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CURVED RADIATORS IN THE NEAR-FIELD AND FAR-FIELD ZONES OF OBSERVATION

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Abstract

In approximation of the given current distribution it has been suggested a solution considering the influence of the circular loop antenna curvature and elementary radiator curvature upon their directional characteristics. On the basis of potential Hertz technique the expressions for calculating al the components of electromagnetic radiation fields of wire loop antennas, stimulated by the running wave of the current, and curved dipole in Spherical and Decart coordinate systems in the near-field zone have been derived. It has been shown that wave processes near by the examined radiators are distinguished by great gradients of amplitudes of the electromagnetic fields.

Keywords: curved dipole, circular loop antenna, near-field-zone, electromagnetic waves

I. INTRODUCTION

As is known [1-3], the Bonch-Bruevich orientation rule of diagram's multiplication in the radiation theory is true only if elementary radiators are identical all over the aerial. In case of a curvilinear emitter the elementary radiators differ in each point on the aerial surface, but the antenna's pattern according to the Fresnel principle is defined by the fields summation of elementary radiators radiation.
The aim of this report is to study the near-field effects of curved dipole and consider the account of conductor curvature upon their directional characteristics in the far-field and near-field zones of observation.

II. MAIN PART

To find the directional characteristics of curved dipole in the near-field zone, let us dispose them perpendicularly to radius of curvature ρ (Fig. 1).

To find $\vec{E}$ and $\vec{H}$ we write:

$$\vec{E} = graddiv\vec{\Pi} + \kappa^2\vec{\Pi},$$

$$\vec{H} = i\omega\varepsilon rot \; .$$

Also take into account:

$$graddiv\int_L \vec{j}\psi dl = j_0\int_L grad\left(\vec{l}, grad\psi\right)dl,$$

$$\begin{cases} \vec{x}^0 = \vec{R}^0\sin\theta\cos\varphi + \vec{\theta}^0\cos\theta\cos\varphi - \vec{\varphi}^0\sin\varphi \\ \vec{y}^0 = \vec{R}^0\sin\theta\sin\varphi + \vec{\theta}^0\cos\theta\sin\varphi + \vec{\varphi}^0\cos\varphi, \\ \vec{z}^0 = \vec{R}^0\cos\theta - \vec{\theta}^0\sin\theta \end{cases}$$

and

$$iw\varepsilon rot\vec{\Pi} =$$

$$= \frac{1}{4\pi}\int\Bigg(\frac{1}{R\sin\theta}\left(\frac{\partial}{\partial\theta}(j_\varphi\psi\sin\theta) - \frac{\partial}{\partial\varphi}(j_\theta\psi)\right)\vec{R}^0 +$$

$$+\frac{1}{R}\left(\frac{1}{\sin\theta}\frac{\partial}{\partial\varphi}(j_R\psi) - \frac{\partial}{\partial R}(Rj_\varphi\psi)\right)\vec{\theta} +$$

$$+\frac{1}{R}\left(\frac{\partial}{\partial R}(Rj_\theta\psi) - \frac{\partial}{\partial\theta}(j_R\psi)\right)\vec{\varphi}^0\Bigg)dl.$$

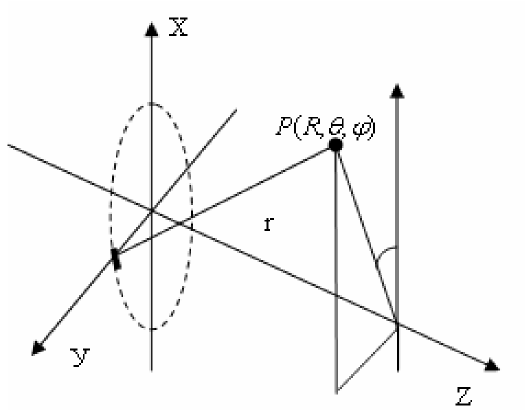


Fig. 1. Geometrical arrangement for finding curvilinear dipole directional characteristics

Due to $\frac{\rho}{\lambda} \ll 1$ the expression for $\vec{j}$ can bee written as: $\vec{j} = \vec{l}^0 j_0$, where $\vec{l}^0 = -\vec{x}^0\sin\varphi' + \vec{y}^0\cos\varphi'$, and $\vec{l}^0$ - unit tangent vector, l - length element. Total length of dipole is $l = 2\rho\Delta\varphi'$.

