Towards using harmonic "contamination" as signal for thin shallow reflectors

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Introduction

Vibroseis is currently the favoured source used for seismic land acquisition where conditions permit. A pilot signal generates a sweep of designed length and frequency range which drives the vibrator to impart a signal into the earth. Due to non-linearity in the vibrator hydraulics and mechanical systems, as well as near surface non-linearities, higher order harmonics of the pilot signal are generated, "contaminating" both sweep and the seismic record.

Figure 1 below shows the a Gabor spectrum of a typical high signal to noise ratio sweep. Harmonics to H8 are noted. These harmonics have traditionally been seen as noise to be attenuated from both sweep and trace data.

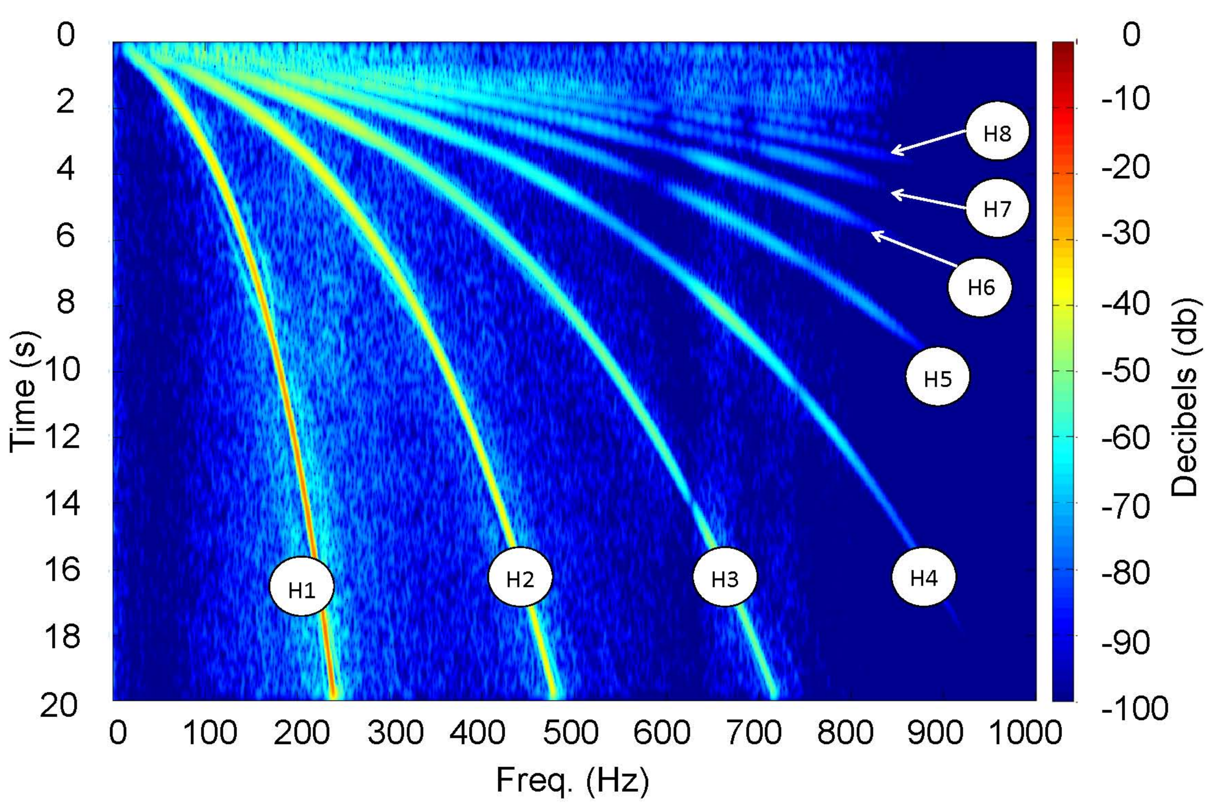

Figure 1. The Gabor spectrum of a typical high signal to noise ratio sweep from field data provide by StatOil.

