Mixed Basis Functions for Fast Analysis of Antennas Near Voxel-Based Human Models

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To support the continuing proliferation of wireless devices that operate near/on/in the human body in the UHF band (0.3-3 GHz), antenna properties (input impedance, radiation patterns, etc.) must be characterized in the presence of human models. In recent years, a significant number of different anatomically accurate high-fidelity human models have been developed for these problems (Massey et al., 34th Annu. Conf. Bioelectromagnetics Society, 2012). With a few exceptions, almost all human models developed to date are based on voxels because the underlying data sets are 2-D medical images, e.g., CT, MRI, and cross-sectional images, and because it is extremely challenging to smooth these models while maintaining their accuracy. Given the difficulty of the problem, it should be expected that voxel-based models will continue to dominate the available human models in the future. As a result, computational methods that are based on regular meshes, such as the finite-difference time-domain (FDTD) and conjugate gradient FFT (CG-FFT) methods, have clear advantages for analyzing scattering from human models; in fact, these methods remain the two most popular approaches in bioelectromagnetics. When antennas must be modeled, however, the classical FDTD and CG-FFT methods constrain the antenna to conform to a regular mesh to avoid significant staircasing errors.

Recently, a massively parallel and preconditioned version of the adaptive integral method (AIM) has been used to analyze antennas near human models (F. Wei and A. E. Yılmaz, Int. Conf. on Electromag. in Advanced Applicat., 869-872, 2012). The AIM approach allows irregular meshes to be used when discretizing integral equations because it introduces an *auxiliary* regular grid to accelerate the method of moments solution. Thus, arbitrarily shaped, located, and oriented antennas can be modeled accurately by using triangular surface and tetrahedral volume meshes when AIM is used. Discretizing voxel-based human models with tetrahedral volume meshes, however, is inefficient. It requires splitting each voxel into five or more tetrahedra and assigning the voxel's material properties to these tetrahedra; this increases the number of elements/unknowns without adding any information on material properties and boundary locations. In this article, the AIM procedure is modified to use mixed basis functions; specifically, voxel-based volume basis functions (rooftops) are used in the human model and triangle-based surface and tetrahedron-based volume basis functions are used in the antenna region. While a single auxiliary grid is used to enclose both the human and antennas models, the remaining AIM parameters (number of auxiliary grid points and the near-zone correction size assigned to the basis functions) are optimized separately for the different types of basis functions. The mixed basis functions are observed to reduce the iterative solution time by a factor of ~5-10.