On the basis of the Hertz potentials technique the expressions for calculating all the components of

electromagnetic radiation fields of the curved dipole have been derived:
in Spherical coordinate system (for $\varphi = 0$) –

$$E_R = \frac{j_0}{4\pi i w \varepsilon}\int_{-\Delta\varphi'}^{\Delta\varphi'} \{(q\psi(g - f^2)(R - \rho\sin\theta\cos(\varphi')) +$$
$$+\psi f \sin\theta\sin(\varphi')\}\rho d\varphi' +$$
$$-\frac{j_0 k^2 \sin\theta}{4\pi i\omega\varepsilon}\int_{-\Delta\varphi'}^{\Delta\varphi'} \psi\sin(\varphi')\rho d\varphi'$$

$$E_\theta = \frac{j_0\cos\theta}{4\pi i\omega\varepsilon}\int_{-\Delta\varphi'}^{\Delta\varphi'} [q\psi(g - f^2)\rho\cos(\varphi')) -$$
$$-\psi f \sin(\varphi')]\rho d\varphi' -$$
$$-\frac{j_0 k^2\cos\theta}{4\pi i\omega\varepsilon}\int_{-\Delta\varphi'}^{\Delta\varphi'} \psi\sin(\varphi')\rho d\varphi'$$

$$E_\varphi = -\frac{j_0}{4\pi i\omega\varepsilon}\int_{-\Delta\varphi'}^{\Delta\varphi'} [q\psi(g - f^2)\rho\sin(\varphi')) -$$
$$-\psi f\cos(\varphi')]\rho d\varphi' + \frac{j_0 k^2}{4\pi i\omega\varepsilon}\int_{-\Delta\varphi'}^{\Delta\varphi'} \psi\cos(\varphi')\rho d\varphi'$$

$$H_R = \frac{i_0\rho\cos\theta}{4\pi}\int_{-\Delta\varphi'}^{\Delta\varphi'} \psi f \rho d\varphi',$$

$$H_\theta = \frac{i_0}{4\pi}\int_{-\Delta\varphi'}^{\Delta\varphi'} \psi f (R - \rho\sin\theta)\cos\varphi'\rho d\varphi',$$

$$H_\varphi = \frac{-i_0\cos\theta}{4\pi}\int_{-\Delta\varphi'}^{\Delta\varphi'} R\psi f\sin\varphi'\rho d\varphi',$$

where:

$$\psi = \frac{\exp(-ikr)}{r},$$
$$r = \sqrt{(R^2 + \rho^2 - 2\rho R\sin\theta\cos(\varphi - \varphi'))},$$
$$f = \frac{ik}{r} + \frac{1}{r^2},$$
$$g = -\frac{ik}{r^3} - \frac{2}{r^4}, \quad q = -R\sin\theta\sin(\varphi - \varphi');$$

in Decart coordinate system –

$$E_x = \frac{1}{4\pi i w\varepsilon}\int_{-\Delta\varphi'}^{\Delta\varphi'} ((q\psi(x - x_a)(g - f^2) +$$
$$+i_0\psi f\sin\varphi')\rho d\varphi' - \frac{k^2 i_0}{4\pi i w\varepsilon}\int_{-\Delta\varphi'}^{-\Delta\varphi'} \sin\varphi'\psi\rho d\varphi',$$

$$E_y = \frac{\rho}{4\pi i w\varepsilon}\int_{-\Delta\varphi'}^{\Delta\varphi'} (q\psi(y - y_a)(g - f^2) -$$
$$-i_0\psi f\cos\varphi')d\varphi' + \frac{i_0 k^2\rho}{4\pi i w\varepsilon}\int_{-\Delta\varphi'}^{\Delta\varphi'} \psi\cos\varphi' d\varphi'$$

$$E_z = \frac{1}{4\pi i w\varepsilon}\int_{-\Delta\varphi'}^{\Delta\varphi'} q\psi z(g - f^2)\rho d\varphi',$$

$$H_x = \frac{i_0\rho z}{4\pi}\int_{-\Delta\varphi'}^{-\Delta\varphi'} \psi f\cos\varphi' d\varphi',$$

$$H_y = \frac{i_0 z\rho}{4\pi}\int_{-\Delta\varphi'}^{-\Delta\varphi'} \psi f\sin\varphi' d\varphi',$$

$$H_z = \frac{-\rho}{4\pi}\int_{-\Delta\varphi'}^{-\Delta\varphi'} \psi f i_0(y - y_a)\sin\varphi' +$$
$$+(x - x_a)\cos\varphi' d\varphi'$$

where:

$$q = i_0(\sin\varphi'(x - x_a) - \cos\varphi'(y - y_a)),$$
$$g = -\frac{ik}{r^2} - \frac{2}{r^3},$$
$$x_a = \rho\cos\varphi', \; y_a = \rho\sin\varphi', \; dl = \rho d\varphi'.$$

This solution considers the influence of the conductor curvature upon their directional characteristics in the near-field zone. Wave processes near the curved dipole are distinguished by great gradients of the electromagnetic fields amplitudes.

