Shielding effectiveness of perforated screens through an inverse problem-based resolution

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Abstract — **In this paper, we aim to evaluate the shielding effectiveness of perforated plane shields excited by a circular radiated loop in near-field. Our technique is based on an inverse problem using genetic algorithm and near-field calculation. Simulation is done using an electromagnetic simulation software tool, based on the method of moments. Using the approach proposed, an equivalent set of magnetic dipoles for each perforated metal screen is obtained. All results are compared with experimental values to check the validation. Such 2-D equivalent model can be used to avoid meshing screens in case a 3-D problem involving an enclosure with apertures.**

***Index Terms*— Electromagnetic compatibility, apertures, genetic algorithm, inverse problem, shielding effectiveness.**

I. Introduction

THERE is a growing need to calculate the shielding effectiveness of enclosures with perforated screens in order to evaluate the radiated fields in electromagnetic compatibility problems. The discretization of such screens using standard three dimensional techniques based on volume meshes may lead to unwanted increase of memory and computational time due to a refined mesh around the multiple holes.

The analysis of the coupling between a plane wave and apertures can be addressed analytically as in [1]. The problem of shielding in the near-field has received much less attention so far. Such problem has been solved analytically for an electric dipole as the source in [2] and a circular loop as the source in [3]. However in these two cases the solution is only valid for periodic screens of infinite extent and cannot be used for realistic problems.

To take into account the radiated field through apertures, we propose in this work to replace the whole screen by one or more equivalent dipoles following the idea of the characterization of radiated fields by electronic equipments [4-6]. Here the infinitesimal magnetic dipoles are used to model the fields through a perforated screen. The parameters of the dipole are evaluated via an inverse problem based on genetic algorithm and using magnetic near-field data. The goal of the proposed approach is to take into account a perforated screen on the walls of an enclosure avoiding a refined mesh around a high number of apertures.

II. Studied Configurations

The considered plane screens are made from copper and present different forms of perforations as shown in figure 1. The shield (S1) presents round apertures, while (S2) and (S3) are metallic structures with slots. All copper shield products are 32 mm as length and 35.10^{-3} mm as thickness.

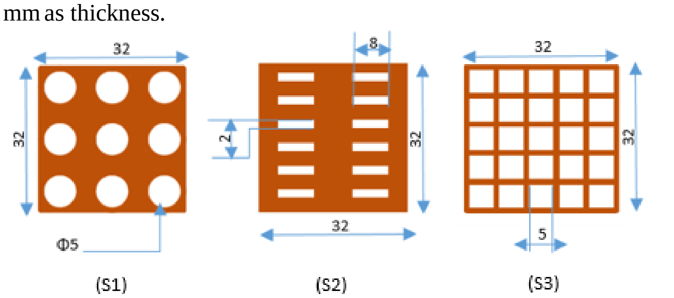

Fig. 1. Geometry of metallic screens

The goal is evaluate the shielding effectiveness given by:

$$SE = 20\log\left(\frac{|H_i|}{|H_t|}\right) \tag{1}$$

where H_i is the magnetic field without the shield and H_t the magnetic field with the shield.

To evaluate SE two consecutive near-field evaluations are necessary, with and without the shield, respectively. Here a 2D-scan method is performed at 469.5 MHz as the excitation frequency. The radiating loop with radius 5 mm is located parallel to the screen, at a distance z=1.5 mm. The scanning probe with radius 2 mm is also positioned at a fixed distance of 3.5 mm from the screen in order to calculate the transmitted fields in the xy-plane.

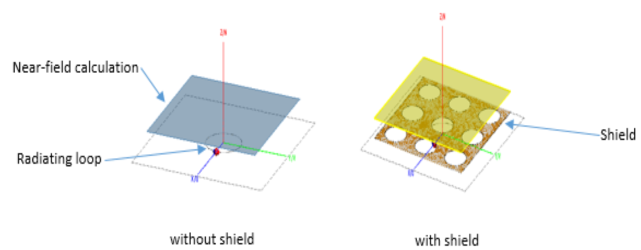

Fig. 2. Near-field configuration

The near-field data is used to validate the shielding effectiveness prediction and to solve the inverse problem detailed in the following section.

III. Inverse Problem

A. Problem definition and validation

In our study, the genetic algorithm is used to solve the inverse problem: find equivalent dipoles from a near field cartography. One of the essential parameters is the fitness function. Among the different optimization functions the best results were obtained with the following expression which has to be minimized:

$$\sum_0^N |H_s - H_{\text{mod}}|^2 \tag{2}$$

Where H_s is the field predicted by the numerical model and H_{mod} is field obtained from the radiation of the dipoles. N is the number of field points on the scanning plane.

