

# Comparison of the near field coupling using spherical and spheroidal harmonics

F. Tavernier<sup>1</sup>, Z. Li<sup>1</sup>, A. Bréard<sup>1</sup>, D. Voyer<sup>1</sup>, C. Sartori<sup>2</sup> and L. Krähenbühl<sup>1</sup>

<sup>1</sup>Université de Lyon, Ampère (CNR UMR5005), ECL, 69134 Ecully, France

<sup>2</sup>Instituto de Pesquisas Energéticas e Nucleares IPEN CNEN/SP, Laboratório de Eletromagnetismo Aplicado, Universidade de São Paulo, 05508-900 São Paulo, SP, Brazil

francois.tavernier@doctorant.ec-lyon.fr

**Abstract**—An important way to decrease the EMC issue is to predict near-field coupling between components. The using of their electromagnetic equivalent model in spherical multipolar expansion, allow to calculate the near-field magnetic coupling. The method cannot be properly applied when the sources are too close. In this paper we use a spheroidal expansion system, propose to solve the problem which enable to extend the efficiency of the method when the sources are close.

**Index Terms**—Electromagnetic compatibility, spherical harmonic, spheroidal harmonic, quasi-static fields, power electronics devices.

## I. INTRODUCTION

Characterization of electromagnetic interference (EMI) generated within power electronic systems is an important activity in electromagnetic compatibility (EMC). However, EMC issue are generally treated after the development of a prototype; this leads to additional costs and significant delays in manufacturing in case of malfunctioning due to EMI. In order to study the problems of EMC directly at the design phase, EMC predictive modeling methods must be developed.

One of the important characteristics to predict EMC issue is the near magnetic field coupling. A new method has been developed in our laboratory based on the multipolar expansion of the near-field around Device Under Test (DUT) [1]. This allows to calculate the near-field coupling with other sources, using only the harmonic expansion of the device, which simplifies the calculation.

The method gives an equivalent source, which is valid only outside a region. The basis function used in the harmonic expansion is define by the shape. In the case of spherical coordinates of center  $O$ , the smallest sphere that surrounds the source is called the *sphere of validity*. We consider that the center of the spherical coordinates system is inside the device and there exists an infinity of possible positions for  $O$ , that implies there are an infinite number of *spheres of validity*.

The natural choice is to use the *sphere of validity* with the smallest radius, in this case the center of the coordinate system is defined as the midpoint of the straight line between the two furthest points of the device. In order to know the coefficients of the harmonic expansion, measurements around the device has to be performed. These measurements must be done on a sphere with the same center as the harmonic expansion. It's interesting to use a gap between the edge of the DUT and the probe to avoid the influence of higher order term. Therefore, the larger gap less information is available and less measurement points are needed, and vice versa.

## II. PROBLEM FORMULATION

Consider now two devices, we suppose the knowledge of the harmonic expansion of each devices and we want calculate the near field coupling. If there are too close, the spheres of validity might be contain a pieces of the two sources, and therefore the modeling by our method becomes invalid.

A first approach to solve this problem is to change the geometry of the multipolar expansion. There are eleven coordinate systems allowing simple separation of the Laplace and Helmholtz equations [2]. For example, the oblate spheroidal coordinate may be adapted when dealing with a flat DUT such as an electronic board, contrary to the prolate spheroidal coordinate, which is adapted to an elongated object. In this case we can choose the optimal *spheroid of validity* using the Minimum Volume Enclosing Ellipsoid Algorithm (MVEE) [3].

A second approach is to translate the center of the multipolar expansion. For example, to represent the near magnetic field in the sphere of validity of a flat source, the solution is to increase the radius of the sphere and translate its center so that the flattened source is close to the surface of the sphere. The aim of our work is to find the most convenient function basis and center of the multipolar expansion to model the sources in typical cases in power electronics.

In the extended paper we use one set of magnetic measurements all around each source to calculate the multipolar expansion. Then, the near magnetic field coupling of any set of sources in any given position becomes possible using only the multipolar expansion. But it becomes invalid when the sources are too close. Finally, we compare the accuracy and the computational complexity of the different expansion methods. For this, the Fast Multipole Method (FMM) [4] could be used, which provides an efficient translation of spherical harmonic coordinates. The knowledge of the shape of the source does not allow to presume the convergence speed and the accuracy of the near-field coupling

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