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Measurements of the electromagnetic field intensity on the seagoing ship within the frequency range 0,1…30 MHz

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Abstract - The measurements results of the electromagnetic field intensity within the frequency range 0,1...30 MHz in the area of navigation bridge of the ship are presented. The analysis of the obtained measurements results of electric and magnetic field intensities at all measurement points were carried out.The uncertainty of the obtained measurements of magnetic and electric field intensities is estimated. Furthermore, obtained results are compared to admissible reference levels found in available normative documents.

I. Introduction

The ship environment is characterized by a wide variety of electromagnetic disturbances of different levels of determined, as well as, random character. As a result of technological development, a continuous increase of number and types of devices and electrical and electronic systems installed on ships can be observed, which causes a rise their mutual interactions. Correct functioning of ship devices and systems which provides ships security can be guaranteed only by a versatile analysis of electromagnetic disturbances occurring in the ship environment, including using effective methods for their measurement.

Available literature does not provide information concerning admissible levels of internal ship disturbances within which ship devices and electrical and electronic systems work properly or the results of investigations that were carried out.

II. The method for measuring the intensity of electric and magnetic field

Investigations of the electromagnetic field were carried out in the area of the navigation bridge of the ship which constitutes a compact metal construction. The main component of the investigated electromagnetic field comes from sources caused by the technical devices installed on the ship. Therefore, the respective measurements of magnetic and electric fields are carried out, should be taken into consideration [1, 2].

The measurements of the intensity of electric and magnetic field were performed in a system containing a set of measuring antennas and a spectrum analyzer. A computer PC was used to analyze obtained results (Fig. 1). In order to measure the intensity of electric field a rod antenna was used, whereas the intensity of magnetic field was determined using a passive loop antenna. A passive antenna consisting of a metal bar of length 104 cm and a frequency range of 1 kHz ÷ 30 MHz was utilized as a rod antenna . It was equipped with a manual switching matching circuits for a frequency range of 1kHz ÷ 5 MHz and 5 MHz ÷ 30 MHz. A loop antenna with a diameter

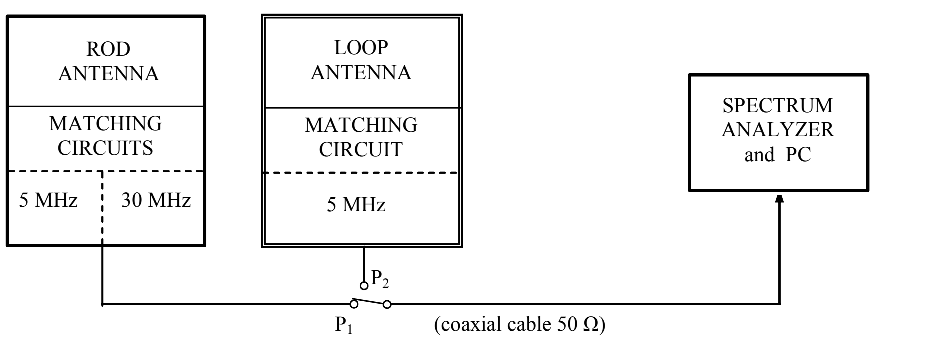

Figure 1. Block diagram for the measurements of the intensity of electric and magnetic fields

of 56 cm and a frequency range of 20 Hz ÷ 5 MHz was used to measure the intensity of magnetic field. Both antennas, as well as, the spectrum analyser possessed a 50 Ω impedance (Fig. 1).
Due to the changing of the impedances of the measuring antennas as a function of frequency and the standardization of their output impedances, so-called antenna factors have to be taken into account while determining directly the intensity of electric field *E* and magnetic field *H*. Antenna factors characterize the properties of a given type of an antenna construction and matching circuits. The units of the factors are usually given in *dB* scale (Fig. 2 and 3). Then, the values of magnetic and electric field intensities can be determined in the logarithmic scale using the equations:

$$E\left[dB\mu V/m\right] = AW\left[dB\mu V\right] + WA_E\left[dB/m\right] \tag{1}$$

$$H\left[dB\mu A/m\right] = AW\left[dB\mu V\right] + WA_H\left[dBS/m\right] \tag{2}$$

where: $AW\left[dB\mu V\right]$ is a level of a voltage root mean square at the antenna clamps (measured using the spectrum analyser), $WA_E\left[dB/m\right]$ is a rod antenna factor and $WA_H\left[dBS/m\right]$ is a loop antenna factor.

