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MESUREMENTS OF ELECTRICAL AND MAGNETIC FIELDS ON BOARD CONTAINER SHIPS

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Abstract: *In this paper we present measurements made on a container ship on radiation levels posed to crew members working on different decks of the ship, with charts showing that electromagnetic radiation exist and therefore merchant navy crews are exposed to radiation produced by the electric field. After the measurements on different decks of the ship, analyzing the observed values, we drew conclusions which are going to be presented and analyzed in accordance with national and international regulations requiring certain permissible radiation limits levels, so within the national and international legal framework to which Romania is part through the Ministry of Transportation as a member of the European Community and as a member of NATO [1,2,3,4,5,6]. This paper aims the necessity of further research in order to obtain means to protect the crew of a ship, against these radiations due to modern equipment used.*
Keywords: *screen material, radio-absorbent, mitigation, electric field intensity, exposure rate, frequency band.*

1. INTRODUCTION

Electromagnetic waves or electromagnetic radiation are generally natural physical phenomena, which consist of an electric field and a magnetic field in the same space, which generates eachother as they propagate. Electromagnetic fields: is all electric and magnetic fields that oscillate and generate eachother. Electromagnetic waves are an electromagnetic field which propagates [7].

Electromagnetic waves were predicted theoretically by "Maxwell's equations" and then discovered experimentally by Heinrich Hertz. Variation of an electric field produces a changing magnetic field, which at the same time it transfers energy. In turn, the changing magnetic field generates an electric field that takes this energy. In this way energy is transformed and constantly alternating from one form to another and repeat the process leading to the spread of this couple of fields.

With the existence of electromagnetic radiation also face merchant navy crews. Radiation sources are antennas of the transceiver stations, existing onboard, the GMDSS console that provides ship-to-ship communications as well as the ship-to-shore communications made both by direct wave or/and by satellite [8,9,10,11].

To achieve the measurements of electromagnetic field on the vessel, corresponding to this phase, we selected a merchant container vessel and chose 3 points (locations) with enhanced concentration of the radiation i.e.: -E deck; -outside the bridge; -inside the bridge. At each location we performed basic measurements and measurements with different broadcasting stations in various ranges of frequency (AM-amplitude modulation and FM-frequency modulation) based on sensors currently available.

Measurement configuration is shown in the figure below:

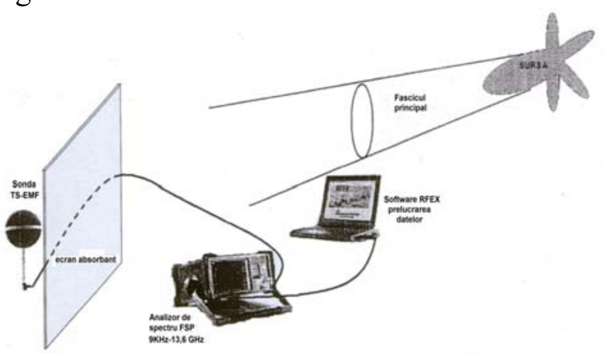

Fig.1. Configuration for measuring electromagnetic radiation

2. DATA FROM MEASUREMENTS. REPRESENTATION TABULAR AND GRAPHICAL

Measurements on the ship led to obtain data on:
-intensity of the electric field E [V / m] for different frequency ranges;
-the level of the electric field [dBμV / m];
-the rate of exposure;
-limit of the field intensity, L [V / m];
-the measurement-error, RE * 1000 [‰];
-the flux-density of electromagnetic power, PD [μW/cm2];
-total field strength (RMS) [V / m].
-the maximum singular-value [V / m].

For each set of measurements values were indicated and also the initial fund value of electric field strength.

For magnetic field data are proportionally smaller than Z_0 times in free space, where Z_0 is the wave impedance in vacuum.

