

## A Fictitious Wave Domain Method for Marine CSEM Using an Explicit High-Order Space and Time FDTD Method

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### SUMMARY

The Fictitious Wave Domain (FWD) method is a novel method for marine controlled-source electromagnetic (CSEM) modeling. This method separates the diffusive CSEM signal attenuation and propagation process into two steps. The first step involves the propagation of a fictitious electromagnetic (EM) wave without decay in the fictitious wave domain. The second step integrates time attenuation from the fictitious wave domain to the diffusive frequency domain.

In the first step, the velocity of the fictitious EM wave and the spatial discretization grids depend solely on the FWD parameters and the geoelectric model. The explicit finite-difference time-domain (FDTD) method is commonly used for time and space discretization in the numerical calculation of the fictitious EM wave time series. This method offers advantages such as parallel computation and reduced computational consumption. However, it is constrained by the Courant–Friedrichs–Lewy (CFL) condition, second-order time accuracy, and the maximum time step determined by the velocity of the fictitious EM wave, the spatial step, and the order of accuracy in space.

A new explicit FDTD method is proposed based on Taylor polynomial approximation theory, featuring high-order accuracy in space and M-th order accuracy in time. This approach can achieve numerical stability independent of the CFL number when M is sufficiently large. Compared to the classical explicit FDTD method, the new method calculates the electric and magnetic fields in the same time layer, rather than using a leapfrog scheme. Consequently, the time step can be much larger than in the classical method, potentially allowing the CFL number to exceed 1.

However, this new method also presents challenges, such as integrating it with the perfectly matched layer (PML) and selecting an appropriate M for temporal discretization.

**Keywords:** Marine CSEM; Fictitious wave domain; Explicit FDTD, CFL number

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