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ASSESSEMENT OF LOW FREQUENCY ELECTROMAGNETIC FIELD INTENSITIES ON BOARD OF SHIPS

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Abstract: The methodology of measurements of low frequency electromagnetic field intensity, existing on the seagoing ships, is presented. The selected results of the tests taken during the ship's stay in the port and at sea, are performed. In some chosen places, the level of electric and magnetic constituents of the field intensity was assessed. The sources of strong magnetic field in the low frequency range have been located, its spectrum course was of 1/f type. Due to the analysis of measurements results, the level of electromagnetic field intensity was evaluated, in reference to standards and recommendations of marine classification societies. The analysis of the emitted disturbances level was carried out, bearing in mind the crew protection against the excessive emission of electromagnetic field.

Keywords: electromagnetic field, low frequency magnetic field.

1. INTRODUCTION

The problem of measurement and assessment of electromagnetic disturbances exists especially hard onboard seagoing ships because of high concentration, in small area, of different power electronic and electronic devices, which are exposed to the influence of many different environment factors, like high temperature, humidity, salinity and also oscillation and vibration [1].

The operation of these devices, in particular in transient states, is the reason of occurrence of the violent changes of electromagnetic field, which have influence on technical equipment, causing in many cases their abnormal functioning, and also badly affect people staying near by [2].

The requirements in electromagnetic compatibility (EMC) to ship equipment, concern mainly to immunity and emission tests of this equipment to the medium and high frequency fields.

In the ship environment, where generators are running, also the transmitters, marine alternators, high power transformers, electric motors, power electronic converters, usually the strong magnetic fields occur in the low frequency range, of which the spectrum course is of 1/f type. In such cases, the electromagnetic field intensity level should be monitored, its electric and magnetic constituents, and relevant counteracting techniques against excessive intensities of those fields should be applied.

2. PROGRAM OF EXPERIMENTS

The tests were performed onboard the training-research vessel staying in the port and at sea, during her trip from Gdynia to Spitzbergen on August 2004.

The purpose of these tests was to check the level of electromagnetic field intensities in low frequency range, because of lack of information about it with respect to sea-going ships.

The rules of classification societies do not contain these problems, it is possible to find there the rules taking into account the level of electromagnetic field intensity in high frequency range, which exists during running of the radars.

The electromagnetic field intensity measurements were done with the use of ESM-100 H/E field-meter of Maschek [3]. This isotropic meter of the electromagnetic field enables measurements of both the electric and magnetic field components within the range 5 Hz up to 400 kHz in four successive measurement sub-ranges: "all" - 5 Hz to 400 kHz (-3 dB limit), at frequency "50 Hz" (for 12 dB of the band-pass filter), "low" - 5 Hz to 2 kHz and "high" - 2 kHz to 400 kHz. In each measurement sub-range the meter enables the measurements of the field intensity in the range: from 1 nT to 20 mT for the magnetic field and from 0,1 V/m to 100 kV/m for the electric field. H (magnetic) and E (electric) fields are displayed simultaneously in 3 dimensional values:

$$H = \sqrt{H_x^2 + H_y^2 + H_z^2} \tag{1}$$

$$E = \sqrt{E_x^2 + E_y^2 + E_z^2} \tag{2}$$

The level of electric and magnetic field was measured in 12 points in Engine Room and in superstructure of the ship. All measurements were carried out on the height of 1 m above the floor surface.

The following measurement points were chosen in Engine Room:

- Main Switchboard Panel No 9 in Engine Control Room (ECR),
- Generator No I,
- Generator No III,
- Power Transformers 3x440/230V,

and inside the superstructure:

– Bridge Navigation Table,
– Bridge Control Console,
– Bridge Global Maritime Distress Safety System (GMDSS) Stand,
– Navigation Deck close to Funnel,
– Crew Cabin No 404,
– Crew Mess,
– Galley,
– Cadet Mess.

Except of the tests results taken in all available ranges: “high”, “low”, “all” and “50 Hz”, the ship heading course, her position, and running generator power were noted in measurement protocols. The average speed of the ship during the trip was about 12 knots.

3. SELECTED RESULTS OF EXPERIMENTS

In the investigated environment, the electric field intensity in frequency range from 5 to 400 kHz is practically negligible (Fig. 1, Fig. 2, Tab. 1). The highest value of electric field intensity, which exceeded 5 V/m, was observed close to GMDSS stand on the bridge (Fig. 2).