2.1 *Background measurements on ship deck*

The outside of bridge *Deck*

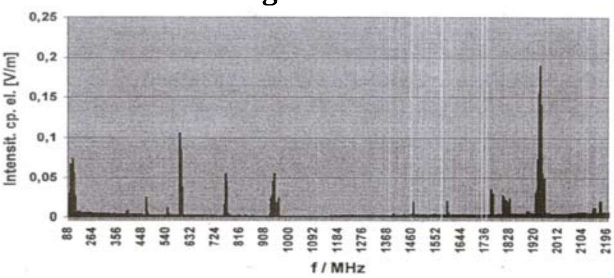

Fig.2. Environmental noise measurement on the outside of bridge

Tab.1. The main values measured

Frequency [MHz]	Electric field intensity E[V/m]	Electric field level [dB μV/m]	Power density [μ W/m^2]	Power density [μ W/cm^2]
97,0000	0,2480	107,8891	163,1420	0,063
99,0000	0,1511	103,5879	60,5965	0,0061
104,0000	0,3808	111,6140	384,6399	0,0385
106,0000	0,1863	105,4039	92,0546	0,0092
1925,0000	0,1837	105,2831	89,5293	0,0090
1932,0000	0,1415	103,0121	53,0722	0,0053
1934,0000	0,1575	103,9454	65,7958	0,0066
1936,0000	0,2167	106,7155	124,5126	0,0125
1939,0000	0,2197	106,8384	128,0839	0,0128
1942,0000	0,1454	103,2501	56,0621	0,0056
Total rate of exposure			3390,6864	0,3391
Total electric field intensity (RMS)	1,130614			
Maximum measured value	0,3808			

The inside of bridge *Deck*

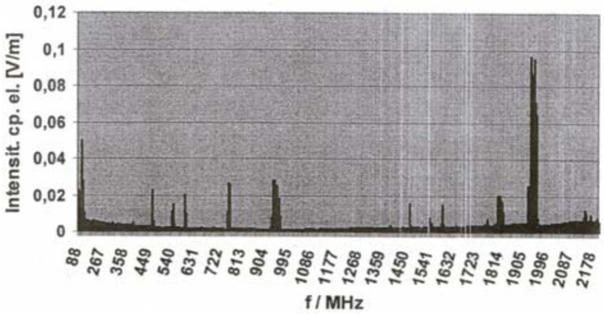

Fig.3. Environmental noise measurement on the bridge (inside)

Tabelul 2. The main values measured

Frequency [MHz]	Electric field intensity E[V/m]	Electric field level [dB μV/m]	Power density [μ W/m^2]	Power density [μ W/cm^2]
104,0000	0,0496	93,9117	6,5287	0,0007
1935,0000	0.0670	96,5181	11,8978	0,0012
1937,0000	0,0803	98,0922	17,0952	0,0017
1939.0000	0.0868	98.7707	19,9860	0,0020
1940,0000	0,0662	96,4141	11,6164	0,0012
1943,0000	0.0594	95,4716	9,3501	0,0009
1946,0000	0,0593	95,4608	9,3270	0,0009
1948,0000	0,0749	97.4845	14,8629	0,0015
1950,0000	0,0687	96,7406	12,5232	0,0013
1955,0000	0,0713	97.0581	13,4730	0,0013
1959,0000	0.0438	92,8296	5,0888	0,0005
Total rate of exposure			412,4174	0,0412
Total electric field intensity (RMS)	0,394311			
Maximum measured value	0,0966			

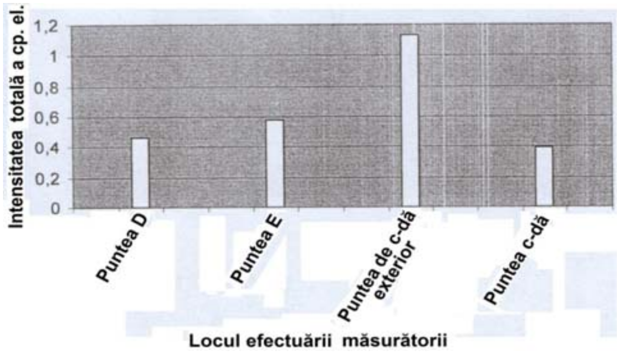

Fig.4. Representation of total intensity level of the electric field of the fund measurements at the different measuring points

In further study, we performed measurements on the same points but using a screen absorbent material made from wire mesh, with the purpose of mitigating the disruptive effects of electromagnetic radiation emitted by the equipment on board.

