International Conference KNOWLEDGE-BASED ORGANIZATION
Vol. XXII No 3 2016

MEASUREMENTS FOR DETERMINING THE EFFICIENCY OF A SCREEN OF ABSORBENT MATERIAL USED ON BOARD MARITIME VESSELS

Gheorghe SAMOILESCU*, Adelina BORDIANU,
Serghei RADU***, Raluca-Aurora APOSTOL-MATEŞ***

***"Mircea cel Batrân" Naval Academy, Constanța, Romania,
** Polytechnic University of Bucharest, Romania
*** Stena Crewing Ag, Constanța, Romania,
samoilescugheorghe@yahoo.com, adelina_vb@yahoo.com,
sergradu@yahoo.com, ucamates@yahoo.com**

***Abstract**: Screening is one of the main ways to achieve the Electromagnetic Compatibility (EMC) in the electric and electronic devices and equipments onboard a vessel. The present paper analyses the results of certain measurements made in order to determine the screen efficiency from the point of view of damping the induction magnetic field. Starting from the calculus for the screen efficiency, measurements of the intensity and level of the electric field, of the power density, of the damping and of the screening factor were made. These measurements were made both in the presence and in the absence of the screen.*

Keywords: screening effect, electromagnetic field, relative damping, screening factor, intensity, electric field, perturbative emission.

1. Introduction

The screening effect consists in the induction of electric charges of currents (with the use of the electromagnetic fields generated by external or internal sources of metallic screens), whose field is opposite to the inductor field, damping the latter to some extent. [1], [2], [3].

In lower frequencies, the damping of the emitted or received magnetic field increases with the abutment and agglutination of the two way routes, braiding, braiding and screening (in a ferromagnetic screen).

In high frequencies, the non-magnetic materials realize the screening of the magnetic field by the consumption of the perturbative energies through the vortex currents. In lower frequencies, the non-magnetic materials screens have no screening effect on the magnetic fields. It is possible though to obtain anti-perturbative screening in low frequencies by using the non-magnetic materials in configurations with the screen connected on both ends, allowing closing a circuit through the screen, and the current flowing through the screen to compensate the perturbative emission of the route in the screen. It is necessary that the closing of the circuit generating the compensation field to be made without absorbing the common mode voltage. That is why the anti-inductive screen is connected with the charge at both ends but only maximum one end is grounded, fact that sometimes implies some conditions (sometimes unacceptable)

DOI: 10.1515/kbo-2016-0093

regarding non-grounding of the reference potential at both ends. [1], [3], [4].

In practice, against the low frequencies inductive couplings, the braiding, screening using screens made of ferromagnetic materials connected only to one end, screening using several layers of screens, out of which one with ferromagnetic properties and similar methods are used.

The calculus of the screening efficiency:

$$SE_{dB} = A_{dB} + R_{dB} + B_{dB} \quad (1)$$

The screening efficiency consists in the sum of the losses through absorbtion, reflection and re-reflection. The A, R, and B terms have the following form:

$$A_{dB} = 20\lg e^{\alpha d}$$

$$R_{dB} = 20\lg\frac{1}{4}\left[\left(377\sqrt{\frac{\sqrt{\Delta}}{\omega\mu}}\right)+\left(2\sqrt{\frac{1}{2}+\frac{\omega\varepsilon}{2\sqrt{\Delta}}}\right)+\frac{1}{377}\sqrt{\frac{\omega\mu}{\sqrt{\Delta}}}\right] \quad (2)$$

$$B_{dB} = 20\lg\frac{\sqrt{A^2+B^2}}{377^2+2\cdot 377\cdot\sqrt{\frac{\omega\mu}{\sqrt{\Delta}}}\cdot\sqrt{\frac{1}{2}+\frac{\omega\varepsilon}{2\sqrt{\Delta}}+\frac{\omega\mu}{\sqrt{\Delta}}}}$$

Calculating, the reflection damping for the electric field R_{dB} may be expressed in two ways – if the source is close to the screen and if the source is far from the screen. The following results are obtained:

Far area:

$$R_{dB} = 108 - 10\lg\frac{\mu_r f_{MHz}}{\sigma_r} \quad (3)$$

Close area:

$$R_{dB} = 142 - 10\lg\frac{\mu_r f_{MHz}^3 r_m^2}{\sigma_r} \quad (4)$$

r – distance between the screen and the source.

