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Towards using harmonic “noise” to image shallow thin reflectors

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Summary

The harmonics generated during Vibroseis acquisition have traditionally been seen as undesired noise to be attenuated from both the source and receiver records. Indeed, techniques to compensate for or completely eliminate these harmonics have been developed for both the acquisition and processing stages of seismic investigation. What if, however, these harmonics that “contaminate” both the source and receivers records could be utilized as signal instead of noise? Previously, we have developed algorithms to estimate these harmonics from a vibrator baseplate, reaction mass, or ground-force recordings. Here, we investigate using these decomposed harmonics for bandwidth expansion and better imaging of thinly spaced reflectors in the near surface.

Introduction

Harmonic production and “contamination” is a well known phenomenon in vibrator seismic acquisition. The harmonics occur due to non-linearities in the vibrator mechanisms (Walker 1995; Wei 2011) and non-linearities in the near surface (Lebedev 2004). Harmonic attenuation methods have been developed for both the acquisition and the processing phases.

In 2011 University of Calgary research groups CREWES and POTSI along with sponsor company, Statoil, developed a set of algorithms that decomposed harmonics from a single vibrator sweep. The Gabor transform and least squares methodology were used by Harrison et al. (2012) to successfully decompose a sweep from its fundamental (H1) to eighth (H8) harmonics. Two slightly different methods for decomposition resulted from the complex-valued time-frequency spectrum produced by the Gabor transform. The first method is time-dependent Gabor decomposition (TDGD), which decomposes the sweep with respect to time, and the second is the frequency-dependent Gabor decomposition (FDGD) which decomposes the sweep within the frequency domain. For brevity, only the TDGD will be shown in this short paper.

A sweep (and survey) decomposed

The pilot sweep used in this test was non-linear with a frequency range of 6-240 Hz, a sample rate of 0.5 ms, and a 0.09 dB/octave boost. Figure 1 shows a single baseplate recording of the sweep with various components decomposed using TDGD. The original decomposition calculated components from the fundamental (H1) to eighth (H8) harmonics. For brevity, only the original sweep (black), analyzed sweep (Anlz), H1+H2, H1, H2, H3 and H4 are presented. The H1+H2 which is a combination of the fundamental (H1) and the second harmonic (H2) is shown because it was also used as a test correlation operator. Both time (top) and frequency (bottom) plots are shown on Figure 1. It is interesting to note the complex character of the various harmonic components, showing modulations in both amplitude and phase. However, a single sweep record does not a survey make.

TDGD was run on all 1877 baseplate recorded sweep points of a survey supplied by Statoil. All components from the fundamental (H1) to H8 were calculated for each sweep point. The harmonics were re-composed into an analyzed sweep and subtracted from the original sweep at their respective sweep points, creating an error record. This produced 18770 harmonics, sweeps and error records for analysis. The root-mean-square (RMS) strength was chosen to help understand the comparative strength and values of these calculations. Figure 2 shows the RMS calculations for the baseplate recorded TDGD results.

The RMS power for the original sweep is plotted in light grey, the analyzed sweep is plotted in black and H1 is plotted in blue and appear almost coincident on Figure 2. The RMS power of harmonics H3 to H8 and error, are all close in power near the bottom of Figure 2. The stand-out feature, and the component we are going to follow for the remainder of this mini-paper, is H2. As seen on Figure 2, H2 has RMS strength well below the analyzed sweep and H1, but is noticeably above the RMS power of H3 to H8 and the error. Due to this extra power, H2 was used as a correlation operator below.