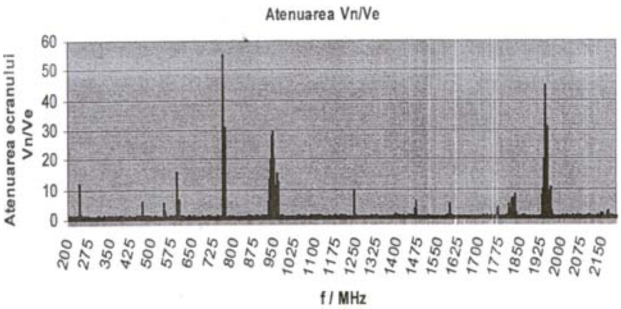

Fig. 5. Representation of attenuation due to a screen made of radioabsorbant material

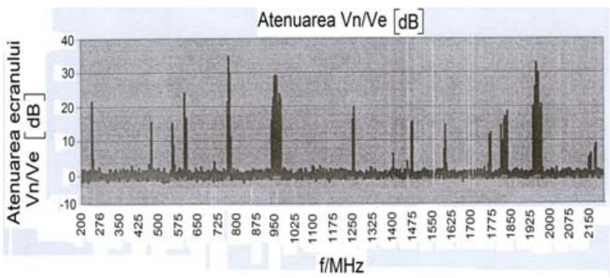

Fig. 6. Representation of attenuation due to a screen made of radioabsorbant material

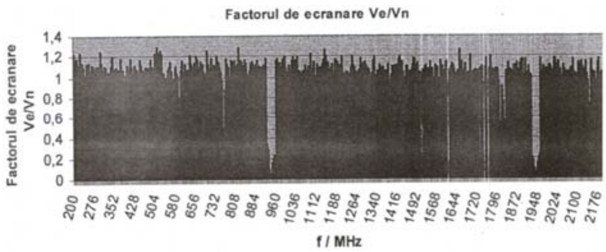

Fig. 7. Representation of shielding factor due to a screen made of radioabsorbant material

From Fig.6 it is observed that the attenuation values were obtained as above unit and subunit values (negative) of the shielding factor. Also, there is a large dispersion of these quantities in the frequency band in which measurements were made.

For detailing, figures are drawn above, for the 100 significant amounts of electric field intensity, attenuation and shielding factor measured in the absence and in the presence of the screen.

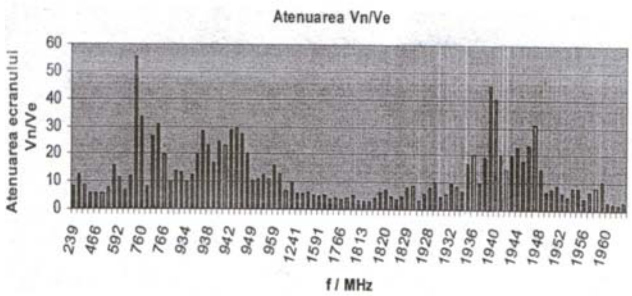

Fig.8. Representation of attenuation done by screen of radio-absorbent material for the first 100 values of electric field strength.