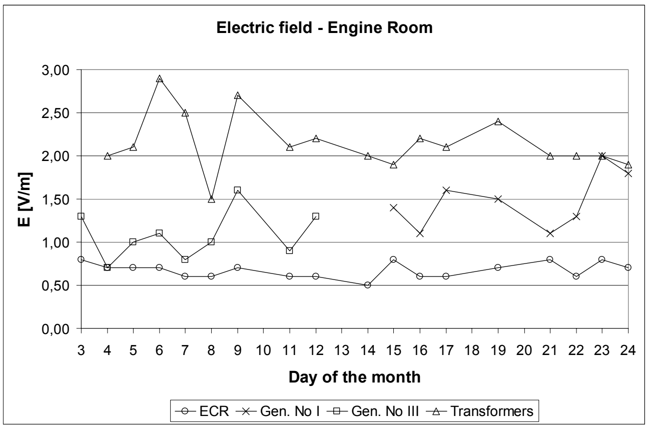

Fig. 1. Electric field intensity in the frequency sub-range 5 Hz to 400 kHz, in the different measurement points of Engine Room

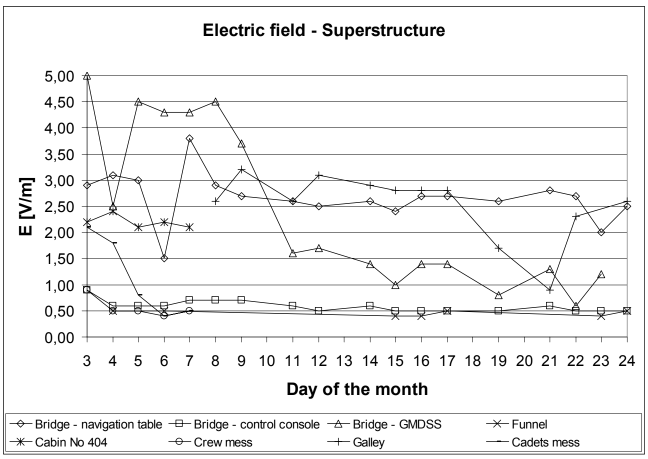

Fig. 2. Electric field intensity in the frequency sub-range 5 Hz to 400 kHz, in the different measurement points of superstructure

The similar values of electric component of electromagnetic field are found close to running equipment of general use, like hair dryer, phone or washing machine [2].

Looking at the results of experiments, it can be found, that the main area of the highest level of magnetic field onboard the ship is the Engine Room (Fig. 3).

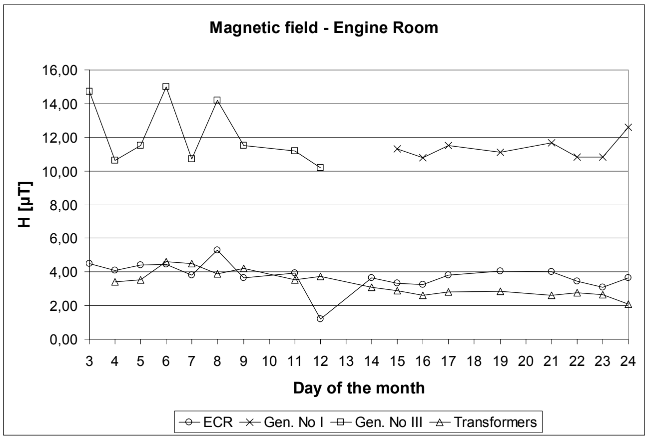

Fig. 3. Magnetic field intensity in the frequency sub-range 5 Hz to 400 kHz, in the different measurement points of Engine Room

The levels of magnetic field intensities measured in superstructure are more then 20 times smaller then those observed in engine room (Fig. 4).

