Independent Domain Decomposition for Finite Element Solution of Complex Problems

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Nowadays, the increasing computer performances permits to deal with very high complexity electromagnetic problems, like semiconductor devices, their interfacing and packaging with Finite Elements (FE) or other numerical techniques. On the other hand the use of FE in synthesis tools, requiring many consecutive analyses, is still dramatically time-consuming. The numerical complexity of an electromagnetic FEM simulation is given mainly by the number of degree of freedom (dof) of the problem itself, which is tightly bound to the geometrical and physical characteristics of the domain. Therefore there is the need to find general techniques to minimize the total dof number, usually by means of problem- specific methods, as for example, the segmentation method (J. Rubio, J. Arroyo, J. Zapata, IEEE Trans. MTT, 49, 509-516, 2001 - E. Martini, G. Pelosi, S. Selleri, IEEE Trans. MTT, 51, 1712-1717, 2003) for waveguide device synthesis problem.

Electromagnetic problems may exhibit a large domain whose geometry is generally simple, except for a small sub-domain in where a very high complexity or simple tiny structures whose position/shapes are to be optimized are present. In this case the computational burden is given by the total problem size, and the number of dof is necessarily high, and by any optimization or special equation to be performed or enforced in the small complex sub-domain.

Here we suggest to use a generalization of the Huygens principle to decouple the global problem into two distinct sub-problems: a Complex Domain (CD) problem spanning the region of the domain in which optimization or special equations are to be applied and a Large Domain (LD) problem characterized by a simple structure but a very large size.

The CD is, therefore, a reduced size problem with a fictitious boundary on which are tangential electric and magnetic field continuity conditions are to be enforced. This can be done by resorting to the Green function of the LD on the fictitious boundary decoupling the two domains and original conditions on physical boundaries of the domain. Being the Green function of the external domain unknown, in general case, a pre-processing analysis is required in order to compute it with the desired accuracy. This process, which can be carried out using FE, is obviously time-expensive, but is required only once for any given problem.

Indeed the proposed technique permits to “project” the LD and its boundary conditions on the fictitious boundary of the CD, obtaining a reduced size problem on which simulations or synthesis will be performed with great speed advantages with respect to the standard full domain FE solution.