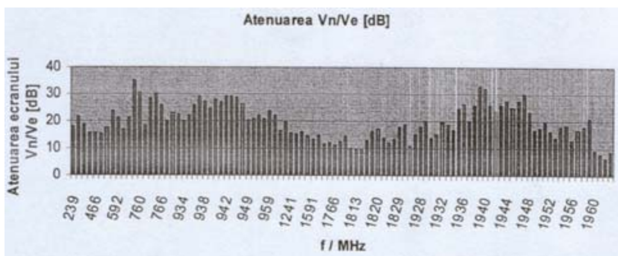

Fig.9. Representation of attenuation done by screen of radio-absorbent material, in dB, for the first 100 values of electric field strength.

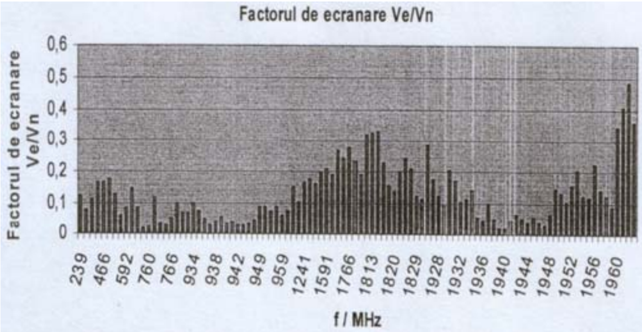

Fig.10. Representation of shield factor done by screen of radio-absorbent material for the first 100 values of electric field strength.

By analyzing graphs above it is apparent that the attenuation done by screen is not constant in the frequency band analyzed. The truth is that the screen attenuation and attenuation factor are sizes that can efficiently characterize the performance of screen when measurements are made under laboratory conditions, i.e. when the intensity radiated of the electromagnetic field (in this case the electric field component) remains constant in the entire frequency band.

For a more effective screen performance measurement in real conditions, I propose to introduce a new value quantity called attenuation / relative difference compared to the incident field, Df, defined by the relation:

$$Df = \frac{Vn - Ve}{Vn} \cdot 100 \qquad (1)$$

Obviously, when the attenuation / relative difference approaches 100%, the screening is better.

From the analysis it is observed that the relative attenuation values remains at over 80%, tending to over 95% for most measurements of the band, which highlights the special qualities of the material used for shielding.

E Deck

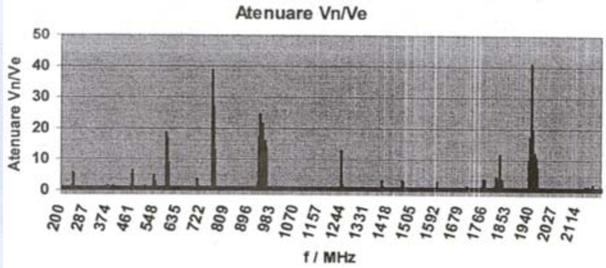

Fig.11. Representation of attenuation due to a screen made of radioabsorbant material on E Deck

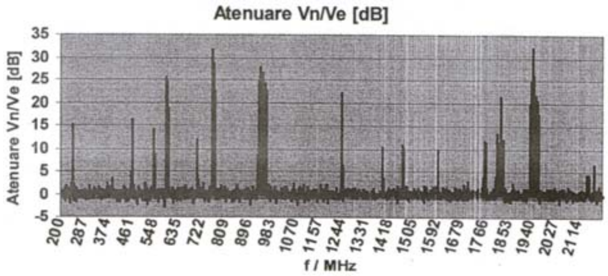

Fig.12. Representation of attenuation due to a screen made of radioabsorbant material on E Deck

Outside Bridge deck

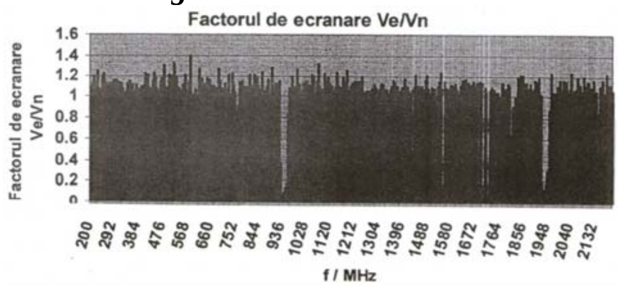

Fig.13. Representation of attenuation due to a screen made of radioabsorbant material on outside of Bridge Deck

