Weak-anisotropy approximation of P-wave phase and ray velocities in anisotropic media of arbitrary symmetry and orientation

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Analytical expressions for the phase and ray velocities in anisotropic media of various symmetries are required, for example, in moveout expressions, in prestack time migration, or in finite-difference computations of traveltimes. We show that the formulae based on the weak-anisotropy approximation represent a useful alternative to the frequently used formulae. Presented formulae are obtained by expansions of the exact phase- and ray-velocity formulae with respect to weak-anisotropy (WA) parameters. No non-physical assumptions like zero S-wave phase velocities, are used.

WA parameters represent an alternative parameterization of the medium to the commonly used parameterization by elements of a stiffness tensor or by elastic moduli in the Voigt notation. The WA parameters are similar to Thomsen-type parameterization. They can, however, be used for anisotropy of arbitrary symmetry and orientation. Although we call them weak-anisotropy parameters, they can be used for anisotropy of arbitrary strength.

The formulae presented and tested in our contribution are based on formulae derived by Farra and Pšenčík (2003, 2013). Several expressions of varying accuracy for the magnitudes of the corresponding velocities, applicable to anisotropy of arbitrary symmetry and orientation, are presented. The phase velocity is given as a function of the phase vector, i.e., a unit vector in the direction of the slowness vector. The ray velocity is given as a function of a ray vector, i.e., a unit vector in the direction of the ray-velocity vector. Both velocities are expressed in terms of three elements of the rotated Christoffel matrix, which depend linearly on WA parameters. The number of WA parameters varies with the considered symmetry. It is 15, 9, 6 and 3 for triclinic, monoclinic, orthorhombic and TI symmetry. The less accurate formulae are fully independent of the choice of a reference isotropic medium, more accurate formulae depend on it only slightly. We show that the relative errors of the more accurate formulae are below 1%, close to the accuracy of the so-called anelliptic approximations, very accurate approximations based on perturbation of elliptical anisotropy (Sripanich and Fomel, 2014; Hao and Stovas, 2015).

References

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