Yu. Krushevskiy Cand. Sc.(Eng); Yu. Kravtsov; V. Chernyga Cand. Sc.(Eng).

STUDY OF FIELD STRUCTURE AND ORIENTATION OF ELECTRIC ELEMENTARY EMITTER IN NEAR AND INTERMEDIATE AREAS

The paper considers theoretical research of field structure of elementary electric emitter in near and intermediate areas. The diagrams of orientation of this vibrator are built on the electric constituent of the field at the distances of 1,0 . 35 cm from .

Keywords: *elementary emitter, near, intermediate areas, diagram of orientation.*

Introduction

Large-scale usage of mobile radiotelephones (MPT) nowadays cannot be neglected .

This type of communications provides the operation of cellular mobile communication network using the equipment of certain standards. Most widely used are GSM-900 and GSM-1800 standards. MPT of these standards operate in transmission mode in frequency ranges 890.915 Mhz and 1710.1785 Mhz correspondingly[3, 4].

Since MPT, while its using is located near the head (near brain) of the user, its radiation has a considerable impact on a human health . It is possible to judge about harmfulness of this impact, comparing actual intensity of radiation of head with the sanitary norm, accepted in Ukraine.

Another actual problem is measuring of radiation intensity of MPT along with the development of methods and measuring facilities.

It is not possible to calculate or measure the real intensity of radiation, without investigation the field of emitter in near and intermediate areas.

Intensity of radiation is characterized by power flux density, depending on power and frequency of MPT radiation , distance to the point of observation, structure of the electromagnetic field in this point and oriented properties of radiotelephone aerial. Dipole or helix aerials are used in modern MPT. Dipole aerial is an asymmetrical quarter- wave vibrator. Helix aerial is cylindrical winding of wire, length of helix turn is far less than the wave-length emitted. Such aerial, as is generally known, is characterized by transversal to the axis of helix direction of radiation. Its diagram of orientation will be the same, as that of vibrator.

Analysis of the recent research and publications

MPT aerials can be considered short in the scale of the wave-lengths of electromagnetic waves radiated by them. The orientation of short symmetric vibrators $2l \le 0,5\,\lambda$ long practically coincides with the orientation of Hertz electric vibrator – physical model of elementary electric emitter. HENCE, for example, the width of orientation diagram of symmetric half-wave vibrator ($2l = 0,5\,\lambda$) equals 80°, and Hertz vibrator – 90°, the coefficients of the directed action equal according 1,64 and 1,50 correspondingly [2, 3].

It is known that the symmetric Hertz electric vibrator radiates electromagnetic field, three constituents of which in spherical co-ordinates equal [1]:

$$\dot{E}_{mr} = \frac{I_m\, l\, k^3}{2\pi\,\omega\,\varepsilon_a}\left[\left(\frac{1}{k\,r}\right)^2 - j\left(\frac{1}{k\,r}\right)^3\right]\cdot e^{-jkr}\cdot\cos\theta\,, \tag{1}$$

$$\dot{E}_{m\theta} = \frac{I_m\, l\, k^3}{4\pi\,\omega\varepsilon_a}\left[\frac{1}{k\,r} - j\left(\frac{1}{k\,r}\right)^2 - \left(\frac{1}{k\,r}\right)^3\right]\cdot e^{-jkr}\cdot\sin\theta, \tag{2}$$

$$\dot{H}_{m\varphi} = j\,\frac{I_m\, l\, k^2}{4\pi}\left[\frac{1}{k\,r} - j\left(\frac{1}{k\,r}\right)^2\right]\cdot e^{-jkr}\cdot\sin\theta\,, \tag{3}$$

where, $\dot{E}_{mr}$, $\dot{E}_{m\theta}$ and $\dot{H}_{m\varphi}$ are complex amplitudes radial, meridional constituents of electric field and equatorial constituent of the magnetic field accordingly; I_m – amplitude of harmonic current, that flows in Hertz vibrator; l – length of vibrator; $\omega = 2\pi f$ – circular frequency of electromagnetic field; ε_a – absolute dielectric permeability of the environment, surrounding the vibrator; $k = 2\pi/\lambda$ – wave number (coefficient of phase) of electro magnetic wave; θ – meridional angular co-ordinate of observation point of vibrator field; r – distance from a vibrator to observation point; λ – wave-length of vibrator field.

