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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.

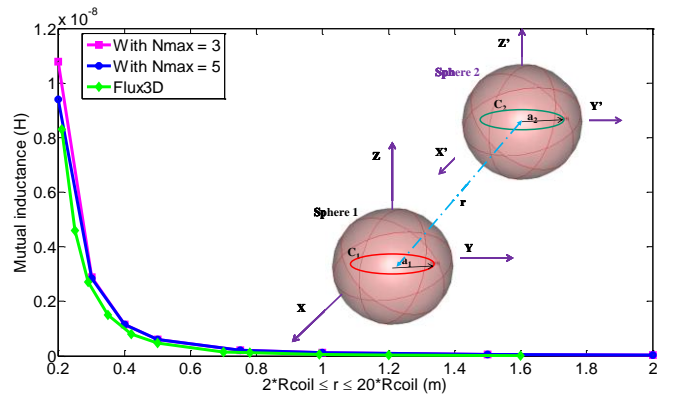


Fig.1. Results and source geometries

## III. REFERENCES

- [1] S. Wang *et al.*, "Controlling the parasitic parameters to improve EMI filter performance," IEEE APEC, Vol.1, pp. 503-509, 2004.
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