Figure 2. The value of antenna factor $WA_E\left[dB/m\right]$ in the frequency function
for the rod antenna of type 3303 made by EMCO [3]

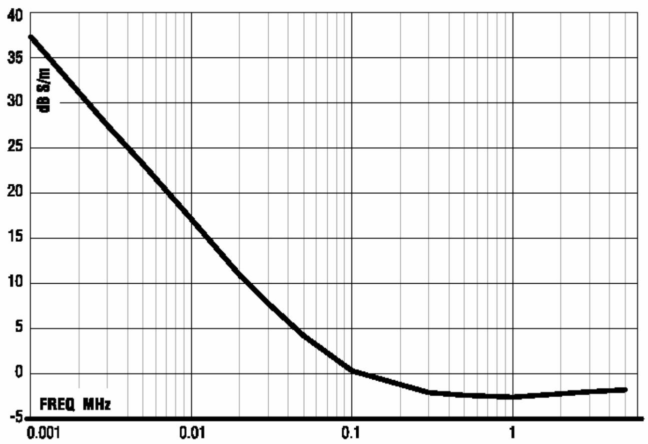

Figure 3. The value of antenna factor $WA_H\left[dBS/m\right]$ in the frequency function
for the loop antenna of type 6511 made by EMCO [3]

III. Results of measurements of magnetic and electric field intensities

The measurements of electric and magnetic field intensities were performed onboard the *Gdynia Maritime University* vessel *Horyzonf II* in the navigation bridge area during her trip trough the waters of Bay of Gdańsk and water surrounding Hel Peninsula (Baltic Sea). They were carried out in 7 measurement points including a whole navigation bridge. During the experiment, all the standard devices present on the navigation bridge were turned on (Fig. 4).

