EVALUATION AND DESIGN OF A SHIELDING SCREEN

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Prezenta lucrare abordează unele aspecte ale optimizării proiectării, din punct de vedere al compatibilității electromagnetice (CEM) a unui ecran pentru un echipament informatic. Pe baza simulărilor prezentate, autorii subliniază faptul că structura ecranantă are o frecvență proprie de rezonanță, a cărei valoare este important a fi cunoscută, existând o legătură între semnalele existente în dispozitiv şi propagarea acestora în interiorul şi în afara ecranului.

This paper describes a work covering some aspects of the electromagnetic compatibility (EMC) design optimization of a shield for a informatic equipment. Based on the presented simulations, the authors stress that the shielding structure has an own resonance frequency, the value of it is important to be known, in conjunction with the frequency of the signals existing and propagating into the electronic equipment shielded.

Keywords: shielding, electromagnetic compatibility (EMC), TEMPEST

1. Introduction

The protection of the electric and electronic equipments against interception of their ones-emitting electromagnetic radiations is a very significant security issue, which, from technical and technological point of view, is covered by the TEMPEST field.

TEMPEST is usually known as a code name referring to theoretical and practical investigations of electromagnetic compromising emanations which can be regarded as unintentional intelligence-bearing signals which, if intercepted or analyzed, may disclose the information transmitted, received, handled or processed by any suitable equipment. The TEMPEST problem, based on some of the EMC approaches and techniques, takes into account the information aspect of the emanated radiations, rather than the energetic aspect, characteristic to the EMC approach. A very used way of protecting electronic devices against being intercepted is electromagnetic shielding.

This paper, taking into account the previous experience in modeling and measuring shielded enclosures, [1] ÷ [4], makes a step forward, by proposing a more detailed design approach, based on numerical analysis and optimization of the electromagnetic shield, seen as a multimode microwave cavity.

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There have been considered only the shield of the “keyboard” part of a portable computer, in a simplified manner, not taking into account the technological particularities supposed by the shielding of the “keyboard face” of the computer. This approach can be accepted as the paper is focused on the behavior of some technological discontinuities in the electromagnetic screen and, in this respect, there have been supposed that the shielding of the keyboard part is present and solved by some other means.

There are some known phenomena and situations which can make a shield less than perfect: diffusion through the shield wall, coupling through wires penetrating the shield and penetration through apertures [1, 4]; in the present paper, the focus is on the last mechanism (as it is strongly influenced by shield design) and can be controlled by proper electrical and mechanical design and the shielding effectiveness is indirectly evaluated by “pass or fall” method, i.e. by comparing the actual level of electric field intensity in the frequency band with the level imposed by the FCC Regulations, part 15, subpart J, (Computing Devices) [5].

2. Numerical modeling of an electromagnetic shield seen as a multimode cavity

The main purpose of our work, presented in this paper, was to estimate the shielding performances of a metallic box, designed to protect, both TEMPEST and EMC, an informatics device; the estimation is based on simulations carried out using a derivation of FDTD general method (as implemented by the CST Microwave Studio software). Simulations were carried out in order to make an evaluation of some real situations, including the existence of both accidental discontinuities (mainly rectangular, or quasi-rectangular slots) as well as unavoidable discontinuities having various destinations (technological, heating / ventilation, etc.), [6, 7].

The shape and dimensions of the shielding box, used for simulations purposes, resulted from some previous optimization carried out in order to make the cavity own resonance frequencies (mainly, the fundamental one) as far as possible from the tact frequency generator of the portable computer (*fig. 1)*.

