

Modeling shielding enclosures of magnetic and conductive composite layers for low frequency power electronics

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Embedded power electronics play a major role in automotive and aerospace. With proliferation of radiation sources, these sensitive power electronics needs to be protect against undesired signals that could cause malfunctioning. Shielding enclosures are used in this scope. For weight reasons, they use magnetic composite material in case of very low frequency and conductive composite material for frequency up to few dozens of kHz . For devices operating from $1 Hz$ to $1 MHz$, using each kind of shielding material is not efficient. In this paper we study association of a magnetic composite material efficient at low frequency, to a conductive composite material efficient when frequency grows up to few dozens kHz . The resulting composite is efficient in the whole frequency range.

Index Terms—Magnetic materials, conductive material, composite material, shielding effectiveness, Finite Element Method, shielding enclosures.

I. INTRODUCTION

Green transition increase the development of full electrical devices in many domains as the transport or energy. In automotive or aerospace industry electronic power devices are embedded for supplying electric power to different system elements. Many of these embedded electronic generate undesired signals that could disrupt system elements. This is the case of power electronic converters that are involved in these systems and play an important role. They need to be protect against undesired signals.

Electromagnetic shielding solutions such as enclosures are manufactured from classical conductive metals such as aluminium [1]. They are the most commonly used system to protect these sensitive systems from electromagnetic interferences (EMI) [2], [3]. Using these classical metals can have a negative impact on the weight, volume and performance of the whole device. In the case of low frequency power electronics, conductive metals of large thickness are often use to achieve high level protection. Unfortunately, large thickness material increases weight and volume. To avoid these negative impacts, magnetic materials are introduced [4]. These materials channel magnetic flux lines and have high absorption properties [5]. Due to their high permeability value, they are efficient at low frequency [6]. However they are less efficient while frequency reaches few hundred of kHz .

To protect in an optimal way low frequency electronic power devices which operate at frequencies lower than $1 MHz$, the used enclosures should be manufacture from light materials. These materials should be as efficient as magnetic materials at low frequencies and as efficient as a conductor when frequency rises above a few hundred of kHz . Composite materials are increasingly introduced in manufacturing such enclosures [7], [8]. They are light and can combine different materials to take advantage of each of them. Polymer composites containing

soft-magnetic powder have been introduced for numerous EMI shielding solutions for microwave applications [9], [10], [11]. Laminate materials that combine conductive layer with ferrite layer are recently proposed for shielding from low frequency to high frequency [12], [13]. In these works, homogeneous MuFero materials are used to improve shielding efficiency at low frequency [14].

In this paper, we propose an association of two composite materials. A magnetic composite material based of low conductivity and a conductive composite material based on aluminium. The shielding effectiveness of the new composite is constant at low frequency and raise without never falling below its low frequency constant value. Measurements will be performed to show relevance of this composite association and an enclosure will be manufactured and tested in real situation.

II. MATERIAL MODELING

In this section, Finite Element Method (FEM) is used to compute the shielding effectiveness of the composite plate. The numerical model consists in illuminating the sample by an incident magnetic field and record the diffracted field in a point probe behind the sample. The magnetic shielding effectiveness is computed as:

$$SE_{dB} = 20 \log \left(\frac{H_{wout}}{H_{with}} \right) \quad (1)$$

Where H_{with} and H_{wout} are respectively the recorded magnetic field with and without the sample.

To have a light and optimal shielding enclosure that can be efficient in a frequency band form $1 Hz$ to $1 MHz$, a composite material is designed. It consists in associating a composite conductive material with a composite magnetic material. The first is a polymer matrix filled by woven aluminium fibers, and the second is a polymer matrix filled by magnetic fibers. For the second one, the magnetic fillers must have the lower

conductivity value as possible, in example ferrite-MnZn whose conductivity is around 10 S.m^{-1} .

In Figure.2, shielding effectiveness of three cases are computed to show how it could be interesting to associate low conductivity magnetic composite with less magnetic conductive composite as show in Figure.1:

- *Sample 1*: it's 0.625 mm thickness non-magnetic conductive composite. It consists in a polymer matrix filled by woven aluminium fibers. Thanks to homogenization technique, its effective conductivity can be computed [15], [16]. Thus we can replace the composite plate by an homogeneous one. The shielding effectiveness of this sample is null at low frequency and progressively increases from 1 dB at 20 kHz to reach 23 dB at 1 MHz .
- *Sample 2*: it's 2.5 mm thickness low conductivity magnetic composite. It consists in a polymer matrix filled by a lower conductivity ferrite fibers. The magnetic permeability is frequency dependent. It is constant for low frequency and decreases from 20 kHz . The shielding effectiveness has a constant value 18 dB at low frequency, and from 20 kHz it begin to decrease as same as the permeability of the material.
- *Sample 3*: it's a 3.125 mm thickness composite. It consists in associating the two first samples. The conductive composite (sample 1) is located on the probe side and the magnetic composite (sample 2) is located on the source side. The obtained shielding effectiveness has a constant value at low frequency 18 dB and from 20 kHz it increases as the shielding effectiveness of the conductive sample.

Experimental study of the proposed composite sample and manufacturing of an enclosure are in progress.

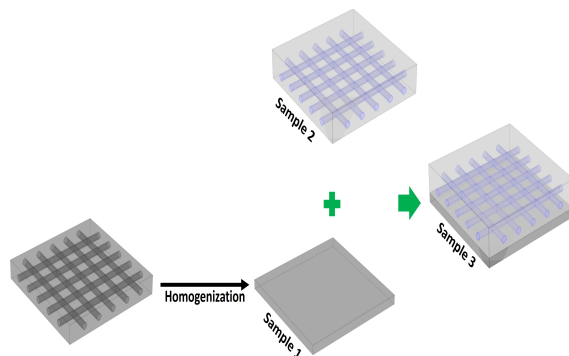


Fig. 1. Studied example.

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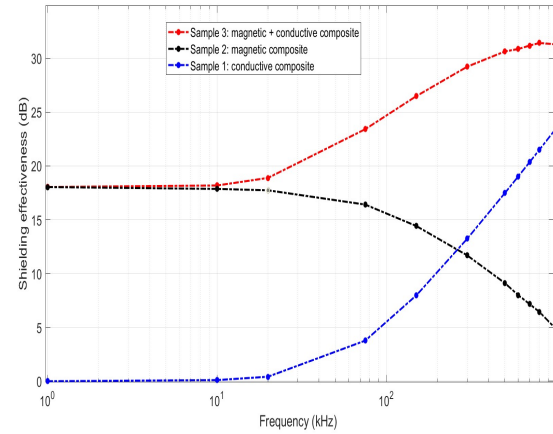


Fig. 2. Comparison shielding effectiveness of three samples. (Blue line) conductive plate of thickness 0.625 mm and $\sigma_{cond} = 48.10^4 \text{ S.m}^{-1}$. It is the equivalent effective medium of a polymer filled by woven aluminium fiber, (black line) magnetic composite of thickness 2.5 mm , consisting in polymer matrix filled by Ferrite-MnZn fiber of diameter 0.22 mm , (red line) composite material of thickness 3.125 mm resulting from association of the two other samples.

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