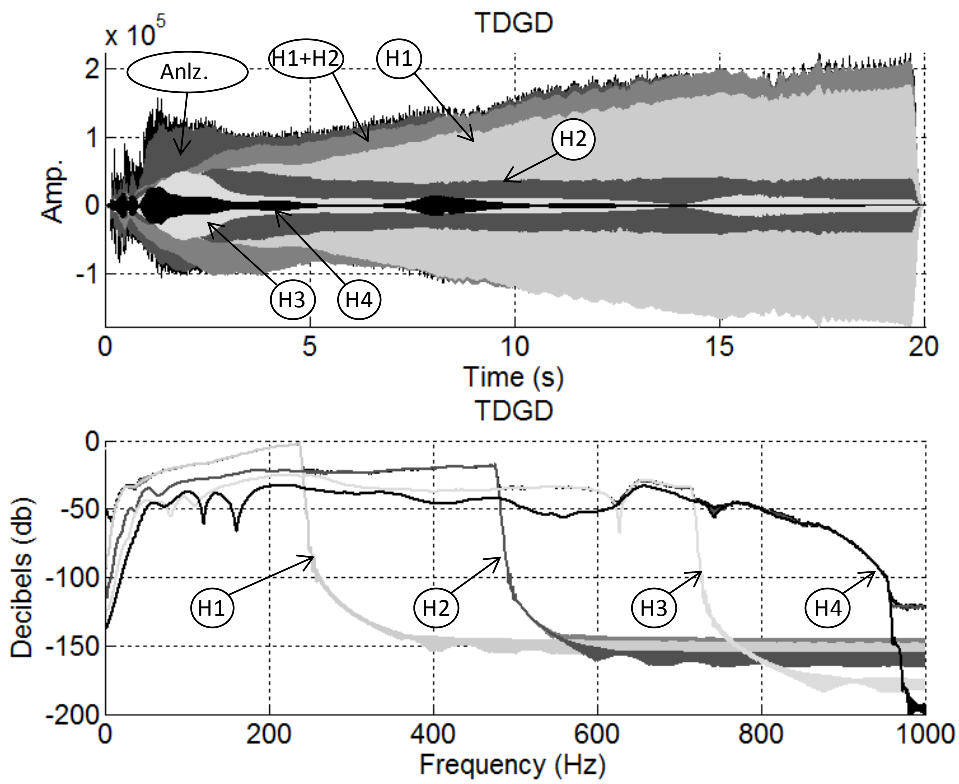

Figure 1. The results of TDGD on a single sweep showing the fundamental (H1), H2, H3 and H4. Time domain view of the decomposition (top) and frequency domain view (bottom) are shown.

Anlz. H1+H2 H1

H2

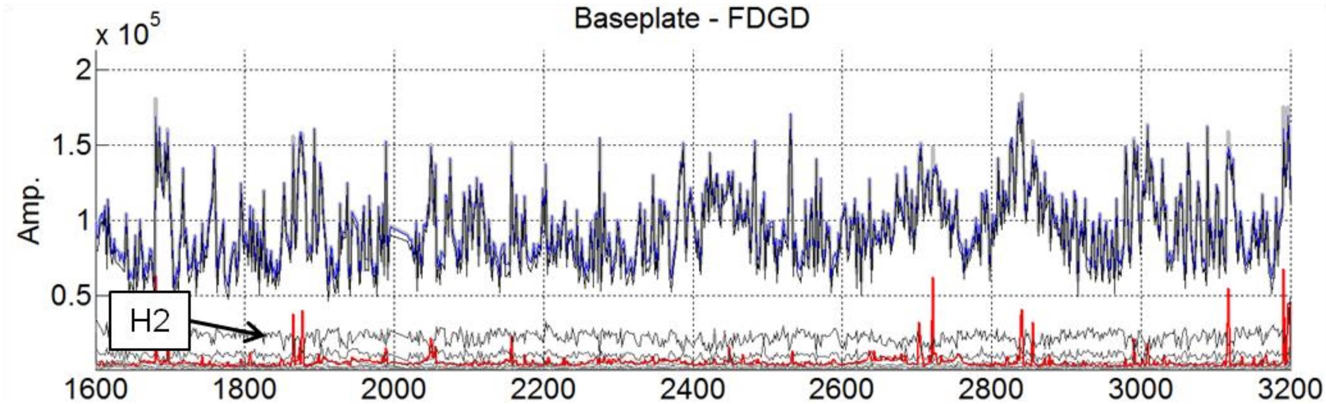

Figure 2. The RMS strength calculated at each shot point for the original sweep (light grey), analyzed sweep (black), and H1 (blue) for baseplate. H2 is indicated in black with H3 to H8 near the bottom. RMS strength of the error between the original sweep and the analyzed sweep is plotted in red.

