0.1 Accuracy of reflection coefficients

The question if finite-difference modeling is adequate for amplitude versus offset analysis (AVO) has long been a subject of discussion. Obviously, if temporal and spatial discretization is small, it can approximate continuous derivatives well, and finite-differences give the correct result. However, the question remains: does it give correct responses for discretizations that are desirable and commonly used? i.e., as large time steps that are desired for usual seismogram discretizations and as large spatial steps that can be tolerated by the model description. A definite answer cannot be given directly, because it depends on several factors: how a staggered grid is employed, how boundary conditions are treated, and what kind of time update is used.

I chose to test whether FD modeling of reflection amplitudes is adequate to allow AVO analyses by comparing it to an analytical solution, the Zoeppritz plane wave energy equations (**?**; **?**) for a single reflector. Based on these findings, I used this FD modeling algorithm to generate synthetic datasets for a number of anisotropic media that had been analyzed for SEG's 1992 AVO workshop (**?**).

Cunha (**?**) described a modeling scheme which takes discontinuities in medium properties into account by applying different FD operators to the wave field and the medium on a non-staggered grid. Different implementations of a staggered grid and derivatives can influence the accuracy of reflection responses. In this thesis, I am not employing this method, but rather use cascaded derivative operators on a staggered grid. The test medium consists of two completely homogeneous blocks. The source is located at some distance from the interface and receivers are parallel to the interface. A P wave source generates an incident wave field that is reflected at the interface and recorded at the receivers. Figure **??** shows the theoretically expected amplitude responses for the reflection experiment in Figure **??**, plotted versus the horizontal slowness. For extracting the modeled amplitudes out of the synthetic dataset I use the following scheme. Since Zoeppritz equations give plane wave amplitude ratios versus a certain emergence angle, I convert from the point source experiment to a plane wave representation. I apply a slant-stack inversion procedure to find the best slant-stack representation of the modeled CMP gather, which reduces artifacts in the $\tau - p$ domain caused by the limited aperture. Secondly, I find the incident amplitude without any reflecting segment. To achieve this I carry out a dual experiment by placing receivers at the mirror image location in depth in the medium. The dual experiment, Figure **??**, estimates all propagation effects but omits reflection at the boundary. For that reason the two signals have different phases. Since the medium properties are known, I can identify the reflection response and extract the appropriate signal for each horizontal slowness. Performing a Fourier Transform on that signal results in a certain amplitude for the dominant frequency component. The ratio of incident versus reflected amplitude is then compared to the analytical solution of the Zoeppritz equations. As can be seen from Figure **??**, the reflection amplitudes produced by the modeling scheme are in nearly perfect agreement with analytical solutions to the reflection amplitudes up to the critical angle. Figures **??** and **??** show the analytically calculated responses in comparison to the modeled extracted responses. Such a test is clearly necessary if one wants to make sure the modeling

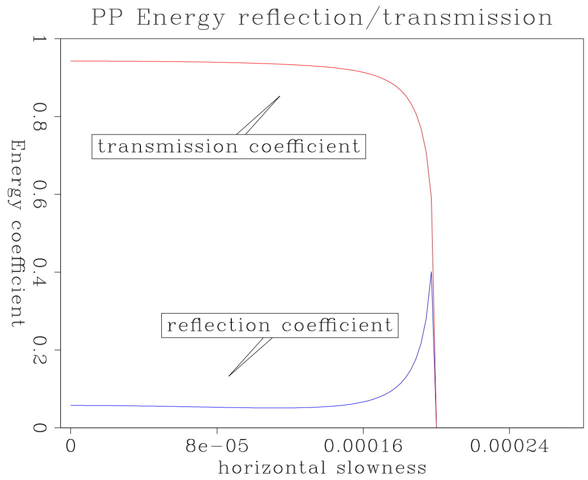

Figure 0.1: Analytically calculated energy reflection and transmission coefficients from Zoeppritz equations. iso1.ref [ER]

