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A New Absorbing Boundary Condition Using MPS Wavefield Reinjection for 2D Vector-Acoustic Wave Equation

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Introduction

One of the strategies used to mitigate unwanted reflections is the implementation of absorbing boundaries, which aim to simulate the continuity of the medium beyond the model limits. In this work, we propose the development of a new absorbing boundary condition for the 2D acoustic-vectorial wave modeling tool, based on the Multiple point source (MPS), in which boundary conditions on the absorbing surface are written in terms of monopoles and dipoles point sources (Vasmel and Robertsson, 2014). The goal is to apply this approach to suppress the propagated wavefield through its reinjection "on the fly" at each time step. This technique aims to perfectly attenuate reflections at the model boundaries, offering a more efficient alternative for simulations in finite domains.

Method and/or Theory

The modeling tool used for the experiments employs the first-order 2D acoustic-vectorial wave equation system to compute the particle velocity and pressure fields in an isotropic medium based in a fourth-order space and second-order time staggered-grid discretization.

By recording the pressure and particle velocity fields created by a "original source" inside the modeling volume V on its absorbing surface S, we can use the pressure field representation theorem in the acoustic case

$$P(x,z,t) = \int_S \left[P(x',z',t) * G^{p,f}(x,z;x',z';t) + \vec{V}(x',z',t) * G^{p,q}(x,z;x',z';t) \right] \cdot \hat{n}\, dS. \qquad (1)$$

to reconstruct, outside V, the wavefield that was originally propagating outward. In the equation above, the Green's functions for the monopole source, $G^{p,q}$, and for the dipole source, $G^{p,f}$, act as propagators that analytically represent the behavior of a modeling algorithm propagating a given source and the resulting recorded wavefield.

The reinjection must be carried out using a combination of auxiliar monopole and dipole sources contructed from both pressure and velocity fields evaluated at S, in the previous time step: the pressure is injected as the strength of the dipole source, and the projection of the velocity field in the direction of the normal vector to S as the strength of the monopole source.

Results and Conclusions

The reinjection of dipole and monopole sources with reversed phases is expected to produce destructive interference from the model boundary out, thereby canceling the originally propagated wavefield to the numerical point flutuation error. While other boundary conditions require an extension of the original model, this strategy aims to extend it as little as possible, targeting lower computational cost without compromising the efficiency of a perfectly absorbing boundary.