The Use of the ADI-FDTD Method for Calculating Recruitment Volume in Human Torso due to Contact Electrodes

N. Kwatra*, V. Singh, G. Lazzi
North Carolina State University, Raleigh, NC 27695, USA

The Alternating-Direction Implicit Finite-Difference Time-Domain (ADI-FDTD) method is an unconditionally stable computational electromagnetic method that allows arbitrarily large time steps, although generally at the expense of accuracy. However, a number of computational problems focus on the calculation of average quantities, which result in significantly reduced effects of local errors. Bioelectromagnetic problems, for example, generally involve the computation of Specific Absorption Rates of power (SARs) or total currents induced in the human body due to electromagnetic sources; in these cases, for example, the ADI FDTD method can be very useful since it allows fine computational mesh resolution in regions of interests without necessarily decreasing proportionally the required computational time step.

In this work, the D-H formulation of the ADI-FDTD method is used to compute the volume of neurons excited (recruitment volume) in a human body due to current injection by contact electrodes of a Human ElectroMuscular Incapacitative (HEMI) device. The threshold for the recruitment is decided based on experimental investigations on laboratory animals found in the literature. As neuron fibers can be excited either by the through electric fields of sufficient magnitude or appropriate electric field spatial gradients, we focus on the utilization of the D-H ADI FDTD method, combined with the expanding grid and quasi-static algorithm simplifications, to efficiently compute these quantities.

In this presentation, we will show that the D-H ADI FDTD method provides accurate results for this application. We will further demonstrate how the expanding grid D-H ADI FDTD method, combined with quasi-static assumption, allows us to solve in a fraction of time required by traditional full-wave methods for the computational problem involving a complete human body model based on the 1mm resolution visible man model exposed to the low frequency (less than 200 kHz) waveforms of the HEMI device.

Performed simulations indicate that the considered HEMI waveforms result in neural excitations that are more likely due to electric field magnitudes than its gradient. Regions of excitation will be presented, and the effect of the positions of the contacts, dielectric properties of the tissue, and electrode penetration will be discussed.