Modeling of Environmental Effects in EM Applications using Domain Decomposition Method

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In many real-life applications, it is quite common to have engineering devices being tested within the same environment. Examples include mobile phones in the vicinity of a human head and antenna arrays mounted on a battle ship. The current practice, for example in the evaluation of the antenna arrays on the battle ship, is to repeat the simulations including the entire environment for different antenna arrays. This process is very time consuming.

In this paper, we propose to solve problems of this kind using the domain decomposition method (DDM). Since DDM allows the independent handling of different domains, one finds that some of the domains can be easily changed without affecting the other domains. Consequently, any information or data for the unchanged domains can be retained and reused in any other instances. Extending this idea, it would be very beneficial to employ the finite element tearing and interconnecting (FETI) technique if a domain should be reused many times. The FETI results in a "transfer function" or a numerical Green's function as a matrix form which, once obtained, can be readily combined with other domains in the solution process of DDM as a matrix-vector multiplication form. Note that through the FETI process, the information in the entire volume of a domain is translated into the information on the boundary surface. It is even more favorable since the matrix represents the numerical Green's function, which can be obtained as long as a numerical method can be used. FETI is especially useful when only a small portion of a problem is repeatedly changed. For example, for the analysis of antenna arrays on a battle ship, the array will be replaced for different designs, but the ship will remain the same. Therefore, it would be beneficial to define the interior domain to include only the antenna array, and calculate the numerical Green's function only once for an exterior domain that includes the ship. This will significantly reduce the computational effort required to simulate each array model or design.

The construction of the numerical Green's function is accomplished mainly through three major ingredients; 1) Decouple the engineering device and the environment by the use of the FETI algorithm; 2) Solve the resulting finite element matrix equation with multiple right-hand-sides using state-of-art pMUS preconditioner; 3) Compress the numerical Green's function by employing an efficient rank-revealing SVD algorithm. The entire process of computing the compressed Green's function may take significant computer resources in terms of CPU times and memory. However, once the compressed numerical Green's function is obtained, it can be reused to simulate different engineering devices with drastically reduced problem sizes.