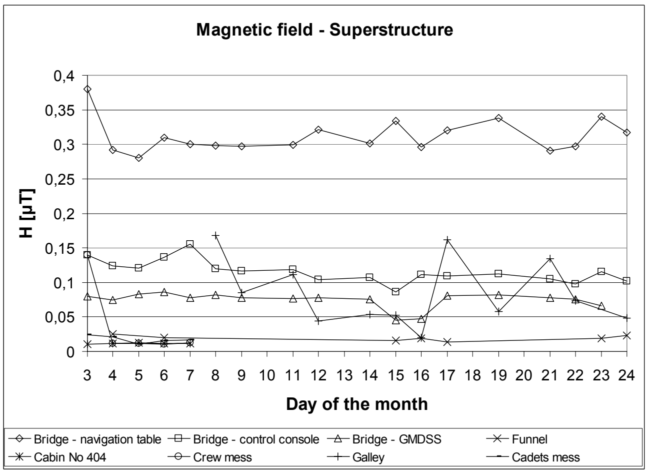

Fig. 4. Magnetic field intensity in the frequency sub-range 5 Hz to 400 kHz, in the different measurement points of superstructure

During the measurements, the great dynamics of changes of magnetic field intensity was observed, which depended both on the place and the time of the measurements.
These changes occurred especially in the areas, where the magnetic field of high intensity existed, especially close to the running generators (Fig. 5). The level of magnetic field intensity was also dependent on loading of generators and was increasing with increase of the output power of generators (Tab. 2).

From the carried out measurements of the magnetic field, it results, that its spectrum depends strongly on frequency (Fig. 6). The magnetic field spectrum spreads out mainly in low frequency range below 2 kHz (Tab. 1).

Table 1. Exemplary measurement results of electric and magnetic field intensities close to generators in Engine Room

Day of the month	Measurement frequency range							
	50Hz		5Hz – 400kHz		5Hz – 2kHz		2kHz – 400kHz	
	E [V/m]	H [µT]	E [V/m]	H [µT]	E [V/m]	H [µT]	E [V/m]	H [µT]
3	0,00	14,30	1,30	14,70	0,00	14,00	0,00	0,25
4	0,00	10,60	0,70	10,64	0,00	10,80		
5	0,00	12,10	1,00	11,50	0,00	11,40	0,00	0,20
6	0,00	13,80	1,10	15,00	0,00	13,60	0,00	0,24
7	0,00	10,60	0,80	10,70	0,00	10,80	0,00	0,17
8	0,00	13,10	1,00	14,20	0,00	13,10	0,00	0,21
9	0,00	11,40	1,60	11,50	0,10	11,50	0,00	0,19
11	0,00	10,40	0,90	11,20	0,00	10,30	0,00	0,18
12	0,00	10,50	1,30	10,20	0,00	9,80	0,00	0,17
15	0,00	11,30	1,40	11,30	0,10	11,60	0,00	0,19
16	0,00	9,97	1,10	10,80	0,00	9,88	0,00	0,17
17	0,00	11,30	1,60	11,50	0,00	11,60	0,00	0,19
19	0,00	11,12	1,50	11,11	0,00	10,84	0,00	0,17
21	0,00	11,43	1,10	11,68	0,00	11,82	0,00	0,19
22	0,00	9,84	1,30	10,84	0,00	9,92	0,00	0,17
23	0,00	10,72	2,00	10,82	0,00	10,84	0,00	0,19
24	0,00	12,38	1,80	12,59	0,30	13,01	0,00	0,24

Table 2. Exemplary measurement results of magnetic flux density in Engine Room, close to Generator No III

Day of the month	Magnetic flux density [µT]				Generator output power [kW]
	50Hz	5Hz – 400kHz	5Hz – 2kHz	2kHz – 400kHz	
4	10,60	10,64	10,80	-	150/160
5	12,10	11,50	11,40	0,20	130/160
6	13,80	15,00	13,60	0,24	150/170
7	10,60	10,70	10,80	0,17	130
8	13,10	14,20	13,10	0,21	150
9	11,40	11,50	11,50	0,19	130
11	10,40	11,20	10,30	0,18	130/150

Moreover, in the time of measurements, the big sensitivity of the H/E field-meter on any its movement was found.

The remarkable influence on results of experiments had the distance of the meter from the source of magnetic field. That's why when the ship was rolling, the uncertainty of readouts was increasing. When the ship was rolling very strong, the readouts of the meter were not possible.

The smallest fluctuations of readouts occurred when the "high" sub-range was chosen.

However, the influence of earth magnetic field on measurements was not noticed, in spite of the trip of the ship to the far North, to Spitzbergen.

