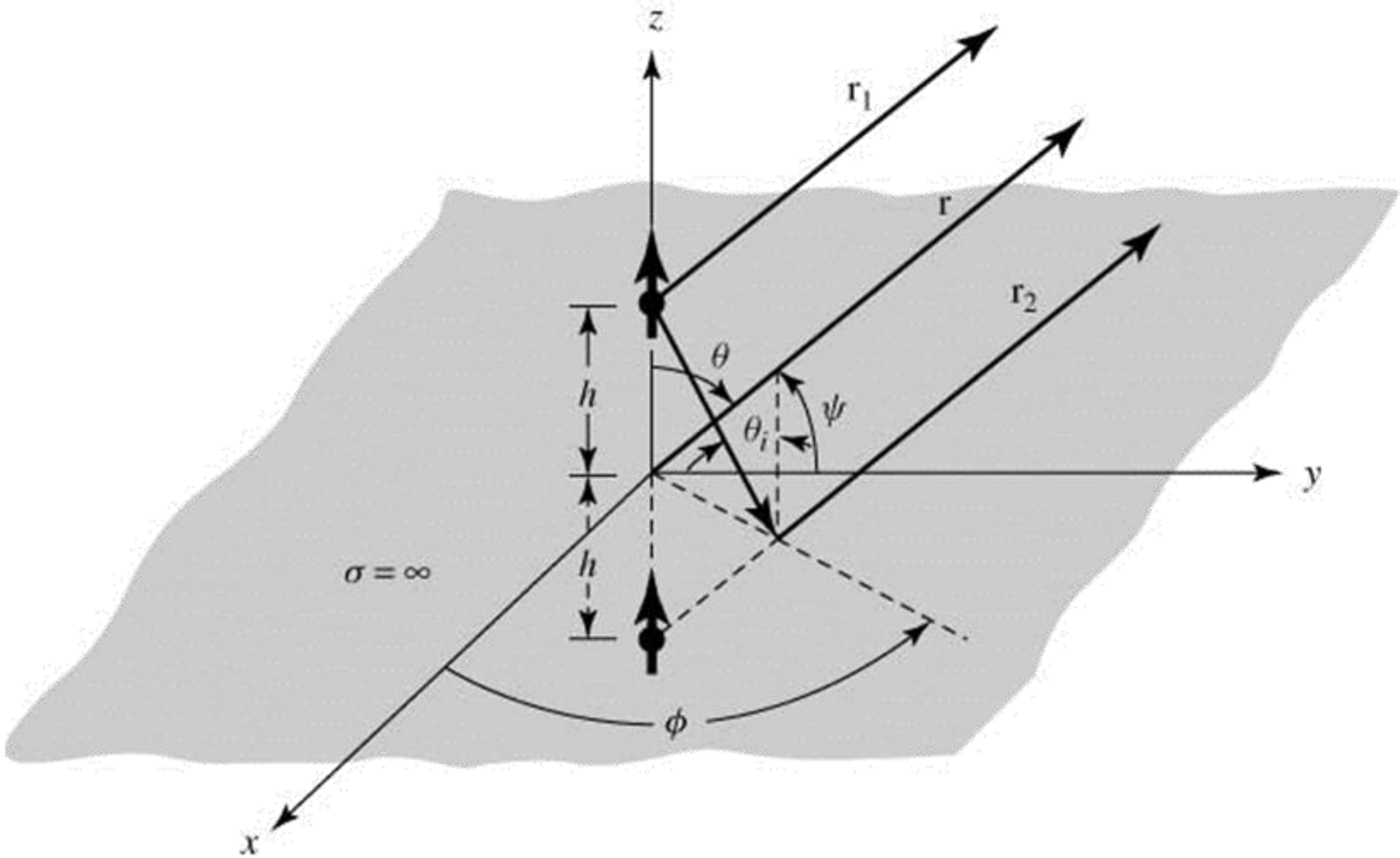


Fig. 4.17(b)

Chapter 4
Linear Wire Antennas

Image Theory – Vertical Dipole

In general, assuming the antenna lies at the origin, we can write that

$$r_1 = [r^2 + h^2 - 2rh\cos(\theta)]^{\frac{1}{2}}$$

$$r_2 = [r^2 + h^2 - 2rh\cos(\pi - \theta)]^{\frac{1}{2}}$$

For components in the far-field ($r \gg h$)

$$r_1 \cong r \; - hcos(\theta)$$

$$r_2 \cong r + hcos(\theta)$$

$$r_1 \cong r_2 \cong r$$

Thus we obtain

$$E_\theta = j\eta \frac{kI_0 l e^{-jkr}}{4\pi r} \sin(\theta)[2\cos(kh\cos\theta)]$$

