Low wavenumber reflectors

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Abstract

A numerical modelling environment was created to accurately evaluate reflections from a 1D interface that has a smooth transition shape between two different velocities. The objective was to accurately propagate a chirp through the transition zone, where the size of the transition zone is similar to the wavelengths within the chirp.

Transition zones in the shape of a raised cosine were evaluated using the incident and reflected chirps to estimate the shape and amplitudes of the transition zones. Reasonable matches were obtained.

Model

The model consisted of two layers with the velocity in the first layer 1,000 m/s and the velocity in the second layer 2,000 m/s. These velocities give a normal incident reflection coefficient of 1/3, and a transmission coefficient of 2/3. The shape of the velocity transition zone was a raised half cosine. The depth was sampled at 1 meter intervals and the times was sampled at 0.25 ms. The wavelet was a chirp that could be a linear or modulated sweep. The reflectivity results used a modulated sweep with a carrier frequency of 40 Hz, and modulation of ± 40 Hz to cover frequencies from 0 to 80 Hz.

Method

The chirp was propagated through the velocity interface and the reflectivity was estimated by dividing the spectrum of the reflected chirp by the spectrum of the incident chirp. The frequencies were tapered to zero above 100 Hz. The inverse Fourier transform produced the shape of the reflectivity.

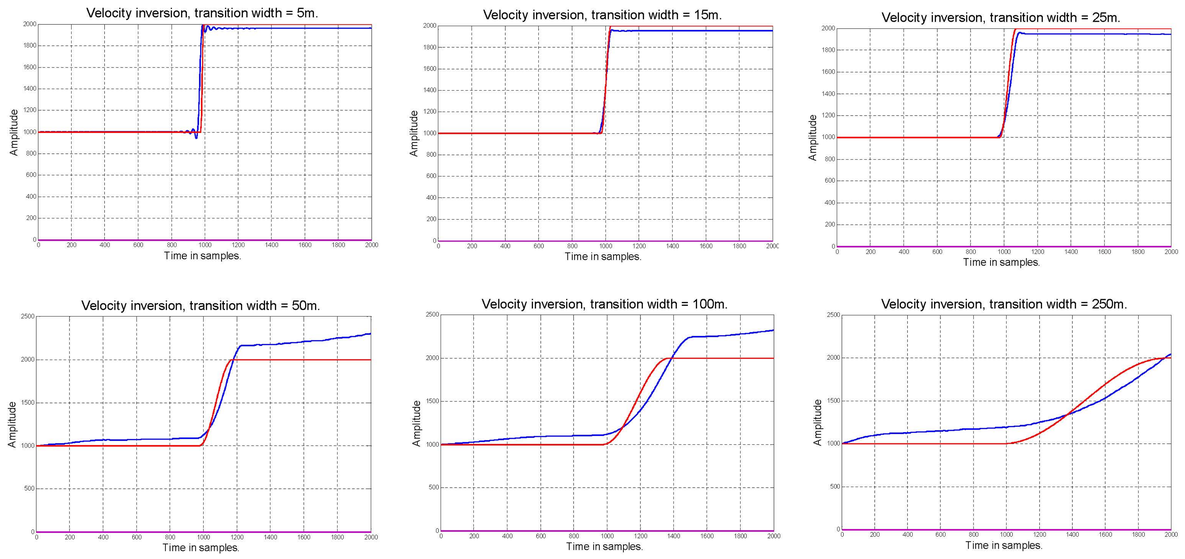
The reflectivity was then converted back to velocities using the Lindseth method of inversion.

