SAR CALCULATION USING FDTD-ADI TECHNIQUE WITH TRANSPARENT ABSORBING BOUNDARY

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Abstract

This paper presents a numerical simulation of electromagnetic fields-head tissue models interactions using the finite-difference-time-domain-alternating-direction-implicit (FDTD-ADI) method. Detailed models of the human head are implemented to investigate the effect of the tissue location and a physical antenna model. The specific absorbtion rates (SAR) in various tissues are calculated at various cross-sections of the head model. Simulations using the FDTD-ADI formulation with the transparent absorbing boundary (TAB) are presented to demonstrate the accuracy and the unconditional stable property of the ADI scheme.

1. Introduction

The FDTD [1-2] is a well-known method which can predict the electromagnetic behavior accurately. The main advantages of FDTD-based techniques are its simplicity and the ability to handle complex geometry. The field at each grid point is calculated explicitly using only adjacent field's values at previous time. Despite its simplicity and flexibility, the FDTD schemes have been limited to only solving electrically small structure problems. The main reason is that the time step in the FDTD scheme must be small enough in order to satisfy the Courant-Friedrich-Levy(CFL) stability condition. The CFL condition can be alleviated by a recently proposed alternating-direction implicit (ADI) time-stepping scheme [3-6]. This greatly increases the computational efficiency of the FDTD method for class of problems where the cell size of the 3-D space is constrained to be much smaller than the shortest wavelength of the source field. In this paper, the FDTD-ADI scheme is implemented for simulating the EM interaction between a handset-mounted antennas and the human head tissues.The FDTD-ADI scheme is developed to solve the Maxwell's equations with the transparent absorbing boundary(TAB) [7].

2. Formulation of the FDTD-ADI method

The FDTD method is derived from Maxwell's time-domain equation which is expressed as

$$e\frac{\partial \vec{E}}{\partial t} = \nabla \times \vec{H} - s\vec{E} \tag{1}$$

$$m\frac{\partial \vec{H}}{\partial t} = -\nabla \times \vec{E} \tag{2}$$

Where E and H are the electric and magnetic field intensities and ε, μ, and σ are the space-dependent permittivity, permeability, and conductivity, respectively. Each vector equation of Maxwell's equations can be cast into three scalar partial differential equations in the Cartesian coordinates. In contrast to the conventional FDTD formulation which only requires one iteration to advance from the n^{th} to $(n+1)^{th}$ time step, the FDTD-ADI formulation [3-4] requires a sub-iteration to advance from n to n +1/2 and a second sub-iteration to advance from n+1/2 to n+1. The detailed of implementation steps of the FDTD-ADI scheme are outlined as follows:

Step 1. Choose Δt and set $t = 0$

Step 2. Update $E^{n+1/2}$ implicitly and Update $H^{n+1/2}$ explicitly

Step 3. Update E^{n+1} implicitly and Update H^{n+1} explicitly

Step 4. $t = t + \Delta t$

Step 5. If $t > t_{max}$ go to step 2

Step 6. Check for convergence. If satisfied, stop. Otherwise, go to step 1.

3. Transparent Absorbing Boundary

The transparent absorbing boundary (TAB) used in this paper was derived by Peng and Balanis [7]. The unbounded computational domain is truncated by using a special function F(r). By introducing a set of auxiliary fields $\vec{\mathrm{E}}(t,r)$ and $\vec{\mathrm{H}}(t,r)$ in the computational domain with the defined definition as

$$\vec{\mathrm{E}}(t,r) = F(r)\mathrm{E}_0(t,r) \tag{3}$$

$$\vec{\mathrm{H}}(t,r) = F(r)\mathrm{H}_0(t,r) \tag{4}$$

for $r < r_0$ where r_0 defines the closed truncation boundary, and $F(r_0) = 0$. Note that all fields at a boundary are reduced to zero. Details of the TAB formulation are presented in [7].

4. Computational results

The FDTD-ADI scheme based on auxiliary fields formulation was employed for calculating the electromagnetic field quantities of a hand-held mobile phone with and without the presence of a human head model in its close proximity. The specific absorbtion rate (SAR) defined as the power absorbing per unit mass of was calculated . The model of the 900 MHz. hand-held cellular phone was taken in the form of 15X6X3 cm perfectly electrically conducting rectangular box with an antenna on its upper plane. A power of 2 W delivered to the antenna is employed in the simulation. SAR distributions at various cross-section of the head model are shown in Fig. 1-2. Comparing results with conventional FDTD[8], the number of time steps in the simulation can be reduced by more than 50%.

