New acoustic approximation for the transversely isotropic media with a vertical symmetry axis

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Seismic data processing in the elastic anisotropic model is complicated due to multi-parameters-dependency. Approximations to the P-wave kinematics are necessary for practical purposes. The acoustic approximation for P-waves in a transversely isotropic medium with a vertical symmetry axis (VTI) simplifies the description of wave propagation in elastic media, and as a result, it is widely adopted in seismic data processing and analysis. However, finite difference implementations of that approximation are plagued with shear wave artifacts. Specifically, the resulting wavefield also includes artificial diamond-shaped S-waves resulting in a redundant signal for many applications that require pure P-wave data. To derive a totally S-wave free acoustic approximation, we propose a new acoustic approximation for pure P-waves that is totally free of S-wave artifacts in the homogenous VTI model. To keep the S-wave velocity equal to zero, we formulate the vertical S-wave velocity to be a function of the model parameters, rather than simply setting it to zero. Then, the corresponding P-wave phase and group velocities for the new acoustic approximation are derived. For this new acoustic approximation, the kinematics is described by a new eikonal equation for pure P-wave propagation, which defines the new vertical slowness for the P-waves. The corresponding perturbation-based approximation for our new eikonal equation is used to compare the new equation with the original acoustic eikonal. The accuracy of our new P-wave acoustic approximation is tested on numerical examples for homogeneous and multilayered VTI models. We find that the accuracy of our new acoustic approximation is as good as the original one for the phase velocity, group velocity and the kinematic parameters like the vertical slowness, traveltime and the relative geometrical spreading. Therefore, the S-wave-free acoustic approximation could be further applied in seismic processing that requires pure P-wave data.
Our newly proposed acoustic approximation is meant to be an alternative to the original formula (Alkhalifah, 1998) in representing the elastic VTI model for P-waves. The SV shear phase velocity is set to zero for all phase angles while for standard acoustic approximation (Alkhalifah, 1998) only vertical S velocity is zero. Compared with the original equation (Alkhalifah, 1998), the expression becomes more complicated while it may not improve the accuracy of P-wave description. However, it provides a S-wave free wavefield necessary for many applications. It can be used for imaging applications. The corresponding eikonal equation for the new acoustic approximation is a sixth-order nonlinear PDE, which can be used to describe the pure P traveltimes. The corresponding perturbation-based approximation for the new eikonal equation is used to compare the accuracy of this new approximation as compared with the original formula. The new approximation yields accurate traveltimes free of shear wave artifacts, but potentially at an additional cost considering the higher-order nature of the formula.

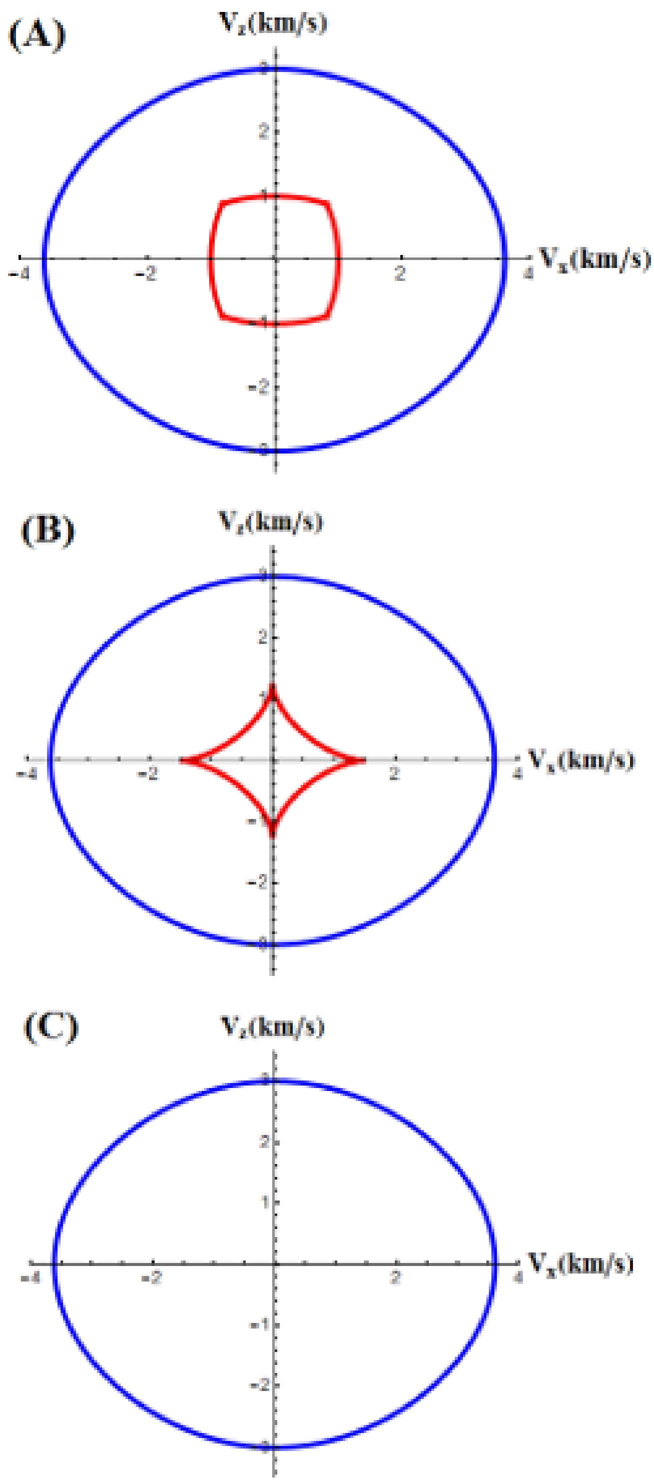

Figure The snapshot for the elastic VTI case (a), the original acoustic approximation (b) and our new acoustic approximation (c), top, middle and bottom, respectively. The P and S-wave velocities are shown in blue and red lines, respectively.