$$v_{i+1} = v_i \frac{(1+r_i)}{1-r_i}.$$

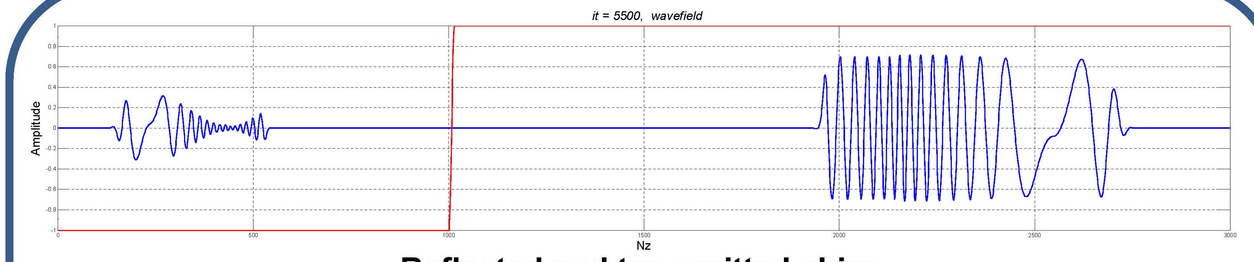
Results

Various snapshots of the 1D wavefield are displayed to illustrate problems and the successes of the modelling. Even with an accurate modelling algorithm, the transition zone could not be a step function as it produced the wrong reflection with the wrong polarity, and required a slight transition zone to prevent model aliasing.

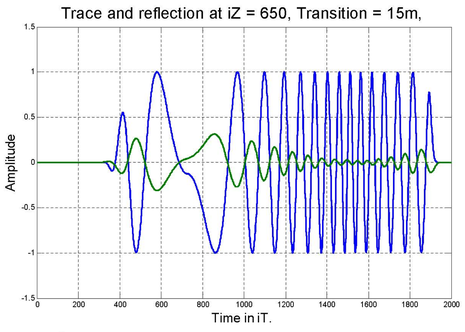
The bandwidth of the chirp was 0 to 80 Hz to provide signal at the lower frequencies. The results of estimating the shape of the transition zone are displayed for various widths. The red line in the shape of the actual transition, and the blue line is the estimated shape.



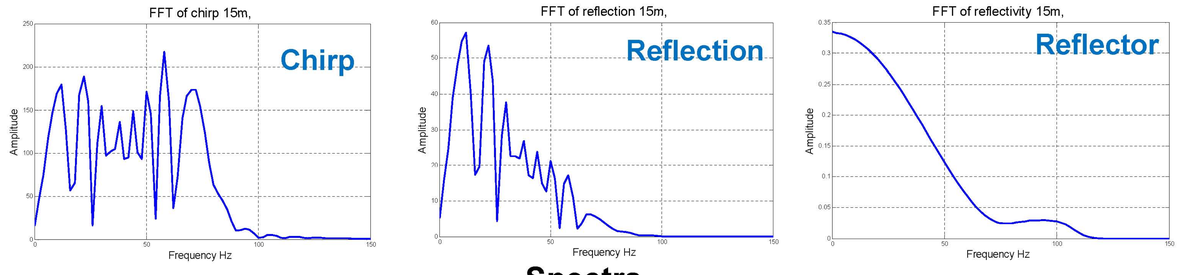
Results: Estimated velocity transition zones



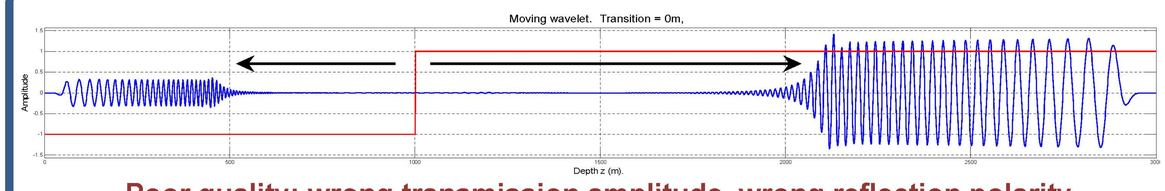
Reflected and transmitted chirp



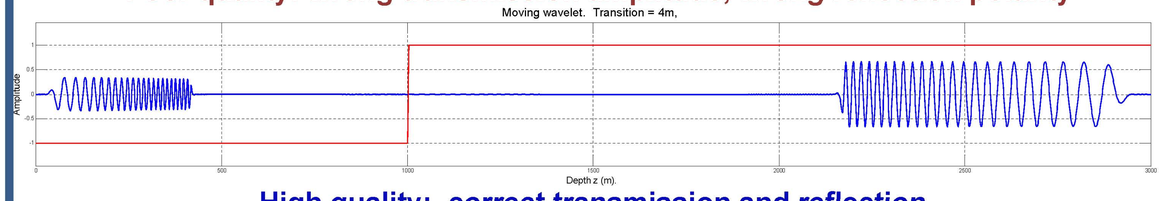
Reflected and transmitted chirp



Spectra



Poor quality: wrong transmission amplitude, wrong reflection polarity



High quality: correct transmission and reflection