Harmonic decomposition

In 2011 CREWES and POTSI developed algorithms to decompose the harmonics that harmonics within a contaminated vibrator sweep. Harrison et al. (2011) used the Gabor transform and least squares to successfully decompose a sweep from the first (H1) to either (H8) harmonic. Two methods, the time dependant Gabor decomposition (TDGD), which decomposes a sweep with respect to time, and the second method is the frequency dependant Gabor decomposition (FDGD) which decomposes a sweep with respect to its namesake we developed.

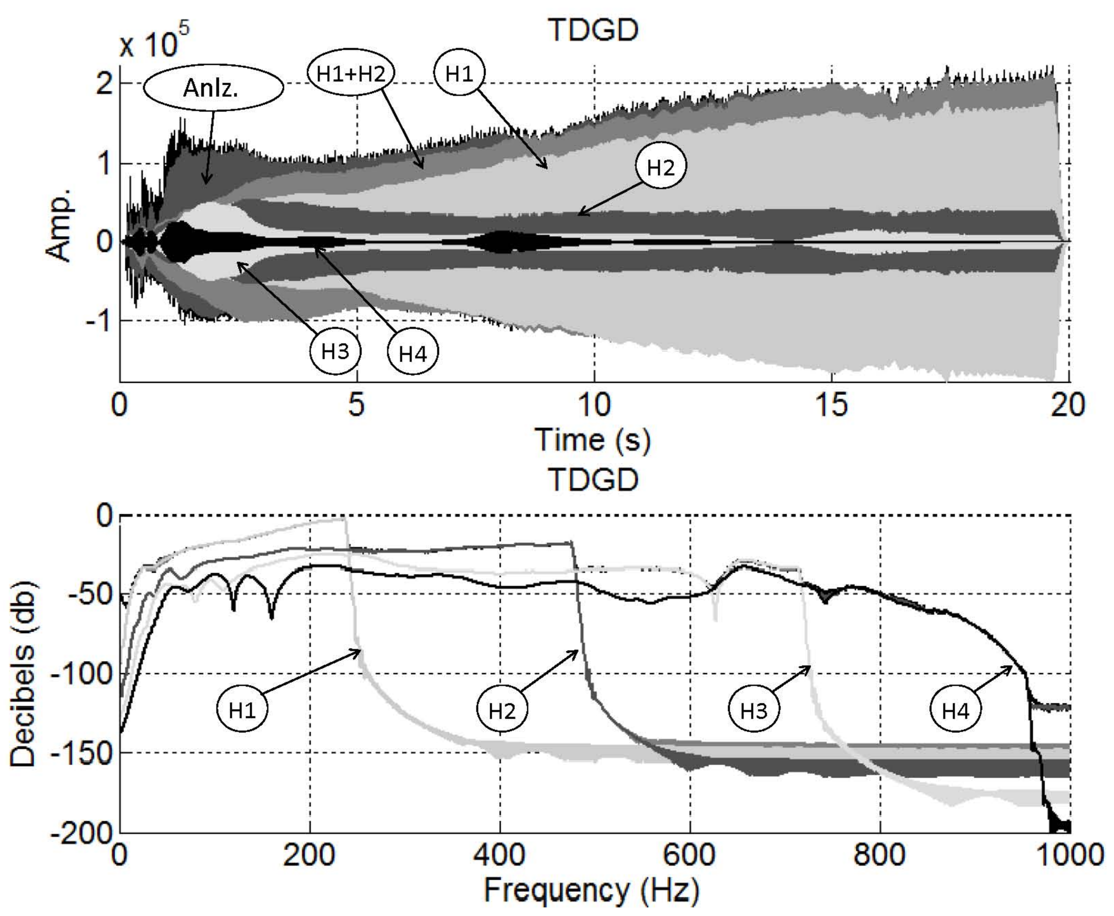

Figure 2. The TDGD results in time (top) and frequency (bottom)

Complete decomposition and RMS Power

The field data used in this research was provided by StatOil and consisted of 1877 sweep points. Each shot point had three separate records including the baseplate record sweep, the reaction mass recorded sweep and the ground force. Each of these records are each sweep point was decomposed into TDGD and FDGD to H8. The relative RMS signal strength of all these components is shown in Figure 4.