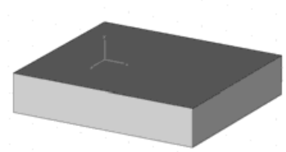
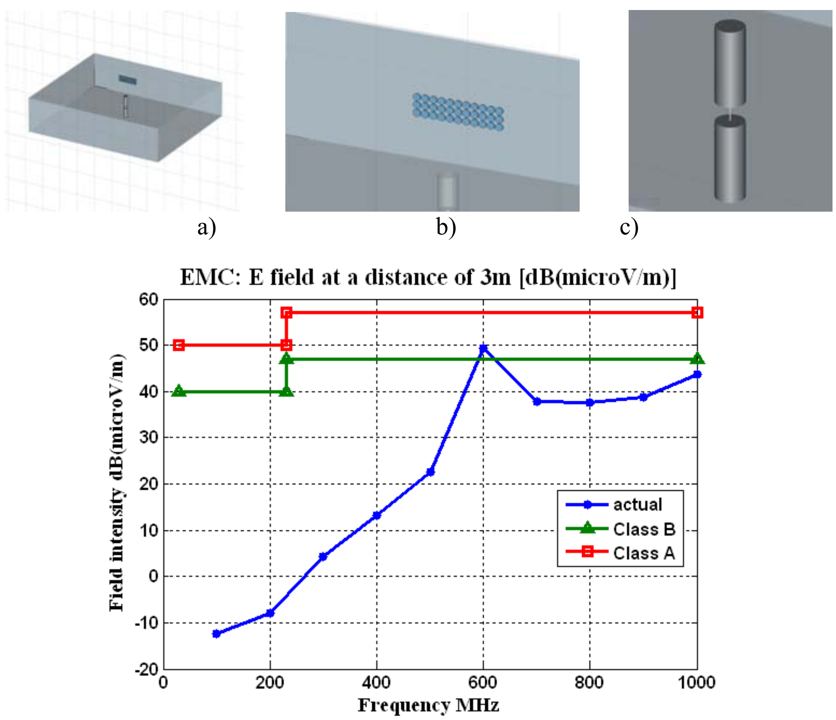


Fig. 1. The shielding box used for EMC and TEMPEST protection of a portable computer (the “keyboard” part); length= 362 mm, height=73,7mm, width=317 mm.

The simulations are carried out according to the general design procedure of an electric shield, which involves, mainly, a compromise between the necessary (i.e. unavoidable) apertures in the screen and the requested shield emanations levels.

Some of the most important simulations results are displayed in *fig. 2* and *fig. 3*. The excitation signal used in the numerical simulation is a Gaussian pulse having 1 V amplitude and a duration of approx. 1.5 ns at 0.1 V level. The excitation signal was applied to the dipole antenna and the resulting electric field was considered as the input value for estimating the radiated field of the cavity. The antenna is a dipole of 45 mm length, the distance between its arms (of 5 mm diameter each one) being 5 mm. There have been used the simulation conditions of the CST Microwave Studio; the boundary conditions were chosen according to the free space antenna problems. For the most complex case (*fig. 3*) the mesh generation by the software application consists of 23940 mesh cells.



a) b) c)

d)

Fig. 2. a) Shielding box having 33 holes, 2 mm diameter each, on three rows, unprotected from EMC and TEMPEST; b) The holes assembly; c) The dipole antenna; d) The frequency variation of the field intensity for the shielding box.

