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► To cite this version:

Sanaa Zangui, Kévin Berger, Benjamin Vincent, Edith Clavel, Ronan Perrussel, et al.. Near-field coupling between EMC filter components. IEEE CEFC, May 2010, Chicago, IL, United States. hal-00485104

HAL Id: hal-00485104

<https://hal.science/hal-00485104>

Submitted on 7 Dec 2010

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NEAR-FIELD COUPLING BETWEEN EMC FILTER COMPONENTS

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Abstract— A method is proposed to compute the electromagnetic couplings between components in EMC filters. The technique is based on multipolar expansion, which provides a representation of generic structures. A simulation illustrates our approach by computing the mutual inductance between components according to their geometrical placement.

I. INTRODUCTION

Two types of parasitic parameters affect EMC filter performances: the well-known self-parasitic parameters and those due to couplings between the filter components. S. Wang *et al.* [1] have shown that these last parasitic parameters are the first to impact filter behavior as the frequency increases. Except by measuring, there is no way to know *a priori* (in the digital mockup) the performances of a filter while accounting for the near-field couplings between components. In this article, we propose a method based on multipolar expansion in order to compute these couplings. The multipolar equivalent model of the component allows us to compute efficiently any type of coupling in a wide range of frequency (up to 100 MHz) by providing a coarse representation of each element. In the present work, we expand on the different steps of our method, ending with a validation using the finite element method.

II. COMPUTING THE COUPLING METHOD

A multipolar expansion allows us to represent the electromagnetic fields in 3D. This expansion is correct only for the example in Fig.1 where the field is computed outside a reference sphere that contains the source. Our explanations focus on an example which deals with a magnetic coupling but a capacitive effect can also be inferred. Our method is composed of two steps.

A. First step: identification of the multipolar components

In the near-field area, the type of source is linked to the radial component of the same type of field (electric or magnetic). By collecting the radial component of the magnetic field B_r on the validity sphere (radius r_V), it is possible to identify the equivalent magnetic multipolar component of the magnetic source:

$$B_r(r, \theta, \varphi) = \frac{\mu_0}{4\pi} \sum_{n=1}^{+\infty} \sum_{m=-n}^{+n} \frac{(n+1)}{r_V^{n+2}} A_{nm}^B S_{nm}(\theta, \varphi), \quad (1)$$

where n is the order and m the degree (there are $2n+1$ degrees in order n), r_M , the distance to the center of the spherical coordinate system, S_{nm} , the real spherical harmonic functions, and A_{nm}^B , the unknown multipolar components to be identified. Depending on the complexity of the object being modeled, we can calculate the radiated \mathbf{B} -field by using a 3D numerical

model of this object or by performing experimental measurements using sensors based on a multipolar representation [2].

B. Second step: mutual inductance computation

When the spheres which contain each of the sources do not intersect, the mutual inductance can be expressed according to the coefficients A_{nm}^B of each source previously identified [3]:

$$M_{12}(r, f) = \frac{1}{j2\pi f i_1 i_2 k^2} \sqrt{\frac{\epsilon_0}{\mu_0}} \sum_{n=1}^{N_{\max}} \sum_{m=-n}^{+n} (-1)^m (A_{nm}^{B1} \cdot A_{nm}^{B2}(r)), \quad (2)$$

where M_{12} is the mutual inductance between the sources 1 and 2, i denotes the current in each source and f , the frequency. The difficulty lies in the computation of the A_{nm}^B components in the same coordinate system. For instance in (2), we have expressed the second source components in the first coordinate system, which is why r , the distance between the origins of the two coordinate systems, shown in Fig.1, is used to modify A_{nm}^{B2} .

C. First Results

To validate our method, we computed the mutual inductance between two similar coils C_1 and C_2 (Fig.1) where r is the distance between the centers of the coils (of radius R_{coil}). In Fig.1, the mutual inductance computed using either Flux3D© software or our method (using a truncated multipolar expansion for $N_{\max} = 3$ and $N_{\max} = 5$ in (2)) are comparable.

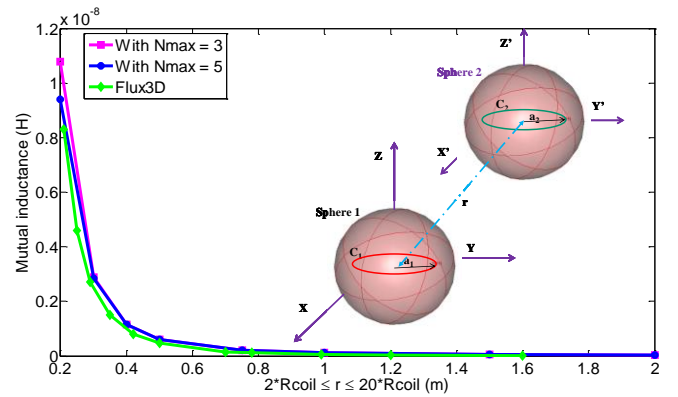


Fig.1. Results and source geometries

III. REFERENCES

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