About the need to analyze the levels of electromagnetic field at radio centers in a marine transport against electromagnetic radiation

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Abstract. The safety of navigation in areas with heavy traffic requires a vessel traffic service (VTS). VTS is a complex system with the branched information part and the completely complex algorithms of information processing. It consists of the following basic subsystems: the collection of information, remote control and transfer of information, processing and mapping information, connection and data base. Each subsystem is represented by the technical equipment, which includes the structurally designed elements with the different level of reliability and frequently having independent designation, as their particular goals and tasks of functioning. Therefore, the problem of the analysis of the levels is immediate in the electromagnetic field of technical equipment for the protection from the action of electromagnetic radiations on the service personnel and the environment. The paper presents the results of calculating the levels of the electromagnetic field in the horizontal and vertical planes. We show the size of the restriction zone along the azimuths of the transmitting antennas. As an example, information about the technical means of the Novorossiysk port VTS is used.

Keyword: electromagnetic field, vessel traffic control system, radio center, electromagnetic compatibility, antenna

1. Introduction

According to the resolution of the international sea organization of A.857 (20), the vessel traffic service (VTS) is the totality of buildings, construction, technical equipment and service personnel. For the organization of daily activities, the operation of technical means and the placement of equipment and personnel, the VTS has created VTS Center and radio technical posts (RTP) VTS. RTP VTS ensures VTS Center by information about the navigable situation in the region of VTS action. They can have an operator personnel or to be unattended and remote controlled from VTS Center. VTS Center carries out information processing, organizes the activities of VTS operators and interaction of the VTS with ships [1].

The functional structure VTS is subdivided into subsystems: the collection of information, remote control and transfer of information, processing and mapping information, connection (Figure 1).
The basic types of the technical equipment VTS ensure obtaining information about the state of water area to the conditions of navigation and vessels in the region of action VTS and interaction VTS with the participating in its work vessels. These types are:
- means of voice radio communication with ships;
- coastal radar stations;
- automatic information (identification) system;
- systems of television surveillance;
- direction finders;
- meteorological and hydrological instruments;
- VTS database [1].

The functioning of technical equipment is accompanied by the generation of electromagnetic environment (EME). It has a specific portrait EMP, whose constant monitoring makes it possible to control the general state of work of units and their equipment. The sources of EMF at the VTS Center site are the transmitting antennas of radio equipment. All sources EMP on the area of center VTS are located on the fence technical with limited access to the transmitting radio-technical facility. However, EMP from objective radiation sources of electromagnetic energy influence the guarantee quality of the electromagnetic compatibility of objective radio-electronic means (EMS REM) and electromagnetic safety (ES) with respect to biological subjects and technical equipment.

The complexity of the electromagnetic environment at marine infrastructure facilities, equipped with a high density of various electronic equipment, leads to an increase in risks during various works. The complex nature of the problem of electromagnetic safety (the effect of the electromagnetic field on critical equipment and components, service personnel) is a prerequisite for the creation of new technical methods for its solution. EME is inherently probabilistic due to many sources of electromagnetic fields and changing operating conditions. The task of providing EME on MIF directly depends on the quality of the assessment of the EME formed on them, amenable to forecasting [2,3].

The method of calculating prediction of electromagnetic fields near technical means is based on strict solutions of the corresponding electrodynamic problems of fine-wire structures, with known distribution functions of currents over emitters, which are determined on the basis of approximate solutions. Calculated and experimental studies are necessary and sufficient when carrying out an electromagnetic examination of emitting objects [4, 5]. A feature of electromagnetic forecasting demonstrates that the field must be determined at distances commensurate with the geometric dimensions of the antennas and the wavelength. The boundaries of the sanitary protection zone and the zone of building restrictions can fall both in the near and intermediate radiation zones of the antennas, and in the far zone. In addition, in
these ranges, the radiation characteristics and the structure of the fields near the antennas largely depend on the electrophysical properties of the earth surface [6,7]. These factors can be taken into account only within the framework of rigorous solutions of the corresponding electrodynamic problems.

Antennas that create fields of predominantly one polarization (horizontal or vertical) in the wave zone create fields of other polarizations in the near-field zone. Their levels are commensurate and sometimes even exceed the levels of the main polarization.

Theoretical studies have shown that, due to the complex dependence of the field on the parameters, it is impossible to obtain simple relations or universal curves [8]. For the practical implementation of electromagnetic forecasting, it is necessary to know the real behavior of each component at various distances and observation heights, which can only be written off within the framework of rigorous solutions.

To determine the boundaries of the sanitary protection zone and the restriction zone, we use the proposed methodology and analyze the levels of the electromagnetic field in the horizontal and vertical planes at the adjacent site to the transmitting radio-technical object of the Center for Vessel Traffic Service using the example of the port of Novorossiysk.

