If a current flows through such an antenna, it launches electric and magnetic fields that can be expressed as

$$E_r = \frac{i_0 L \cos\theta}{2\pi\varepsilon_0 c}\left\{\frac{1}{d^2} + \frac{c}{j\omega_c d^3}\right\}e^{j\omega_c(t - d/c)} \tag{4.10}$$

$$E_\theta = \frac{i_0 L \sin\theta}{4\pi\varepsilon_0 c^2}\left\{\frac{j\omega_c}{d} + \frac{c}{d^2} + \frac{c^2}{j\omega_c d^3}\right\}e^{-j\omega_c(t - d/c)} \tag{4.11}$$

$$H_\phi = \frac{i_0 L \sin\theta}{4\pi c}\left\{\frac{j\omega_c}{d} + \frac{c}{d^2}\right\}e^{j\omega_c(t - d/c)} \tag{4.12}$$

with $E_\phi = H_r = H_\theta = 0$. In the above equations, all $1/d$ terms represent the radiation field component, all $1/d^2$ terms represent the induction field component, and all $1/d^3$ terms represent the electrostatic field component. As seen from Equations (4.10) to (4.12), the electrostatic and inductive fields decay much faster with distance than the radiation field. At regions far away from the transmitter (far-field region), the electrostatic and inductive fields become negligible and only the radiated field components of E_θ and H_ϕ need be considered.

In free space, the *power flux density* P_d (expressed in W/m^2) is given by

$$P_d = \frac{EIRP}{4\pi d^2} = \frac{P_t G_t}{4\pi d^2} = \frac{E^2}{R_{fs}} = \frac{E^2}{\eta}\ \text{W/m}^2 \tag{4.13}$$

where R_{fs} is the intrinsic impedance of free space given by $\eta = 120\,\pi\Omega$ (377 Ω). Thus, the power flux density is

$$P_d = \frac{|E|^2}{377\Omega}\ \text{W/m}^2 \tag{4.14}$$

where $|E|$ represents the magnitude of the radiating portion of the electric field in the far field. Figure 4.3a illustrates how the power flux density disperses in free space from an isotropic point source. P_d may be thought of as the *EIRP* divided by the surface area of a sphere with radius d. The power received at distance d, $P_r(d)$, is given by the power flux density times the effective aperture of the receiver antenna, and can be related to the electric field using Equations (4.1), (4.2), (4.13), and (4.14).

$$P_r(d) = P_d A_e = \frac{|E|^2}{120\pi}A_e = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2} = \frac{|E|^2 G_r \lambda^2}{480\pi^2}\ \text{W} \tag{4.15}$$

Equation (4.15) relates electric field (with units of V/m) to received power (with units of watts), and is identical to Equation (4.1) with $L = 1$.

Often it is useful to relate the received power level to a receiver input voltage, as well as to an induced E-field at the receiver antenna. If the receiver antenna is modeled as a matched resistive load to the receiver, then the receiver antenna will induce an rms voltage into the receiver