Higher Order Fully Overlapping Domain Decomposition Method for EMI/EMC Modeling

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Abstract

We propose a fully overlapping domain decomposition method (DDM) for the analysis of small radiating/receiving features situated in electrically large enclosures for EMI/EMC analysis. The proposed method decouples the relatively dense finite element mesh (representing the RF environment of low-noise amplifier front ends and/or output power amplifiers with high fidelity), from a coarse background mesh modeling propagation and coupling effects with enclosures and nearby cable bundles. This overlapping decomposition allows for unstructured meshing of the small features within large domains, providing great flexibility in modeling multi-scale electromagnetic environments. We also demonstrate a higher-order version of the proposed method to further improve computational efficiency.

1 Introduction

High fidelity modeling of EMI/EMC effects in complex electromagnetic environments is an inherently multi-scale problem due to the presence of small microwave and electronic components (such as circuit boards) and large enclosures to shield the RF circuitry. Various domain decomposition (DDM) approaches have been developed (see e.g. [1]) to tackle this challenge by partitioning the problem domain into smaller, more manageable pieces and combining individual pieces to arrive at a solution using an iterative solver. More recently, we proposed a fully overlapping DDM scheme [2]. This new approach is particularly efficient to accurately model small details within large domains. The new approach relies on two unstructured finite element meshes. A fine mesh is used in the neighborhood of electrically small features, where as a coarse mesh is constructed for the larger background domain. This mesh decoupling allows for the two meshes to be completely unstructured and independent of one another. Thus, they are easy to construct and attractive for design in the detail domain. Electromagnetic field coupling between the background domain and detail domain is then accomplished by a combination of boundary transmission conditions and direct volumetric field projections. Since the two meshes are decoupled, the method does not require repetitively re-meshing for design and optimization problems.

In this paper, a hierarchical higher order version of our fully overlapping DDM is also developed for EMI/EMC modeling. As noted, this approach results in further improvement in computational efficiency since the coarser mesh is quite uniform whereas the detail-domain is kept very small. In this paper, h-refinement convergence is numerically demonstrated as well. These benefits are crucial for fast and accurate EMI/EMC analysis of multiple sources and complex structures.

The details of the proposed approach can be found in [2]. Below, we demonstrate the h- and p-refinement (higher order basis functions) performance of the proposed fully overlapping DDM. We will demonstrate the efficiency of the proposed method for EMI/EMC problems at the conference.

2 *h*-refinement Analysis of Fully Overlapping DDM

To demonstrate the h-refinement convergence, we consider electromagnetic scattering by a PEC sphere. The problem was analyzed using the proposed fully overlapping DDM, the conventional non-overlapping DDM [1], and the Chimera DDM schemes [3]. In particular, the Chimera method is a *partially* overlapping

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scheme that relies purely on boundary field couplings for DDM iterations. For the Chimera scheme, no auxiliary cement variables are needed. Fig. 1 depicts the h-refinement convergence for each of the three DDM approaches. We note that for all three DDM implementations, first order vector finite elements were used along with the first order Robin transmission condition.

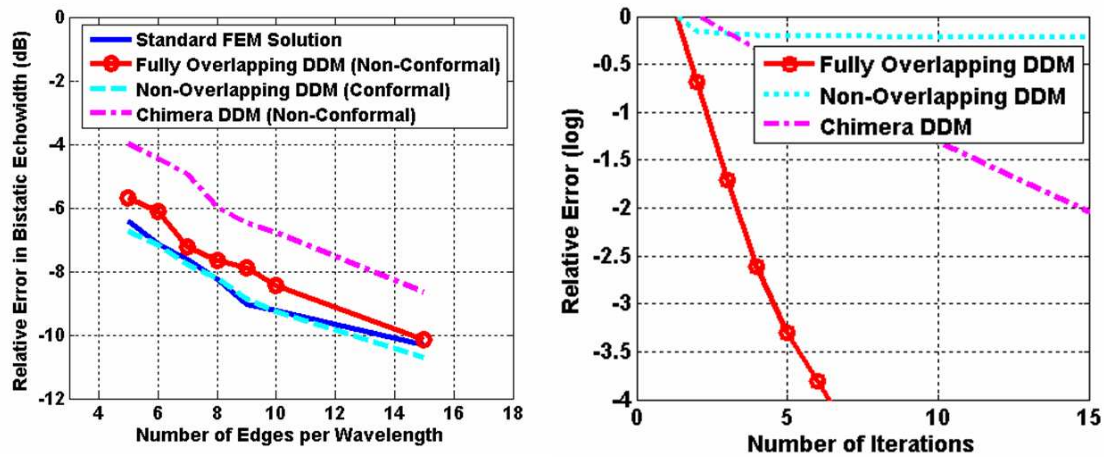

Figure 1: Left: h-refinement convergence of the three domain decomposition schemes when computing the scattering by a $0.5\lambda_0$-radius PEC sphere. Right: Iterative DDM convergence.

