A Different Picture of Radiation

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Introduction

A major difference between radiating and non-radiating fields is that the level of a non-radiating field decreases with the third power of the radius (volume), while the level of a radiating field decreases with the first power. The analysis presented here provides evidence as to how and why this occurs. The conclusions are somewhat surprising. It has been accepted as fact that waves cannot move faster than the speed of light. However, it is only the propagation of signals in the radial direction that is limited to the speed of light. Tangential waves travel much faster. Electromagnetic waves are not seen to "break away", but to vary with the high tangential velocity of the field, producing a compression of the wave and a corresponding time delay with distance.

Analysis

The radiation equations for a dipole antenna can be found in various reference texts, including an early text by R. Mesny [*1*], and in more recent reference texts [*2*]:

$$E_r = -\frac{30\ell\lambda I}{\pi}\frac{\cos\theta}{r^3}(\cos u - \alpha r\sin u) \qquad (1)$$

$$E_t = +\frac{30\ell\lambda I}{2\pi}\frac{\sin\theta}{r^3}(\cos u - \alpha r\sin u - \alpha^2 r^2\cos u) \qquad (2)$$

$$H = -\frac{\ell I}{4\pi}\frac{\sin\theta}{r^2}\left(\sin u - \alpha r\cos u\right) \qquad (3)$$

where

ℓ = length of dipole	λ = wavelength
f = frequency	I = current in dipole
θ = angle transverse to dipole axis	$\omega = 2\pi f$
r = radial distance from center of the dipole	$\alpha = 2\pi/\lambda$
$u = (\omega t - \alpha r)$	

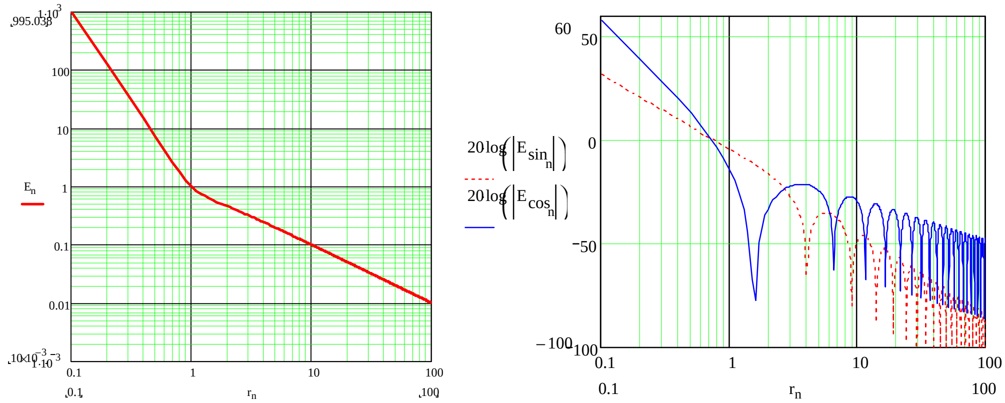
Then substituting the values of α, u, $\lambda = c/f$, $\omega = 2\pi f$ and $v_t = \omega r$

$$E_r = -\frac{30\lambda\ell I}{\pi}\frac{\cos\theta}{r^3}\left(\cos\omega(t-\frac{r}{c}) - \frac{v_t}{c}\sin\omega(t-\frac{r}{c}\right) \qquad (4)$$

$$E_t = +\frac{30\ell I\sin\theta}{\omega r^3}\left(-\frac{v_t}{c}\sin\omega\left(t-\frac{r}{c}\right)+\left(1-\frac{v_t^2}{c^2}\right)\cos\omega\left(t-\frac{r}{c}\right)\right) \qquad (5)$$

$$H = +\frac{\ell I}{4\pi}\frac{\sin\theta}{r^2}\left(\sin\omega(t-\frac{r}{c}) - \frac{v_t}{c}\cos\omega(t-\frac{r}{c})\right) \qquad (6)$$

The absolute value of the *E*-field level of equation (5) is plotted versus radius in Figures 1(a) and (b).



