

ELECTRIC AND MAGNETIC FIELD MEASUREMENTS FROM A SHIP FOUND IN THE PORT AREA

Gheorghe SAMOILESCU¹

Florentiu DELIU²

Adelina BORDIANU³

Serghei RADU⁴

¹Captain Professor engineer, Ph.D, “Mircea cel Batran” Naval Academy, Constanta

²Engineer, Ph.D, “Mircea cel Batran” Naval Academy, Constanta

³Lecturer engineer Ph D, University “Politehnica” of Bucharest

⁴Marine Chief Engineer, PdD, Stena Crewing

Abstract: In order to conduct electromagnetic field measurements on board a ship four different locations have been used: the upper deck; the aft; the command point- exterior; the navigating bridge - inside. Within each location measurements were performed with different stations located in broadcasting, on different frequency ranges and operating modes (AM - amplitude modulation and FM - frequency modulation), depending on the available sensors. The measurements made on the ship targeted the following frequency ranges: 88-200 MHz, 200-2500 MHz. Measurements carried out on the vessel gaved data on: the electric field E [V / m], for different frequency ranges; the electric field [dB μ V / m]; rate exposure; ER: $E2/L2$; field strength limit, L [V / m]; measurement error, $ER * 1000$ [%]; electromagnetic power flux density, PD (or S) [μ W / cm²]; total field strength (RMS) [V / m]; maximum single [V / m].

Key words: electric field, magnetic field measurements, exposure rate, flux density

Introduction

The measuring equipment used in order to perform field measurements consists of:

1. **Portable spectrum analyzer with accessories and specialized software - R&S FSP13** (1164.4391.13)-Spectrum analyzer 9 kHz - 13 GHz, -140 - +30 dBm, RBW 10 Hz - 10 MHz, TFT color display; **R&S FSP-B1** (1129.7998.02)-Rugged case with variable carrying handle for all FSP models; **R&S FSP-B16** (1129.8042.03)-LAN interface 10/100 base T for FSP with Nr.1164.4391.XX; **R&S FSP-B9** (1129.6991.02)-Tracking generator for FSP, 9 kHz - 3 GHz, I/Q modulator; **R&S FSP-B28** (1162.9915.02)-Trigger port for FSP; for indication of trigger conditions (necessary for operation with TS-EMF); **R&S FSP-B30** (1155.1158.02)-DC power supply 12 - 28 V for FSP spectrum analyzer and ESPI test receiver; **R&S FSP-B31** (1155.1258.02)-NiMH battery pack + charger for FSP, requires FSP-B1 and FSP-B30; **R&S FS-K9** (1157.3006.02) Measurements with NRP power sensors NRP-Z11 / Z21 / Z22 / Z23 / Z24 / Z51 / Z55 / Z91 requires NRP-Z3 or NRP-Z4; **R&S NRP-Z4** (1146.8001.02) USB adapter (passive) for NRP-Z sensors powered via USB; **R&S NRP-Z22** (1137.7506.02) Average power sensor, 10 MHz - 18 GHz, 2 nW - 2 W for universal use; **RF Cable Huber & Suhner (23005046)** 13GHz, 1m long, N male connectors.

2. **TS-EMF system – portable isotropic antenna - R&S TS-EMF** (1158.9295.03)-Portable EMF measurement system 30 MHz - 3 GHz, 1 mV/m - 100 V/m (without FSH 3, laptop and carrier bag);

R&S TS-EMF22 (1166.5708.02)-Cable set for TS-EMF; **R&S TS-EMF-O3** (1101.8477.03)-EMC-tripod for TS-EMF; **R&S RNB** (0272.4910.50)-Termination (50 Ohm, 1 W, DC-4 GHz, N-male) [1].

Measurements data - tabular and graphical representation

The measurements were conducted in three locations within the port for four different points from the ship: the upper deck (1); the aft (2); the command point- exterior (3); the navigating bridge – inside (4). Different specialty papers were taken into account [2-10].

Representation in a fixed set of coordination (on the aft deck).

The chart presented in figure 1 is based on the performed measurements – see Table 1.