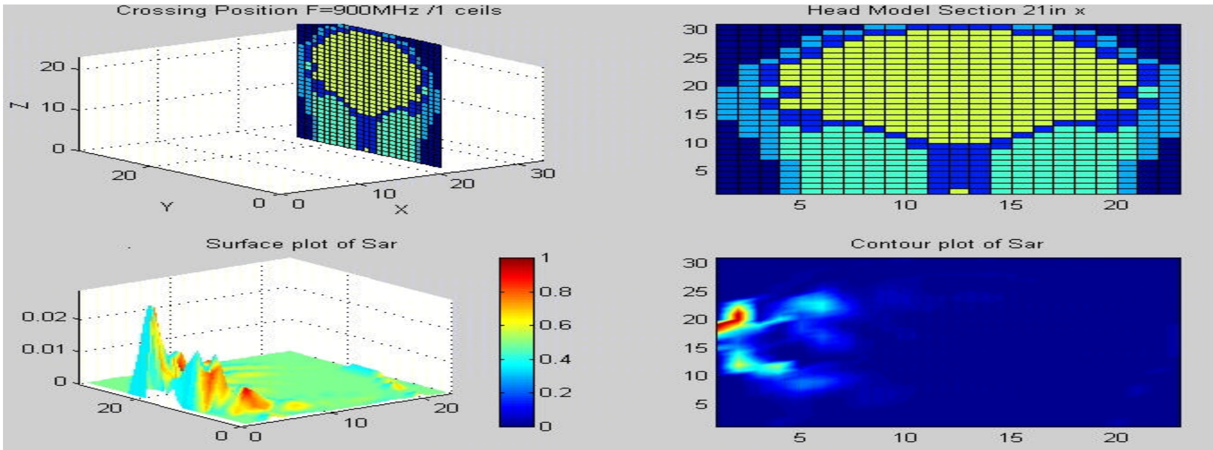

Fig. 1. SAR distribution at the X-cross section in the head model

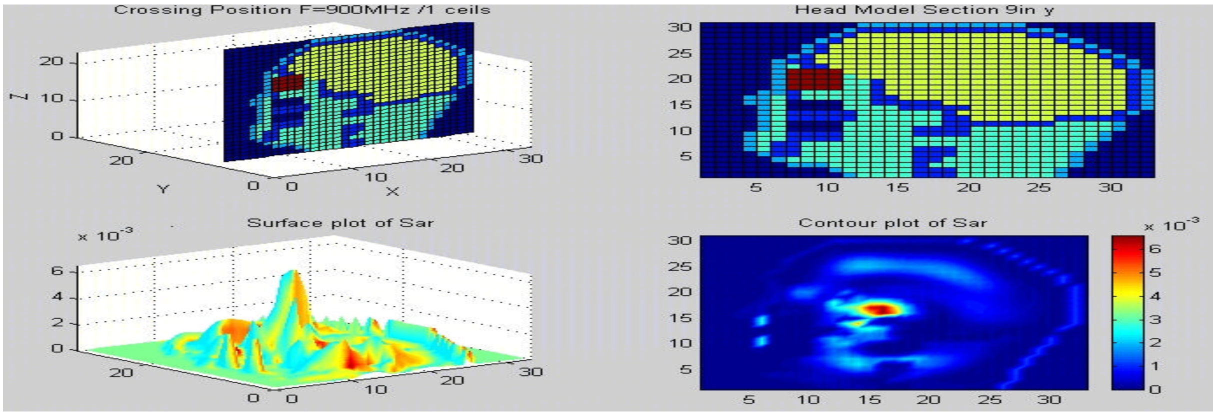

Fig. 2. SAR distribution at the Y-cross section in the head model

5. Conclusion

The FDTD-ADI scheme with the transparent absorbing boundary (TAB) is implemented to analyze problems of electromagnetic field-human head interaction. The algorithm has significant promise for stable and accurate FDTD modeling of electromagnetic wave phenomena. As demonstrated in this paper and comparing results with the standard FDTD, the number of time step in the simulation can be greatly reduced and the algorithm is unconditionally stable . Also, the time-step size does not depend on the CFL condition.

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