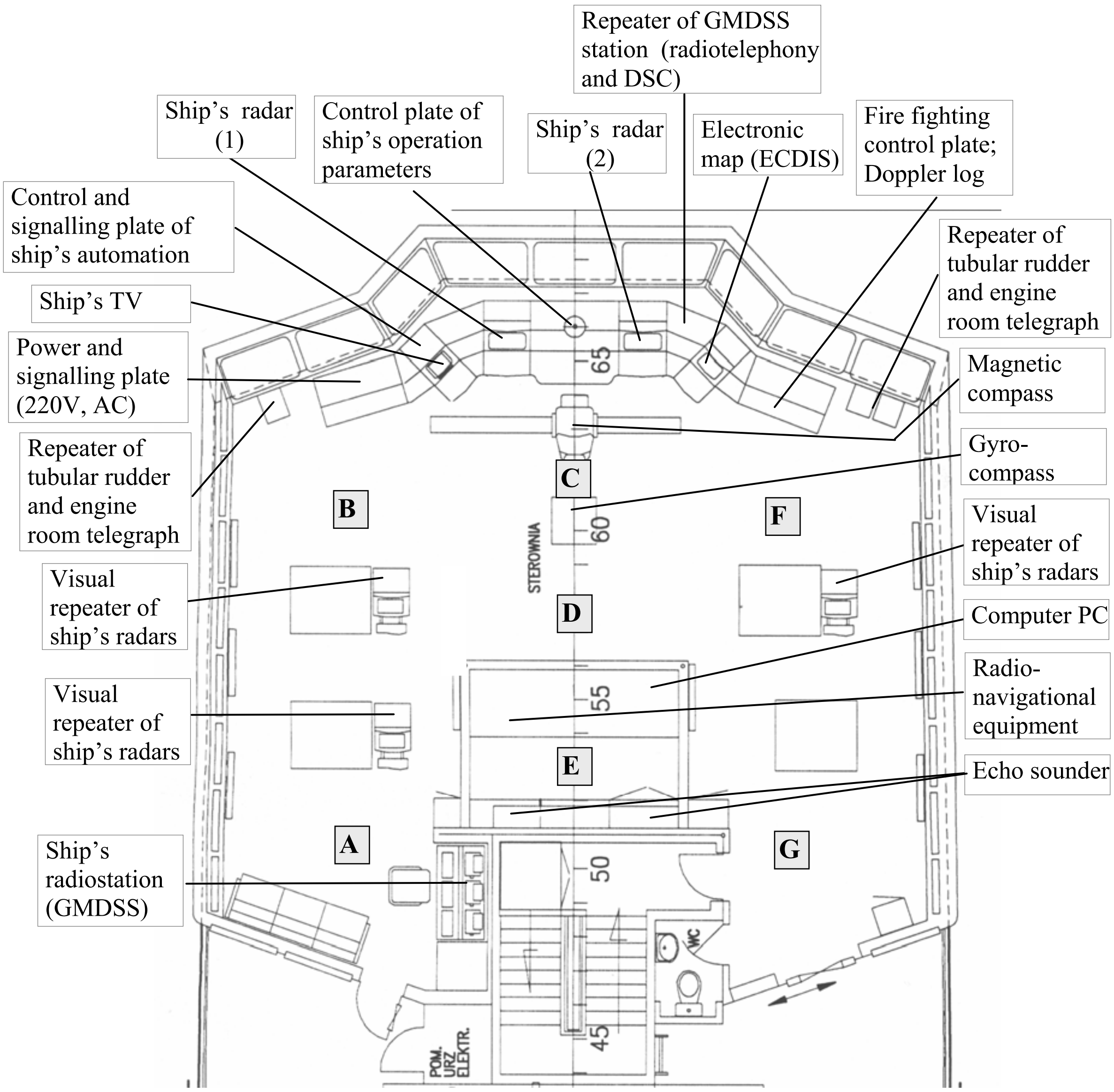

Figure 4. Topology of measurement points of electric and magnetic field intensities in the navigation bridge area of the vessel *Horyzont II*; on the drawing: A... G - measurement points; GMDSS – Global Maritime Distress and Safety System; DSC – Digital Selective Calling; ECDIS – Electronic Chart Display and Information System

In each points following measurements were carried out:

- measurement of the magnetic field intensity in the frequency range of 0,1 ÷ 5 MHz;
- measurement of the electric field intensity in the frequency range of 0,1 ÷ 30 MHz;
- measurement of the electric field intensities around the international frequencies used for radiotelephone communication in case of danger (2182 kHz, 4125 kHz, 6215 kHz, 8291 kHz, 12290 kHz, 16420 kHz, 18817 kHz, 22151 kHz oraz 25092 kHz) in a band 1 MHz (+/- 0,5 MHz).

Due to the fact that two work ranges of the rod antenna matching circuits were used and in order to increase the frequency resolution, the measurements of electric field intentsity were performed in three sub-ranges of frequency: 1000 ÷ 5000 kHz, 5 ÷ 15 MHz i 15 ÷ 30 MHz. The spectrum analyzer used during tests automatically registered only ten highest values of magnetic and electric field intensity occuring in a given frequency range. The sampling frequency of the spectrum analyzer was equal to 30 Hz in all cases.
The measurement results for an exemplary measurement point A, positioned near the ship's radiostation, are presented on the Fig. 5 (a-c). The values of electric field intensity measured within the frequency band +/- 0,5 MHz around the most important in marine radiocommunication international radiotelephone frequency 2182 kHz are shown on the Fig. 5d.

