Complex Antenna Simulation By Using Embedded Domain Decomposition

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An overall full wave electromagnetic (EM) analysis consists of three steps: CAD modeling, mesh generation, and numerical simulation. In antenna and microwave engineering, we usually need to design a device in a number of scenarios with respect to geometrical parameters, components, and material properties. As a consequence, device modelings, meshings, and simulations are required to be conducted repetitively. This is especially true for complicated industrial applications, where a substantial amount of time could be wasted on system simulations and optimizations. Unfortunately, most existing numerical techniques in electromagnetics do not aim at addressing repetitive discretizations and simulations. As a matter of fact, a simple geometrical modification could cause complete problem rediscretization.

In this work, we present an embedded domain decomposition method (DDM) for analyzing complex antenna structures. A target problem is decomposed into a background subdomain Ω_1 and multiple embedded subdomains $\Omega_m\,(m = 2, ..., N)$. The background covers the basic shape of the problem while the fine geometric details can be modeled as embedded subdomains. The overall simulation is achieved in an iterative way. Firstly, we mesh each subdomain independently and solve them separately by employing a standard single domain FEM solver. Afterwards, Ω_1 imposes surface sources onto $\partial\Omega_m$ to ensure tangential $\mathbf{E}$, $\mathbf{H}$ continuities. Meanwhile, Ω_m gives Ω_1 modified volume/surface sources that represent the material properties, PECs, ports, and impedance boundary conditions. Ω_1 and Ω_m will exchange information between each other iteratively until the overall solution converges.

To demonstrate the proposed method, we have investigated the analysis of a complex leaky wave antenna model. The antenna structures are very complex, and the conductor shapes may need to be adjusted repetitively for optimization purpose. Herein, we discretize the antenna details by employing an embedded subdomain, while the substrate, a surface wave launcher, cable excitation and an air box constitute the background subdomain. For such simulation/design tasks, embedded DDM can be a beneficial simulation engine. We can decouple complex geometries into simpler subdomains, thereby mitigating the burden of mesh generations. Furthermore, the subdomains are meshed completely independently, and the modification of the embedded subdomain would hardly influence the discretization and matrix computation of the background. This provides us the flexibility to modify/add/replace specific geometrical components without changing the rest object discretizations.

The simulation results are compared with simulation and measurement references. Reasonable agreements can be observed, indicating the EM properties of the leaky wave antenna are correctly captured by our proposed method. More importantly, the biggest benefit of embedded DDM is its flexibility in utilizing completely nonconformal meshes between the subdomains. Such feature in geometric modelings and discretizations would significantly speed up the repetitive simulations in designs and optimizations.