In approximation of the given current distribution a solution considering the influence of the circular loop antennas curvature upon their directional characteristics has been suggested(Fig.2). In the decision various orientations of elementary radiators in space were considered.

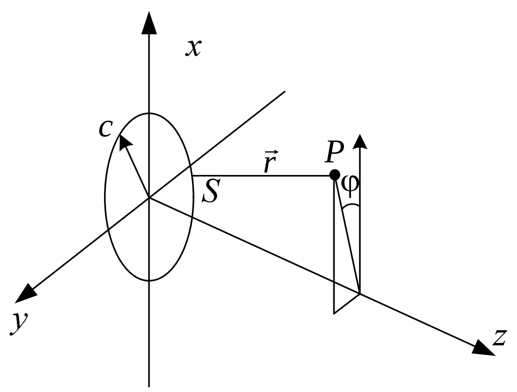


Fig. 2. Loop antenna in Spherical coordinate system

The radiated fields of circular loop antenna in the far-field zone can be written as:

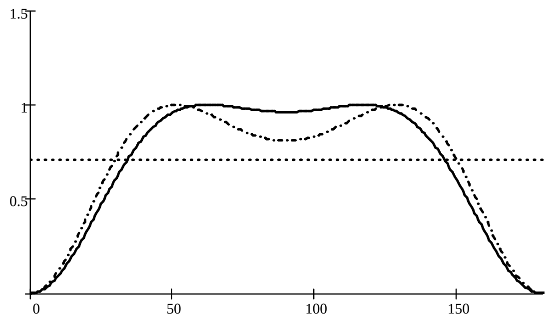
$$E_\theta = \frac{-j_0 \psi(R) k^2 \rho \Delta\varphi}{2\pi i \omega\varepsilon}\cos\theta \bullet$$

$$\bullet \int_0^{2\pi} \sin\varphi' e^{-i\frac{2\pi\rho\varphi'}{\lambda}} e^{ik\rho\sin\theta\cos\varphi'} d\varphi'$$

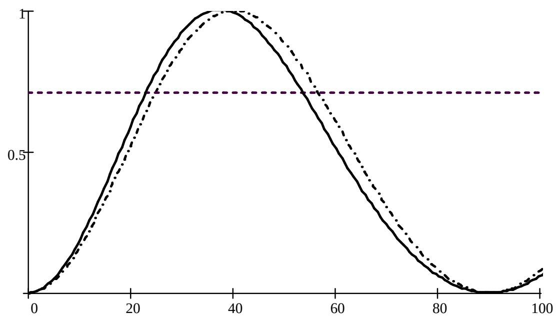
$$E_\varphi = \frac{j_0 \psi(R) k^2 \rho \Delta\varphi}{2\pi i \omega\varepsilon} \bullet$$

$$\bullet \int_0^{2\pi} \cos\varphi' e^{-i\frac{2\pi\rho\varphi'}{\lambda}} e^{ik\rho\sin\theta\cos\varphi'} d\varphi'$$

The approach of the given current was used. The influence of conductor curvature upon its directional characteristics in the far- and near-field zones are significant.



a)



б)

$$m = {}^{2\pi\rho}\!/\!_{\lambda} = 2$$

Fig. 3. Radiation pattern of loop antenna: a) $E\theta(\varphi)$ field component б) $E\varphi(\varphi)$ field component: dotted graph - without conductor curvature, solid graph - subject to conductor curvature

Table 1. Half-power beam width $\frac{1}{2}P_{\max}$ for electric field (for loop dimension $m = {}^{2\pi\rho}\!/\!_{\lambda} = 2$).

fields component	degrees
E_φ , without conductor curvature	137.5
E_φ , subject to conductor curvature	112.7
E_θ , without conductor curvature	44.1
E_θ , subject to conductor curvature	42.6

The more relative sizes of the circular loop the less these differences.

III. CONCLUSION

The account of conductor curvature upon their directional characteristics in the far-field and near-field zones are considered.

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