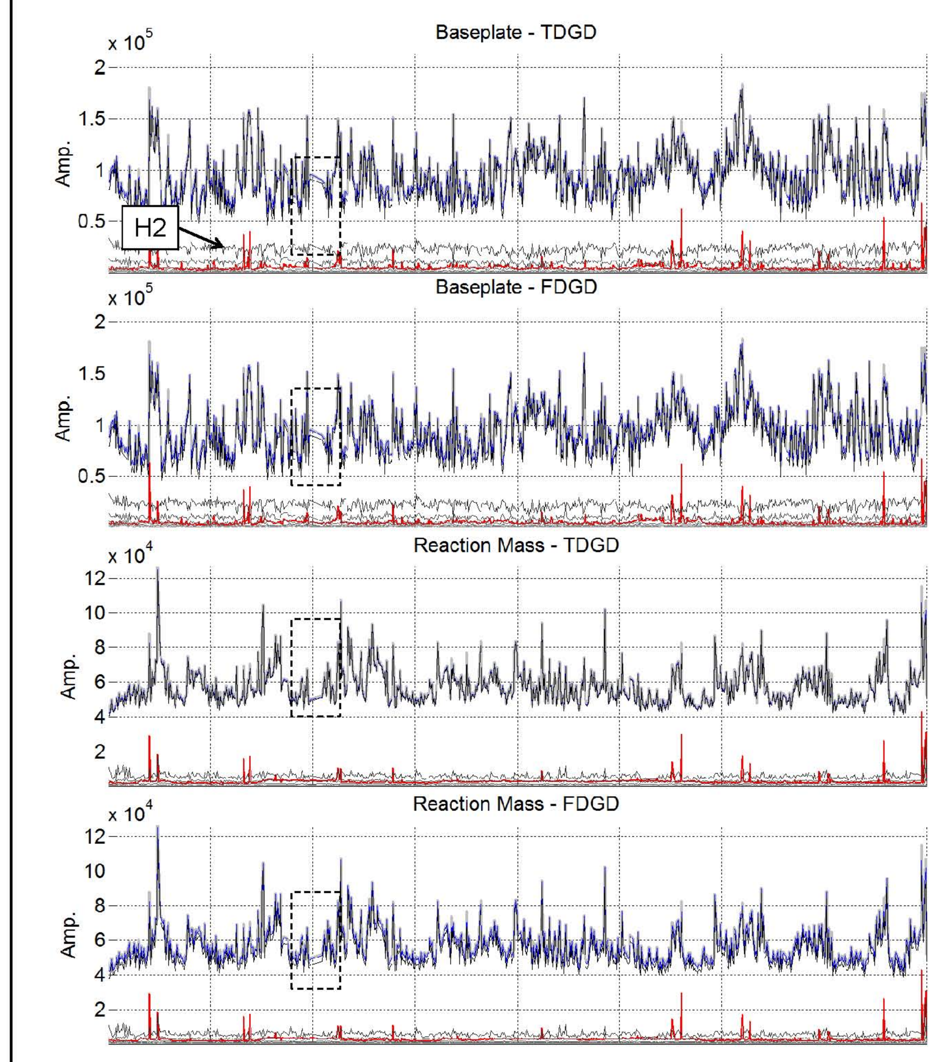

Figure 3. Relative root mean square (RMS) power for all components decomposed from the baseplate and reaction mass.

Synthetic trace

Test reflectivity was created with decreasing space between reflector spikes and convolved with the baseplate recorded sweep. The trace was then correlated with 7 different operators (Figure 4), to observe their spike resolving ability.