The absorbtion damping A_{dB} is:

$$A_{dB} = 1314 d_{cm}\sqrt{f_{MHz}\mu_r\sigma_r} \quad (5)$$

The reflection damping B_{dB} is:

$$B_{dB} = 20\lg\left|1 - e^{-2d\sqrt{\pi f\mu\sigma}} e^{-j2d\sqrt{\pi f\mu\sigma}}\right| \quad (6)$$

In the treaties on EMC/EMI [1-4], [6-10], in order to describe the efficiency of a screen, the screen damping or the screening grade indicator is used, defined as the logarithm of the ratio between the value of the electromagnetic field, in dB, in a certain point in the protected space, in the absence of the screen, and the value in the same point, the screen being present. The screen damping has to be positive and supraunitary. The reciprocal of the screen damping is the screening factor. Obviously, the screening factor has to have subunitary values.

The dimension of the screening is described by the screening factor Q

$\underline{Q}=\underline{H}_i/\underline{H}_o$ (7)

H_i – the field inside the screened space

H_o – the field outside the screened space

Usually, the logarithm of the inverted screening factor is used, namely the screen damping:

$a_E = 20\ lg\ 1/Q$ (dB) (8)

Both for minimizing the stray radiation and the capacitive coupling, the screen must be constructed of high conductive materials (Cu, Al), thicker than the depth of the Kelvin effect (Skin). Therefore, the thickness of the screen is frequency-variable.

Rules for connecting the screen [1], [2], [3]

a – the screen should close the perturbed circuit as much as possible.

b – the screen should be connected to the electronic mass through a connection as shorter as possible.

c – the screen should not have other galvanic couplings.

d – the screen is connected to the electronic mass at both ends or only at one end, in the latter case like the following:

- at the transducer, if this has grounded mass point;
- at the amplifier, if the amplifier has the electronic mass grounded;
- if both the transducer and the amplifier are grounded, it must be used a

galvanic disjunction on the transmitting line of the receiver.

Connecting the screen to only one end or to both ends depends on the quality of the electronic mass.

It is very important that the perturbation and perturbed circuits to enclose surface as reduced as possible because the induced voltage in a conductive coil is proportional with the magnetic induction and with the surface enclosed by the circuit.

The properties of the materials used for minimising the electromagnetic pollution should contribute to the counteraction of the unwanted influences of the electromagnetic field.

The requests imposed to the materials used for the minimisation of the radiated perturbation depend on the screening necessities. The choice of the material for the screen should be matched with the existent conditions of the environment in which the electric system is used.

For the representation of the dumping and the screening factor the following notations will be used: V_n – the intensity of the electric field measured with the unscreened sensor, V_e – the intensity of the electric field measured with the screened sensor.

2. Measurements

Following several measurements made within a research project [5], and also after further measurements and researches, the following results were obtained – Fig 1,2.

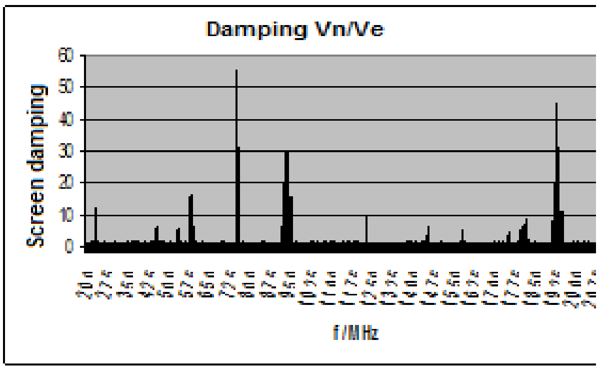

Fig.1 The damping representation for a radio-absorbing material screen

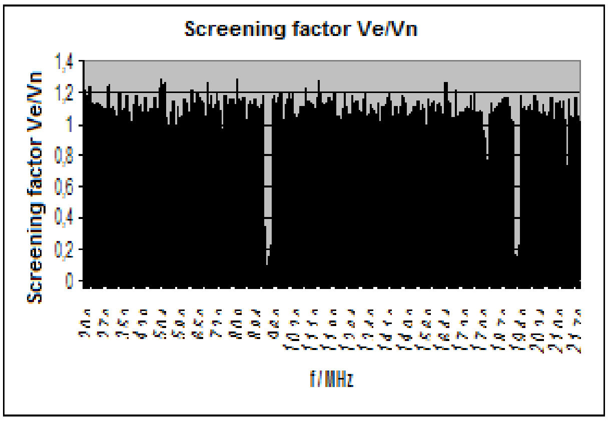

Fig. 2 The screening factor representation for a radio-absorbing material screen

Figure 2 shows that for the screening factor there were obtained both supraunitary and subunitary values. Also, it shows a great dispersion of these values in the frequency band used for the measurements.

