On the Use of the ADI-FDTD Method for Bioelectromagnetic Simulations

***Ajeet*, V. Singh, G. Lazzi**

Department of Electrical and Computer Engineering, North Carolina State University, Raleigh, NC 27695, USA
alnu@ncsu.edu, vsingh@ncsu.edu, lazzi@ncsu.edu

The traditional explicit Finite-Difference Time-Domain (FDTD) method is conditionally stable where the time step must adhere to Courant-Friedrichs-Lewy (CFL) limit. In problems such as those encountered in bioelectromagnetics and VLSI circuits, the spatial resolution is dictated by the geometric detail rather than the resolution of the smallest wavelength. Thus, severe limitations are often imposed on the time step, leading to long time-domain simulations.

The Alternating-Direction Implicit (ADI)-FDTD method is theoretically unconditionally stable and arbitrarily large time steps can be used for simulations. However, it should be noted that the simulation speed-up is not proportional to the increase in the time step. It was obtained that the ADI-FDTD method gives speed advantage over explicit FDTD only when the acceleration factor (CFL number) is greater than 4. Further, the downside with the ADI-FDTD is that the accuracy tends to degrade with the increase of the CFL number. However, in bioelectromagnetics problems, because of a higher tolerance to phase errors and reduced effect of these and magnitude errors on averaged quantities such as the Specific Absorption Rate (SAR), the ADI-FDTD could be a suitable method.

In this work, we have used the ADI-FDTD method in the D-H formulation to compute the induced fields in the human body due to current injection by contact electrodes of a HEMI device. An expanding grid scheme was used to reduce the number of computational nodes such that the volume near the energy source was discretized at a higher resolution with progressively decreasing resolution towards the perimeter of the model. Low-frequency (below 200 kHz) solutions utilizing the quasi-static assumptions and Discrete Fourier Transforms (DFT) have been obtained. Further, using the above mentioned techniques, a comparative study of the effects of different electrode contact positions and electrode penetration through the epidermis on the induced current densities in key organs, such as the human heart, has been done. A discussion of the modeling, low-frequency techniques and variation in induced current densities with electrode size and position will be presented.