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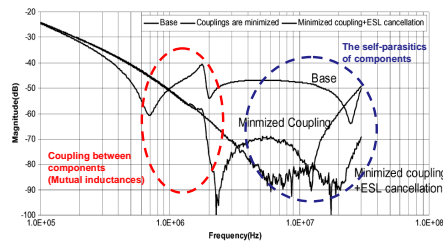
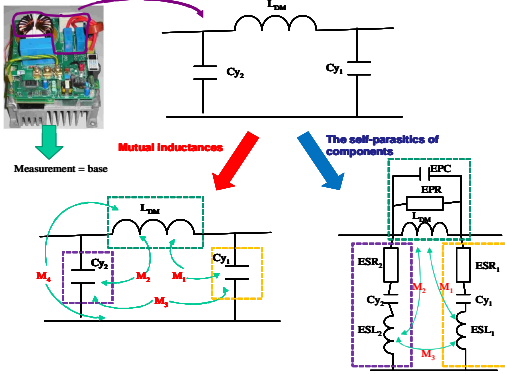
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1-Abstract

EMC filters are increasingly integrated into power-parasitics applications. To improve the filter performance, it is important to model the electromagnetic interference between components to optimize their positions in the filter. A method is proposed to compute the electromagnetic coupling between components. The technique is based on multipolar expansion, which provides a representation of generic structures. A simulation illustrates our approach that involves computing the mutual inductance between components based on their geometrical placement.

2-Introduction



Two types of parasitic parameters affect EMC filter performances:

- the self-parasitic parameters
- those due to coupling between filter components.

Parasitic parameters due to coupling are the first to impact filter behavior as the frequency increases [1].

- In this work, only magnetic coupling effects are studied.
- Due to the weak distance between components and the maximum frequency (100MHz), modeling is based on near-field approximations.

3-Aims

Construct models equivalent to components that:

- Model the magnetic near-field of the filter components.
- Take into account the near electromagnetic environment.
- Are Integrated in electrical circuit software.

Inductive coupling:

- Using equivalent components
- As determined by mutual inductance based on distance between components.

4-Numerical approach

Multipolar expansion

Allowed the 3D representation of the electromagnetic fields on a sphere (radius r_V) surrounding the study system [2].

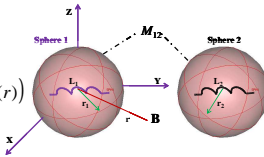
$$B_r(r, \theta, \varphi) = \frac{\mu_0}{4\pi} \sum_{n=1}^{N_{max}} \sum_{m=-n}^{+n} \frac{(n+1)}{r_V^{n+2}} A_{nm}^B S_{nm}(\theta, \varphi)$$

- Calculation of the **B** radial component on the measurement sphere
- A_{nm}^B are the **unknown multipolar components that must be identified**
- Source of order " N_{max} "

Mutual inductance

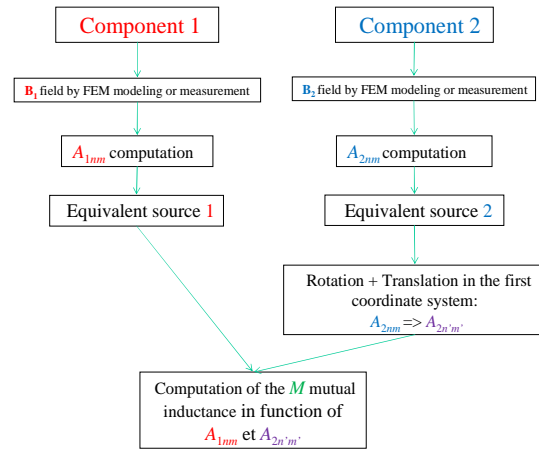
When the spheres containing each of the sources do not intersect [2]:

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



The difficulty lies in the computation of the components in the same coordinate system.

5-Calculus method



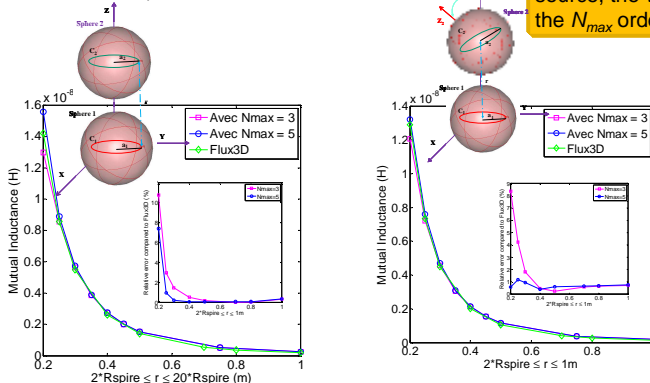
The translation is based on the "Addition Theorem for Vector Spherical Harmonics," which is equivalent to L2M transformation in the FMM algorithm [3].

The rotation is based on Euler angle formulas where only the first 2 angles are necessary, due to symmetrical behaviors [4].

6-First numerical validation

In the case of 2 simple coils (C_1 and C_2 with same radius of 10cm) with a distance of r .

The further the source, the weaker the N_{max} order.



7-Perspectives

- Apply this method to more complex components.
- Use spheroidal harmonic expansion in order to fit the shape of the component.
- Couple this method with PEEC [5] => filter modeling including all coupling (traces/traces, components/components, components/traces).
- Use a measurement system that measures A_{nm} components [6].
- Provide component libraries including models of coupling between power electronic components.

References:

- [1] S.Wang, F.C.Lee and W.G.Odendaal, "Cancellation of capacitor parasitic parameters for noise reduction application", IEEE Transactions on power electronics, Vol.21, No.4, July 2006.
- [2] Billy C.Brock « Using vector spherical harmonics to compute antenna mutual impedance from measured or computed fields », SANDIA Report, April 2001.
- [3] Greengard, L. and Rokhlin, V., "A fast algorithm for particle simulations". J. Comput. Phys. 73, 2 325-348, December 1987.
- [4] Miguel A.Blanco, M.Florez and M.bernejo, « Evaluation of the rotation matrices in the basis of the real spherical harmonics », Journal of Molecular Structure : Theochem, Vol.419, Issues 1-3, 8 december 1997, pp. 19-27.
- [5] V.Ardon, O.Chadebec, E. Clavel, J-M. Guichon, E. Vialardi V. "EMC Modeling of an Industrial Variable Speed Drive with an Adapted PEEC Method", COMPUMAG, Florianopolis, Brazil, 22-26 Nov 2009.
- [6] B. Vincent, O. Chadebec, J.-L. Schanen, K. Berger, « Loop antennas for Near Field Multipolar Expansion Identification: First experimental Validations », to be published in ICONIC 2009 – Special Issue of IEEE Transactions on Instrumentation and Measurement.