Inside Bridge deck

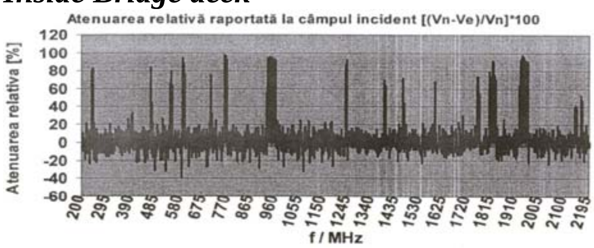

Fig.14. Representation of relative attenuation due to a screen made of radioabsorbant material on inside of Bridge Deck

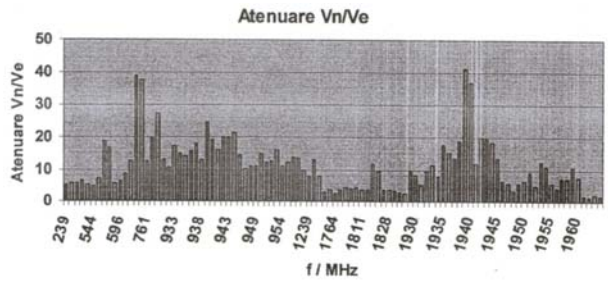

Fig.15. Representation of attenuation done by screen of radio-absorbent material, in dB, for the first 100 values of electric field strength on E Deck

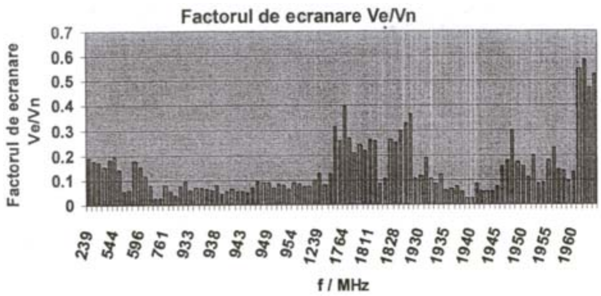

Fig.16. Representation of shield factor done by screen of radio-absorbent material for the first 100 values of electric field strength on inside Bridge Deck

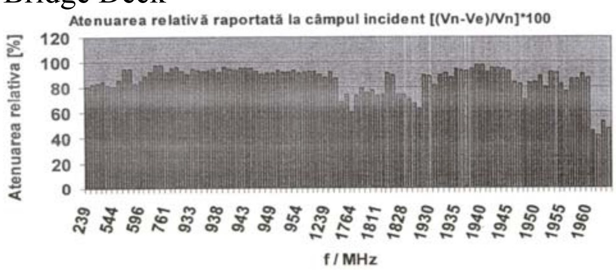

Fig.17. Representation of relative attenuation done by screen of radio-absorbent material, in dB, for the first 100 values of electric field strength on outside Bridge Deck

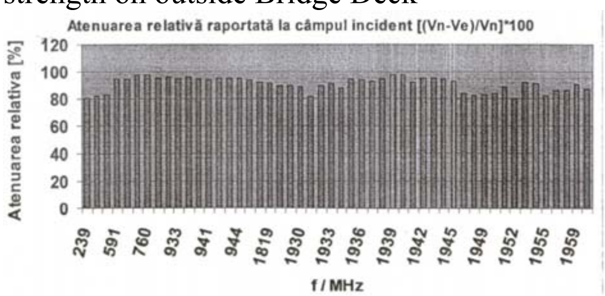

Fig.18. Representation of relative attenuation done by screen of radio-absorbent material, in dB, for the first 100 values of electric field strength on Boath Deck