The parameters of the genetic algorithm are the followings : the generation number is 150. The Population's size is 15 times the number of dipoles parameters. The crossover probability and mutation probability are 0.8 and 0.4 respectively. The magnetic field radiated by a magnetic dipole can be found in [7]. The parameters for one dipole are five: the three components of the magnetic moment and the two coordinates of the dipole on the plane of the screen. The inverse problem was solved for the three screens. Results are presented on figure 3. The magnetic field computed by the method of moment is shown on figure 3(a). The experimental approach gives the near field data (b) which is used to find the equivalent dipoles. The magnetic field predicted by the dipole is presented in (c). A rather good agreement between the numerical results obtained with the method of moment is observed. Screen 1 and Screen 2 are modeled by one magnetic dipole while screen 3 is replaced by two dipoles. Results can be more efficient via implicating the cartography of the difference. However, we can accept this level of accuracy concerning the cartography because our goal is not looking for a very precise radiating model, but it is to demonstrate the performance of the inverse method to evaluate the shielding effectiveness.

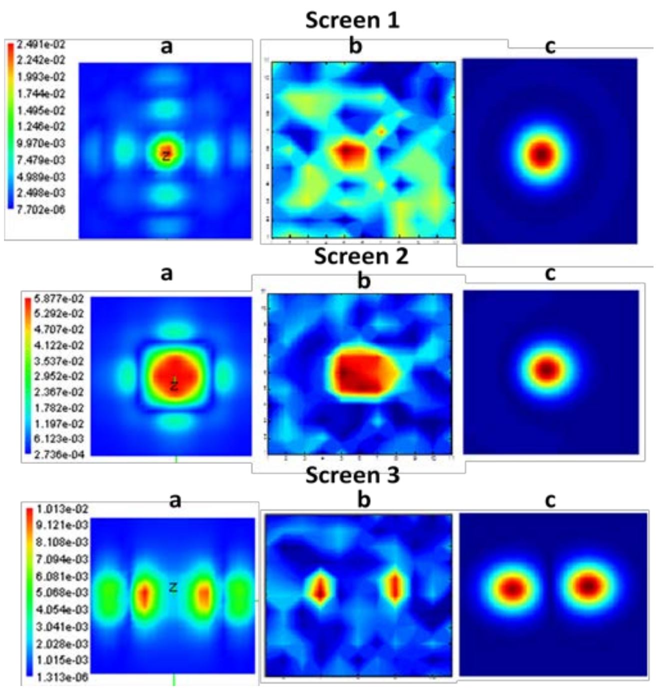

Fig. 3. 2D XY mapping of H_z: numerical modeling (a), experimental approach (b) and inverse problem (c).

B. Shielding effectiveness evaluation

The shielding effectiveness of each structure at a single frequency and with height z=5 mm has been evaluated and a comparison between the results given by different approaches is shown in table I. The results in column 1 are those obtained using the theoretical formulas included in [1].

TABLE I

SE OBTAINED WITH DIFFERENT APPROACHES

Screen	Theoretical analysis	Experimental approach	Moment method	Inverse problem
S1	16,4	17.8	16.9	18.2
S2	5.1	7.6	6.8	7.7
S3	18.8	24.9	26.8	23.5

The ability of this model to predict the radiated fields and so the shielding effectiveness at a different height z1= 10 mm has been studied. The comparison between the results obtained with method of moment SE_S and the dipoles SE_{mod} is illustrated in figure 4. A satisfactory correspondence is obtained for the three configurations.

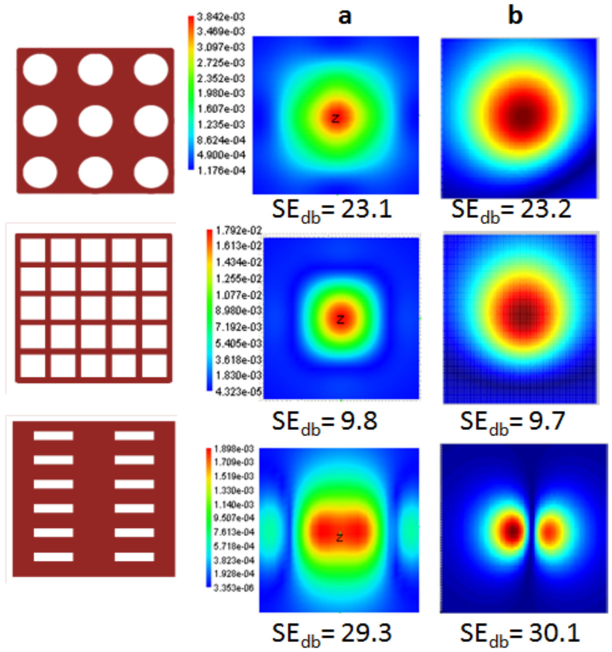

Fig. 4. Evaluation the SE by simulation (a) and using the inverse problem approach (b) with 10 mm as height.

IV. CONCLUSION

In this work an inverse problem based resolution was proposed to find the equivalent models of different perforated screens with finite sizes. A comparison of the results predicted by the dipoles with those obtained with a method of moment and measurements has demonstrated the validity of the equivalent model. These dipoles can be directly incorporated in a 3D computational problem involving enclosures with apertures to avoid a refined mesh around the perforations. At the conference additional type of screens will be presented and the study will cover a wide range of frequencies.

V. REFERENCES

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