Theoretical Seismograms of Core Phases Calculated by a Frequency-Dependent Full Wave Theory, and Their Interpretation

G.L. Choy*

Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964, USA

A frequency-dependent full wave theory is successfully employed to synthesize long period seismograms of the core phases SmKS ($m=1,2, \ldots$) in the distance range 100° to 125°. Body wave displacements are calculated by numerically integrating in the complex ray parameter plane. Langer's method is employed to obtain a uniformly asymptotic approximation to the vertical wave functions. Plane wave reflection and transmission coefficients are adequately corrected for the effect of the curvature at the core-mantle discontinuity by the use of generalized cosines. Results are presented in the time domain, after a numerical Fourier (inverse) transform.

The computed seismograms exhibit many non-ray effects that the SmKS incur upon interacting with the core-mantle boundary. For SKS, the amplitude, group delay and phase delay are very strong functions of frequency at less than 0.5 Hz, both because of the frequency dependence of the reflection/transmission coefficients at the core-mantle boundary, and because of the presence of diffracted energy, called SP(diff)KS, perturbing the waveform. The diffracted energy of the type that perturbs SKS may also interact with shear waves to give rise to a precursor to the body wave ScS, called SP(diff)S. The major complication in synthesizing the portion of the seismogram containing SmKS for $m \geqq 2$ is that the arrival time of each successively higher order reflection is within the waveform of previous lower order reflections. It is found that a summation of body wave displacements from S2KS through S15KS gives an adequate seismogram. Each individual reflection has an amplitude spectrum, group delay and phase delay which are strongly frequency-dependent at less than 0.2 Hz. It is shown that picking conventional arrival times for SmKS, $m \geqq 2$, is nearly impossible. Furthermore, neglecting the frequency dependence of reflection/transmission coefficients can significantly distort the interpretation of amplitude and phase data.

The seismograms generated by this method agree so remarkably well with observed records that the synthetic waveforms provide a powerful test of the validity of particular earth models. In particular, we find that the waveforms of SmKS are exceedingly sensitive to velocity gradients of the upper 200 km of the outer core, and indications are that the velocities in the outer 200 km of the core are higher than that predicted by Hales and Roberts (1971) or earth model 1066B. The pulse widths of SmKS are also used to determine some fault parameters.

Reference

Choy, G.L.: Theoretical seismograms of core phases calculated by a frequency-dependent full wave theory, and their interpretation. Submitted to Geophys. J.R.A.S., 1976

* Now with the U. S. Geological Survey, Office of Earthquake Studies, Denver, Colorado 80225, USA