For particularization the above figures are drawn for the first 100 important values of intensity of the electric field, damping and screening factor, measured in the presence and absence of the screen – fig 3-7.

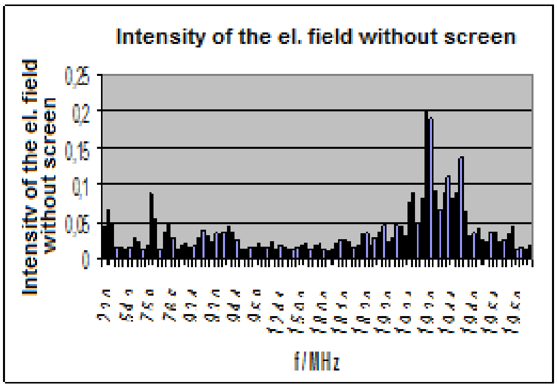

Fig.3 The representation of the first 100 values of the electric field with the station emitting from the poop deck on the frequency of 240 MHz, without screen

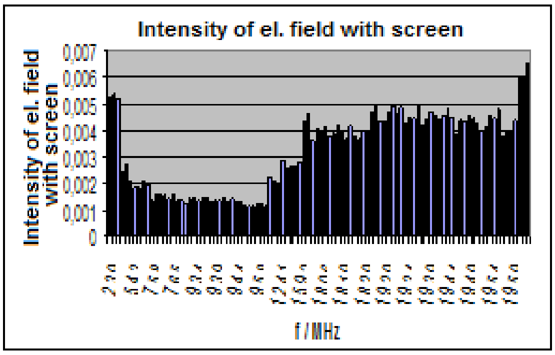

Fig.4 The representation of the first 100 values of the electric field with the station emitting from the poop deck on the frequency of 240 MHz, with screen

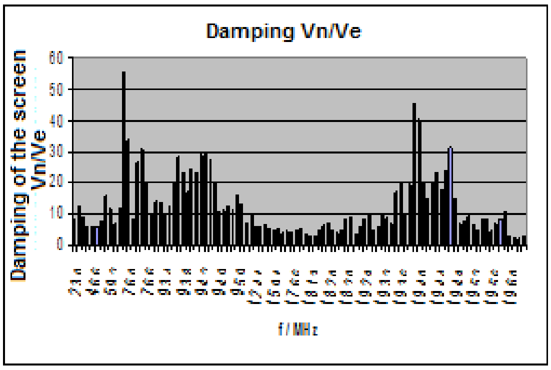

Fig.5 The representation of the damping of the screen made of radio-absorbing materials for the first 100 values of the intensity of the electric field

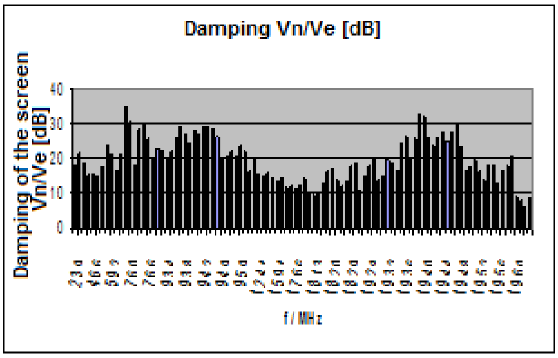

Fig.6 The representation of the damping of the screen made of radio-absorbing materials, in dB, for the first 100 values of the intensity of the electric field

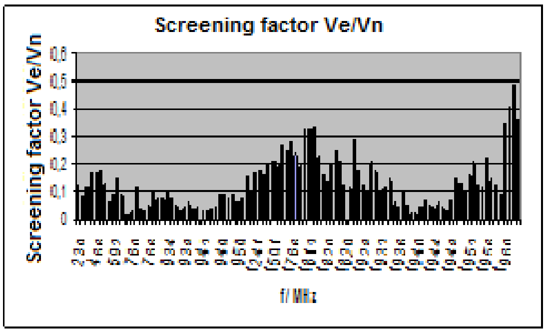

Fig.7 The representation of the screening factor for a screen made of radio-absorbing materials for the first 100 values of the intensity of the electric field

Analyzing the above diagrams issues the fact that the screen damping is not constant through the analyzed frequency band. The damping of the screen and the screening factor are values that can efficiently describe the performance of the screen, in the situation that the measurements are made in an ideal lab environment, namely the intensity of the radiated electromagnetic field (in this particular case the electric field component) is constant through the entire frequency band.