All the problems of radio communication provide that observation point is in a distant area, where *kr >>1,* and constituent $\dot{E}_{mr}$ compared with $\dot{E}_{m\theta}$ con be neglected, i.e. in this area only two orthogonal component field components are taken into account:

$$\dot{E}_{m\theta} = \frac{I_m\, l\, k}{4\pi\, \omega \varepsilon_a\, r} e^{-jkr} \cdot \sin\theta ,$$

$$\dot{H}_{m\varphi} = j \frac{I_m\, l\, k}{4\pi\, r} e^{-jkr} \cdot \sin\theta .$$

Here the average value of power flux density vector has one radial constituent [2,3]

$$\bar{\Pi}_{cep} = \frac{1}{2} \mathrm{Re}\left[\dot{\bar{E}}_{m\theta}\, \overset{*}{\bar{H}}_{m\varphi} \right],$$

which can be defined by simple formula [2]

$$\Pi_{cep} = \frac{P_{\Sigma}}{4\pi\, r^2}, \qquad (4)$$

where P_{Σ} - power of Hertz vibrator radiation of Hertz.

In case of study of MPT field, which exposes to the rays the head of the user, distance r is such, that strong inequality $kr << 1$ or $kr >> 1$ is not executed. For example, if $r \approx 5\,see$ - to the least distance from the emitter to human brain, on frequency 912,5 Mhz (mean value of GSM-900 standard frequency) of the value. Consequently, in expressions (1).(3) in square brackets, no simplifications can be done. O

At such distances there are points of the space which belong to the intermediate area [2], where electromagnetic field will have more complex structure, since it will be determined by three by constituents, described by expressions (1).(3). Thus, for calculation of power flux density the application of the formula (4) will give a considerable error.

By magnetic constituent, as it is seen from the expression (3), the diagram of orientation of emitter fully coincides with the known results [1, 2] and for the investigated case is presented in Fig. 1.

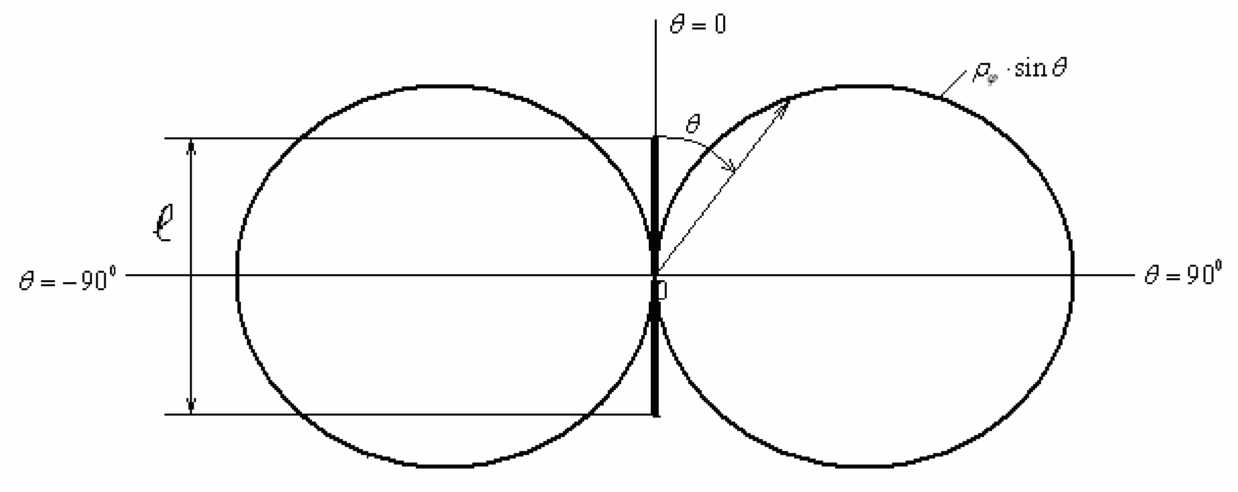

Fig. 1. Diagram of elementary electric emitter orientation by the magnetic constituent of the field

Problem setup

The electromagnetic field of the base stations aerials is of interest only in a distant area. It is well studied and described in technical literature and manuals.

Of practical interest is the field of aerial of mobile radiotelephone in near and intermediate (*kr = 0,5 . 5)* areas, description of which cannot be found in literature.

