MANAGEMENT AND RELIABILITY ASSURANCE OF A MILITARY FIELD NETWORK FUNCTIONING. ELECTROMAGNETIC FIELD CALCULATIONS

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In given paper there has been considered a management and a reliability assurance of a military field network functioning. The calculation method of electromagnetic field strength of radiated antennas in the site of a field network site of military radio communication of high frequency and super high frequency with low and mean power up to 1 kW has been offered. The offered method of EMF calculation in limited site is based on the solution of electrodynamics' tasks of thinly wire structures at known distribution functions of current radiators, which are determined based on approximate solutions. This method can be applied for the radio technical means radiating in both one frequency and various ranges. These formulas help to calculate a compact displacement of radio stations and antennas system in the site of a military field communication network with taking account of an electromagnetic compatibility of radio devices.

***Key words**: electromagnetic field strength, electromagnetic compatibility, radio station, military field communication network, frequency range*

1. INTRODUCTION

The investigation of a map of an electromagnetic field (EMF) strength is especially important for taking account of electromagnetic compatibility (EMC) during local and compact displacement and a reliability assurance of radioelectronic stations (RES) functioning. These RES function in the site of a field network site of military radio communication of high frequency (HF) and super high frequency (SHF) with low and mean power up to 1 kW [Bayramov, et al. 2020; Imanov & Bayramov, 2020]. It will be recalled, that HF range includes electromagnetic waves (EW) with the frequency in the range of (30÷300) MHs and with the wavelength in the range of (1÷10) m. SHF range includes EW with the frequency in the range of (3÷30) MHs and with the wavelength in the range of (10÷100) m.

There are many scientific works devoted a problem of EMC in the site with local and compact placed various radiated devices and antennas. There are some of them referred in [Agreement, 2013; Buzov, et al. 2000; The control, 2006; Efanov, et al. 2012; Zhezhelenko et al., 2013].

There have been considered tasks of analysis and EMC assurance of compact groups of RES. Mobile radio technical objects (military field radio communication site, military wheeled locomotion techniques, track-type vehicle, combat trucks, etc.) are such objects. One of the distinctive characteristics of considered groups is a very compact displacement of many antennas of various types, purposes, and ranges on the limited site. It is clear, that in these conditions the problem of EMC assurance is became more actually.

The offered method of EMF calculation in limited site is based on the solution of electrodynamics's tasks of thinly wire structures at known distribution functions of current radiators, which are determined based on approximate solutions. Given method is applied for radio technical means radiating both in single and various ranges [Aronov et al., 2016; Buzov, et al., 2000]. EMF of radio technical means can differ by the intensity, the polarization, the frequency, the dependence on soil parameters, etc.

The method had been calculated for directed in horizontal plane of irradiative in HF and SHF ranges in-phase, rhombic and log-periodic antennas. The EMF structure near the antenna is very complex and is depended on many factors: the type of antenna, working frequency, radiation power, polarization of EMF, the electrophysical parameters of soil, the relief of terrain, plant cover, the character of antennas placement. It is impossible to take account of all these factors, therefore for simplification of calculations the plane terrain has taken without re-radiated objects. During calculations, EMF is determined for certain values of electrophysical parameters of soil: dielectric conductivity ε and conductivity δ. In the real conditions EMF near of antenna is depended on local values of soil which can change in wide range [Buzov, 2000; The control, 2006].

In given paper, the calculation method of EMF of antennas in a site of military field radio communication has been offered. The aim of paper is a forecast of EMF levels when displacement of radio communication means in military field site.

2. EMF OF ELEMENTARY ELECTRIC OSCILLATORS

Generating in wave zone EMF with mainly one polarization (horizontal or vertical) antennas generates EMF with another polarization near-field region and their levels are compared. EMF of complex antennas are determined by integration of EMF of the appropriate elementary electric oscillators in linear size of these antennas. Let considered below the offered calculation method of EMF of elementary electric oscillators on the basis of which EMF of complex antennas of directed radiation can be calculated.

The calculations of radiation of the elementary oscillations placed above semiconductive surface are basis of offered EMF calculation method near the transmitting antennas. The complex components of magnetic field and of vertical elementary oscillator (fig. 1) placed in cylindrical coordinate system along of Z-axis (Z-axis is perpendicular to separation surface and z=0 point is placed on the separation surface) are calculated by the next formulas:

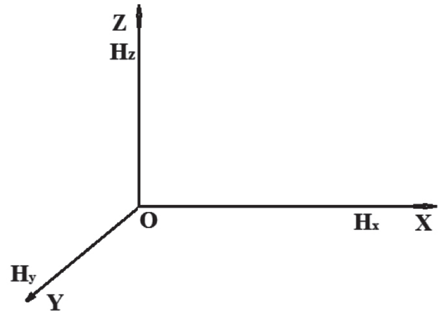

Fig. no. 1. The complex components of magnetic field of vertical elementary oscillator.

$$H_x = -\frac{k_1 \omega p}{4\pi} h_{fs} \cdot sin\varphi \cdot \frac{e^{ik_1 R_1}}{R_1} \cdot x_0 \quad (1)$$

$$H_y = -\frac{k_1 \omega p}{4\pi} h_{fs} \cdot cos\varphi \cdot \frac{e^{ik_1 R_1}}{R_1} \cdot y_0 \quad (2)$$