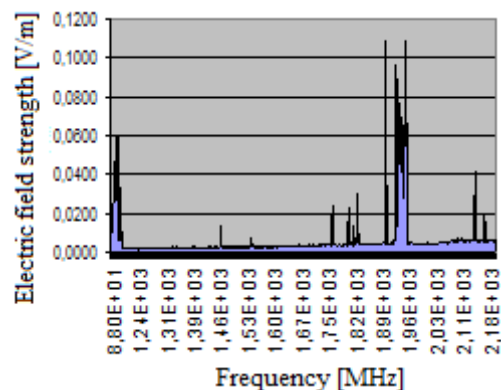


Fig. 1. Ambient noise measurements at 09.43 (background 1, point 1)

Table 1

Frequency MHz	Field Strength V/m	Power Density $\mu\text{W}/\text{cm}^2$
1,91E+03	0,1097	0,0032
1,96E+03	0,1087	0,0031
1,90E+03	0,1044	0,0029
1,93E+03	0,0962	0,0025
1,96E+03	0,0913	0,0022
1,94E+03	0,0897	0,0021
1,96E+03	0,0766	0,0016
1,96E+03	0,0739	0,0014
1,93E+03	0,0733	0,0014
1,95E+03	0,0717	0,0014
1,94E+03	0,0709	0,0013
1,95E+03	0,0703	0,0013
1,94E+03	0,0689	0,0013
1,94E+03	0,0676	0,0012
1,94E+03	0,0643	0,0011

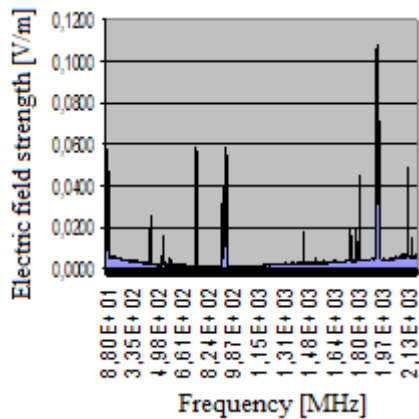


Fig. 2. Ambient noise measurements at 11.36 (background 2, point 1)

The graph is based on the following measurements - Table 2.

Frequency MHz	Field Strength V/m	Power Density $\mu\text{W}/\text{cm}^2$
1,95E+03	0,1079	0,0031
1,93E+03	0,1065	0,0030
1,95E+03	0,0933	0,0023
1,94E+03	0,0864	0,0020
1,95E+03	0,0832	0,0018
1,93E+03	0,0782	0,0016
1,95E+03	0,0714	0,0014
1,96E+03	0,0706	0,0013
1,95E+03	0,0693	0,0013
1,95E+03	0,0681	0,0012
1,94E+03	0,0642	0,0011
1,94E+03	0,0630	0,0011
1,96E+03	0,0604	0,0010
1,96E+03	0,0594	0,0009

9,59E+02	0,0589	0,0009
1,04E+02	0,0581	0,0009

The chart presented in figure 3 is based on the following measurements -Table 3.

Frequency MHz	Field Strength V/m	Power Density $\mu\text{W}/\text{cm}^2$
1,95E+03	0,1094	0,0032
1,96E+03	0,1084	0,0031
1,94E+03	0,1020	0,0028
1,95E+03	0,0965	0,0025
1,93E+03	0,0892	0,0021
1,94E+03	0,0832	0,0018
1,96E+03	0,0824	0,0018
1,96E+03	0,0822	0,0018
1,94E+03	0,0780	0,0016
7,59E+02	0,0780	0,0016
1,94E+03	0,0775	0,0016
1,93E+03	0,0774	0,0016
1,95E+03	0,0758	0,0015
1,94E+03	0,0746	0,0015
1,91E+02	0,0740	0,0015
1,94E+03	0,0731	0,0014

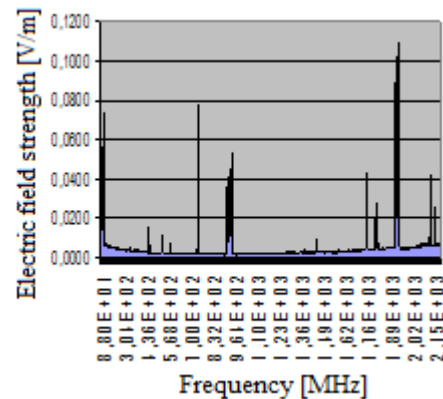


Fig.3. Ambient noise measurements at 14.41 (background 3, point1)

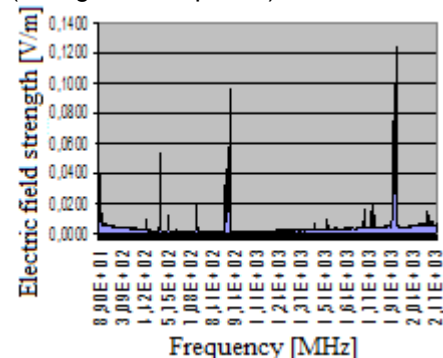


Fig. 4. Ambient noise measurements at 15.54 (background 4, point 1- below aft deck)

The above chart is based on the measurements listed below – Table 4.