Since basic parameters of MPT aerials are practically identical to corresponding parameters of elementary electric emitter, we will conduct research of the field structure and orientation diagrams of the latter, and will generalize the obtained results of MPT aerials.

Such approach to the problem will allow to specify field distribution , exposing to the rays the user of the cellular phone.

Basic materials of the article

If complex values in the square brackets of expressions (1).(3) are presented in indicative form and take into account that $\frac{k}{\omega\varepsilon_a} = \sqrt{\frac{\mu_a}{\varepsilon_a}}$, then they will be written as:

$$\dot{E}_{mr} = 2E_0\sqrt{\left(\frac{1}{kr}\right)^4 + \left(\frac{1}{kr}\right)^6} \cdot e^{-j\left(kr + arctg\,\frac{1}{kr}\right)} \cdot \cos\theta \,, \tag{5}$$

$$\dot{E}_{m\theta} = E_0\sqrt{\left[\frac{1}{kr} - \left(\frac{1}{kr}\right)^3\right]^2 + \left(\frac{1}{kr}\right)^4} \cdot e^{-j\left(kr - \frac{\pi}{2} + arctg\,\frac{kr}{k^2r^2 - 1}\right)} \cdot \sin\theta \,, \tag{6}$$

$$\dot{H}_{m\varphi} = H_0\sqrt{\left(\frac{1}{k}\right)^2 + \left(\frac{1}{kr}\right)^4} \cdot e^{-j\left(kr - \frac{\pi}{2} + arctg\frac{1}{kr}\right)} \cdot \sin\theta \,, \tag{7}$$

where

Expressions (5), (7) are complex amplitudes of constituents of the harmonic electromagnetic field of elementary emitter which are corresponded by the instantaneous values of intensities at any moment of time t:

$$E_r = 2E_0\sqrt{\left(\frac{1}{kr}\right)^4 + \left(\frac{1}{kr}\right)^6} \cdot \cos\left(\omega t - kr - arctg\,\frac{1}{kr}\right) \cdot \cos\theta \,, \tag{8}$$

$$E_\theta = E_0 \sqrt{\left[\frac{1}{kr} - \left(\frac{1}{kr}\right)^3\right]^2 + \left(\frac{1}{kr}\right)^4} \cdot \cos\left(\omega t - kr + \frac{\pi}{2} - arctg\,\frac{kr}{k^2 r^2 - 1}\right) \cdot \sin\theta\,, \tag{9}$$

$$H_\varphi = H_0 \sqrt{\left(\frac{1}{kr}\right)^2 + \left(\frac{1}{kr}\right)^4} \cdot \cos\left(\omega t - kr - arctg\,\frac{1}{kr}\right) \cdot \sin\theta\,. \tag{10}$$

Having chosen t=0, expressions (8).(10) will be rewritten as:

$$E_r = 2E_0 \sqrt{\left(\frac{1}{kr}\right)^4 + \left(\frac{1}{kr}\right)^6} \cdot \cos\left(kr + arctg\,\frac{1}{kr}\right) \cdot \cos\theta\,, \tag{11}$$

$$E_\theta = E_0 \sqrt{\left[\frac{1}{kr} - \left(\frac{1}{kr}\right)^3\right]^2 + \left(\frac{1}{kr}\right)^4} \cdot \cos\left(kr + arctg\,\frac{kr}{k^2 r^2 - 1} - \frac{\pi}{2}\right) \cdot \sin\theta\,, \tag{12}$$

$$H_\varphi = H_0 \sqrt{\left(\frac{1}{kr}\right)^2 + \left(\frac{1}{kr}\right)^4} \cdot \cos\left(kr + arctg\,\frac{1}{kr} - \frac{\pi}{2}\right) \cdot \sin\theta\,. \tag{13}$$

or:

$$E_r = E_{mr} \cos\theta\,, \tag{14}$$

$$E_\theta = E_{m\theta} \sin\theta\,, \tag{15}$$

$$H_\varphi = H_{m\varphi} \sin\theta\,, \tag{16}$$

where

$$E_{mr} = 2E_0 \sqrt{\left(\frac{1}{kr}\right)^4 + \left(\frac{1}{kr}\right)^6}$$

$$E_{m\theta} = E_0 \sqrt{\left[\frac{1}{kr} - \left(\frac{1}{kr}\right)^3\right]^2 + \left(\frac{1}{kr}\right)^4}$$

$$H_{m\varphi} = H_0 \sqrt{\left(\frac{1}{kr}\right)^2 + \left(\frac{1}{kr}\right)^4}$$

are the amplitude values of corresponding constituents of emitter field at the distance r from it.