2. Methodology for calculating the levels of the electromagnetic field

Let us analyze the levels of the electromagnetic field in the horizontal and vertical planes at the adjacent site to the transmitting radio-technical object of the VTS Center to determine the boundaries of the sanitary protection zone and the restricted zone. The maximum permissible values of the electromagnetic field (MPL EMF) are adopted in accordance with [9]. The lowest boundary of the biologically hazardous zone is taken as the height of the restricted zone.

With simultaneous irradiation from several sources of EMF, for which different remote controls are installed, the following conditions must be observed:

\[
\sum_j^m \left( \frac{E_{\text{SUM}j}}{E_{\text{MPV}j}} \right)^2 + \sum_k^q \left( \frac{TED_{\text{SUM}k}}{TED_{\text{MPV}k}} \right) \leq 1
\]  

(1)

where \( E_{\text{SUM}j} \) is the total electric field strength generated by the sources of EMF \( j \)-th normalized range; \( E_{\text{MPV}j} \) is the maximum permissible value of the electric field strength \( j \)-th normalized range; \( TED_{\text{SUM}k} \) is total energy flux density created by EMF sources \( k \)-th normalized range; \( TED_{\text{MPV}k} \) is maximum permissible value of energy flux density \( k \)-th normalized range; \( m \) is the number of ranges for which \( E \) is normalized; \( q \) is the number of ranges for which the \( TED \) is normalized.

Calculating EMF levels in the horizontal plane requires to take into account the display of areas for which the safety criterion (SC) \( \geq 1 \), i.e. the level of the electromagnetic field exceeds the maximum permissible level (MPL) [10]:

\[
SC = \sum_j^m \left( \frac{E_{\text{SUM}j}}{E_{\text{MPV}j}} \right)^2 + \sum_k^q \left( \frac{TED_{\text{SUM}k}}{TED_{\text{MPV}k}} \right) \leq 1
\]  

(2)

The calculations and modeling procedures were performed using the SanZone software, version 5.1.

The calculation of the levels of the electromagnetic field according to the passport radiation patterns (DP) is performed in the following sequence:

- instead of the pattern in the vertical and horizontal planes, calculated from the antenna current, normalized amplitude passport patterns are used in the vertical and horizontal planes;
- the spherical coordinates of the observation point are determined not relative to the geometric center of the antenna, but relative to the point taken as the phase center of the antenna (i.e., the spherical coordinates are determined in a spherical system, the origin of which is aligned with the specified point);
- the spherical coordinates for the mirror image of the antenna are determined in a spherical system, the beginning of which is aligned with the mirror image of the point taken as the phase center of the antenna;
- the directional factor is determined according to the passport data.

If there is no information about the device (design) of the antenna (i.e., it is not possible to build an electrodynamic model and calculate the antenna current), but its passport DN is known, then the calculation of the EMF levels is performed using the data.
The influence of the underlying surface is not taken into account in the following cases: the observation point is located below the level of the underlying surface (here we mean surfaces of limited dimensions, for example, roofs of buildings); the height of the antenna center and the height of the observation point relative to the underlying surface is 10 or more times greater than the distance between the antenna center and the observation point [4].

In the presence of influencing metal structures and (or) the underlying surface, the calculation of EMF levels differs only in terms of determining the vector of the electric field strength.

3. Analysis of the EMF levels in the horizontal plane at the adjacent site to the transmitting radio-technical object of the Center for the ship traffic control system using the example of the port of Novorossiysk

The following types of antennas are used at the adjacent site to the transmitting radio technical object (PRTO) of the Novorossiysk VTS (Figure 2): UHF antennas ANT 1500D; UHF antenna D1; a parabolic mirror with a diameter of 1.2 m, a beam pattern of 1.20, in the vertical and horizontal planes, with a gain of 41.8 dB; parabolic mirror: 0.6 m in diameter, 3.80 in the vertical and horizontal plane, 30.6 dB gain.

Antenna patterns were calculated using the Antenna Pattern Editor software and manufacturer reference data. Figure 3 shows the calculation of the directional pattern of the antenna ANT150D in the horizontal and vertical planes. The diagrams of the other antennas are calculated in the same way.

Figure 2. Technical characteristics of the antennas of the VTS equipment in the port of Novorossiysk
Figure 3. Directional patterns of the antenna ANT150D in the horizontal and vertical planes

The calculation of the horizontal section of the biologically hazardous zone was conducted at various heights of the antenna suspension from the ground level (Figure 4).

The control points were determined and the calculation of the EMF SC and its components for each radiation source at the control points was performed (Figure 5).

The values of the EMF SC and its components for each radiation source at the control points are shown in Figure 6.