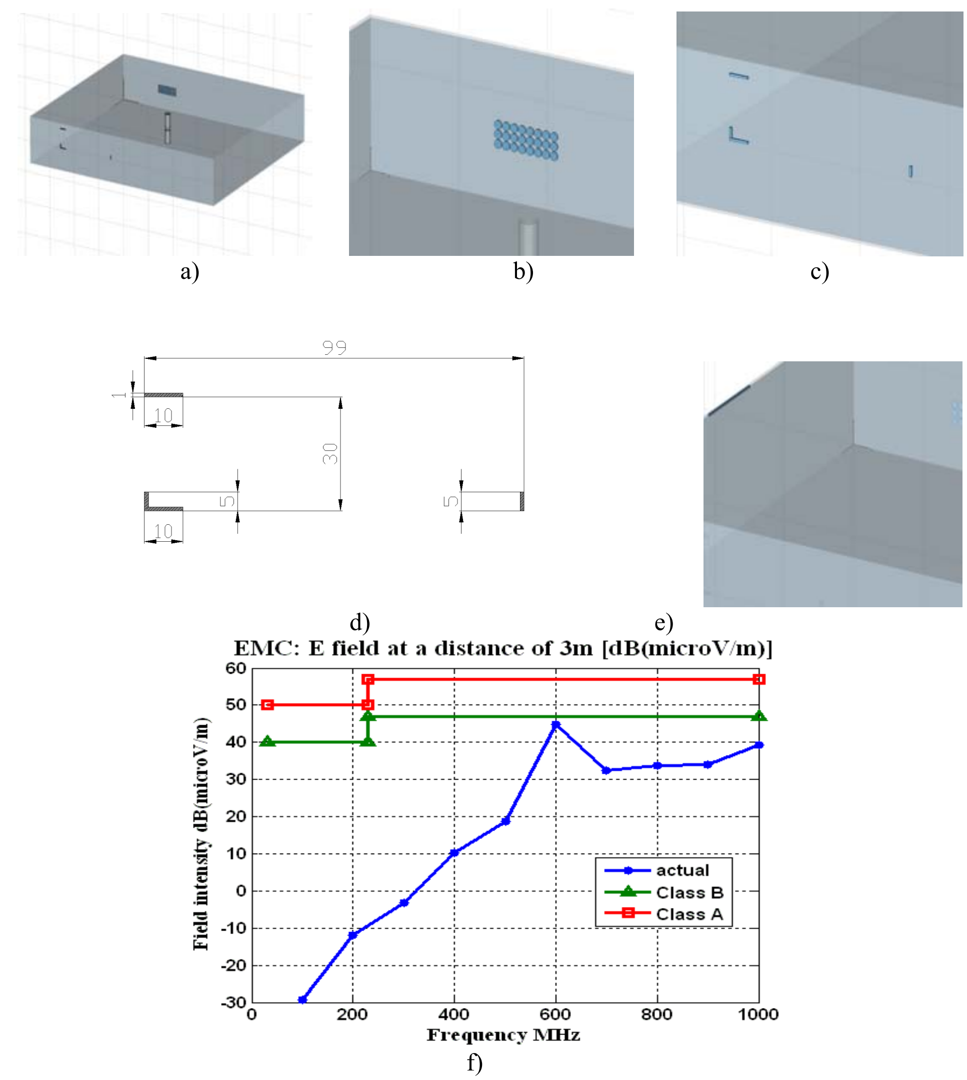


Fig. 3. a) Shielding box having 24 holes, 2 mm diameter each, on three rows, one slot of 5 mm on one edge, and an assembly of slots modeling an non-perfect DVD contour slot, EMC and TEMPEST unprotected; b) The holes assembly; c) The non-perfect DVD contour slot; d) Shape and dimensions (in millimeters) of the slots from fig. 3c); e) The slot modeling a technological imperfection between both parts of the portable computer; f) The frequency variation of the field intensity for the shielding box.

The emanations levels are imposed by various standards - in this paper there have been used the limits from FCC Regulations, part 15, subpart J, (Computing Devices) [5]. According to this standard, there are two classes of devices, each one being characterized by different level of the radiated electric field intensity: class A (intended for commercial, industrial and business use) and class B, for home use.

As one can see from *fig. 2*, making the ventilation assembly of 33 holes results in a greater value for the electric field intensity, (the class B case). However, the shielding box has to have some accesses for the optical unit (i.e. the CD-DVD reader/writer). These accesses are designed and realized to be protected from the TEMPEST and EMC point of view. In practice, situations when this protection is not well realized are quite often; such a situation is modeled by the assembly of slots simulating a non-perfect DVD contour slot, as shown in *fig. 3.a*. If the slot dimensions are under some limits, which can be determined by a trial method, there is no any over-level situation, as shown in the plot of the frequency variation of the field intensity (*fig. 3.f*).

The plots of the variation of the electric field transmitted by the shielded box (*fig. 2.d* and *fig. 3.f*), show clearly the existence of a resonance, located around 600 MHz; the exact value of the resonance frequency is f_{101}=632 MHz, calculated with relation (2):

$$f_{mnp} = 0{,}15 \cdot \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{c}\right)^2} \quad (2)$$

where: f_{mnp} is the resonance frequencies of the TE_{mnp} and TM_{mnp} modes of the cavity,
m, n, p are the number of semi wavelengths along the *a, b, c* edges of the cavity.