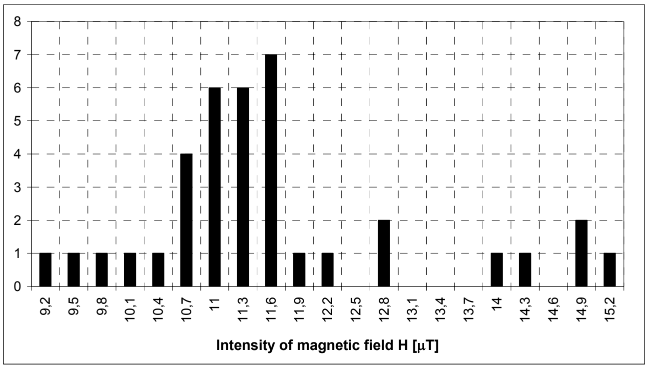

Fig. 5. The histogram of magnetic field intensity close to generators in Engine Room

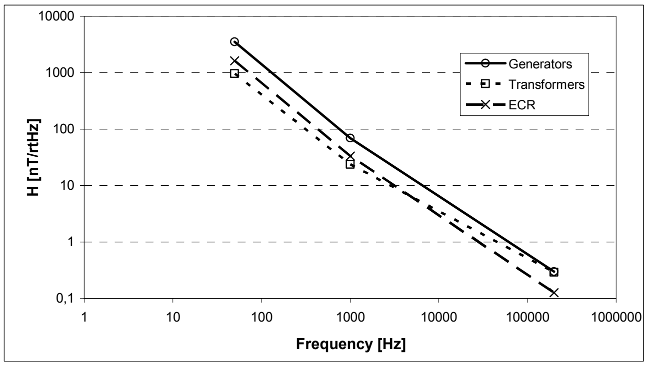

Fig. 6. Magnetic field spectrum in Engine Room - an assessment on the basis of values of magnetic field intensities, for the results obtained in all measurement frequency sub-ranges

4. ADMISSIBLE REFERENCE LEVELS OF EMF INTENSITIES

The rules of classification societies don't include the problems of crew health protection against the low frequency Electro-Magnetic Fields (EMF), which are met in occupational environment.

It is generally known, that energy of electromagnetic field, which exposures directly on human body, may cause undesirable biological effects, like changes in functioning of its cells, or even whole body [4].

Occupational EMF exposure of high strength and long time duration may have influence on health and labour ability. The national guidelines [5, 6] apply to limitations on access, where the protective zones borders and EMF strengths are stated, also the rules of admissible exposure in each zone.

Taking into account, that results o exposure are very strong dependent, not only on EMF strength, but also on time duration and EMF time-varying - exposure limits are changing with EMF frequency and radiation level, which affects the man.

The above recommendations apply to reference levels for general public and occupational exposures, proposed by International Commission on Non-Ionizing Radiation Protection (ICNIRP'98) [7].

Comparing the results of electric field measurements (Fig.1, Fig.2) with reference levels (Tab. 3, Tab. 4), it can be found, that these limits were not exceed. The highest observed values were some tens times smaller then admissible.

Table 3. Electric field strength admissible values [6]

Frequency range	E-field strength ($V m^{-1}$)		
	E_0	E_1	E_2
up to 0.5 Hz	10 000	20 000	40 000
0.5 – 300 Hz	5 000	10 000	20 000
0.3 – 1 kHz	100/3*f*	100/*f*	1000/*f*
1 – 400 kHz	33,3	100	1000

where:
E_0 - the lower border of intermediate zone (E-field strength, which divides intermediate and safe zones),
E_1 - the lower border of hazard zone (E-field strength, which divides hazard and intermediate zones),
E_2 - the lower order of dangerous zone (E-field strength, which divides dangerous and hazard zones).

Table 4. Reference levels for different exposure to time-varying electric fields (unperturbed rms values) [7]

Frequency range	E-field strength ($V m^{-1}$)	
	general public exposure	occupational exposure
up to 1 Hz	-	-
1 – 25 Hz	10 000	20 000
0.025 – 0.82 kHz	250/*f*	500/*f*
0.82 – 400 kHz	87	610

Comparison of the highest registered values of magnetic field intensities in Engine Room with the reference levels, was carried out first of all for M-field strengths, which divide hazard and intermediate zones, dangerous and hazard zones, and reference level of occupational exposure (Fig. 7). In this case, the magnetic field intensity measurements taken close to the generators in frequency range 5 Hz to 2 kHz, insignificantly exceeded the lower border of hazard zone.

