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An optimized Convolution-Perfectly Matched Layer (C-PML) absorbing technique for 3D seismic wave simulation based on a finite-difference method

R. Martin (1) and D. Komatitsch

(1) Laboratoire de Modélisation et Imagerie en Géosciences UMR 5212, Université de Pau, France (roland.martin@univ-pau.fr)

The Perfectly Matched Layer (PML) technique, introduced in 1994 by Bérenger for Maxwell's equations, has become classical in the context of numerical simulations in electromagnetics, in particular for 3D finite difference in the time domain (FDTD) calculations. One of the most attractive properties of a PML model is that no reflection occurs at the interface between the physical domain and the absorbing layer before truncation to a finite-size layer and discretization by a numerical scheme. Therefore, the absorbing layer does not send spurious energy back into the medium. This property holds for any frequency and angle of incidence. However, the layer must be truncated in order to be able to perform numerical simulations, and such truncation creates a reflected wave whose amplitude is amplified by the discretization process.

In 2001, Collino and Tsogka introduced a PML model for the elastodynamics equation written as a first-order system in velocity and stress with split unknowns, and discretized it based on the standard 2D staggered-grid finite-difference scheme of Virieux (1986). Unfortunately, this standard PML suffers from two drawbacks: the fact that the unknowns are split adds to the memory cost of the simulations because additional arrays must be used to store all the split components; and after numerical discretization, the numerical reflection coefficient between the physical domain and the PML region becomes large at grazing incidence and therefore the efficiency of the absorbing layer is poor.

In 2000, Roden and Gedney introduced an implementation of the PML for Maxwell's equations based on the original (unsplit) components of the wave field and optimized for grazing incidence using an analytical integration of the convolution term. This

formulation, which is commonly known as the Convolution-Perfectly Matched Layer (C-PML), overcomes the two main drawbacks of the classical PML formulation mentioned above.

In this work, we use a similar idea to develop an unsplit C-PML formulation for the 3D seismic wave equation based on a velocity-stress staggered-grid finite-difference technique. Using numerical experiments and comparisons to analytical reference solutions, we show that this C-PML efficiently absorbs body waves at grazing incidence as well as surface waves. Such a formulation allows one to use very thin mesh slices to study a given region of the Earth, thus significantly reducing the cost of 3D simulations, which is of particular interest in the context of inverse problems.