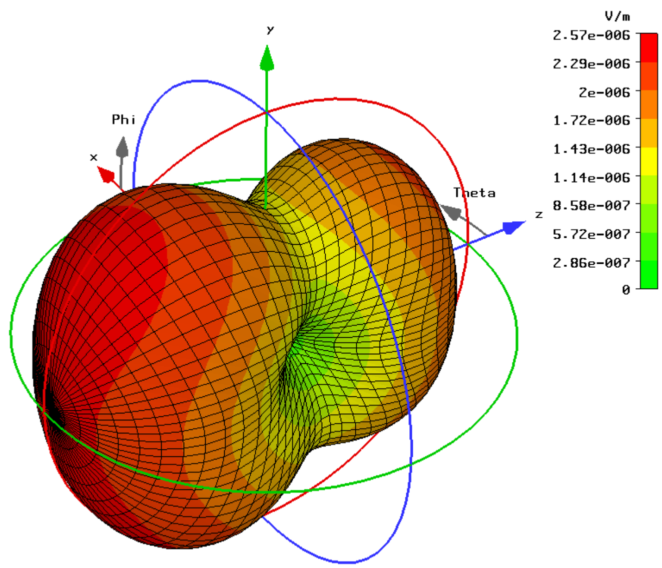
This frequency resonance (which, being the lowest, is the fundamental resonance of the shield), is due to the fact that the shielded box is a microwave multimode cavity; the variation of the resonance frequency (fundamental resonance, as well the other resonances), as shown in *fig. 2* and *fig. 3*, is a direct result of the fact that changing the number and shape of the couplings of the cavity (i.e. holes and slots), their different reactance influences in different manners and amounts the resonance frequency of the cavity (in fact the assembly cavity plus couplings).

In the evaluation of the shielding effectiveness there have been considered only the fundamental resonance frequency, as its value is closer to the value of the tact frequency of the device to be protected by the shielding box than all the other resonance frequencies of the cavity.

The radiation behavior of the electromagnetic shielding box is clearly seen from the plots of the radiation patterns, which are shown in *fig. 4*, *fig. 5* and *fig. 6*, for the case of the box from *fig. 3.a.*

On the other hand, the device to be protected by electromagnetic shield is modeled, in this paper, only by the presence of the dipole antenna, acting as a source of the electromagnetic field, at a frequency equal to that of the tact generator of the device (portable computer).

In a future work, a special attention will be given to the influence of the portable computer placed in the cavity on the radiation characteristics of the shielded computer. This influence is supposed to be noticeable, as the device put inside the shield acts like a perturbator of the field distribution and modes and, consequently, of the radiation of the cavity slots and holes.



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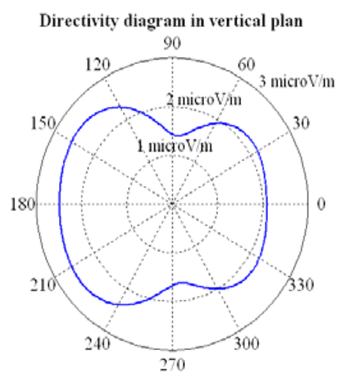
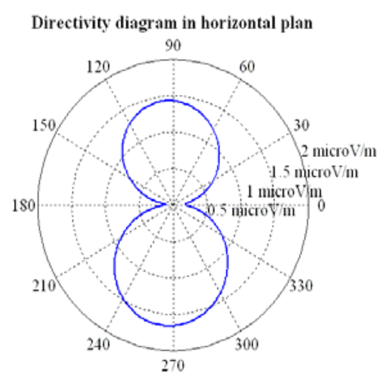
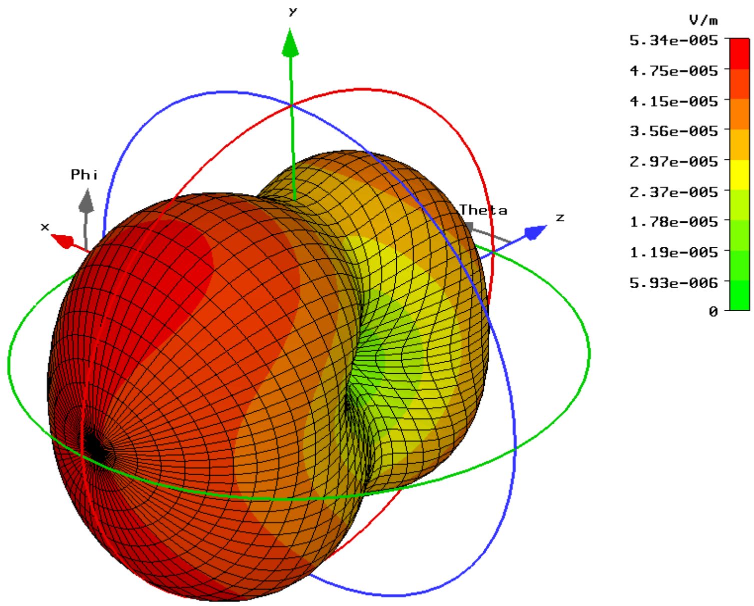