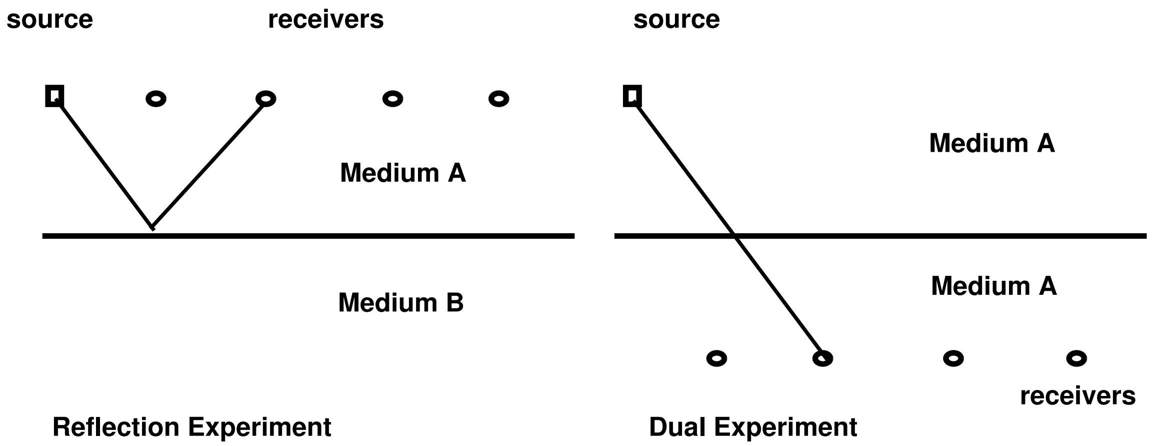

Figure 0.2: The reflection experiment records reflected energy from the interface. The dual experiment determines the energy that would have been recorded if the interface had not been present. This double experiment can be used to measure reflected as well as incident energy uniquely. dual [NR]

algorithm produces correct reflection coefficients at medium interfaces. The above test gives one confidence in the modeling algorithm for this type of blocky model.

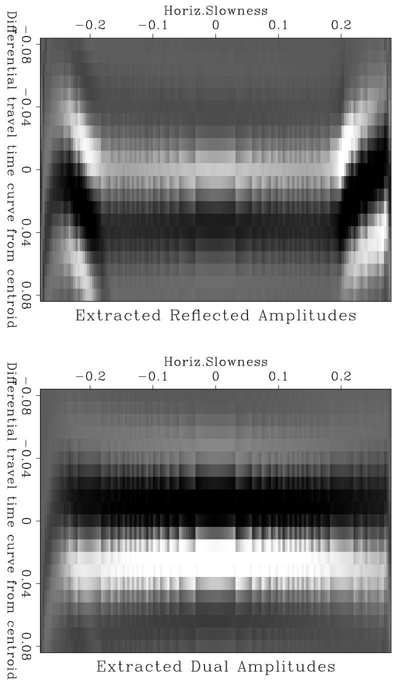

Figure 0.3: Extracted amplitudes from the FD modeling experiment and the dual experiment. The dual experiment estimates all propagation effects but omits reflection at the boundary. For that reason the two signals have different phases. extraiso [ER]

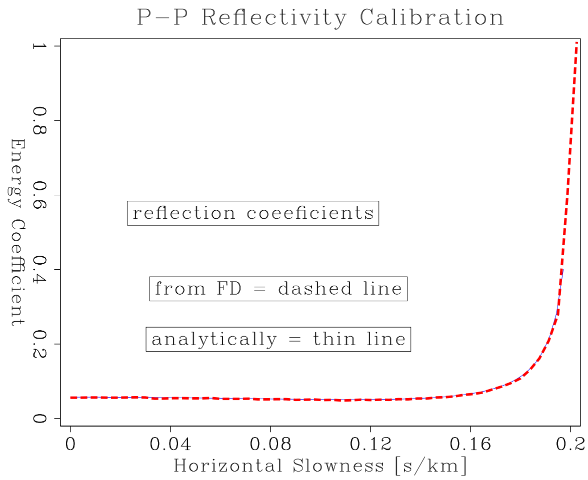

Figure 0.4: PP calibration curve for the FD modeling response. Reflection amplitudes were extracted using the dual experiment. Zoeppritz plane-wave energy reflection coefficients are calculated analytically. ppcalibrate [ER]