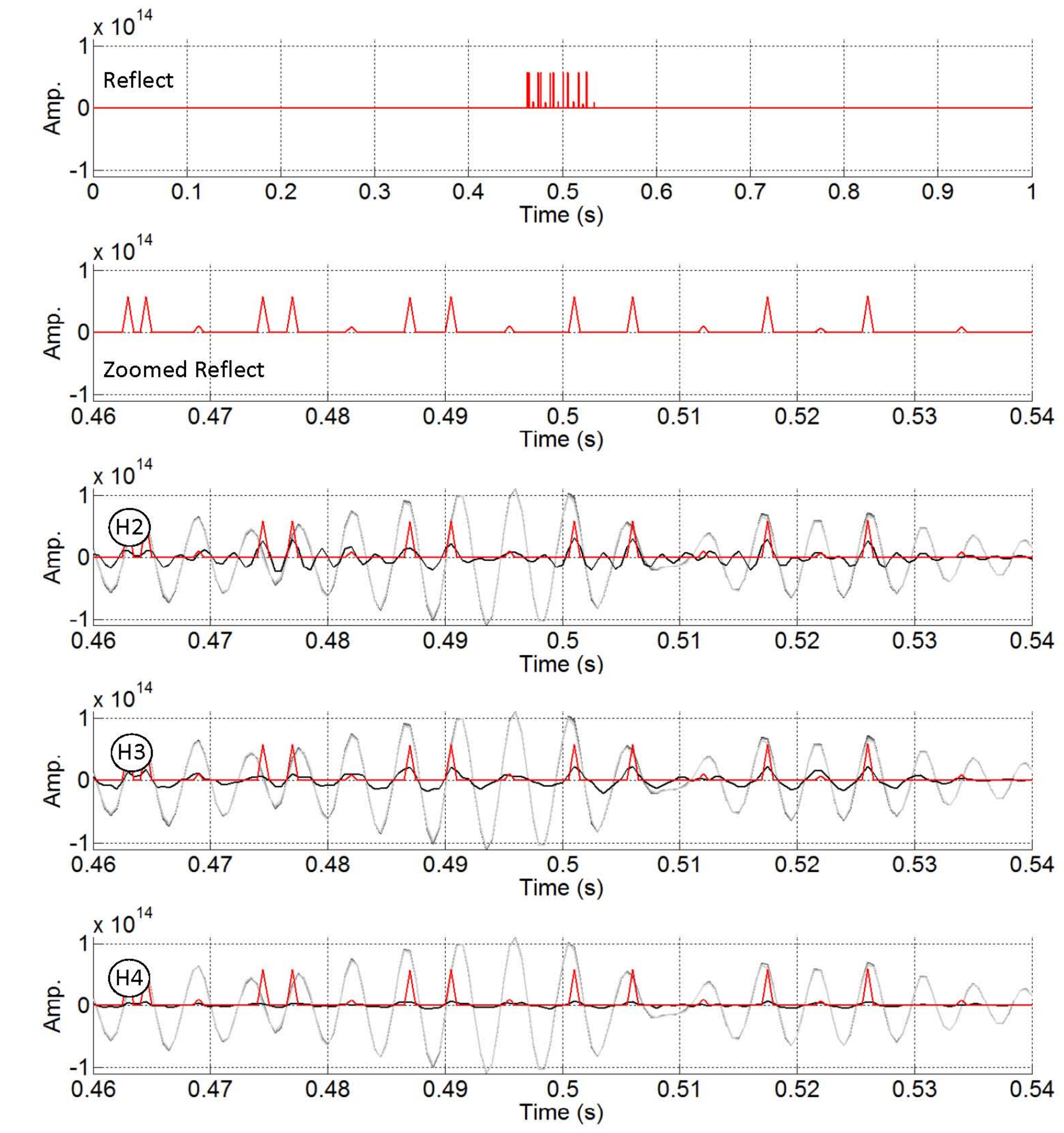

Figure 4. Synthetic trace correlated with H2, H3 and H4 to reveal to investigate better resolving power of harmonics.

Pilot correlated seismic image

The field data was first correlated with the industry standard pilot sweep. Gabor deconvolution was applied, and two rounds of velocity analysis were conduct before the final stack was achieved (Figure 5). Important features are annotated on the image.

H2 correlated seismic image

The seismic data was then correlated using the TDGD H2 component as the correlation operator. Processing of this data used the same parameters as the pilot correlation processing other than an added bandpass filter (0-12-240-270) and near offset stacking (0-350 m).