Uncertainty Quantification in the Shielding Effectiveness Evaluation of Planar Sheets

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Abstract – The paper addresses the uncertainty quantification of physical and geometrical material parameters in the design of planar shields. A Monte Carlo Simulation is used to obtain the mean and confidence interval of the shielding effectiveness (SE) for conducting and composite materials over a wide frequency range. Two different situations are considered: a circular loop in front of a planar shield and an incident plane wave propagating through a multilayered shield. Such prediction of uncertainties improves the design of shields in the development of inductive power transfer systems considering health and safety standards.

Keywords—EMC, Shielding, Wireless transfer, composite materials, uncertainty quantification

I. INTRODUCTION

In recent years, inductive power transfer (IPT) systems have been widely developed in several fields such as biomedical engineering, consumer electronics and automotive industry. With such increasing use, the human exposure to the radiated electromagnetic fields from these systems in day to day life has to be deeply investigated. It is therefore needed to design effective shielding materials to meet health and safety guidelines [1, 2]. Furthermore, it is also important to evaluate the shielding effectiveness due to uncertainties in the electromagnetic and physical properties of a material; for instance, electrical conductivity of new composite materials have a strong impact on the shielding effectiveness (SE) of sheets [3,4]. The properties of shields are very dependent on many parameters (thickness, number of layers, electromagnetic properties, etc.) and these parameters are corrupted by many uncertainties (measurements errors, approximations) that may have a significant impact on the shielding effect.

This paper studies the uncertainty propagation of these parameters on the SE evaluation for planar sheets. Two simple standard configurations are analyzed. The first case considers a source loop in a low frequency range of 0-100kHz. Such standard geometry is a basic situation in IPT [1,5]. The second one deals with a plane wave in a high frequency range of 0-10 GHz which is relevant to general EMC studies involving composite materials [3]. In both cases normally distributed variable parameters were accounted. A Monte Carlo simulation [6] is then applied where a hundred of tests were run at each frequency point. The mean of the results calculated is then plotted with the confidence interval against the frequency. Such study easily visualizes the uncertainties propagation effects on SE in the of case different varying parameters.

II. ELECTROMAGNETIC PROBLEMS

In both electromagnetic problems, an analytical solution is available, and the shielding effectiveness is obtained at low cost. This allows us to make many calculations rapidly with a Monte Carlo simulation. The case of the circular loop has been studied in [5]. The model consists of a single planar shield lying in the x-y plane, parallel to a current carrying loop also lying in the x-y plane, with radius "a" and centered at the origin. The shielding effectiveness is evaluated at some observation point along the z axis. Note that the distance between the shield and the observation point z does not affect the value of the shielding effectiveness.

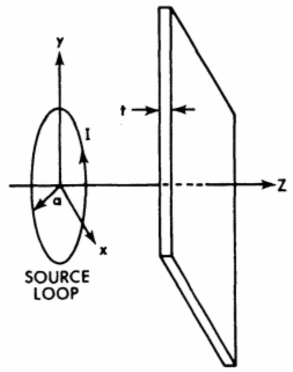

Fig. 1. Circular loop case [5]

The second case deals with several planar shields lying in the x-y plane [7]. The incident wave illuminates the shields at a perpendicular angle to the plane. The shielding effectiveness is then determined along the z axis.

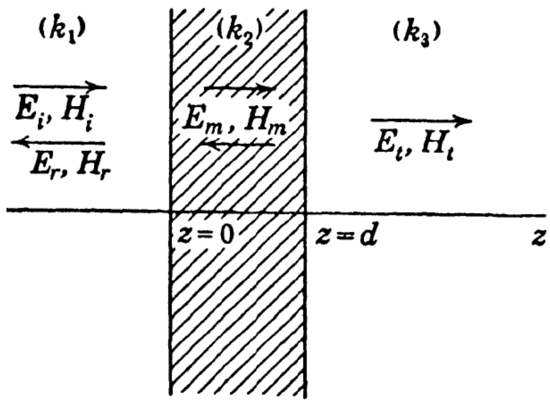

Fig. 2. Plane wave case [7]

III. Results and discussion

A. *Circular loop case*

The case of a 2mm aluminum sheet with variable thickness and conductivity is compared to the same system with a given thickness. The radius of the loop is a = 50 mm and SE is evaluated at z = 100 mm. The statistical properties are shown in Table 1. Gaussian distributions are considered. While the mean of SE appears unaffected, figure 1 shows that a slight variance in the thickness results in a far larger standard deviation. It results a confidence interval of SE around 10 dB.