Element Factor — Array Factor

And the scalloping (number of total lobes) is

$$\text{number of lobes } \cong \frac{2h}{\lambda} + 1 \text{ (for } h \gg \lambda)$$

Image Theory – Vertical Dipole

The normalized power pattern is equal to

$$U = r^2\left(\frac{1}{2\eta}|E_\theta|^2\right) = \frac{\eta}{2}\left|\frac{I_0 l}{\lambda}\right|^2 \sin^2(\theta)\cos^2(kh\cos\theta)$$

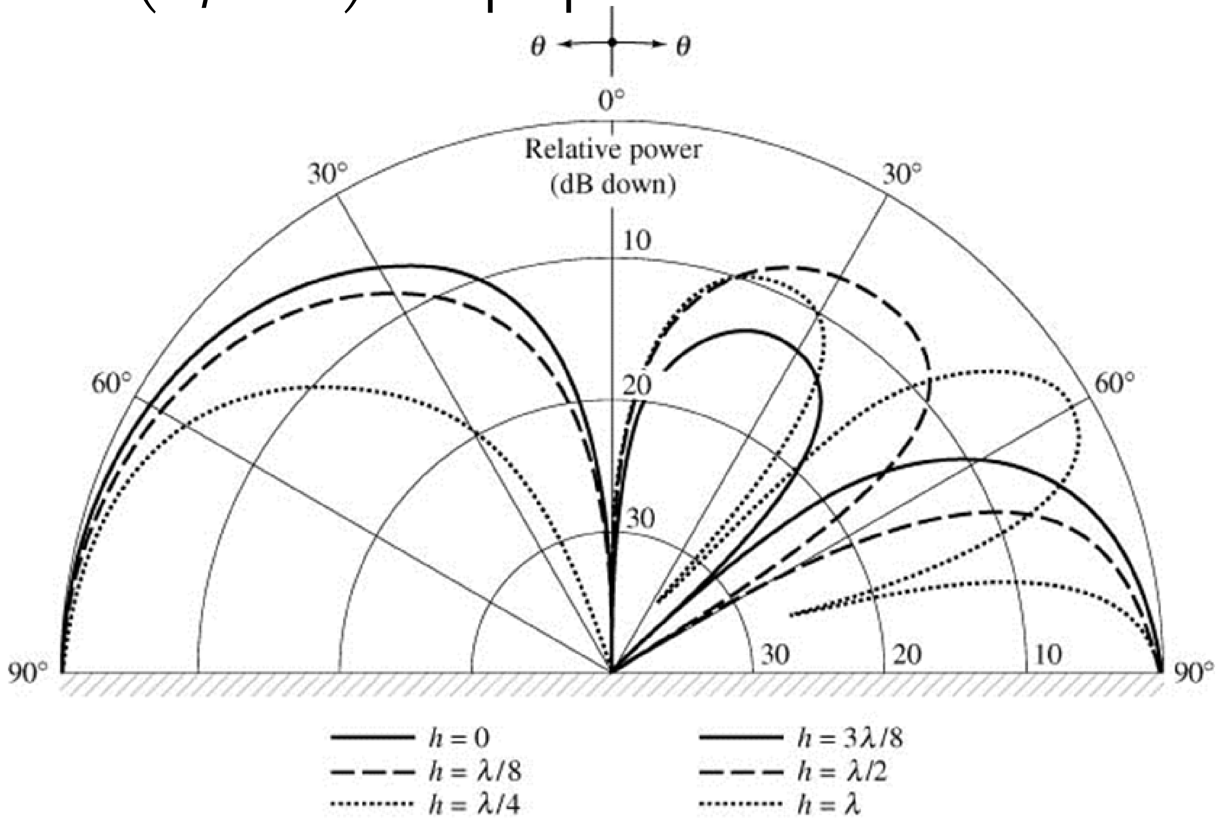


Fig. 4.18

Vertical Dipole Above Ground

Directivity and Radiation Resistance of Vertical Element Above a Ground Plane

$$D_0 = \frac{4\pi U_{\max}}{P_{rad}} = \frac{2}{\left[\frac{1}{3} - \frac{\cos(2kh)}{(2kh)^2} + \frac{\sin(2kh)}{(2kh)^3}\right]} \quad (4\text{-}104)$$

$$R_r = \frac{2P_{rad}}{|I_0|^2} = 2\pi\eta\left(\frac{l}{\lambda}\right)^2\left[\frac{1}{3} - \frac{\cos(2kh)}{(2kh)^2} + \frac{\sin(2kh)}{(2kh)^3}\right] \quad (4\text{-}105)$$