Inside Bridge Deck, 240 MHz AM, 100W

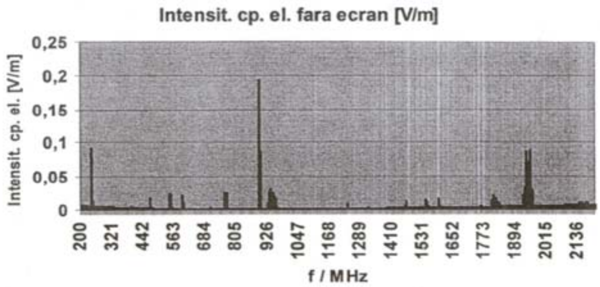

Fig.19. Representation of intensity level of the electric field in the presence of HF maritime station emission, on the frequency of 240 MHz, AM-100W, on Brige Deck without shielding.

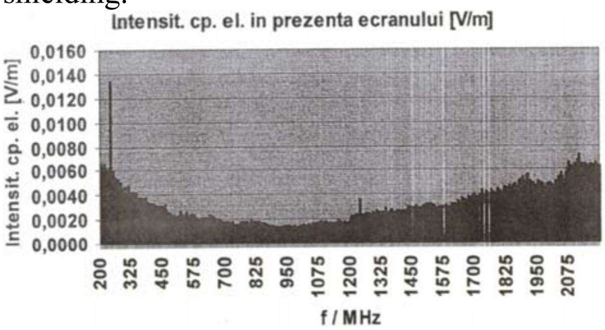

Fig.20. Representation of intensity level of the electric field in the presence of HF maritime station emission, on the frequency of 240 MHz, AM-100W, on Brige Deck with shielded probe.

The measured values show that electromagnetic field lines pass through the screen.

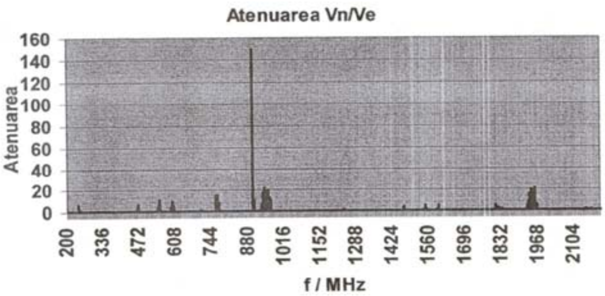

Fig.21. Representation of measured attenuation due to a screen made of radioabsorbent material on E

It is noted that the frequency range between 800 and 1016 attenuation is higher than at other frequencies. So attenuation being small, it means that magnetic field radiation passes through radio-absorbent material.

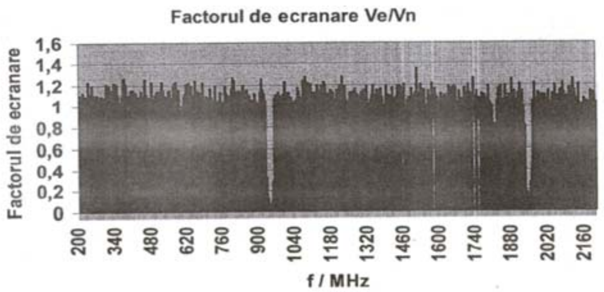

Fig.22. Representation of measured shield factor due to a screen made of radioabsorbant material on outside of Bridge Deck

We have a pretty high intensity of the electromagnetic field, due to its proximity to broadcasting antennas, and also which leads to increased shielding factor.

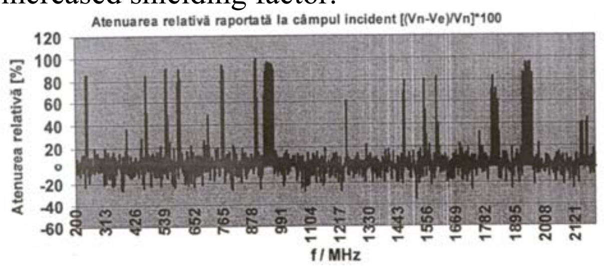

Fig.23. Representation of relative attenuation reported to incident field of a screen made of radioabsorbent material with maritime HF station transmission frequency of 240 MHz AM-100W, measurement performed on the outside Bridge Deck.