For a more efficient analysis of the performance of the screen in real measuring conditions, a new parameter is introduced – *damping/relative difference related to the incident field, Df*, described by the relation:

$$Df = \frac{Vn - Ve}{Vn} \cdot 100 \qquad (8)$$

Evidential, as the damping/relative difference approaches 100%, the screen becomes more efficient.

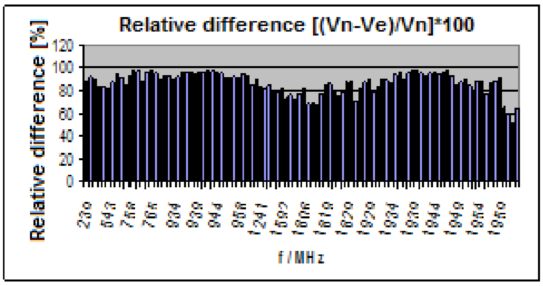

Fig.8 The variation of the relative damping related to frequency, on the poop deck

Analyzing Fig.8 and Table 1 & 2 becomes obvious that the relative damping have constant values above 80%, converging to more than 95% for the majority of the measurements from the frequency band.

Table 1 Measured data used for the calculus of the relative damping (poop deck)

Frequency [MHz]	Values measured in the absence of the screen		
	El. Field Intensity E [V/m]	El. Field Level [dBμV/m]	Power Density [μW/m²]
240	0,0658	96,3599	11,4722
241	0,0452	93,0934	5,4075
759	0,0880	98,8908	20,5464
760	0,0532	94,5264	7,5213
765	0,0480	93,6295	6,1181
1932	0,0441	92,8824	5,1511
1935	0,0761	97,6241	15,3485
1936	0,0901	99,0901	21,5114
1937	0,0491	93,8209	6,3937
1938	0,0815	98,2242	17,6231
1939	0,1982	105,9442	104,2497
1940	0,1905	105,5972	96,2452
1941	0,0911	99,1883	22,0035
1942	0,0661	96,4050	11,5919
1943	0,0888	98,9682	20,9162
1944	0,1117	100,9587	33,0771
1945	0,0810	98,1723	17,4136
1946	0,0897	99,0560	21,3433
1947	0,1368	102,7200	49,6202
1948	0,0642	96,1440	10,9159
Total rate of exposure	-	-	700,7345
Total Intensity of El. Field (RMS)	0,5140	-	-
Maximum measured value	0,1982	-	-

Frequency [MHz]	Valued measured in the presence of the screen		
	El. Field Intensity E [V/m]	El. Field Level [dBμV/m]	Power Density [μW/m²]
240	0,0054	74,5803	0,0762
241	0,0052	74,3015	0,0714
759	0,0016	64,0664	0,0068
760	0,0016	64,0083	0,0067
765	0,0016	63,8234	0,0064
1932	0,0046	73,2983	0,0567
1935	0,0045	73,0731	0,0538
1936	0,0045	72,9926	0,0528
1937	0,0050	73,9772	0,0663
1938	0,0042	72,5344	0,0475
1939	0,0044	72,8609	0,0513
1940	0,0047	73,4739	0,0590
1941	0,0046	73,1694	0,0550
1942	0,0044	72,8167	0,0507
1943	0,0045	73,1551	0,0548
1944	0,0048	73,6356	0,0613
1945	0,0045	73,0674	0,0538
1946	0,0038	71,6592	0,0389
1947	0,0044	72,8499	0,0511
1948	0,0044	72,7932	0,0505
Total rate of exposure	-	-	57,2525
Total Intensity of El. Field (RMS)	0,1469	-	
Maxi-mum measured value	0,0069	-	