The form of emitter orientation diagram by constituent H_φ remains identical for any distances r to observation point and presented in meridional plane (Fig1).

Function of emitter orientation by electric constituent of *E*, being the sum of orthogonall constituents E_r and E_θ, which is by the formula:

$$E = \sqrt{E_r^2 + E_\theta^2}\,, \tag{17}$$

will depend on relation of these constituents, which, in their turn, will depend on the distance r to observation point. Correlation between these components will change, since, first, their amplitudes with growth of r will decrease with different speed, and, secondly, there is phase shift $\varphi = \left(arctg\frac{1}{kr} - arctg\frac{kr}{k^2 r^2 - 1} + \frac{\pi}{2}\right)$, between them which also depends on r. Consequently the component E can be found as the sum of instantaneous values of orthogonal components of this field from the expression (17) taking into account (12), (13):

$$E = E_0 \sqrt{4\left[\left(\frac{1}{kr}\right)^4 + \left(\frac{1}{kr}\right)^6\right]\cdot \cos^2\left(kr + arctg\frac{1}{kr}\right)\cdot \cos^2\theta + \left\{\left[\frac{1}{kr} - \left(\frac{1}{kr}\right)^3\right]^2 + \left(\frac{1}{kr}\right)^4\right\}\cdot \cos^2\left(kr + arctg\frac{kr}{k^2r^2 - 1} - \frac{\pi}{2}\right)\cdot \sin^2\theta} \qquad (18)$$

Using the expression (18), we will construct the dependence $E(\theta)$ for different distances r, considering elementary electric emitter as the aerial of cellular phone according to the standard of GSM-900 ($\lambda_{cep} = 32{,}8$ cm).

Case 1, when r = 1 see (kr = 0.2), $\dot{E}_{mr}$ = 2,04 $\dot{E}_{m\theta}$.

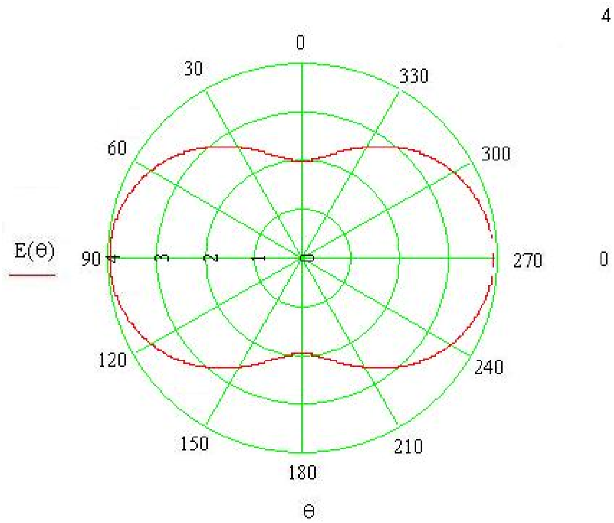

Fig. 1. Diagram of elementary electric emitter orientation by the electric component of the field at *r = 1 cm*

Case 2, when r = 5 cm (kr = 1), $\dot{E}_{mr}$ = 2,82 $\dot{E}_{m\theta}$.

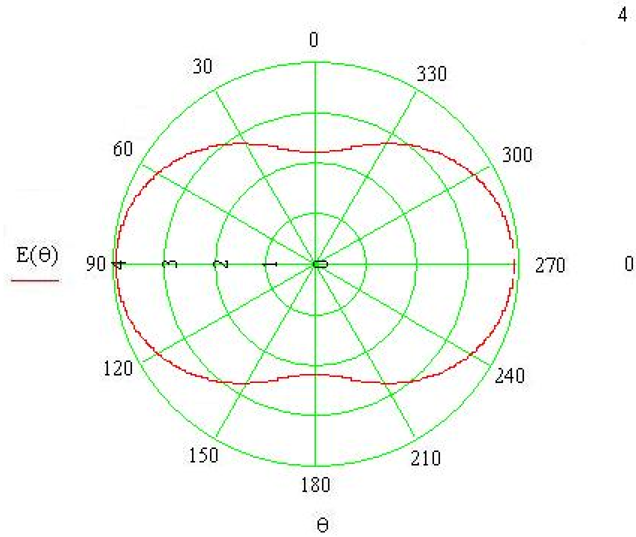

Fig. 3. Diagram of elementary electric emitter orientation by electric constituent at *r = 5 cm*

Case 3, when r = 10 cm (kr = 2), $\dot{E}_{mr}$ = 1,24 $\dot{E}_{m\theta}$.