Frequency MHz	Field Strength V/m	Power Density $\mu\text{W}/\text{cm}^2$
1,96E+03	0,1246	0,0041
1,95E+03	0,1004	0,0027
9,59E+02	0,0961	0,0024
1,96E+03	0,0938	0,0023
1,95E+03	0,0925	0,0023
1,95E+03	0,0803	0,0017
9,60E+02	0,0753	0,0015
1,93E+03	0,0750	0,0015
1,94E+03	0,0744	0,0015
1,95E+03	0,0689	0,0013
1,95E+03	0,0644	0,0011
1,96E+03	0,0634	0,0011
1,93E+03	0,0612	0,0010
1,94E+03	0,0589	0,0009
9,52E+02	0,0580	0,0009
1,94E+03	0,0578	0,0009

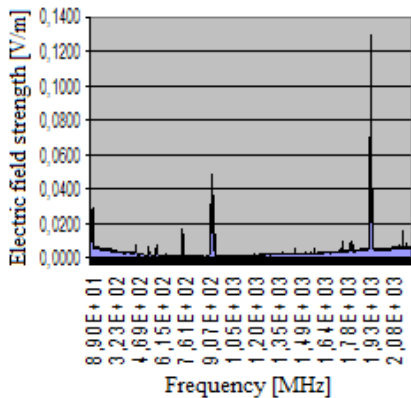


Fig. 5. Ambient noise measurements at 16.42 (background 5, point 2)

Figure 5 is based on the following measurements -Table 5.

Frequency MHz	Field Strength V/m	Power Density $\mu\text{W}/\text{cm}^2$
1,95E+03	0,1301	0,0045
1,95E+03	0,1123	0,0033
1,94E+03	0,0918	0,0022
1,94E+03	0,0902	0,0022
1,94E+03	0,0854	0,0019
1,95E+03	0,0821	0,0018
1,95E+03	0,0647	0,0011
1,94E+03	0,0504	0,0007
9,44E+02	0,0487	0,0006
1,94E+03	0,0437	0,0005
1,96E+03	0,0406	0,0004
1,94E+03	0,0397	0,0004
9,45E+02	0,0359	0,0003
1,93E+03	0,0334	0,0003
1,96E+03	0,0320	0,0003

9,37E+02	0,0317	0,0003
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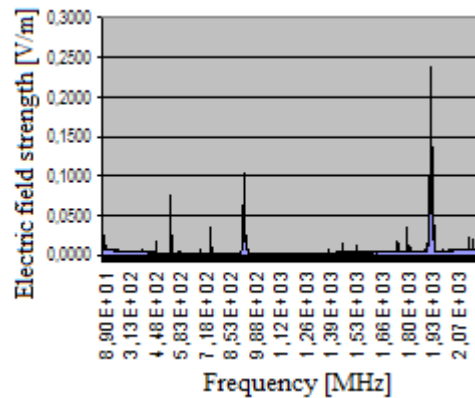


Fig. 6. Ambient noise measurements at 17.05 (background 6, point 3)

The graph is based on the following measurements - Table 6.

Frequency MHz	Field Strength V/m	Power Density $\mu\text{W}/\text{cm}^2$
5,43E+02	0,0769	0,0016
9,45E+02	0,1031	0,0028
9,46E+02	0,0955	0,0024
1,95E+03	0,1115	0,0033
1,93E+03	0,0859	0,0020
1,95E+03	0,1365	0,0049
1,95E+03	0,1324	0,0047
1,94E+03	0,1049	0,0029
1,94E+03	0,1633	0,0071
1,94E+03	0,1571	0,0065
1,94E+03	0,0909	0,0022
1,94E+03	0,2383	0,0151
1,94E+03	0,0870	0,0020
1,94E+03	0,2129	0,0120
1,94E+03	0,1070	0,0030
1,93E+03	0,1039	0,0029

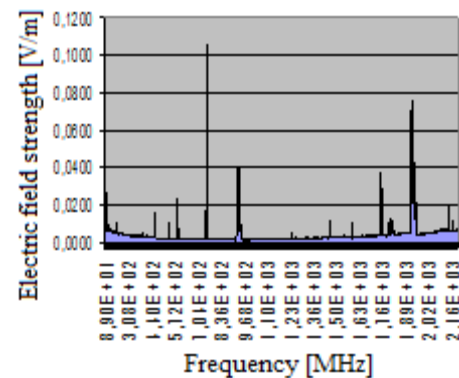


Fig. 7. Ambient noise measurements at 17.44 (background 7, point 4)

Figure 7 is based on the following measurements -Table 7.

