Dipolar radiation: expressions.

We use the expression for the radiating (not static) electric field at large distance from the dipole:

$$\mathbf{E}_{rad} = - \frac{p_m k^2 \exp(j\omega t')}{4\pi \varepsilon_o r} \sin\theta \ \mathbf{e}_\theta \qquad (1)$$

with: $j = \sqrt{-1}$,

- E_{rad} = field strength of the radiating field [N/C=V/m],
- p_m = amplitude of the oscillating dipole [Cm],
- $k = 2\pi/\lambda$ = wavevector [1/m], λ = wavelength [m],
- ω = angular oscillation frequency [1/s],
- r, θ = distance and angle between dipole vector and observer (at position P) (fig.1),
- t' = **retarded time** $t' = t - r/c$ (c=light velocity).

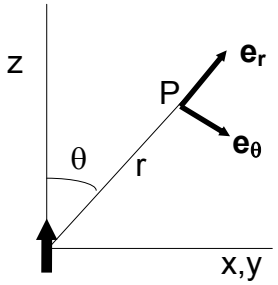

Fig. 1. Dipole and unit vectors.

From eq.(1) we can derive: $$\mathbf{E} = \frac{j}{2\pi\varepsilon_0 cr} \frac{\cos(\frac{1}{2}\pi\cos\theta)}{\sin\theta} I_m \exp[\, j(\omega t' + \alpha)]\, \mathbf{e}_\theta \qquad (2)$$

with I_m = amplitude of the alternating current through the antenna, $\omega = 2\pi f$ (f = send frequency) and α = the phase angle (with respect to a certain chosen zero phase).
This equation is used in the program.
The user may define a number of dipoles at different positions, under varying angles, with varying currents and phases. The program calculates sums of both the real and imaginary parts of the field strengths of all individual dipoles, and the modulus E_{tot} (square root of the sum of the squares of these sums).

Moreover, the program also calculates a "**Quality index**" Q , measuring the *energy efficiency* and the *directivity*:

$$Q = \frac{|E_{tot}|^2}{(FWHM)\,.\,I_{tot}{}^2.} \quad ; \text{waarin} \quad I_{tot} = \sum_{i=1}^{N} I_i \qquad (3)$$

with $|E_{tot}|$ = amplitude of the field strength, and $|E_{tot}|^2$ proportional with the intensity [Watt/m^2] at the position of the observer, *FWHM* the full-width-at-half-maximum of the "peak", N the number of antennas, I_{tot} the total current through all antennas together. $I_{tot}{}^2$ is proportional to the energy supplied..

Literature:

Griffiths : *Introduction to Electrodynamics*: Ch. 9: Electromagnetic Radiation.
Lorrain, Corson & Lorrain : *Electromagnetic Fields and Waves*,

- ch. 37: Radiation I: V and E: (par 1,2,4);
- ch. 38: Radiation II: Electric Dipole Transmitting Antenna: (par. 2, sub 1 t/m 4);
- ch. 39: Radiation III: Half-wave Antenna, Antenna Arrays; (par. 1,2).