(a) (b)

Figure 1. Field Potential as a Function of Distance for a Half Wave Antenna (normalized for $\omega = 1 = c$). Note that the transition region begins at $r = 2/\pi$)

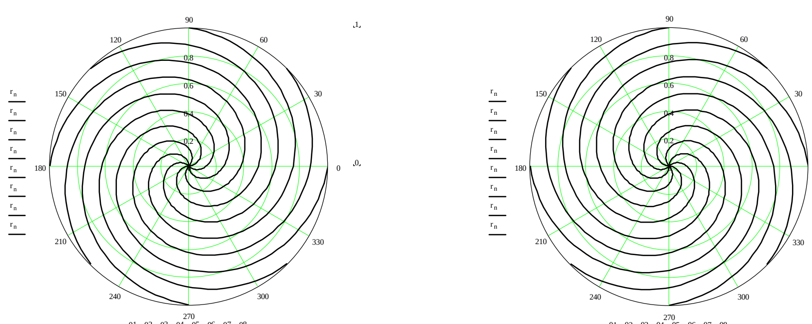
The radial component of the *E*-field becomes negligible in comparison with the tangential component when $\omega r >> c$. For simplification, the angle with respect to the axis of the dipole, θ, is set to $\pi/2$, and the antenna current is set to unity. The normalized electromagnetic and electric and strengths in far field of a half-wave dipole antenna at this angle are

$$E_t \cong -\frac{30\pi}{r}\cos\omega(t-\frac{r}{c}) = -\frac{30\pi}{2r}\left(e^{j\omega(t-\frac{r}{c})} + e^{-j\omega(t-\frac{r}{c})}\right) = -\frac{30\pi}{2r}\left(e^{j\varphi} + e^{-j\varphi}\right) \quad (7)$$

$$H \cong -\frac{1}{4r}\left(e^{j\omega(t-\frac{r}{c})} + e^{-j\omega(t-\frac{r}{c})}\right) = -\frac{1}{4r}\left(e^{j\varphi} + e^{-j\varphi}\right) \quad (8)$$

The field equations for the *E*-field and the *H*-field are coincident in the far field, differing only by a scale factor.

The r/c term in the exponent produces a phase shift that increases with distance. When the phase angle, φ, is equal to $\pi/2$, the vectors of equation (7) cross the vertical axis. Figure 2 depicts the corresponding r/φ curve for the *x*-*z* plane in the far field,



(a) (b)

Figure 2 Plots of the angle versus radius for the two vectors of equation (7) at eight succeeding time increments. The waves are moving CW in (a) and CCW in (b).

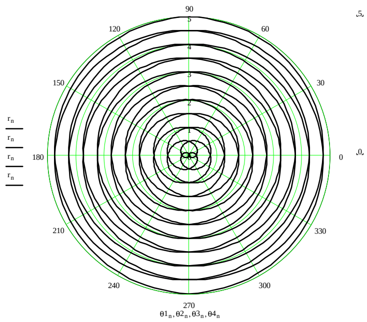


Figure 3(a). Plot of the two vectors of equation (7) versus radius

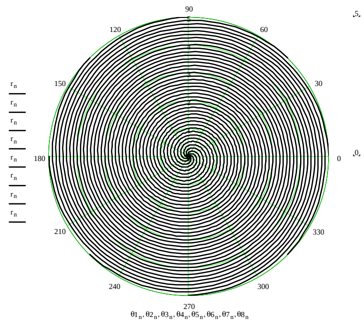


Figure 3(b). Rotating vectors at greater distances produces nearly circular patterns

Figure 3(a) includes both sets of vectors of Equation (2). Note that these vectors add along the vertical axis and subtract along the horizontal axis. Figure 3(b) shows that the shape of the vectors becomes nearly circular in the far field. The three-dimensional waves are actually in the form of hyperboloids (of two sheets).

