Full Wave Extension of a Microlocal Seismic Inversion Algorithm: Wave Tracing

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Recently, de Hoop and co-workers developed a microlocal, asymptotic, seismic inversion algorithm for application in complex environments supporting multi-pathed and multi-mode wave propagation. This inversion is based on the Born/Kirchhoff approximation, and employs the global, uniform asymptotic extension of the geometrical method of tracing rays to account for caustic phenomena. While this microlocal, asymptotic, seismic inversion approach has successfully inverted the multicomponent, ocean-bottom data from the Valhall field off the coast of Norway, accounting for severe focusing effects, it is still an inherently high-frequency approximation, which neglects wave effects, in addition to being incapa ble of treating the more rapidly-varying medium properties (as measured on the scale of a typical wavelength). This algorithm can be extended to incorporate wave phenomena in, ultimately, a nonlinear inversion scheme through the application of two construction s which are well-known (at least physically and from a formal mathematical viewpoint) in the wave propagation communities: (1) directional wavefield decomposition and (2) the generalized Bremmer coupling series.

While seismic wave propagation modeling is often most appropriately formulated in the time domain, numerical calculations are most often carried out, by computational necessity, in the frequency domain. In the frequency-domain formulation, the square-root Helmholtz operator is the focus of both the directional wavefield decomposition and generalized Bremmer coupling series constructions. This operator provides for the construction of the right- and left-traveling wavefield components, and, in exponential form, represents the formal, fundamental, one-way wavefield solutions (propagators) in the tracking of the multiple scattering in the generalized Bremmer coupling series. The application of phase space and path (functional) integral methods then provides for explicit, exact and uniform asymptotic constructions of the square-root Helmholtz operator symbol, and, subsequently, phase space path integral representations of the fundamental wavefield solutions. Taken together, these methods and constructions suggest a seismic inversion algorithm, which can be interpreted as a method of tracing waves.

This talk is intended t o provide an overview of these approaches to direct and inverse wave propagation and scattering, intertwining some of the most recent new results with the basic outline of the theory, culminating in an outline of the extended, asymptotic, seismic inversion algorithm.