Comparison of High-order Spectral Element and Finite Difference Methods for Electromagnetic Wave Propagation

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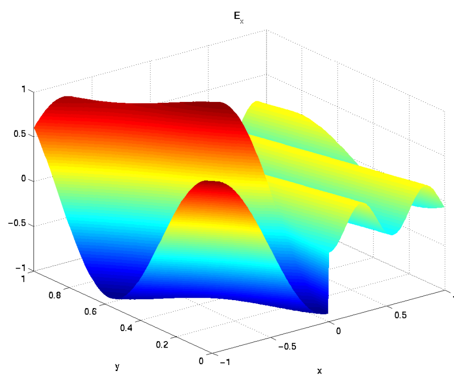
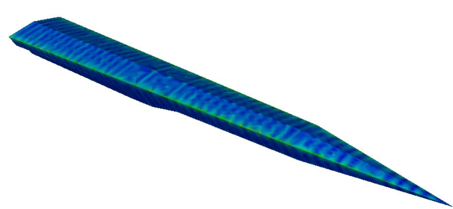
As the demands on accuracy increase for complicated problems in electromagnetics, the focus naturally turns to higher-order numerical methods, two of which have been validated, evaluated and compared in this paper.

The first time-domain method is the unstructured spectral element method, a type of discontinuous Galerkin method based on a collection of elements, on which Lagrangian polynomials of varying order act as basis functions. The second type of method is the finite difference time domain scheme. This method is based on a structured grid, and deals with discontinuities by means of a penalty procedure similar to the one used in the spectral element method. In both cases, a high-order Runge-Kutta scheme is implemented for the time development.

Emphasizing efficiency and long-time stability, a comparison of the spectral element and finite difference methods has been carried out in a two-dimensional reflection-refraction situation where a plane electromagnetic wave encounters a dielectric material discontinuity. In the paper, this comparison is discussed in detail.



For both methods, the use of proper characteristic boundary conditions ensures an error-boundedness in time which is necessary in calculations that run over long periods of time. The finite difference scheme also proves to be about a factor of 5 more efficient than the spectral scheme. However, this Cartesian sample problem is more or less tailored for finite differences. A more complicated geometry would favor the spectral scheme, mainly because of the relative ease of constructing an unstructured grid for such a geometry.



We also relate this comparison to problems closer to real life by considering a full-size radar scattering calculation on a 7 m generic missile. With the spectral element method and an incoming radiation of 1 GHz, the calculation took about 30 CPU-hours. This and corresponding calculations are also discussed in the paper.