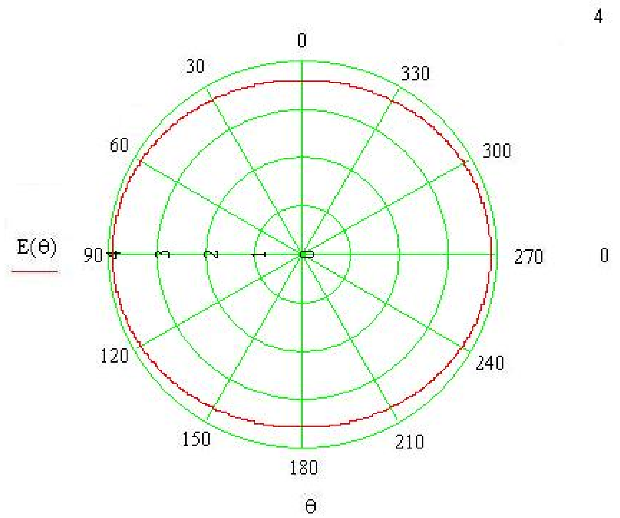

Fig. 4. Diagram of elementary electric emitter orientation by electric field at *r = 10 cm*

Case 4, when r = 12.5 cm (kr = 2.5), $\dot{E}_{mr}$ =0,93 $\dot{E}_{m\theta}$.

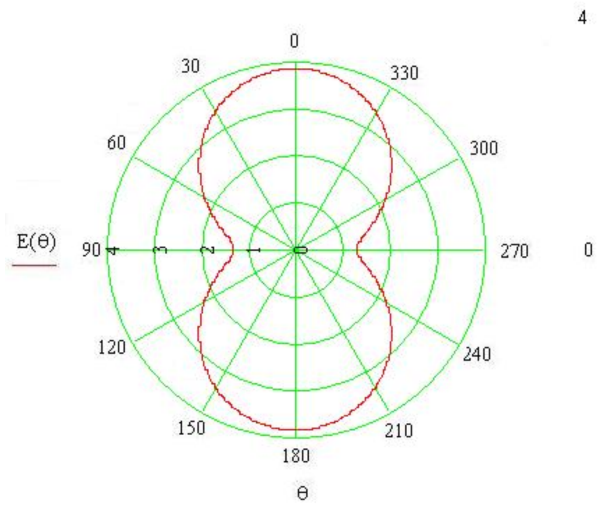

Fig. 5. Diagram of elementary electric emitter orientation by electric field at *r = 12, cm*

Case 5, when r = 14,1 cm (kr = 2,75), $\dot{E}_{mr}$ = 0,77 $\dot{E}_{m\theta}$.

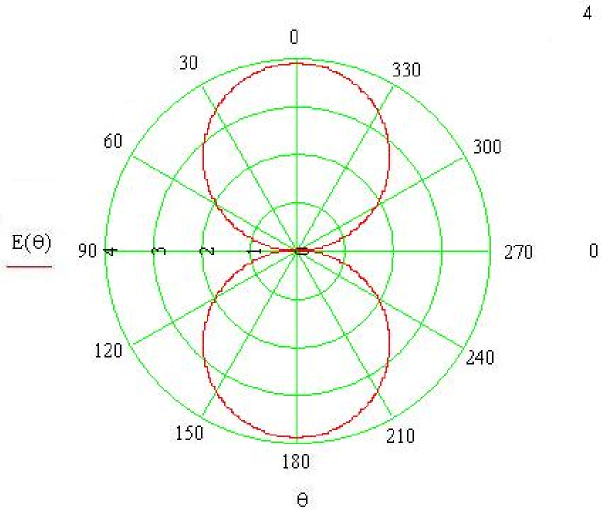

Fig. 6. Diagram of elementary electric emitter orientation by electric field at *r=14,1 cm*

Case 6, when r = 15cm (kr = 3), $\dot{E}_{mr} = 0{,}74\ \dot{E}_{m\theta}$.