b) c)

Fig. 4. Radiation patterns of the shielding box, for the case shown in *fig. 3.a*. for f = 500 MHz, where f is the frequency of the electric field wave: a) the 3D radiation pattern; b) 2D vertical radiation pattern; c) the 2D horizontal radiation pattern.



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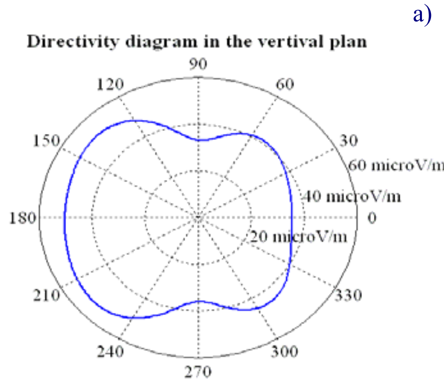

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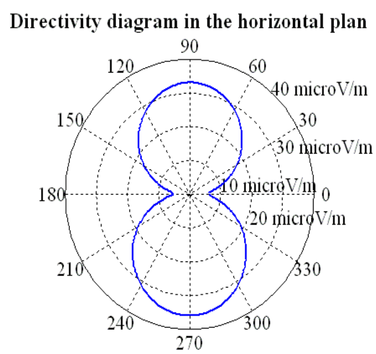
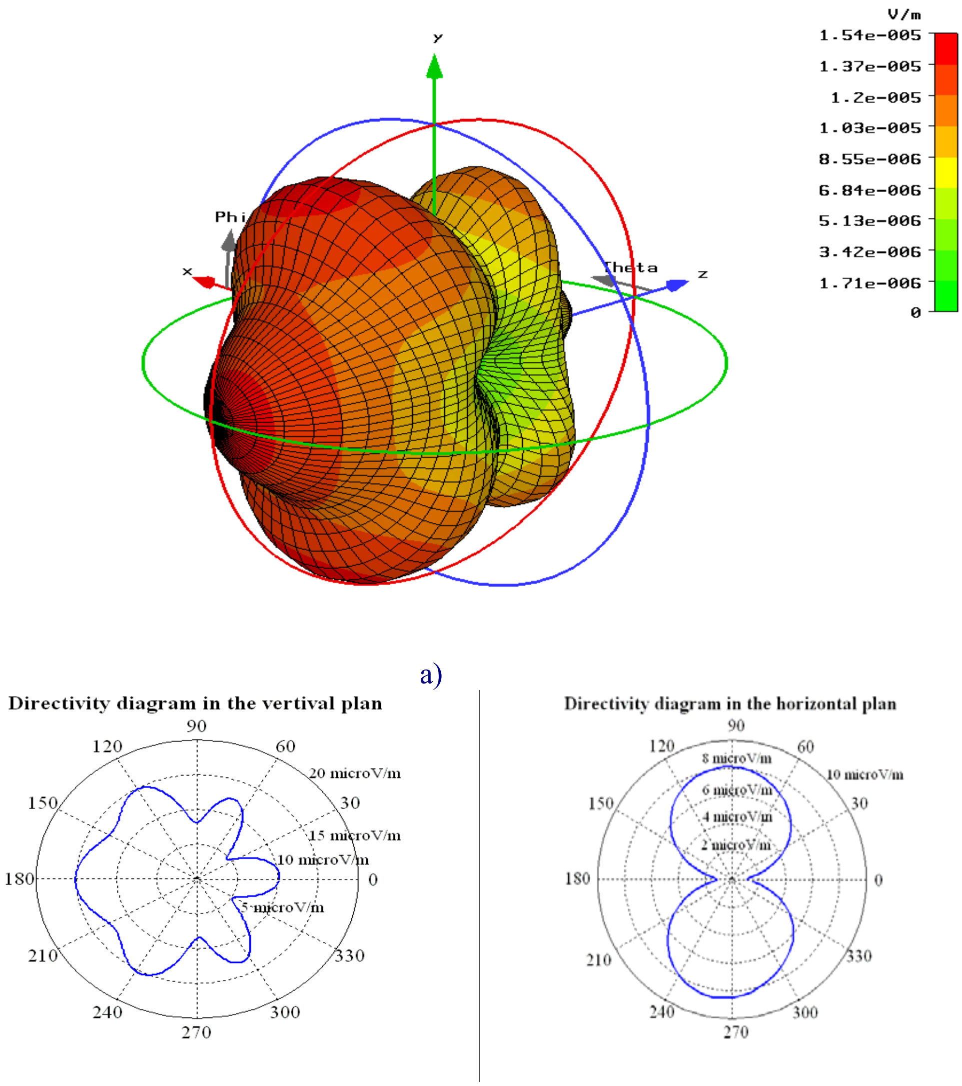