Frequency MHz	Field Strength V/m	Power Density $\mu\text{W}/\text{cm}^2$
9,70E+01	0,0349	0,0003
9,80E+01	0,0412	0,0004
7,59E+02	0,1067	0,0030
7,60E+02	0,0761	0,0015
9,42E+02	0,0402	0,0004
1,76E+03	0,0375	0,0004
1,93E+03	0,0707	0,0013
1,93E+03	0,0708	0,0013
1,94E+03	0,0413	0,0005
1,94E+03	0,0499	0,0007
1,94E+03	0,0410	0,0004
1,94E+03	0,0386	0,0004
1,94E+03	0,0677	0,0012
1,94E+03	0,0761	0,0015
1,94E+03	0,0433	0,0005
1,95E+03	0,0425	0,0005

2.2. Electromagnetic power spectral density representation, with station 3 in broadcasting (250MHz), on the ship – below the helipad deck and in the harbor area

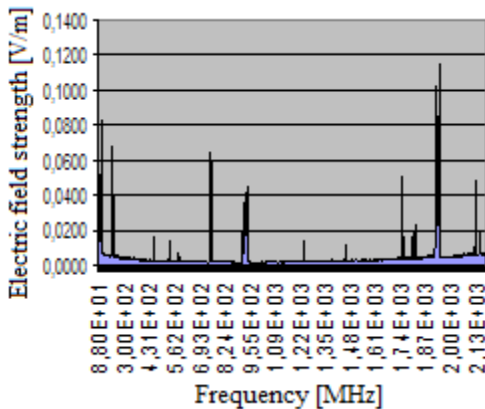


Fig. 8. Ambient noise measurements at 14:47 (point 1). The station broadcasts unmodulated at 250 MHz.

The chart is based on the following measurements –Table 8.

Frequency MHz	Field Strength V/m	Power Density $\mu\text{W}/\text{cm}^2$
1,96E+03	0,1147	0,0035
1,93E+03	0,1029	0,0028
1,94E+03	0,0961	0,0024
1,96E+03	0,0926	0,0023
1,96E+03	0,0916	0,0022
1,93E+03	0,0869	0,0020
1,96E+03	0,0866	0,0020

1,94E+03	0,0846	0,0019
1,91E+02	0,0827	0,0018
1,96E+03	0,0753	0,0015
1,95E+03	0,0731	0,0014
1,92E+02	0,0729	0,0014
1,94E+03	0,0715	0,0014
1,93E+03	0,0711	0,0013
1,94E+03	0,0711	0,0013
2,50E+02	0,0683	0,0012
7,60E+02	0,0653	0,0011
1,94E+03	0,0609	0,0010
1,95E+03	0,0603	0,0010

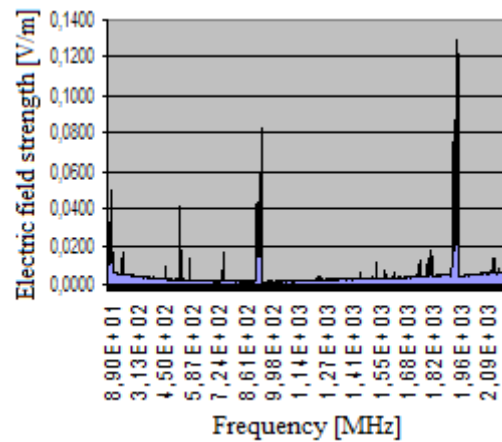


Fig. 9. Ambient noise measurements at 15:57 (point 1). The station broadcasts unmodulated at 250 MHz.

Figure 9 was drawn using the values from Table 9.