Chapter 4
Linear Wire Antennas

Vertical Dipole Above Ground

Maximum Directivity Occurs When:

$$kh = 2.881$$

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

$$D_o = 6.566 = 8.173 \ \ \text{(dB)}$$

Vertical Dipole Above Ground

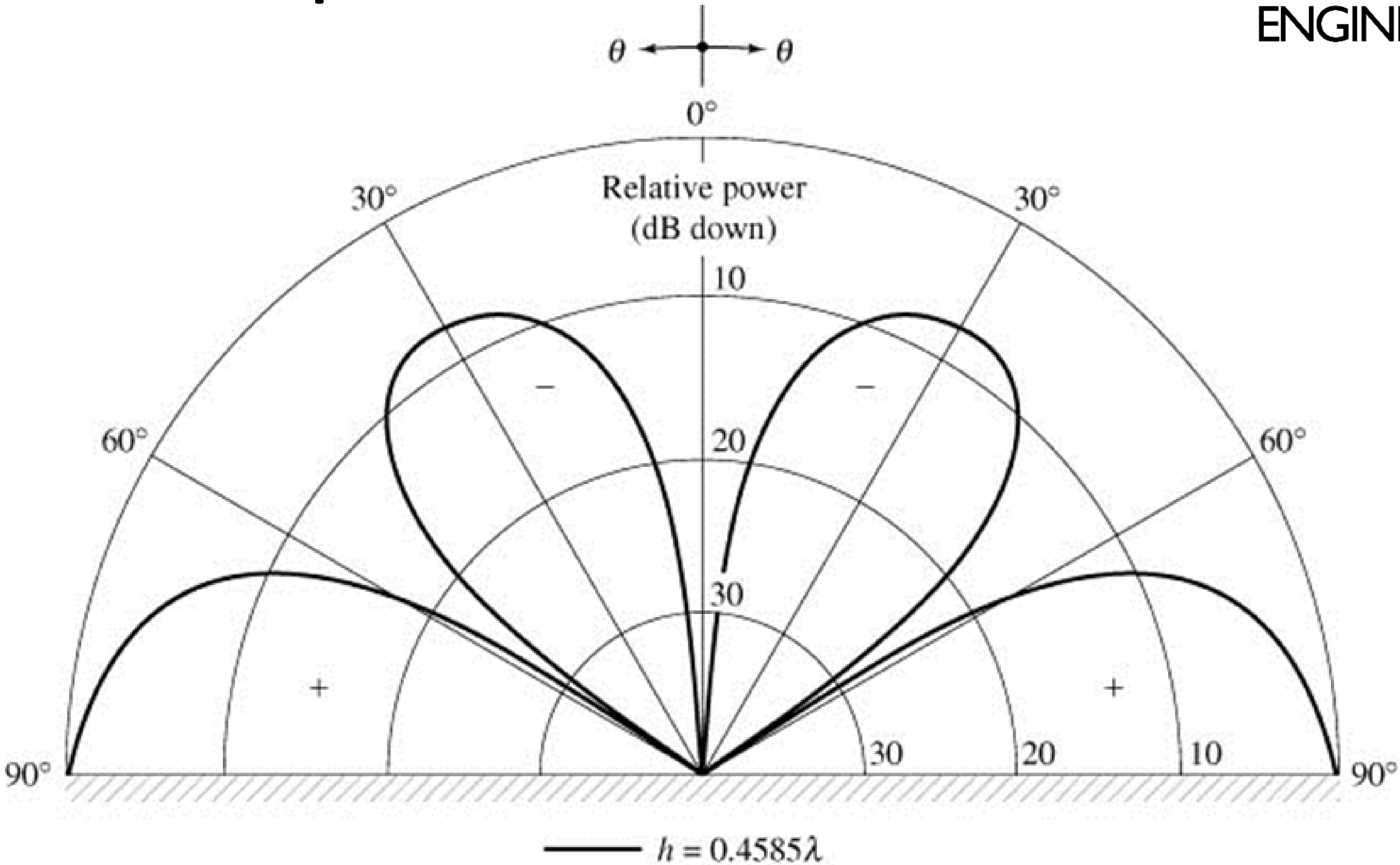
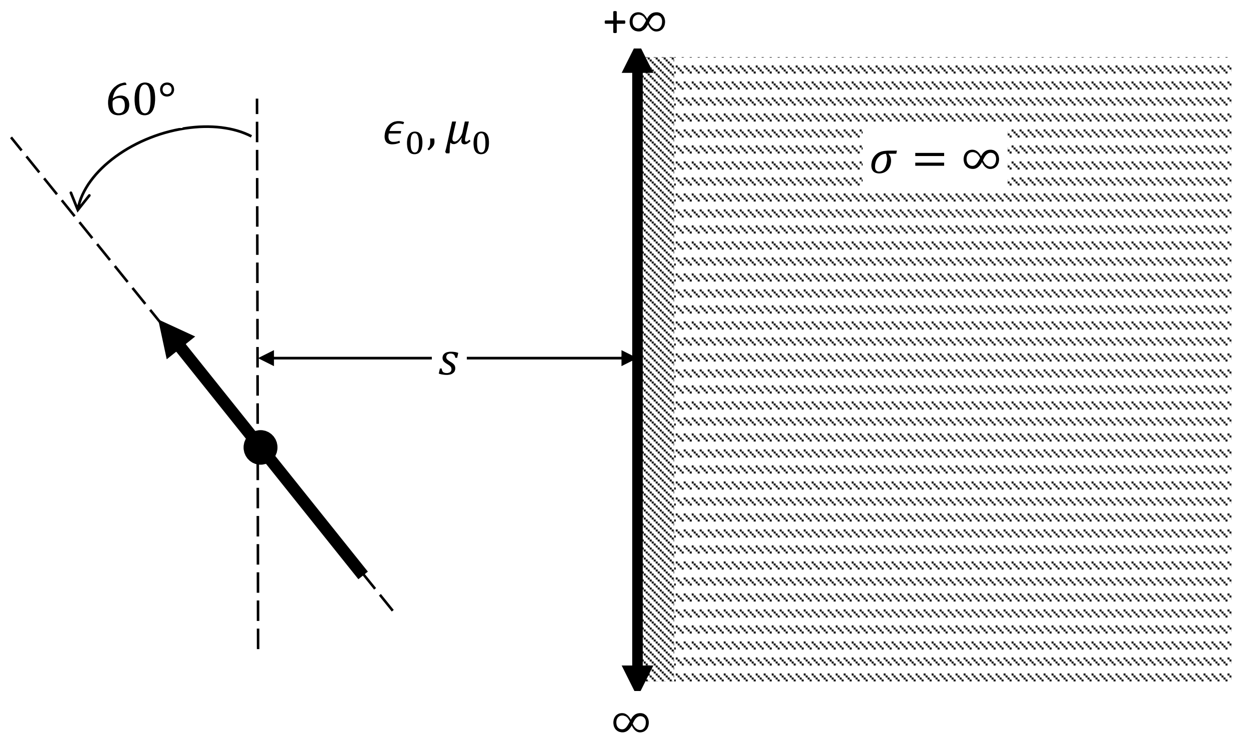


Fig. 4.20

Chapter 4
Linear Wire Antennas

Ground Effects - Example

An infinitesimal dipole of length l is placed a distance s from an air-conductor interface and at an angle of $\theta = 60°$ from the vertical axis, as shown in the figure. Sketch the location and direction of the image source which can be used to account for reflections. Be very clear when indicating the location and direction of the image.



Ground Effects - Example

An infinitesimal vertical dipole of length l is mounted on a pole at a height h above the ground, which is assumed to be flat, perfectly conducting, and of infinite extent. The dipole transmits in the VHF band ($f = 50 \text{ MHz}$) for ground-to-air communications. In order for the transmitting antenna to not interfere with a nearby radio station, it is necessary to place a null in the dipole pattern at an angle $80°$ from the vertical. What should the shortest height in meters be of the pole to achieve the desired null?