

PREVAILING-FREQUENCY APPROXIMATION OF THE COUPLING RAY THEORY FOR S WAVES

Petr Bulant & Luděk Klimeš

*Department of Geophysics, Faculty of Mathematics and Physics
Charles University in Prague
Ke Karlovu 3, 121 16 Praha 2, Czech Republic, <http://sw3d.cz>*

There are two different high-frequency asymptotic ray theories for S waves with frequency-independent amplitudes: the *isotropic ray theory* based on the assumption of equal velocities of both S waves, and the *anisotropic ray theory* assuming both S waves strictly decoupled. Here the term “different” means that the isotropic ray theory is not a special case of the anisotropic ray theory for decreasing anisotropy, and that both theories yield different S waves in equal velocity models.

In the isotropic ray theory, the S-wave polarization vectors do not rotate about the ray, whereas in the anisotropic ray theory they coincide with the eigenvectors of the Christoffel matrix which may rotate rapidly about the ray.

In “weakly anisotropic” media, at moderate frequencies, the actual S-wave polarization tends to remain unrotated round the ray, but is partly attracted by the rotation of the eigenvectors of the Christoffel matrix. The intensity of the attraction increases with frequency. This behaviour of the actual S-wave polarization is described by the *coupling ray theory* proposed by Coates & Chapman (1990). The frequency-dependent coupling ray theory is the generalization of both the zero-order isotropic and anisotropic ray theories and provides continuous transition between them. The coupling ray theory is applicable to S waves at all degrees of anisotropy, from isotropic to considerably anisotropic velocity models. The numerical algorithm for calculating the frequency-dependent coupling-ray-theory S-wave Green tensor has been designed by Bulant & Klimeš (2002).

The coupling-ray-theory S-wave Green tensor is frequency dependent, and is usually calculated for many frequencies. This frequency dependence represents no problem in calculating the Green tensor, but may represent a great problem in storing the Green tensor at the nodes of dense grids (Klimeš & Bulant, 2013), typical for applications such as seismic migrations. This contribution is devoted to the approximation of the coupling-ray-theory Green tensor, which eliminates this frequency dependence within a limited frequency band.

We approximate the frequency-domain coupling-ray-theory S-wave Green tensor in the vicinity of a given prevailing frequency by two Green tensors corresponding to two S waves described by their travel times and amplitudes (Klimeš & Bulant, 2012). We refer to these travel times and amplitudes as the coupling-ray-theory travel times and the coupling-ray-theory amplitudes. The presented numerical examples suggest that the coupling-ray-theory travel times are usually close to the anisotropic-ray-theory travel times. However, if the rays pass close to a conical or similar S-wave singularity, the singularity acts as an interface and smoothly but very rapidly converts the actual S-wave polarizations from the approximately anisotropic-ray-theory polarization S1 to the approximately anisotropic-ray-theory polarization S2, and vice versa. In this case, the coupling-ray-theory travel times correspond approximately to the anisotropic-ray-theory travel times of the S1S2 and S2S1 waves converted at the S-wave singularity.

References

- Bulant, P. & Klimeš, L. (2002): Numerical algorithm of the coupling ray theory in weakly anisotropic media. *Pure appl. Geophys.*, **159**, 1419–1435.
- Coates, R.T. & Chapman, C.H. (1990): Quasi-shear wave coupling in weakly anisotropic 3-D media. *Geophys. J. int.*, **103**, 301–320.
- Klimeš, L. & Bulant, P. (2012): Single-frequency approximation of the coupling ray theory. *Seismic Waves in Complex 3-D Structures*, **22**, 143–167, online at “<http://sw3d.cz>”.
- Klimeš, L. & Bulant, P. (2013): Interpolation of the coupling-ray-theory S-wave Green tensor within ray cells. *Seismic Waves in Complex 3-D Structures*, **23**, 203–218, online at “<http://sw3d.cz>”.