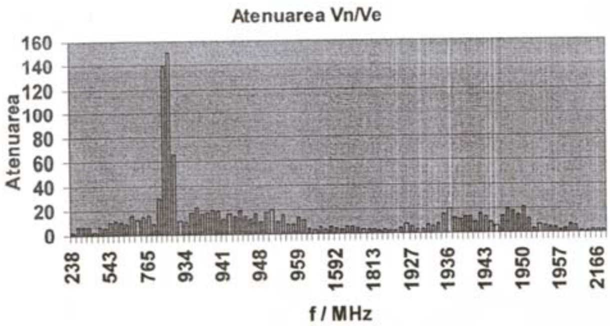

Fig.24. Representation of attenuation done by screen of radio-absorbent material, for the first 100 values of electric field strength measured on inside Bridge Deck

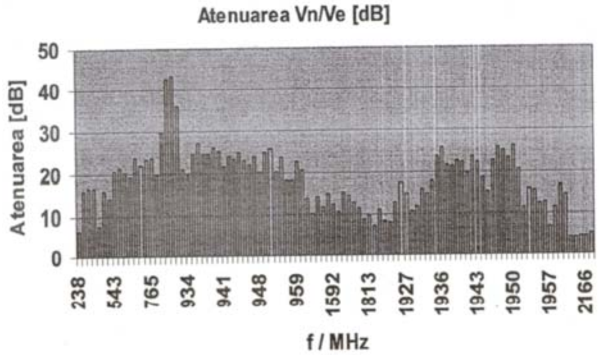

Fig.25. Representation of relative attenuation done by screen of radio-absorbent material, in dB, for the first 100 values of electric field strength on outside Bridge Deck

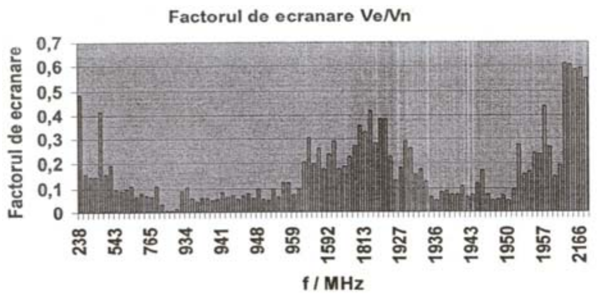

Fig.26. Representation of shield factor done by screen of radio-absorbent material, in dB, for the first 100 values of electric field strength measured on outside Bridge Deck

It is noted that at high frequencies above 2000 MHz radiation passes through the radioabsorbent material.

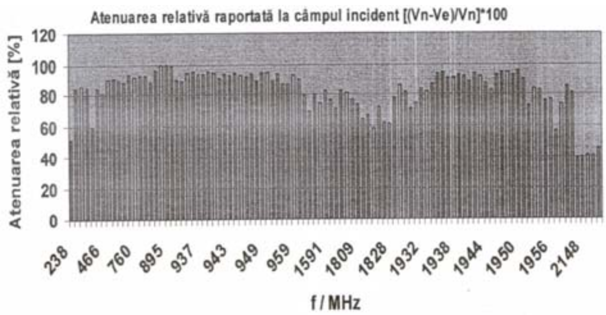

Fig.27. Representation of relative attenuation reported to incident field at screen of radioabsorbent material for the first 100 values of electric field strength.

Observed values of shielding factor are relatively very high as a result of the existence of electromagnetic radiation.

