New FDTD Scheme for the Modeling of Arbitrarily Curved Thin Conductive Sheets

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Motivation & Objectives

One of the major drawbacks of the Finite-Difference Time-Domain (FDTD) method in EM simulations is its inefficiency for small structures due to the direct relation between grid and time resolution. This study shows that thin conductive sheets (TCS) can be effectively treated within FDTD by assigning special update coefficients to the conventional Yee scheme without the need for additional field components. Thus, the linearity and stability of the FDTD method are preserved.

The objectives of this study were the development of a novel TCS algorithm as well as its integration into a commercial FDTD software. It is shown that the algorithm allows for the accurate treatment of arbitrarily shaped 3D sheets in complex models without introduction of additional field components. Furthermore, the study is focused on a verification of the new algorithm based on canonical validations as well as its application to problems in RF technology and optoelectronics.

Methods & Implementation

Most of the existing approaches to thin material layers in FDTD add new field components and thus new dependencies. Problem specific physics equations are rewritten into a numerically applicable form. This study is based on a reversed scheme: The wave equations describing the behavior of a general TCS are applied to the Yee-scheme and solved for the update coefficients. It is shown that the FDTD equations do offer sufficient degrees of freedom for the treatment of TCS.

The described approach is extended to be applicable to arbitrarily curved sheets in 3D. Correctional terms account for non-cubic grids. The final algorithm is integrated into the fully featured EM simulation platform SEMCAD X.

Results & Discussion

It is shown that the special physics that apply in the case of TCS render the proposed method possible. However, a detailed analysis reveals that only a subset of the degrees of freedom offered by the FDTD scheme is employed, suggesting that it can be extended to support a more general material model.

In the example of a harmonic RF simulation at 1, 8 GHz with a tilted sheet of 15 μm thickness, the proposed model can be run with a standard grid step $\Delta G = \lambda_0/10 \approx$ 15 mm. However, a conventional simulation cannot serve as a validation: Given the necessary 1000 times smaller spatial and temporal resolution, the simulation time would be 10^{12} times larger. Thus, a comparison of canonical plane wave simulations with their analytical solutions proves that the dependence of reflection and transmission on the angle of incidence, the surrounding material, and the polarization are correctly resolved. Also, more general examples show a correct energy balance.

Moreover, the model is applied to real world cases in the field of RF cell phone coatings and optical waveguides. The results are in very good agreement with the findings from other simulation methods and with existing measurements.