NUMERICAL TIME-DOMAIN MODELING OF ACOUSTIC, ELECTROMAGNETIC, AND ELASTODYNAMIC WAVE PHENOMENA WITH A NOVEL OPTIMALLY ACCURATE SECOND-ORDER MODIFIED FINITE DIFFERENCE SCHEME

René Marklein[(1)], **Chakrapani Bommaraju**[(2)]

[(1)] ***University of Kassel, Department of Electrical Engineering and Computer Science, Electromagnetic Field Theory, Wilhelmshöher Allee 71, D-34121 Kassel, Germany***
Email: marklein@uni-kassel.de

[(2)] ***Darmstadt University of Technology, Computational Electromagnetics Laboratory, Schlossgartenstraße 8, D-64289 Darmstadt, Germany, Email: pani@temf.de***

ABSTRACT

Numerical methods are extremely useful in solving real-life problems with complex materials and geometries. However, numerical methods in the time domain suffer from artificial numerical dispersion. Standard numerical techniques which are second-order in space and time, like the conventional Finite Difference 3-point (FD3) method, Finite-Difference Time-Domain (FDTD), Alternating Direction Implicit-FDTD (ADI-FDTD) method, and Finite Integration Technique (FIT) provide estimates of the error of discretized numerical operators rather than the error of the numerical solutions computed using these operators. Here optimally accurate time-domain FD operators which are second-order in time as well as in space are derived. Optimal accuracy means the greatest attainable accuracy for a particular type of scheme, e.g., second-order FD, for some particular grid spacing. The modified operators lead to an implicit scheme. Using the first order Born approximation, this implicit scheme is transformed into a two step explicit scheme, namely predictor-corrector scheme. The stability condition (maximum time step for a given spatial grid interval) for the various modified schemes is roughly equal to that for the corresponding conventional scheme. The modified FD scheme (FDM) attains reduction of numerical dispersion almost by a factor of 40 in 1-D case, compared to the FD3, FDTD, and FIT. The CPU time for the FDM scheme is twice of that required by the FD3 method. The simulated synthetic data for a 2-D TM, 2-D TE, or 2-D P-SV (elastodynamics) problem computed using the modified scheme are 30 times more accurate than synthetics computed using a conventional scheme, at a cost of only 3.5 times as much CPU time. The FDM is of particular interest in the modeling of large scale (spatial dimension is more or equal to one thousand wave lengths or observation time interval is very high compared to reference time step) wave propagation and scattering problems, for instance, in electromagnetic and ultrasonic antenna modelling and the generation of synthetic scattering data for Non-Destructive Testing (NDT) applications, where other standard numerical methods fail due to artificial numerical dispersion effects. The possibility of extending this method to staggered grid approach is also discussed. The numerical results of the FD3, FDTD, FIT, FDM as well as ADI–FDTD method are presented, compared and interpreted.