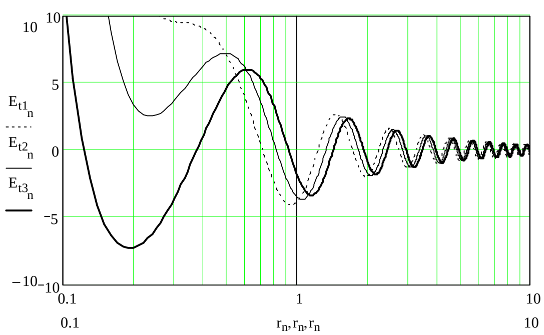


Figure 4(a). A plot of the radiation equation as a function of radius at three consecutive time increments.

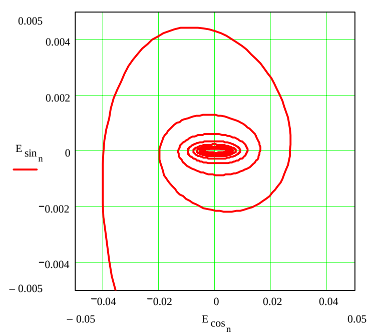


Figure 4(b).The orthogonal components of the radiating wave plotted against one another at one instant of time.

The linear plots of Figure 4 illustrate smooth progressions through the transition region.

Comments and Observations

1. The above plots portray a gradual process where the ratio of the tangential field level to that of the radial field increases with distance, thus contradicting earlier assertions that electromagnetic waves "break away from the dipole and form closed loops that travel through free space with speed *c*" [*4*].

2. The curve of Figure 1(a) has a rather sharp break in the curve near $r = \lambda$. However, the signal component curves of Figure 1(b) depict a smooth and more gradual transition from the near field to the far field.

3. The "principle of Huyghens" [*5*] asserts that sharp signals are transmitted as sharp signals, propagating in rays through space. For a ray whose angle is fixed,

$$\theta = \omega\left(t - \frac{r}{c}\right) = const\,. \qquad (8)$$

Solving equation (9) for *r* and differentiating,

$$\frac{dr}{dt} = c \qquad (9)$$

for any given ray.

4. It has been argued that the propagation of waves through space occur by virtue of the electric field creating an electromagnetic wave, which in turn creates a subsequent electric wave [*3*], similar to the action of an oscillating *L-C* circuit. However, in the far field, both the transverse electric wave and the electromagnetic wave peak <u>at the same instant of time</u> [equations (7) and (8)], whereas exactly the opposite occurs for an L-C circuit.

5. The $(1 - v^2/c^2)$ term in equations (16), (17) and (18) appear in various mathematical models of physics and engineering. The Irish physicist, G. F. Fitzgerald proposed that objects grew shorter in the direction of their absolute motion, due to the pressure of the "ether wind" [*4*]

$$L = L_0\sqrt{1 - \frac{v^2}{c^2}}\,. \qquad (10)$$

The Fitzgerald contraction was analyzed by the Dutch physicist, H.A. Lorentz, who deduced that mass increases inversely with the Fitzgerald ratio. Einstein argued that time decreases in proportion to the Fitzgerald ratio in his General Theory of Relativity. A new model of the hydrogen atom, analyzed as an electric circuit, showed that the forces acting upon the electron are proportional to $(1 - v^2/c^2)$, and other substantiating evidence for the above assertion of the bending of electromagnetic waves was also presented [*5*].

Concluding Remarks

The plots of the radiation equations show that rotating or lateral motions of an electric field wave must bend with its tangential velocity. If the rotating waves didn't bend, then the transfer of information through space would be instantaneous. Topological analysis allows a visualization of electromagnetic waves in space that are not always obtainable by the methods of abstract mathematics. This can lead to a better comprehension of the process by which radiation occurs. In this case, the issue of the change in dimensionality of a radiating wave becomes clear. There are new systems that are being designed at the molecular level, which are potentially important in the future of science. Such designs may involve treating atoms as tiny electrical circuits. The radiating and non-radiating fields surrounding equations atoms and molecules will consequently be of concern.

References

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