S-WAVE COUPLING IN HETEROGENEOUS ANISOTROPIC MEDIA

Petr Bulant and Luděk Klimeš

Department of Geophysics, Faculty of Mathematics and Physics,
Charles University in Prague, Czech Republic; http://sw3d.cz

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Traditionally, there are two different high–frequency asymptotic ray theories: the *isotropic ray theory* assuming equal velocities of both S waves, and the *anisotropic ray theory* assuming both S waves strictly decoupled. In the isotropic ray theory, the S–wave polarization vectors do not rotate about the ray, whereas in the anisotropic ray theory they may rotate rapidly about the ray.

In weakly anisotropic models, at moderate frequencies, the S–wave polarization vector tends to remain unrotated about 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 S–wave polarization vector is described by the *coupling ray theory* proposed by Coates & Chapman in [1]. The coupling ray theory is applicable at all degrees of anisotropy, from isotropic models to considerably anisotropic ones. 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 particularly important for calculating S waves at degrees of anisotropy and frequencies typical in seismic exploration and structural seismology on all scales, because the isotropic ray theory does not describe the two S waves from the principle, and the anisotropic ray theory often fails to determine correct S–wave polarization.

Both S waves can be calculated along a single reference ray. The numerical algorithm for calculating the frequency–dependent complex–valued S–wave polarization vectors of the coupling ray theory is described in [2] and [3]. For a concise overview of the coupling ray theory refer to [4].

S–wave coupling decreases and S–wave splitting increases with increasing anisotropy and frequency. This behaviour is illustrated in Figure 1 in similar elastic media QIH, QI, QI2 and QI4 of different degrees of anisotropy. The vertically heterogeneous 1–D anisotropic model QI (model WA rotated by 45°) was used by Pšenčík & Dellinger [5] for comparing the coupling–ray–theory synthetic seismograms with the reflectivity method. For a description of models QI, QI2 and QI4 and measurement configuration, refer to [6]. For weak anisotropy, the change of polarization with increasing anisotropy is indicated by a clear increment of the transverse amplitudes in the two upper models. The clear development of S–wave splitting, if anisotropy is increased further, can be observed in the two bottom models.

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References

[1] R.T. Coates, C.H. Chapman. Quasi–shear wave coupling in weakly anisotropic 3-D media. *Geophys. J. int.*, **103**, 301–320, 1990.

[2] P. Bulant, L. Klimeš. Numerical algorithm of the coupling ray theory in weakly anisotropic media. *Pure appl. Geophys.*, **159**, 1419–1435, 2002.

[3] L. Klimeš. Common–ray tracing and dynamic ray tracing for S waves in a smooth elastic anisotropic medium. *Stud. geophys. geod.*, **50**, 449–461, 2006.

[4] V. Červený, L. Klimeš, I. Pšenčík. Seismic ray method: Recent developments. *Advances in Geophysics*, **48**, 1–126, 2007.

[5] I. Pšenčík, J. Dellinger. Quasi–shear waves in inhomogeneous weakly anisotropic media by the quasi–isotropic approach: A model study. *Geophysics*, **66**, 308–319, 2001.

[6] P. Bulant, L. Klimeš. Numerical comparison of the isotropic–common–ray and anisotropic–common–ray approximations of the coupling ray theory. *Geophys. J. int.*, **175**, 357–374, 2008.

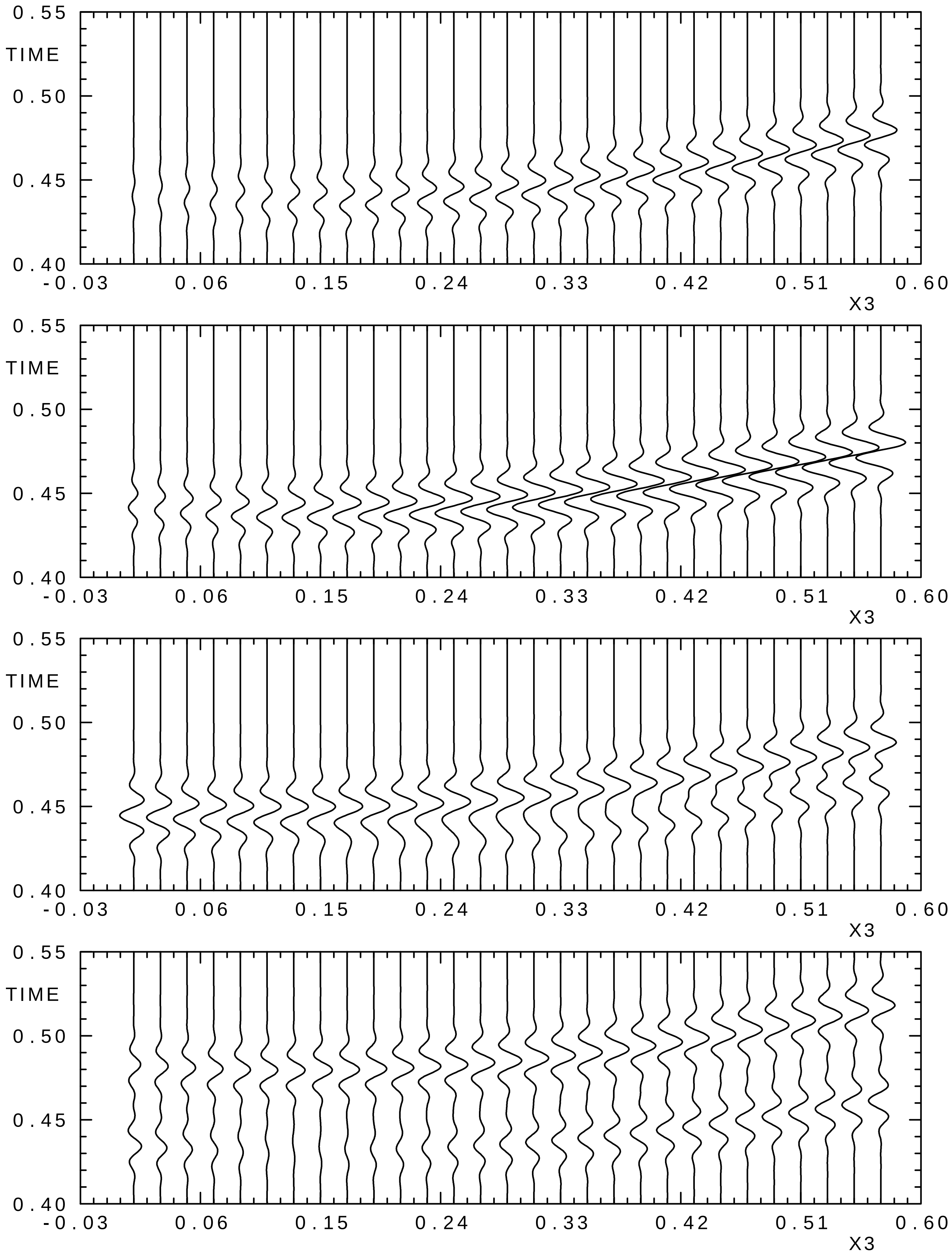

Figure 1: Coupling–ray–theory seismograms in similar elastic media of different degrees of anisotropy. Anisotropy increases from the top to the bottom in the ratio 1:2:4:8. Only the second (transverse) component is shown. This component vanishes in the analogous isotropic medium. See the change of polarization indicated by clear increment of transverse amplitudes in the two upper media, and the clear development of S–wave splitting in the two bottom media.