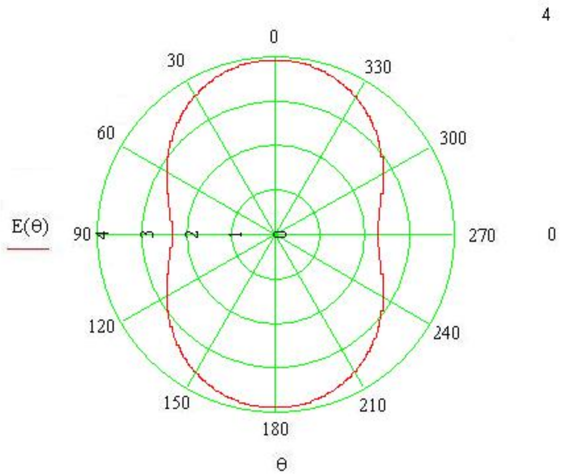

Fig. 7. Diagram of elementary electric emitter orientation by the electric field at *r = 15 cm*

Case 7, when r = 16 cm (kr = 3.2), $\dot{E}_{mr} = 0{,}71\,\dot{E}_{m\theta}$.

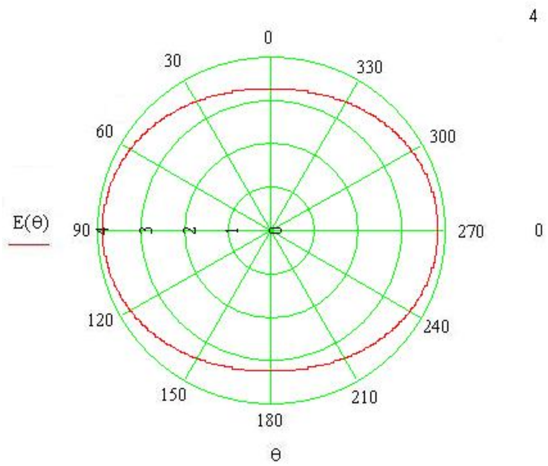

Fig. 8. Diagram of elementary electric emitter orientation by the electric field at *r = 16 cm*

Case 8, when r = 17 cm(kr = 3.4), $\dot{E}_{mr}$ = 0,68 $\dot{E}_{m\theta}$.

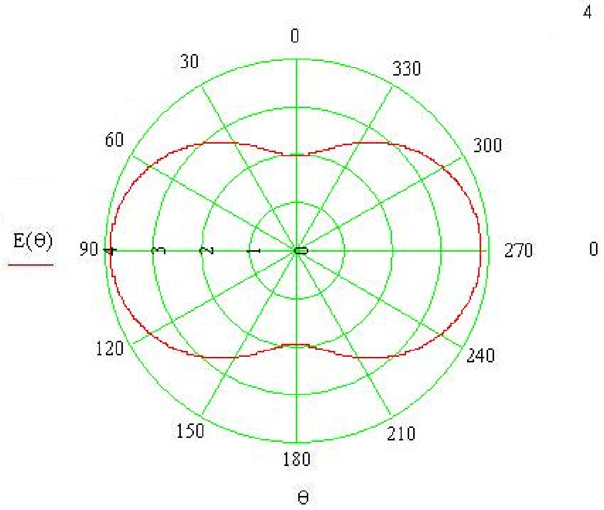

Fig. 9. Diagram of elementary electric emitter orientation by the electric field at *r = 17 cm*

Case 9, when r = 20 cm (kr = 4), $\dot{E}_{mr}$ = 0,53 $\dot{E}_{m\theta}$.