By using of (1) и (2), the H_φ component of cylindrical coordinate system can be obtained:

$$H_\varphi = H_y \cos\varphi - H_x \sin\varphi. \quad (3)$$

There are below notations in (1)÷(3):
$p = il \cdot I/\omega$ is a complex amplitude of dipole moment;
I is an exceeded oscillator current;
l is a length of oscillator;
i is an imaginary unit;
ω is a circle frequency;
$k_1 = 2\pi/\lambda$;
r, R_1, R_2 – are geometric parameters:

$$R_1 = \sqrt{x^2 + y^2 + (z-h)^2},$$
$$R_2 = \sqrt{x^2 + y^2 + (z+h)^2},$$
$$r = \sqrt{x^2 + y^2}$$

x, y, z are the coordinates of point in where EMF is determined;
h is a height of oscillator bracket;

$$h_{fs} = ia_r - i\Delta b_r + 2\cdot i\Delta u^*(\delta)$$

$$a_r = i\left(1+\frac{i}{k_1R_1}\right)sin\theta$$
$$b_r = i\left(1+\frac{i}{k_1R_1}\right)sin\theta'$$

$$\sin\theta = \frac{r}{R}$$

$$sin\theta' = \sqrt{1-\frac{(z+h)^2}{R_2^2}}$$

$$\Delta = \frac{R_1}{R_2}e^{[-ik_1(R_1-R_2)]}$$

The complex components of field , and of horizontal elementary electric oscillator placed in the Cartesian coordinate system in a XOZ plane (fig. 1), where a XOY plane is a separation surface, are calculated by below formulas:

$$H_x = \frac{k_1\omega p}{4\pi}\cdot h_{xx}\cdot\frac{e^{ik_1R_1}}{R_1}\cdot x_0, \quad (4)$$
$$H_y = \frac{k_1\omega p}{4\pi}\cdot h_{yx}\cdot\frac{e^{ik_1R_1}}{R_1}\cdot y_0, \quad (5)$$
$$H_z = \frac{k_1\omega p}{4\pi}\cdot h_{zx}\cdot\frac{e^{ik_1R_1}}{R_1}\cdot z_0 \quad (6)$$

There are below notations in (4)-(6):

$$h_{xx} = -(h_{rf} + h_{fr})\cdot\cos\varphi\cdot\sin\varphi;$$

$$h_{yx} = -h_{rf}\cdot\sin2\varphi + h_{fr}\cdot\cos2\varphi;$$

$$h_{zx} = -h_{sf}\cdot\sin\varphi;$$

$$h_{rf} = ia_s + i\Delta b_s - 2\Omega' U^v\delta^{-1} + 2\Omega' U^v\delta + $$
$$+ 2\Delta' I^v\delta^{-1}$$

$$h_{fr} = -ia_s + i\Delta b_s - 2\Omega' U^v\delta^{-1} + 2\Omega' U^v\delta + $$
$$+ 2\Delta' I^v\delta$$

$$h_{sf} = -ia_r + i\Delta b_r - 2i\Delta U^v\delta^{-1}$$

Included in these expressions the parameters are calculated by next:

$$a_s = i\left(1+\frac{i}{k_1R_1}\right)cos\theta,\ \ cos\theta = \frac{z-h}{R_1}$$

$$b_s = i\left(1+\frac{i}{k_1R_2}\right)cos\theta',\ \ cos\theta' = \frac{z+h}{R_2}$$

$$a_r = i\left(1+\frac{i}{k_1R_1}\right)cos\theta,\ \ sin\theta = \frac{r}{R_1}$$

$$b_r = i\left(1+\frac{i}{k_1R_1}\right)sin\theta',\ \ sin\theta' = \sqrt{1-\frac{(z+h)^2}{R_2^2}}$$

$$\Delta = \frac{R_1}{R_2}e^{-ik_1(R_1-R_2)},\ \ \delta = \frac{1}{\sqrt{\varepsilon + i60\lambda\sigma + 1}}$$

$$\Omega = \frac{\delta^2\Delta}{k_1 r(1-\delta^2)},\ \ \Omega' = \frac{\Omega}{\delta},\ \ \Delta' = \frac{\Delta}{\delta}$$

The auxiliary functions $I(\delta)$ and $U(\delta)$ are expressed via attenuation functions $y(z,r)$ by next:

$$I(\delta) = y(z,r),$$

$$U(\delta) = r\left(i - \frac{1}{k_1 R_1}\right)\frac{y(z,r)}{R_1}$$

With aim of calculation of the attenuation function that contents probability integral with complex argument, the convergent and asymptotic expansions are used:

$$|S| < 12 \Rightarrow y(z,r) = 1 + j\sqrt{\pi S_0}e^{-s} - 2\sqrt{S \cdot S_0}\sum_{\nu}^{n}\frac{(-2S)^{\nu}}{(2\nu+1)!}$$

$$|S| \geq 12 \wedge ImS^{0.5} \geq 0 \Rightarrow y(z,r) = 1 - \sqrt{\frac{S_0}{S}}\sum_{\nu=0}^{n}\frac{(2\nu-1)!}{2S^{\nu}},$$

$$ImS^{0.5} < 0 \Rightarrow y(z,r) = 1 + 2j\sqrt{\pi S_0}e^{-S} - \sqrt{\frac{S_0}{S}}\sum_{\nu=0}^{n}\frac{(2\nu-1)!}{2S^{\nu}},$$

here, $$S_0 = 0.5ik_1R_2\delta^2R_2^2r^{-2}$$

$$S = S_0\left[1 + \frac{z+h}{\delta R_2}\right]^2$$

3. CONCLUSIONS

1. By using of the methods based on the integral Fredholm equations of first and second kinds, the analysis of the futures of EMC assurance of a compact group of radio stations in military field communication has been done.

2. By using of the methods of electrodynamics analysis, the mathematical expressions have been obtained for estimation of EMF levels of antenna's systems for the HF and SHF ranges with low and mean power up to 1 kW with aim of reliability assurance of military field site of radio communication.

3. This method and formulas can be used for compact placement of radio stations and antennas in military field site of radio communication.

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