As depicted in Fig. 1, all three DDM solutions converge as the mesh density is increased. More importantly, the convergence of all three methods are of the same rate as the standard FEM h-refinement. However, the proposed fully overlapping DDM approach has slightly larger error when compared to the non-overlapping DDM method. This is attributed to the completely unstructured, geometrically non-conformal mesh used to model the two domains. But, as the mesh density is increased (a necessary condition for small embedded details), the proposed fully overlapping DDM exhibits much faster iterative convergence (see Fig. 1-right). This fast convergence is another important benefit of the proposed method. To further improve the computational efficiency, we next consider higher-order vector finite elements in the context of the fully overlapping DDM.

3 Higher-order Fully Overlapping DDM

To implement a higher-order fully overlapping DDM, higher order Robin transmission conditions [4] at the interface boundaries must be incorporated as well. In particular, the gradient divergence term in the second order Robin transmission condition requires auxiliary variables to represent the surface charges on the domain boundary. The pertinent details of the implementation will be presented at the conference.

To illustrate the improvements afforded by the higher-order fully overlapping DDM, below we consider the input impedance of a simple dipole antenna. As seen in Fig. 2, the overlapping DDM accurately captures the impedance variation over a large bandwidth. For reference, the standard FEM solution as well as the commercial HFSS software (with built-in adaptive h-refinement) results are also shown.

4 Conclusions

We presented initial simulation results to demonstrate the accuracy and computational efficiency of a newly developed fully overlapping DDM. A key aspect of the proposed fully overlapping DDM is its flexibility in meshing small features within large domains. This feature makes it attractive for *in-situ* design and

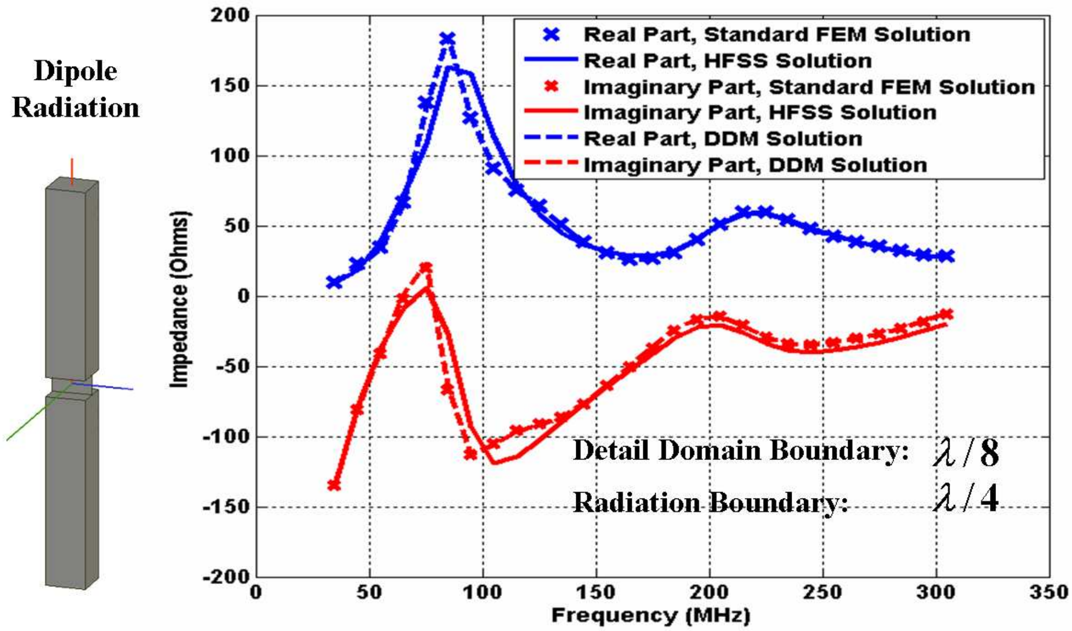

Figure 2: Computed input impedance of a thick square dipole antenna using i) high order fully overlapping DDM approach, ii) standard FEM solution and iii) Commercial HFSS Software.

optimization problems, such as those encountered in EMI/EMC analysis. Uniform h-refinement for the fully overlapping DDM shows the same accuracy can be achieved as the standard FEM but with faster iterative convergence. This paper also proposes, for the first time, higher order vector basis functions incorporated into the DDM scheme.

5 References

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