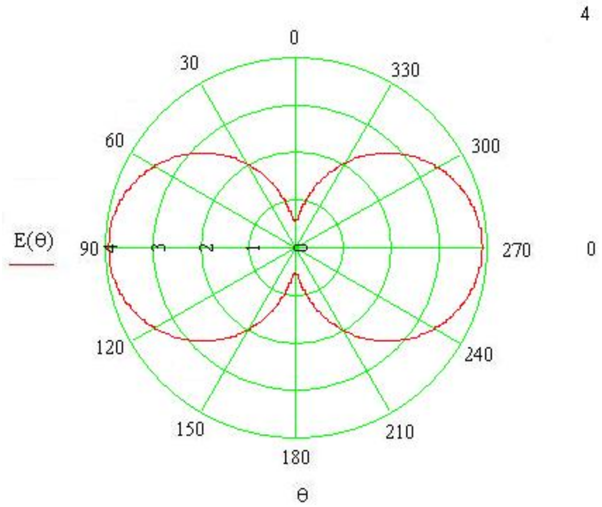

Fig. 10. Diagram of elementary electric emitter orientation by the electric field at *r = 20 cm*

Case 10, when r = 35 cm (kr = 7), $\dot{E}_{mr}$ = 0,29 $\dot{E}_{m\theta}$.

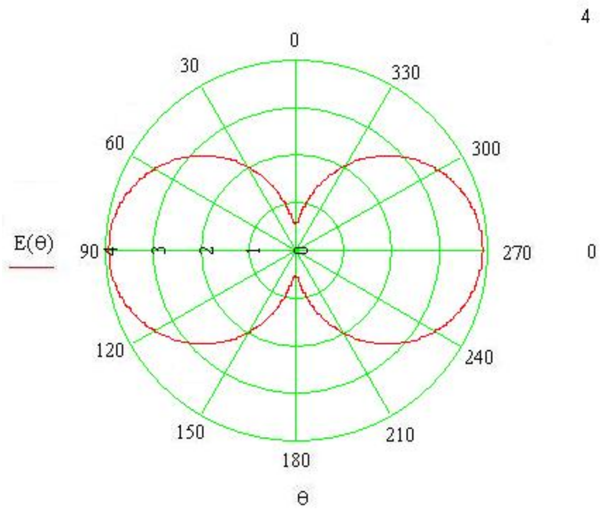

Fig. 11. Diagram of elementary electric emitter orientation by the electric field at *r = 35 cm*

Analysis of the results obtained

At small distances, when $kr \leq 5$, amplitudes of the electric field E_{m2} and $E_{m\theta}$ components are the values of the same order and the result of vector addition will be influenced by phase shift $< \varphi$. Within the limits of $0 \leq kr \leq 5$ $\Delta\varphi(r)$ will change from π to almost $\pi/2$, and $\cos\Delta\varphi$ – from 0 to 1. Due to this fact the diagrams of emitter orientation the electric field change from horizontal “eight” (Fig.2) to vertical (Fig.6) and again to horizontal (Fig.10).

At the distance of approximately 12,33cm ($kr \approx 2{,}36$) amplitudes of the electric field components will become even. Further the amplitude of radial component E_{mr}, decreasing faster than the amplitude of meridial component E_{m0}, at the distance $r = 100$ cm ($kr = 19{,}57$) $E_{mr} = 0{,}1E_{\theta}$. Phase shift at the distances $r \geq 25 см$ becomes permanent, equal to $\pi/2$ and practically stops influencing the form of orientation diagram.

Consequently, at the distances of r>100см ($r \geq 3\lambda$) radial component in comparison with meridial can be ($E_{mr} \prec 0{,}1E_m\theta$) neglected and consider orientation diagram the of emitter finally formed.

Conclusions

1. The form of diagram of orientation of elementary electric emitter by the electric component of its field in near and intermediate areas substantially depends on the distance to the observation point, conditioned by dependence on this distance of not only by the relation of amplitudes of radial and meridional components of the field but also, mainly, by phases shift between them.

2. On the border between near and intermediate areas ($0{,}5 \leq kr \leq 5$) amplitude of electric field components are the values of one order and that is why , basic influence on the form of orientation diagram will have phase shift between these components.

3. At distances, when $kr \geq 5$, phase shift between becomes electric field components becomes practically independent of the distance r and equals permanent value $\pi/2$. Due to this fact the form of orientation diagram becomes dependent only on relation of κ amplitudes of the electric field components and acquires the final form at the distance of at least 3 λ.

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Krushevskiy Yuriy – associate professor of the Department of Radioengineering;.

Kravtsov Yuriy – senior lecturer of the Department of Computer and Telecommunication equipment design;

Chernyga Vyacheslav – associate professor of the Department of Radioengineering.

Vinnitcia National Technical University.