c)

Fig. 5. Radiation patterns of the shielding box, for the case shown in *fig. 3.a.* for f = 600 MHz: a) the 3D radiation pattern; b) 2D vertical radiation pattern; c) the 2D horizontal radiation pattern.



a)

b) c)

Fig. 6. Radiation patterns of the shielding box, for the case shown in *fig. 3.a.* for f = 900 MHz: a) the 3D radiation pattern; b) 2D vertical radiation pattern; c) the 2D horizontal radiation pattern.

It can be seen (*fig. 4*), that the radiation level is maximum on the face containing the holes, showing that the contribution of these ones is more consistent than of the slots' one (the slots are situated on as seen in *fig. 3.a.*).

The holes behavior is an antenna array one, the holes assembly being, in fact, an array of elementary radiators of circular shape. As a consequence, one can notice some issues specific to the arrays' field:

- main beam of the radiation pattern scanning with respect with the frequency (from *140°*, for f = *500 MHz* (see *fig. 4.b* - the 2D vertical pattern) up to *158°*, for f = *900 MHz* (see *fig. 6.b* - the 2D vertical pattern);
- grating lobes apparition (see *fig. 6.b* - the 2D vertical pattern),
- variation of the angular width (both in vertical and horizontal planes - see *fig. 4, fig. 5* and *fig. 6*, the 2D patterns).

3. Conclusions

This paper describes a work covering some aspects of the design optimization, from the electromagnetic protection point of view, of a shield for a portable computer.

There are several mechanisms which make a shield less than perfect: diffusion through the shield wall, coupling through wires penetrating the shield, penetration through apertures.

The results of the simulation presented in the paper were carried out in order to make an evaluation of some real situations, including the existence of both some accidental discontinuities (mainly rectangular, or quasi-rectangular slots) - which can be eliminated by use of proper technology and unavoidable discontinuities (mainly holes) having various destinations (technological, heating / ventilation, etc.).

Based on the presented simulations, one can see that the shielding structure has an own resonance frequency. The value of that frequency is important to be known, in conjunction with the frequency of the signals existing and propagating into the electronic equipment shielded, in order to take the appropriate measures in the design and implementation of the shield and of the shielded electronic equipment, viewed as an assembly. The simulations pointed out the fact that, when slots and holes are present in the shield, the shielding box has a radiating behavior, acting like an antenna.

The present paper is a first step approach to the problem of electromagnetic shielding of an electronic device; simulating the presence and influence of the personal computer placed inside the cavity is not a trivial task and will be treated separately in some future papers.

The level of the radiating electromagnetic field can be controlled, in order to be maintained bellow the limits from both EMC and TEMPEST standards, by proper use of radiofrequency and microwave simulation techniques and by a good design and technology.

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