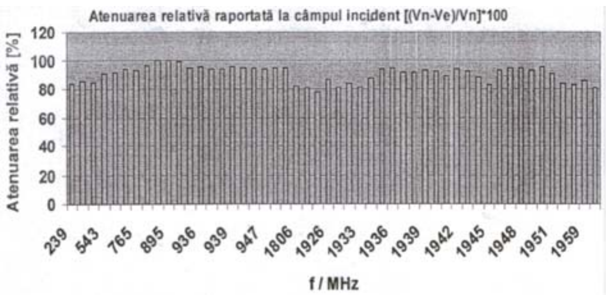

Fig.28. Representation of relative attenuation reported to incident field at screen of radioabsorbent material for the first 50 values of electric field strength.

Tabelul 3. The main values for measurements made on inside Bridge Deck, at the frequency of 240 MHz, AM, 100W

Frequency [MHz]	Measured values in absence of a screen			Measured values in presence of a screen		
	Electric Field Intensity	Electric Field Level	Power density [μV/m²]	Electric Field Intensity E[V/m]	Electric Field Level [dBμV/m]	Power Density [μV/m²]
239	0,0598	95,5286	9,4736	0,0096	79,6125	0,2426
241	0,0621	95,8562	10,2159	0,0092	79,2834	0,2249
894	0,1828	105,2403	88,6515	0,0013	62,3933	0,0046
896	0,0857	98,6640	19,5010	0,0013	62,3417	0,0045
1935	0,0723	97,1833	13,8671	0,0046	73,3126	0,0569
1937	0,0557	94,9129	8,2214	0,0047	73,3845	0,0578
1939	0,0655	96,3291	11,3911	0,0047	73,4948	0,0593
1942	0,0710	97,0302	13,3869	0,0046	73,2956	0,0567
1946	0,0607	95,6600	9,7646	0,0044	72,8724	0,0514
1948	0,0772	97,7531	15,8113	0,0043	72,7435	0,0499
1950	0,0880	98,8898	20,5418	0,0043	72,5855	0,0481
Total exposure rate			576,3028			58,0850
Total Electric Field	0,4661			0,1489		
Max. Measured	0,1941			0,0135		

Tabelul 4. The main values of attenuation and shielding factor for measurements on inside Bridge Deck, at the frequency of 240 MHz, AM, 100W

Frequence [MHz]	Attenuation Vn/Ve	Attenuation Vn/Ve dB	Shield Factor	Relative Difference
239	6,248934	15,9161	0,160027	83,99727
241	6,73966	16,5728	0,148375	85,16246
894	138,7872	42,8470	0,007205	99,27947
896	65,48106	36,3223	0,015272	98,47284
1935	15,61477	23,8707	0,064042	93,59581
1937	11,92394	21,5284	0,083865	91.61351
1939	13,85846	22,8343	0,072158	92,78419
1942	15,37194	23,7346	0,065054	93,49464
1946	13,78405	22,7875	0,072548	92,74524

Frequence [MHz]	Attenuation Vn/Ve	Attenuation Vn/Ve dB	Shield Factor	Relative Difference
1947	19,55823	25,8266	0,051129	94,88706
1949	14,99734	23,5203	0,066678	93,33215
1951	10,80149	20,6697	0,09258	90.74202
Total rate of exposure	9,8002	19,8247	0,102038	89,79617
Total Electric Field intensity RMS)	3,130533	9,9124	0,319434	68,05656
Maximum measured value	14,40444	23,1699	0,069423	93,05769

3. CONCLUSIONS

It is worth a special attention to be paid to the values recorded around the 894-896 MHz frequency band for which there has been relative attenuation values reported to incident field close to 100%. Following table values is observed that during the measurements without shielding sensor measurement in this frequency band have recorded the highest values of electric field strength, power density respectively, values much higher than those for that emitted by radio station frequency (240 MHz). Analyzing the values obtained for the measurements with shielded measuring sensor is found that at the frequency band of 894-896 MHz were obtained normal background values for this band (0.0013 V/m).

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