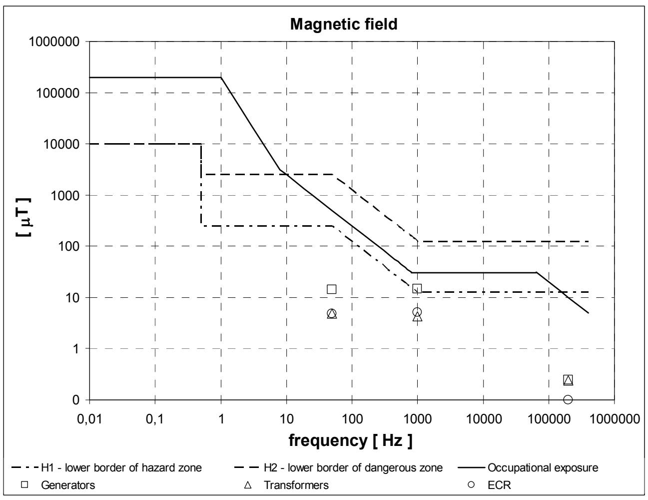

Fig. 7. Admissible levels of M-field strength , which divide hazard and intermediate zones, dangerous and hazard zones, and reference levels for occupational exposure to magnetic fields [6 ,7]

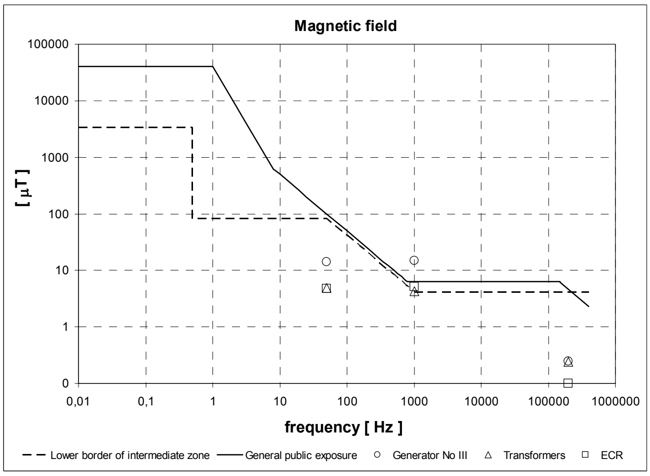

Fig. 8. Admissible levels of M-field strength , which divide intermediate and safe zones and reference levels for general public exposure to magnetic fields [6 ,7]

The other observed values of magnetic field intensities in Engine Room are lower then magnetic field strength admissible values.

Next the highest registered values of magnetic field intensities were compared with the reference levels for safe zone and reference level for general public exposure (Fig. 8). In the frequency range 5 Hz to 2 kHz, magnetic field intensities measured close to the running generators, exceeded admissible levels - the lower border of intermediate zone and reference levels for general public exposure. But for the Main Switchboard Panel No 9 in Engine Control Room (ECR) and Power Transformers, the measurement values were at the lower border of intermediate zone.

For the other frequency ranges, recommendations of the rules were fulfilled.

5. FINAL REMARKS

In the investigated environment, in frequency range 5 Hz to 400 kHz, there is a low intensity electric field. During research works the high dynamics of magnetic field level changes was observed, which was dependent on the place and time of the tests. Those changes occurred especially in the areas with high intensity of magnetic field.

The highest levels of magnetic field strengths were observed in Engine Room, close to the running generators.

About three times smaller values of magnetic field strengths had been registered close to the No 9 Panel of Main Switchboard in ECR and close to the power transformers. The measurements had exerted, that magnetic field intensity in Engine Room achieved notable values and varied in time, and the level of its spectrum increased with decrease of frequency.

The spectrum of increased magnetic field intensity extends mainly in the low frequency range, below 2 kHz. In this frequency range, the observed values of magnetic field strength, measured close to the running generators, exceeded the lower border of hazard zone, which divides hazard and intermediate zones.

Taking into account the results of experiments, it can be said, that magnetic field strength in superstructure is small and there is no danger to the health of the crew.

In the paper, the selected results of preliminary tests made onboard the seagoing ship were performed. The purpose of these tests was to find the areas with the high level of electromagnetic field.

The next stage is to make detailed measurements of magnetic field strength, close to the running generators in Engine Room, for the frequency range up to 2 kHz.

The authors are going to record time waveforms of this magnetic field strength and later to make spectral analysis.

The results of the carried out tests, are used by the authors for research works, which lead to application of selective techniques for decreasing of the low frequency EMF disturbances level on ships.

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