Frequency MHz	Field Strength V/m	Power Density $\mu\text{W}/\text{cm}^2$
1,96E+03	0,1293	0,1293
1,95E+03	0,1084	0,1084
1,96E+03	0,0957	0,0957
1,96E+03	0,0928	0,0928
1,95E+03	0,0871	0,0871
9,59E+02	0,0827	0,0827
1,93E+03	0,0756	0,0756
1,95E+03	0,0704	0,0704
1,96E+03	0,0680	0,0680
1,93E+03	0,0647	0,0647
1,95E+03	0,0633	0,0633
9,60E+02	0,0622	0,0622
1,94E+03	0,0611	0,0611
9,53E+02	0,0590	0,0590
1,94E+03	0,0589	0,0589
2,50E+02	0,0170	0,0001

Figure 10 is based on the measurements from the following table -Table 10.

Frequency MHz	Field Strength V/m	Power Density $\mu\text{W}/\text{cm}^2$
1,95E+03	0,1383	0,0051
1,95E+03	0,0969	0,0025
1,94E+03	0,0956	0,0024
1,94E+03	0,0848	0,0019
1,95E+03	0,0757	0,0015
2,50E+02	0,0737	0,0014
1,94E+03	0,0723	0,0014
1,94E+03	0,0644	0,0011
1,95E+03	0,0643	0,0011
1,94E+03	0,0577	0,0009
1,94E+03	0,0571	0,0009
1,96E+03	0,0556	0,0008
9,37E+02	0,0547	0,0008
2,51E+02	0,0546	0,0008
1,94E+03	0,0527	0,0007
1,96E+03	0,0508	0,0007

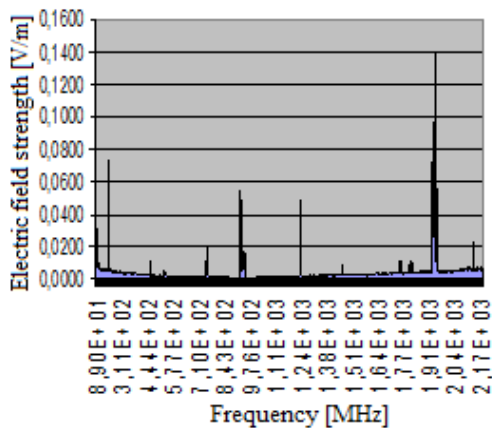


Fig. 10. Ambient noise measurements at 16:46 (point 2). The station broadcasts unmodulated at 250 MHz.

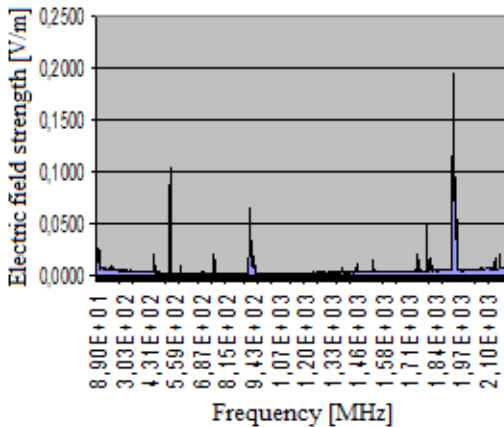


Fig. 11. Ambient noise measurements at 17:08 (point 3 – at approximate 150m from The Green Lighthouse). The military station number 3 broadcasts unmodulated at 250 MHz.

Chart 11 is based on the measurements from table 11.

Frequency MHz	Field Strength V/m	Power Density $\mu\text{W}/\text{cm}^2$
1,94E+03	0,1947	0,0101
1,94E+03	0,1475	0,0058
1,94E+03	0,1407	0,0053
1,94E+03	0,1373	0,0050
1,94E+03	0,1205	0,0038
1,93E+03	0,1158	0,0036
1,94E+03	0,1149	0,0035
1,94E+03	0,1102	0,0032
1,94E+03	0,1089	0,0031
5,44E+02	0,1028	0,0028
1,95E+03	0,0954	0,0024
1,95E+03	0,0884	0,0021
1,93E+03	0,0851	0,0019
1,94E+03	0,0832	0,0018
5,43E+02	0,0824	0,0018
2,50E+02	0,0098	0,0098

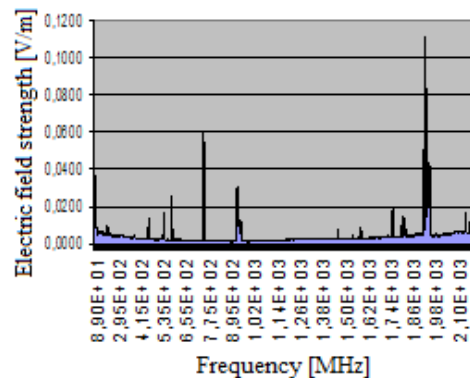


Fig. 12. Ambient noise measurements at 17:47 (point 4 – Berth 30). The station broadcasts unmodulated at 250 MHz.

