The Prolate Pseudospectral Time-Domain Method

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Abstract

In the last few decades pseudospectral methods have emerged as a powerful approach for the numerical solution of frequency and time-domain problems of computational electromagnetics. Conventional pseudospectral frequency-domain (PSFD) and pseudospectral time-domain (PSTD) schemes make use of trigonometric and orthogonal polynomials and related functions as basis functions for representing the electromagnetic fields. These numerical techniques are known to produce highly accurate solutions at very low discretization rates (i.e., using very few unknowns). However, the natural tool for representing the bandlimited functions which characterize wave-phenomena encountered in these—and many other science and engineering—applications are not trigonometric or orthogonal polynomials but prolate spheroidal wave functions (PSWFs). In this work we investigate the applicability of PSWFs as basis functions in the pseudospectral method for time-domain electromagnetic simulation problems.

The pseudospectral method based on PSWFs has already been applied successfully in the solution of frequency-domain problems of computational electromagnetics, where it has been shown to possess strong advantages over the conventional PSFD methods based on trigonometric and orthogonal polynomials. These advantages include higher accuracy using a smaller number of unknowns, and a more uniform spatial collocation grid which leads to better resolution near the domain center. The prolate pseudospectral method is also equipped with a fast transform (like the conventional pseudospectral methods), retaining its utility for the efficient solution of large-scale real-world problems. In this work we show that the prolate PSTD method affords another important advantage as compared to the conventional PSTD methods: the stability restriction on the time-step for explicit time-stepping is a lot less stringent. These and other related issues are examined in light of numerical experiments.

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