THE CGM AND THE FDTD FOR SAR STUDIES

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ABSTRACT

In the study of electromagnetic radiation effects over dielectric bodies, effective numerical methods are needed. At present, there is a lack of tools for measuring this effects and due to the huge growth of microwave devices, like cellular radio telephones working close to the human body, it is necessary to develop accurate numerical methods for evaluating those effects. Two of the most efficient and extensively used methods are the FFT-CGM (Fast-Fourier-Transform Conjugate Gradient Method) and the FDTD (Finite Difference Time Domain Method). Since both methods use a rectangular grid, it is interesting to compare the two solutions in order to validate the results. In this paper, algorithms for solving the two-dimensional scattering of transversal magnetic (TM) polarized waves by a lossy dielectric objects are presented. At the same time, the SAR (Specific Absorption Rate) of tissues is obtained from the diffracted fields.

0. INTRODUCTION

The development of biological applications in electromagnetics and the study of the radiation effects require fast and accurate methods for the computation of electromagnetic fields inside inhomogeneous lossy dielectrics exposed to a known incident field. The case of metallic structures is interesting too. Analytical solutions exist only for simple geometries such as the cylindrical and the spherical ones. Those solutions are mainly used to check the accuracy and behavior of numerical results.

1. DESCRIPTION OF THE ALGORITHMS

1.1 Conjugate Gradient Method

In the TM case the integral equation can be expressed as

$$\vec{E}^i(\vec{r}) = \vec{E}(\vec{r}) - \vec{E}^s(\vec{r}) = \vec{E}(\vec{r}) + k_0^2 \int_{S'} \frac{\varepsilon_0 - \varepsilon(\vec{r}\,')}{\varepsilon_0} \vec{E}(\vec{r}\,') G(\|\vec{r} - \vec{r}\,'\|) ds' \qquad (1)$$

with $\vec{E}^i(\vec{r})$, the incident field, $\vec{E}(\vec{r})$, the diffracted field and $\vec{E}^s(\vec{r})$, the scattered field. The Green's function, $G(\|\vec{r}-\vec{r}\,'\|)$, in the 2D case is given by

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$$G(\|\vec{r}-\vec{r}'\|)=\frac{1}{4j}H_0^{(2)}(k_0\|\vec{r}-\vec{r}'\|) \quad (2)$$

Equation (1) can be solved by using the method of moments with pulse expansion functions and point matching, Richmond [1]. This method reduces the integral equation to a linear system and requires a matrix inversion, that can be optimized in computational time and memory storage by using the FFT algorithm and the iterative CGM [2].

In the presence of metallic bodies, it is necessary to express the former equations in terms of the density current in order to avoid singularities in the integral equations. Real scattered fields are obtained from non-physical volumetric density currents defined on each cell of the body.

$$\vec{E}^i(\vec{r})=\frac{\vec{J}(\vec{r})}{\varepsilon_0-\varepsilon(\vec{r})}+k_0^2\int_{S'}\frac{J(\vec{r}')}{\varepsilon_0}G(\|\vec{r}-\vec{r}'\|)ds' \quad (3)$$

This equation is only valid inside the body, because in the outside medium the term $1/(\varepsilon_0-\varepsilon(\vec{r}))$ is singular. Moreover, $\vec{E}^s(\vec{r})=-\vec{E}^i(\vec{r})$ must be forced inside the metal where the total field has to be zero.

1.2 Finite Differences in Time Domain

The FDTD algorithm is well known and we will not present it here. The centered difference approach was used with Yee's mesh. A simple two-point time-space extrapolation was used as an absorbing boundary condition on the scattered component of the fields only. This way the excitation of the problem is applied on the boundary at the same time as the absorbing boundary condition. To assure stability and to simplify the space-time extrapolation, we chose a time step of one half the propagation time for one space step.

SPECIFIC ABSORPTION RATE (SAR)

One way of measuring the power effects of the electromagnetic radiation inside biological bodies is the SAR (Specific Absorption Rate). Because of the power absorption distribution is highly dependent on electrical conductivity levels in tissues, the SAR is a function of the conductivity, the density and the electrical field intensity

$$SAR=\frac{1}{2}\frac{\sigma\|E\|^2}{\rho} \quad W.kg^{-1} \quad (5)$$

With good discretized models of biological bodies, the effects of radiation inside them, for instance the dissipation power dissipated by cellular phones in the head, can be evaluated, in terms of SAR, from diffracted fields.

NUMERICAL RESULTS

The figure shows the hand-drawn 2D model of a human head (left) and the SAR due to a cylindrical TM wave of 1.89 GHz incident from the left. The dimensions and permittivities used are realistic, and the main limitation of this model is that it is two-dimensional.

Fig. 1 Magnitude of permittivity of the hand-draw 2D model of a human head used in the simulations (left) and SAR due to a cylindrical wave.

CONCLUSIONS

Effective algorithms for computing the SAR inside lossy dielectric and metallic bodies are presented. This bidimensional solutions are in the process of extension to the 3-D case and will be a useful tool for mobile communications antenna analysis and design and for the study of power dissipation inside biological tissues. Having to completely different algorithm run simulations on the same model will allow the validation of the numerical results.

ACKNOWLEDGEMENT

This work has been sponsored by the Comisión Interministerial de Ciencia y Tecnología (CICYT) under Grant TIC 93-0518.

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