Input parameter	Mean	Standard deviation
Thickness (mm)	2	0.1
Conductivity (S/m)	3.8×10^{7}	7.4×10^{5}

Table 1. Statistical properties of input variables (loop case)

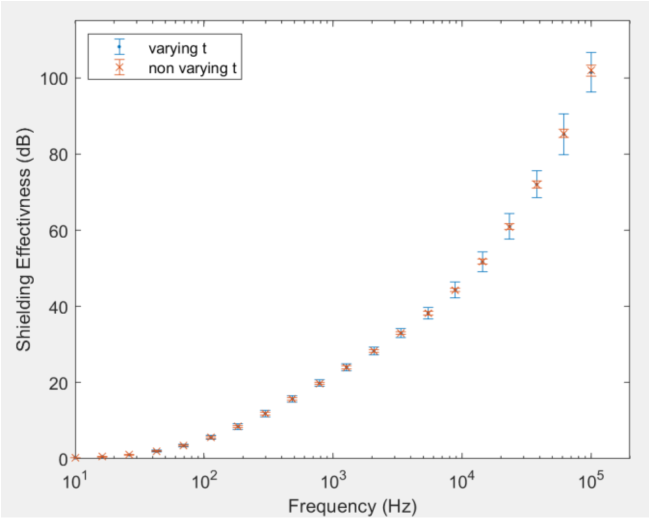

Fig. 3. Shielding effectiveness vs frequency for variant and non-variant thickness

B. *Plane wave case*

For the plane wave situation several multilayered structures are analyzed. To illustrate and as a test configuration, a thin aluminium plate stuck to a composite plate is compared to the case of the composite plate considered alone. The statistical parameters are shown in Table 2. When the aluminium plate is present, a massive gain in shielding effectiveness occurs while the standard deviation of the obtained SE was not greatly affected (figure 2.). The case of a thin metal sheet wedged between two 1mm composite layers was also investigated. It was shown that Aluminum gives a higher SE than copper for a constant mass of the sheet.

Input parameter	Mean	Standard deviation
Thickness (mm)	2	0.1
Aluminium Conductivity (S/m)	3.8×10^{7}	7.4×10^{5}
Composite conductivity (S/m)	1000	250

Table 2. Statistical properties of input variables (plane wave case)

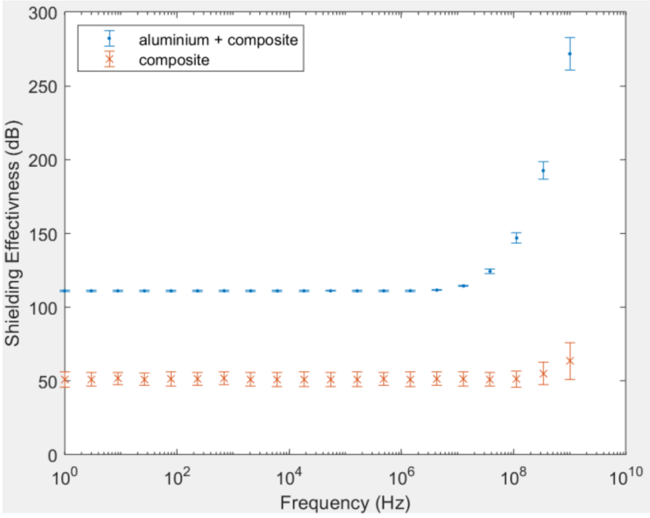

Fig. 4. Shielding effectiveness vs frequency for the composite plate with and without an aluminium sheet

Analytical solutions allow fast calculations, which permits us to evaluate the effects of uncertainties of material properties on the shielding effectiveness, using a Monte Carlo Simulation. Such preliminary study is now expanded upon more complex systems using numerical electromagnetic models. Results will be presented at the conference.

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