Fast Computation of Macro-Basis Functions in the Context of Modeling the Problem of Scattering from Forests

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The aim of this research work is to discuss the use of the diagonal representation (DR) for the construction of the macro-basis functions (MBFs) when applying the Characteristic Basis Function Method (CBFM) to the problem of modeling of scattering from forests. We have applied the CBFM to improve the performances of a previously studied 3D full-wave model in order to solve electrically large forest simulation scenes. This efficient domain decomposition method has shown good performance both in terms of CPU time and memory while achieving a satisfactory level of accuracy compared to that of a conventional Method of Moments (MoM). Therefore, it enables us to solve forest EM problems of upward of 2 million unknowns by consuming only a reasonable amount of CPU time and using just 48 GB of shared memory (Fenni I.; Roussel H.; Darces M.; Mittra R., AP IEEE Trans., 62-8, 4282-4291, 2014).

However, the CBFM is still intensive in terms of the CPU time, especially while considering large CBFM blocks. Here, we focus on the reduction of the computation time spent for the generation of the CBFs. To achieve this goal, we propose the use of the diagonal representation of the MBFs, which consists of approximating the inversion of each sub-matrix Z_{ii}, of size $3N_i$ x $3N_i$, with a vector-vector simple division, where N_i is the number of cells per block i, and Z_{ii} is the MoM sub-matrix representing the interactions between these N_i cells, along the axes x, y and z. Thus, instead of inverting the entire Z_{ii} to compute the MBFs for each block, we expressed them as:

$$\tilde{E}_i(l,j) = \frac{\tilde{E}_{i,ref}(l,j)}{Z_{ii}(l,l)} \quad \text{for } l = 1,2,\ldots,3N_i \text{ and } j = 1,2,\ldots,N_{IPWs}$$

where N_{IPWs} is the number of incident waves used to generate the characteristic basis functions (CBFs). Admittedly, this approach can reduce the accuracy of the CBFM solution somewhat, however, in our case, the question is whether or not this slight loss of accuracy of the computed fields inside the tree trunk is so important as to affect the accuracy of the results for the scattered fields, since the ultimate goal of our 3D dielectric model is to compute the fields scattered by the forest medium. Numerical results have shown that the DR of the MBFs enables us to significantly reduce the CPU time required to generate the CBFs, especially for large blocks, without degrading the accuracy of the CBFM solution for the scattered field. Therefore, one may be tempted to increase the size of the CBFM block as far as the available memory resources allows it, in order to achieve a high compression rate while enjoying a better gain in CPU time, thanks to the DR approach. However, we have observed that the impact of the diagonal representation technique on the accuracy of the CBFM solution is highly dependent on R_s the radius of the cylinder modeling the tree trunk. But, we also find that, under a certain value of tree-trunk cross-section ($R_s < 2\lambda_s/3$), where λ_s is the wavelength inside the scatterer, the results obtained with this enhancement technique match relatively well with those given by a classical CBFM-E, and the use of this method substantially decreases the total CPU time (from hours to a few minutes) and maintains a high compression rate. Therefore, it enables us to simulate larger forest simulation scenes at higher frequencies with the same available memory resources.