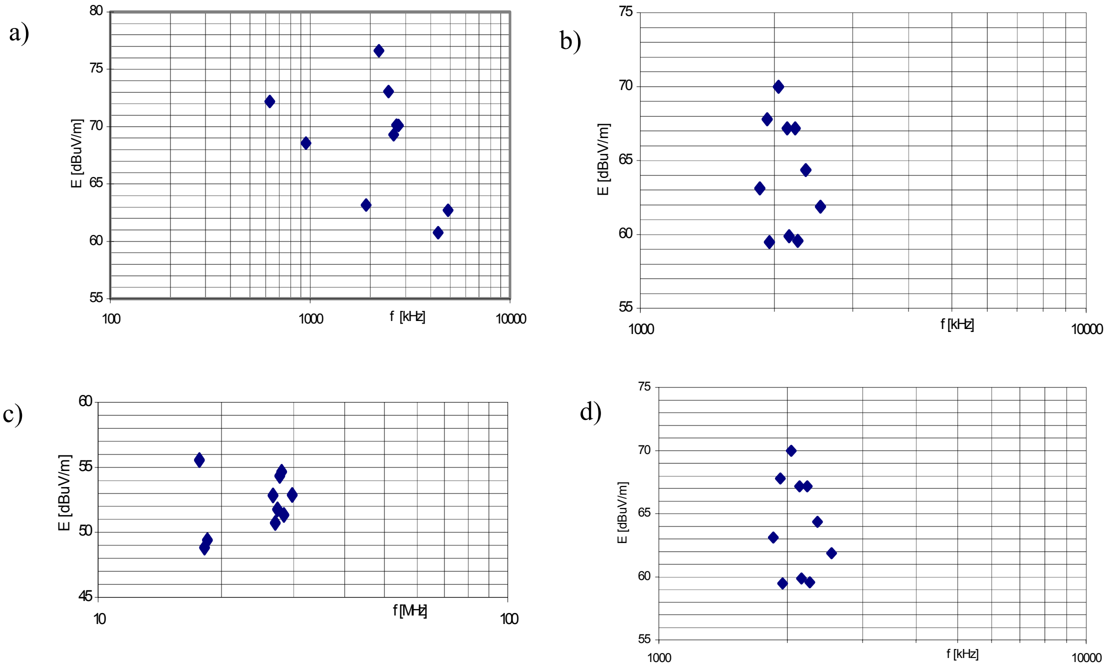

Figure 5. The ten highest values of electric field intensity in the measurement point A within the frequency range: a) 100 ÷ 5000 kHz, b) 5 ÷ 15 MHz i c) 15 ÷ 30 MHz
d) +/- 500 kHz around frequency 2182 kHz

The measured ten highest values of electric field intensity in each of seven measurement points were occuring at the different frequencies. It occured in each of given for electric field intensity measurement frequency sub-ranges. Therefore it can not be stated that the measured electric field disturbance come from the same disturbance sources.
Comparing the maximum values of intensity of electric field measured for given sub-ranges in every measurement points, it might be stated that they had the different levels.
For the sub-range 100 kHz ÷ 5 MHz, among all measured maximum values of intensity of electric field the bigest maximum value was in measurement point G and it equals $E_{G\max} = 86{,}5\ dB\mu V/m$, and the smallest one was in measurement point D - $E_{D\max} = 73{,}9\ dB\mu V/m$. For the sub-ranges 5 ÷ 15 MHz and 15 ÷ 30 MHz above mentioned values were adequately:

- $E_{D\max} = 63{,}8\ dB\mu V/m$ in measurement point D and $E_{B\max} = 58{,}2\ dB\mu V/m$ in measurement point B and
- $E_{F\max} = 69{,}8\ dB\mu V/m$ in measurement point F and $E_{A\max} = 55{,}5\ dB\mu V/m$ in measurement point A.

In every considered frequancy sub-range, the ranges of changes the measured ten maximum values of the electric field intensity for every measuring point was compared as well.
For the sub-range 100 kHz ÷ 5 MHz the largest range of change was measured in measurement point F and it equals 18 dB, for the maximum value of the electric field intensity equals $E_{F\max} = 78{,}7\ dB\mu V/m$ and the smallest range of change equals 12 dB in measurement point D. For the sub-ranges 5 ÷ 15 MHz and 15 ÷ 30

MHz above mentioned values were adequately:

- 12 dB in measurement point G, for the maximum value of intensity of electric field equals $E_{G\max} = 62{,}7\ dB\mu V / m$ and 8 dB in measurement point B and
- 8 dB in measurement point A and 3 dB in measurement point D, for the maximum value of intensity of the electric field equals $E_{D\max} = 64{,}6\ dB\mu V / m$.

The values of magnetic field intensity obtained for the same measurement point A are presented on the Fig. 6. It was observed that the highest values of magnetic field intensity occurred within the frequency range of 100 kHz ÷ 500 kHz. Therefore, measurements were carried out only within above frequency range in order to increase the frequency resolution.

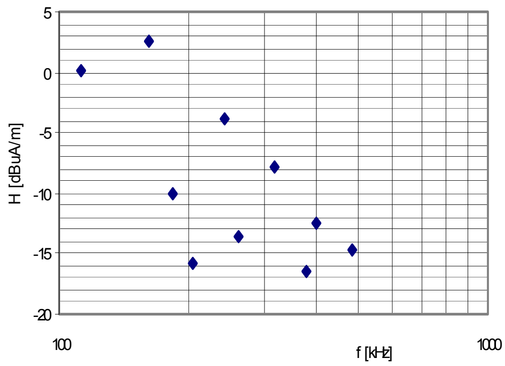

Figure 6. The ten highest values of magnetic field intensity in the measurement point A, within the frequency range 100 kHz ÷ 500 kHz