Chart 12 is based on the measurements from table 12.

Frequency MHz	Field Strength V/m	Power Density $\mu\text{W}/\text{cm}^2$
1,93E+03	0,1109	0,0033
1,93E+03	0,1100	0,0032
1,94E+03	0,0829	0,0018
1,94E+03	0,0642	0,0011
1,93E+03	0,0623	0,0010
7,60E+02	0,0608	0,0010
7,59E+02	0,0590	0,0009
7,65E+02	0,0546	0,0008
1,93E+03	0,0519	0,0007

1,93E+03	0,0511	0,0007
1,94E+03	0,0479	0,0006
1,94E+03	0,0475	0,0006
1,94E+03	0,0474	0,0006
1,93E+03	0,0458	0,0006

1,95E+03	0,0430	0,0005
2,50E+02	0,0102	0,0000

CONCLUSIONS

From the data obtained by measurements it can be observed, that in the measured frequency range (80 MHz - 2,2 GHz), the radiated power densities and the electric field strength values do not exceed the basic restrictions for health protection, both for European standards (EN 60215: 1994 Safety Requirements for Radio Transmitting Equipment, En 50371) and American rules (FCC's Rule Parts 1. 1310, 2.1091 and 2.1093). The radio stations that work in the frequency ranges that are covered by the measurements issue small value powers. For example, the power standard for the civil stations that work between 156 - 174 MHz (VHF maritime) is 1W inside the harbour area and 25 W outside. Thus, the maximum measured value for the electric field strength is not exceeding 1V/m, and for the electromagnetic power density the value of 0,01 $\mu\text{W}/\text{cm}^2$. The European Standard provides a level of 28 V / m to 200 $\mu\text{W} / \text{cm}^2$ in the range 10-400 MHz,

respectively $1375 \cdot \sqrt{f}$ and $\frac{f \cdot 10^2}{200} \mu\text{W} / \text{cm}^2$ in the frequency range of 0.4 - 2GHz. The American Rule provides:

- a level of 27,5 V/m and 200 $\mu\text{W}/\text{cm}^2$ in the range of 30 - 300 MHz; respectively $\frac{f \cdot 10^3}{1500} \mu\text{W}/\text{cm}^2$ in the range of 300 - 400 MHz and 0,4 - 1,5 GHz; respectively 1 mW/cm^2 in the range of 1,5 - 2 GHz;

Due to the lack of measurement sensors for the analyzer used in frequency range below 80 MHz and higher than 2GHz no measurements were performed in frequency ranges with strong signal sources. For example, for the radio stations, in the range of 4-30 MHz (HF maritime) the emission power is between 400-750 W and the special stations use power up to 1.5 kW. For the radiolocation stations the emission powers for 9 GHz are 15 and 25 kW. Thus, if we extrapolate the value of the electric field strength radiated by the radio station with the power of 25 watts (0.1324 V / m) for 25 kW emission power one can a value of 132.4 V / m for the radiated electric field strength. Such value is dangerous for the human factor.

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- [8] *** Directiva Specifică 96/98/EC, referitoare la „Echipamentul maritim”, obligatorie de la 1 ianuarie 1999, transpusă în România prin Ordinul ministrului lucrărilor publice, transporturilor și locuinței nr. 582/2003, pentru aprobarea normelor tehnice de tip a echipamentelor și produselor pentru nave maritime, prevăzute de convențiile internaționale la care România este parte, cod MLPLTL.ANR-EM 2003;
- [9] *** Standardul românesc SREN 60945:2001 – Echipamente și sisteme de navigație și radiocomunicații maritime. Reguli generale. Metode de încercare și rezultate impuse;

[10] ***Analiza comparativă a normelor europene și americane cu privire la limitele de expunere la câmp electromagnetic a organismului uman în gama de frecvență 0 Hz la 300 GHz, lucrarea „Radio-Frequency Radiation for Transmitters: A Comparison of U.S. and European Requirements”, autori: Steve Dillingham și Nick Cobb);

[11] ***Standardele românești SREN 50166-1 și SREN 50166-2, referitoare la limitele admise ale densității curentului indus și efectele biologice asociate, limitele ratei specifice de absorbție – SAR, limitele admise ale intensității câmpului electric ale celui magnetic și ale densității de putere de vârf în corpul omenesc, pentru medii controlate și necontrolate, în gama de frecvență 3kHz - 300GHz;