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A time-integration method for the wave propagation in one-dimensional periodic media based on Suzuki's matrix-exponential-decomposition approach

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The finite difference time-domain (FDTD) method, which is based on the numerical scheme proposed by Yee, has been widely used in solving the various kinds of wave propagation problems in electromagnetics, acoustics and elastic dynamics, etc. However, a notable disadvantage of the conventional FDTD method is the conditional stability, which requires the time-step used in the method should be smaller than the one determined by the Courant-Friedrichs-Lewy (CFL) stability condition. An unconditionally stable time-integration method for solving the time dependent Maxwell equations, which was based on Suzuki's approach for matrix-exponential decomposition (see *Phys. Lett. A 146 (1990) 319-323*), has been proposed by Kole et al (see *Phys. Rew. E 65 (2002) 066705*). However, the unconditional stability of the method necessitates conductor boundary conditions applied in the considered problem. In this report, Kole's method is extended to the wave propagation in one-dimensional (1D) electromagnetic/elastic periodic media (i.e., photonic/phononic crystals). Detailed mathematic derivations, which demonstrate how the Floquet-Bloch boundary condition for a periodic medium is incorporated into Kole's scheme, are presented by us. The numerical results show that, although the proposed method is still conditionally stable, the stability condition is found to be not stricter than that required by the CFL condition. And additionally, the proposed method has higher-ordered temporal accuracy. For the estimation of the eigenfrequencies of the 1D periodic systems, the proposed method has significantly better convergence with respect to the time-step than that of the conventional FDTD method.

Keywords: Finite difference time-domain method, conditional stability, time integration, matrix-exponential decomposition