Table 2 The variation of the relative damping linked with the frequency

Frequency [MHz]	Damping Vn/Ve	Damping Vn/Ve dB	Screening factor Ve/Vn	Damping/ Relative difference (rated)
240	12,2738	21,7796	0,0815	91,8526
241	8,7015	18,7919	0,1149	88,5078
759	55,1083	34,8243	0,0181	98,1854
760	33,5663	30,5181	0,0298	97,0208
765	30,9250	29,8062	0,0323	96,7664
1932	9,5325	19,5841	0,1049	89,5095
1935	16,8869	24,5510	0,0592	94,0782
1936	20,1779	26,0975	0,0496	95,0441
1937	9,8217	19,8437	0,1018	89,8185
1938	19,2528	25,6899	0,0519	94,8059
1939	45,0984	33,0832	0,0222	97,7826
1940	40,3799	32,1233	0,0248	97,5235
1941	19,9963	26,0190	0,0500	94,9991
1942	15,1151	23,5882	0,0662	93,3841
1943	19,5280	25,8131	0,0512	94,8791
1944	23,2356	27,3231	0,0430	95,6963
1945	17,9989	25,1049	0,0556	94,4441
1946	23,4338	27,3969	0,0427	95,7327
1947	31,1533	29,8701	0,0321	96,7901
1948	14,7076	23,3508	0,0680	93,2008
Total rate of exposure	12,2394	21,7552	0,0817	91,8296
Total Intensity	3,4985	10,8776	0,2858	71,4161

of El. Field (RMS)				
Maximum measured value	28,6700	29,1485	0,0349	96,51203

3. Conclusions

Analyzing the above material the following conclusions can be drawn:

- the intensity of the electric field decreases as the distance to the emission antenna is increased and increases while the height of the place of measurement is increased;
- the order for the decrement of the values of the electric field measured is: bridge deck - outside, artillery deck, bridge deck – inside, heliport deck; the values measured on the bridge deck inside are not so different than the values measured outside on the heliport deck;
- using different transmitters for measurements, the values obtained outside on the heliport deck are smaller than the ones measured inside, on the bridge deck. The same results were obtained at the measurements carried with the NARDA 8718 apparatus, serial number 1507, using plungers in the 300 kHz – 50 GHz frequency range in the days of 19,20.05.2005;
- for the small values of the intensity of the incident electric field, for damping (in dB), and for relative damping respectively, negative values were obtained. This fact may result because, in order to be efficient, the radio-absorptive material needs a minimum value for the intensity of the incident electric field;
- the relative damping stays in the range of over 80%, converging to more than 95% for the most of the measurements within the frequency band, underlining the qualities of the protection material used.

References

[1] Schwab, J.A., *Compatibilitatea Electromagnetică*, Bucureşti, Romania, Ed. Tehnică, 1996.

[2] Sotir A., *Interferenţe electromagnetice perturbatoare. Baze teoretice*, Bucuresti, Ed. Centrul Editorial al Armatei, 2005.

[3] Anisimov I.A., *Elektromagnitnaia sovmestimosti poluprovodnikovih preobrazovatelei i sudovih elektroustanovok*, Ed. Sudostroienie, 1990.

[4] Samoilescu Gheorgh, *Perturbatiile electromagnetice ale sistemului electromagnetic al navei*, Constanta, Romania, Ed. Academiei Navale "Mircea cel Batran", 2000.

[5] *** – *Ecologie electromagnetică-caracterizarea surselor, diagnosticarea efectelor-prevenirea şi combaterea lor-Contract 6115 CEEX,* 2005.

[6] *** *Expunerea omului la câmpuri electromagnetice din domeniul de frecvenţă 10 kHz-300 GHz*, Proiect de Standard Român: SR EN 50166-2, IRS, Bucureşti (conform cu standardul EN 50166-2/1994).

[7] *** Hotărârea Guvernului României, HG nr. 59, din 06.09.2006, privind cerinţele minime de securitate şi sănătate referitoare la expunerea lucrătorilor la riscuri generate de câmpurile electromagnetice – Anexă: Valori limită de expunere şi valori de declanşare a acţiunii pentru câmpurile electromagnetice.

[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 şi locuinţei nr. 582/2003, pentru aprobarea normelor tehnice de tip a echipamentelor şi produselor pentru nave maritime, prevăzute de convenţiile internaţionale la care România este parte, cod MLPLTL.ANR-EM 2003;

[9] *** Standardul românesc SREN 60945:2001 – Echipamente şi sisteme de navigaţie şi radiocomunicaţii maritime. Reguli generale. Metode de încercare şi rezultate impuse;

[10]***Standardele româneşti SREN 50166-1 şi SREN 50166-2, referitoare la limitele admise ale densităţii curentului indus şi efectele biologice asociate, limitele ratei specifice de absorbţie – SAR, limitele admise ale intensităţii câmpului electric ale celui magnetic şi ale densităţii de putere de vârf în corpul omenesc, pentru medii controlate şi necontrolate, în gama de frecvenţă 3kHz - 300GHz.