The measured ten highest values of the magnetic field intensity in every measurement points, similarly how for the electric field, were occuring at the different frequencies. Therefore it can not be stated that the measured disturbance come from the same disturbance sources as well.
Comparing the maximum values of intensity of the magnetic field measured in each of seven measurement points, it might be stated that they had the different levels.
For the given for the magnetic field measurement frequency range 100 kHz ÷ 500 kHz, among all measured maximum values of intensity of magnetic field the bigest maximum value was in measurement point F and it equals $H_{F\max} = 20{,}8\ dB\mu A / m$, and the smallest one was in measurement point A - $H_{A\max} = 2{,}5\ dB\mu A / m$.
Using obtained results of measurements, the ranges of changes the measured ten maximum values of intensity of the magnetic field for every measurement point was compared as well.
For the considered range 100 kHz ÷ 500 kHz the largest range of change was measured in measurement point D and it equals 26 dB, for the maximum value of the magnetic field intensity equals $H_{D\max} = 12{,}6\ dB\mu A / m$ and the smallest one equals 17 dB in measurement point A.

IV. Assessment of uncertainties in measurement of the magnetic and electric field intensities

The uncertainty of type B corresponding to systematic errors was determined for performed measurements [4]. According to the measurement methodology, during estimating the uncertainty of above measurements, one should take into account the uncertainty constituents caused by systematic effects such as: calibration of the antenna factors, reading the values of antenna factor from the graphs, measurement of the voltage root mean square on the antenna clamps with the use of spectrum analyzer. Standard uncertainties were estimated assuming that systematic errors of measurements can be described by means of the rectangular probability distribution. Expanded uncertainty was estimated at a 95% confidence level, given that antenna factor is equal to k=2 [4]. Taking into consideration the catalogue data of the measuring antennas and the spectrum analyzer, the standard compound uncertainty of measurement of the magnetic and electric field intensity equals to 2,18 dB, whereas the expanded uncertainty is equal to 4,36 dB.

V. Conclusions

Above considerations suggest that within the frequency range 0,1…30 MHz, the levels of the electric and magnetic field intensity are strongly dependent on the frequency and that the main electromagnetic field constituent is the electric field.

Measurements of the electromagnetic field performed onboard the *Gdynia Maritime University* vessel *Horyzont II* show that within the frequency range 0,1… 30 MHz the level of electric field can exceed admissible values (Fig. 5). This statement is justified by the fact that in the standard documents [5] for the frequency range above 30 MHz, the value of admissible electric field intensity is equal to 30 dBµV/m, whereas the expected admissible value for the frequency range within which the electromagnetic field was measured should be lower than that value. Every kind of a seagoing ship possess its own distinct characteristics of these disturbances. Therefore, the thesis stated above should be confirmed by further investigations of the level of the electromagnetic field in the environment of other ships.

The results of measurements performed in seven different points allow to precisely surface analyse the levels of electric field intensity in the area of the navigation bridge of the vessel *Horyzont II*.

With analysis of the measured ten highest values of field intensity (electric and magnetic) in each of seven measurement points it can be stated that they were occuring at the different frequencies. Above mentioned conclusion refers to each of considered in paper the frequency sub-ranges. Therefore it can not be stated that the measured disturbance, both magnetic and electric, come from the same disturbance sources.

Comparing the measured maximum values of the field intensity (electric and magnetic) for given sub-ranges in every measurement points, it might be stated that they were occurring at the different frequencies and the different levels.

Definitely the largest values of the electric field disturbance from installed on the *Horyzont II* navigation bridge devices, as their dynamics occurred in the frequency sub-range 100 kHz ÷ 5 MHz (Fig. 5).

The comparison of the ranges of changes the measured ten maximum values of the field intensity (both electric and magnetic) in every considered frequancy sub-ranges shows on different ranges of changes these values and the different distribution of desturbance in individual measuring points.

Recapitulating, it can be affirmed that the presented method of measurement of electric and magnetic fields and the number of obtained measurement results to allow to estimate fields levels only but it doesn't allow to come to the detailed conclusions.

It should be emphasized that available literature does not provide information about relevant recommendations and guidelines concerning limiting levels of disturbances on the seagoing ships, the methods for measuring them or the results of experimental investigations.

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