Figure 4. Horizontal section of a biohazard zone at a height of 37.4 m from ground level
Figure 5. Location of control points

Figure 6. Values of the safety criterion for EMF and its components for each radiation source at control points

Calculations showed that the presence of a biologically hazardous zone with an EMF level exceeding the MPL for the population at observation points № 1-10 constitute particular interest from the point of view of the SC of the impact of electromagnetic fields on the population. SC at points № 1,2,3,4 exceeds the MPL for the population, which leads to the presence of a zone on the roof of the technical building, where the total EMF levels exceed the MPL for the population, due to the influence of existing sources of EMR. At the control points, in which the SC exceeds 1, the calculation of the maximum possible time of exposure to EMF on the operating personnel was performed:
- at control point № 1, the maximum possible time of exposure to EMF on service personnel is 35 hours 19 minutes;
- at control point № 2, the maximum possible time of exposure to EMF on service personnel is 35 hours 11 minutes;
- at control point № 3, the maximum possible time of exposure to EMF on service personnel is 63 hours 42 minutes;
- at control point № 4, the maximum possible time of exposure to EMF on service personnel is 58 hours and 20 minutes.

4. Analysis of the EMF levels in vertical planes at the adjacent site to the transmitting radio-technical object of the Center for the ship traffic control system using the example of the port of Novorossiysk

The list of vertical sections is formed for each radiation source. The planes of each sections pass through the corresponding source in the direction of its radiation. The list and individual parameters of each section can be edited. The situational plan with sources and directions of radiation is shown in Figure 7. The lowest boundary of the biologically hazardous zone is taken as the height of the restricted zone. Vertical sections of the biologically hazardous zone were made along different azimuths of the antenna location. Figure 8 shows a vertical section of the biological hazardous area in azimuth 600 along the direction of antenna № 04. IC-M604A; 05. IC-M604A.

![Figure 7](image-url)
Figure 8. Vertical section of a biohazard zone in azimuth 60° (along the direction of antenna № 04. IC-M604A; 05. IC-M604A)

Calculation of EMF levels in vertical planes showed the size of the restricted zone (RZ) along the azimuths of the transmitting antennas shows:
- the length of the RZ in the direction of 60° is 31.1 m, the maximum length is reached at an altitude of 39.2 m, the lower boundary is at a height of 30.1 m (azimuth along the direction of antenna № 04. IC-M604A);
- the length of the RZ in the direction of 60° is 15.5 m, the maximum length is reached at an altitude of 39.2 m, the lower boundary is at a height of 31 m (azimuth along the direction of antenna № 05. IC-M604A);
- the length of the RZ in the direction of 90° is 15.5 m, the maximum length is reached at an altitude of 40 m, the lower boundary at an altitude of 29 m (azimuth along the direction of antenna № 09. Mini-Link TN; 10. Mini-Link TN);
- the length of the RZ in the direction of 90° is 38.6 m, the maximum length is reached at an altitude of 40 m, the lower boundary at an altitude of 29 m (azimuth along the direction of antenna № 09. Mini-Link TN; 10. Mini-Link TN);
- the length of the RZ in the direction of 120° is 42.4 m, the maximum length is reached at an altitude of 40 m, the lower boundary at an altitude of 29.4 m (azimuth along the direction of antenna № 11. Mini-Link TN; 12. Mini-Link TN);
- the length of the RZ in the direction of 120° is 41.4 m, the maximum length is reached at an altitude of 40 m, the lower boundary at an altitude of 29.4 m (azimuth along the direction of antenna № 11. Mini-Link TN; 12. Mini-Link TN);
- the length of the RZ in the direction of 120° is 41.6 m, the maximum length is reached at an altitude of 41.6 m, the lower boundary at an altitude of 29.8 m (azimuth along the direction of antenna № 01. Spectra MX800);
- the length of the RZ in the direction of 120° is 54.3 m, the maximum length is reached at an altitude of 39.8 m, the lower boundary at an altitude of 29.2 m (azimuth along the direction of antenna № 02. Spectra MX800);
- the length of the RZ in the direction of 120° is 29.4 m, the maximum length is reached at an altitude of 41.6 m, the lower boundary at an altitude of 29.8 m (azimuth along the direction of antenna № 03. Spectra MX800);
- the length of the RZ in the direction of 120° is 29.4 m, the maximum length is reached at an altitude of 40 m, the lower boundary at an altitude of 31.2 m (azimuth along the direction of antenna № 08. Mini-Link TN).
5. Conclusion
High integral levels of EMF created during the operation of the infrastructure of maritime transport, which include the VTS, can lead to negative consequences due to unintentional effects on the quality of functioning the radioelectronic device (RED) of the facility, the RES of neighboring facilities, the personnel of the facilities and the population living in the surrounding areas.

The analysis of the used methodology for calculating EMF levels in conditions of deep urbanization at the location of the radio center of the ship traffic control service, high requirements for digital spatially coordinated data on the propagation environment of radio waves and the user interface shows the need to use advanced modern software to obtain reliable results of calculation and modeling.

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