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Singularity points in multi-layered anisotropic medium

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The slowness surfaces for P, S1 and S2 waves in anisotropic medium are defined by solving the Christoffel equation. The regular point on the slowness surface can be mapped on corresponding group velocity surface. The irregular (singularity) point on the slowness surface results in the plane curve in the group velocity domain (Stovas et al., 2024).

The characteristic equations for double and triple singularity points define the tangent cone of second and third order, respectively. If the plane wave passes through singularity points in some layers of multilayered model, the effective characteristic equation has order given by product of orders of characteristic equations from individual layers. Therefore, the order of effective characteristic equation can be computed as $N=2^K3^L$, where K and L are the number of layers with double and triple singularity points, respectively. The effective characteristic polynomial $F_N(\Delta p_1,\Delta p_2,\Delta p_3)$ (the N-th order tangential cone) for multi-layered model can be computed by resultant of individual characteristic polynomials,where Δp_j,j=1,2,3, are the increments in slowness projections.The number of individual branches is given by J=Floor[(N+1)/2]. The dual curve $\Phi_M(V_1,V_2,V_3)=0$ is the group velocity umage of Nth-order singularity point, where M=N(N-1)-2n-3c (Quine, 1982), with n and c being respectively the number of nodes and cusps for curve $F_N=0$. It is shown that the tangential cone does not have cusps (c=0) but can have nodes if N≥6. The inflection points and bitangents for curve $F_N=0$ respectively result in cusps and nodes for dual curve $\Phi_M=0$. The cusps affect the Gaussian curvature computed in vicinity of singularity point (Stovas et al., 2025). The irregularities in phase and group domain are illustrated in Figure by dots for two-layer model with double singularity points in both layers (N=4, J=2, n=2 and M=8).

Figure. Two-layer model with double singularity points. a) Curve F_4=0 in affine plane (phase domain). Four inflection points on converted wave branch are shown by black dots. Two bitangents are shown by dotted lines limited by gray dots. b) Group velocity image ($\breve{C}_8$=0) of quartic singularity point (dual curve). Four cusps are shown by black dots, and two nodes are shown by gray dots. Solid and dashed lines stand for pure wave modes (S1S1 and S2S2) and converted (S1S2 and S2S1) waves, respectively.

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