Complete Identification for Near-Field Multipolar Expansion of Electromagnetic Sources

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***Abstract*—In EMC behavior of power electronic converters, it is important to predict near-field coupling between the complex components (e.g. in EMC filter). By using the components of near-field multipolar expansion of electromagnetic sources, the close magnetic coupling between two radiating elements is determined from their equivalent model. It is shown that the increase in degree up to the fourth degree together with the complete identification of all components of multipolar expansion provide a more precise representation of the radiating elements and thus a better accuracy of the near-field coupling prediction.**

***Index Terms*—Electromagnetic Compatibility, near magnetic field coupling, power electronic, spherical harmonic.**

I. Introduction

Characterization of electromagnetic interference (EMI) generated within the power electronic systems is an important activity in electromagnetic compatibility (EMC). However, EMC behaviors are currently 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 things to predict is the near magnetic field coupling. The method developed in our laboratory is based on the multipolar expansion in spherical harmonic of the radiation field near the element. This element is represented by an equivalent punctual source composed of all the components of the multipolar expansion, which then allows us to calculate the near-field coupling between the radiating elements [1]. In a previous work, a measurement method together with its prototype was developed to determine the zeroth-order components of the first two degrees of the multipolar expansion (Q_{10} and Q_{20}). However, when applied to a complex element, these components are not sufficient to represent correctly its radiation near-field. Thus, the aim of this work is improving the accuracy of the electromagnetic source's equivalent model by increasing the degree of multipolar-expansion and also by completing the different-zeroth-order components of this expansion.

II. Theoretical and Experimental Development

The multipolar expansion is used for electromagnetic field representation. For our near-field studies at 20 kHz to 20 MHz frequency band, the quasi-static approximation is suitable.

Two considerations are presented in this paper. Firstly, in order to improve the accuracy of the inductive coupling calculation, we aimed to improve the equivalent model of the radiating element by increasing the degree of the multipolar expansion. The measurement prototype with added sensors for the third and fourth degree consists of twelve sensors. The design principle of these sensors is to calculate the shape of the spatial filtering to cancel, in the case of the 3rd degree sensor, the even-degree components and the component of the 5th degree, assuming superior degrees (7th, 9th, etc.) are negligible compared to the 3rd degree. Only the 1st and 3rd degree components contribute to the flux measured by this sensor. The same principle is used to design the sensors of the 4th degree. We obtained a system of three equations with three unknowns for odd orders and similarly for even orders.

Secondly, in order to represent elements with complex radiation behavior, the identification of all components of the multipolar-expansion has to be considered. Based on the approach of rotating sensors presented in a previous work [2], whose idea is to generate the different-zeroth-order components from the rotational and linear combination of the zeroth-order component of the same degree, we designed a support with the rotations in 3D on which placed the radiating element to identify a complete component set of multipolar-expansion representing the element of interest. The rotation matrix and the components interfering with rotated sensors are calculated up to fourth degree.

According to Fig. 1, the relative error is considerably improved when increasing up to the fourth degree and using all components of multipolar expansion. The theoretical development and others experimental validations will be detailed in the extended version.

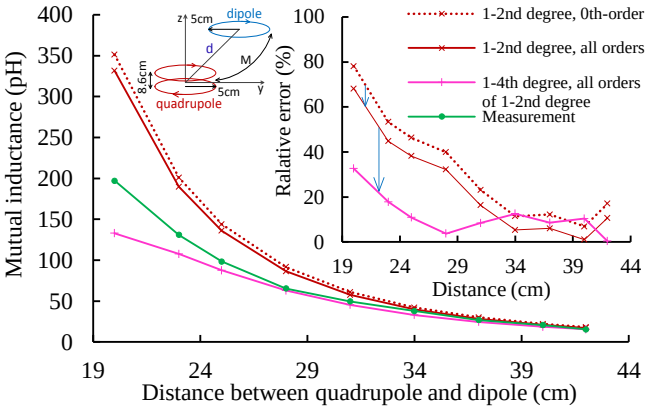

Fig. 1. Inductive coupling between a quadrupole and a dipole

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