Imaging with the second harmonic

A test survey provided by Statoil was processed in two near identical fashions. The first processing utilized the industry standard pilot sweep as the correlation operator with the final result annotated in Figure 3. The second processing flow utilized the second harmonic (H2) decomposed as the correlation operator at each respective sweep point with the final result annotated in Figure 4. The H2 correlated seismic image (Figure 4) appears "washed out" below 250 ms compared to the pilot signal correlated image in Figure 3. However, the H2 correlated image appears to reveal more reflections between 50-100 ms in the near surface. This shallow thin reflector imaging is promising, but also requires further research to confirm whether the H2 (and possibly H3!) can be made to contribute to increased seismic resolution.

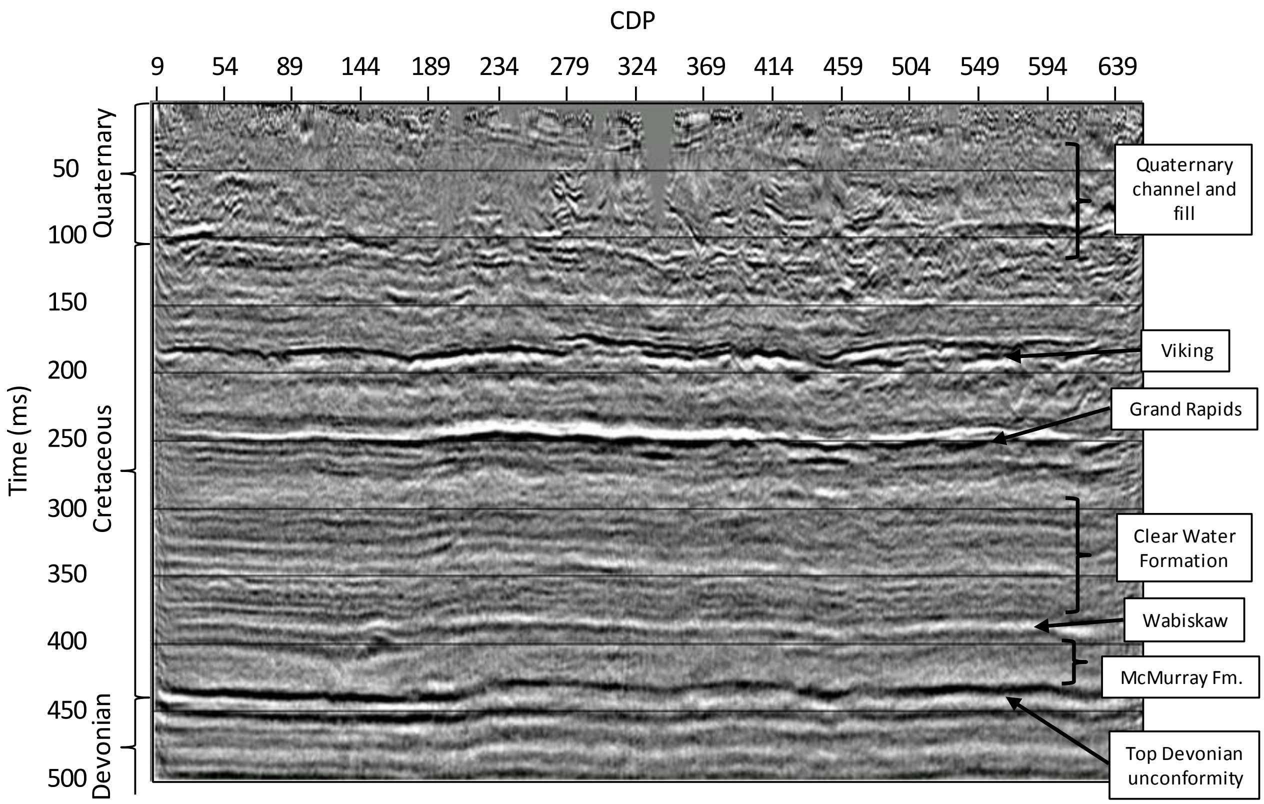

Figure 3. The pilot sweep correlated processed seismic image with annotation.

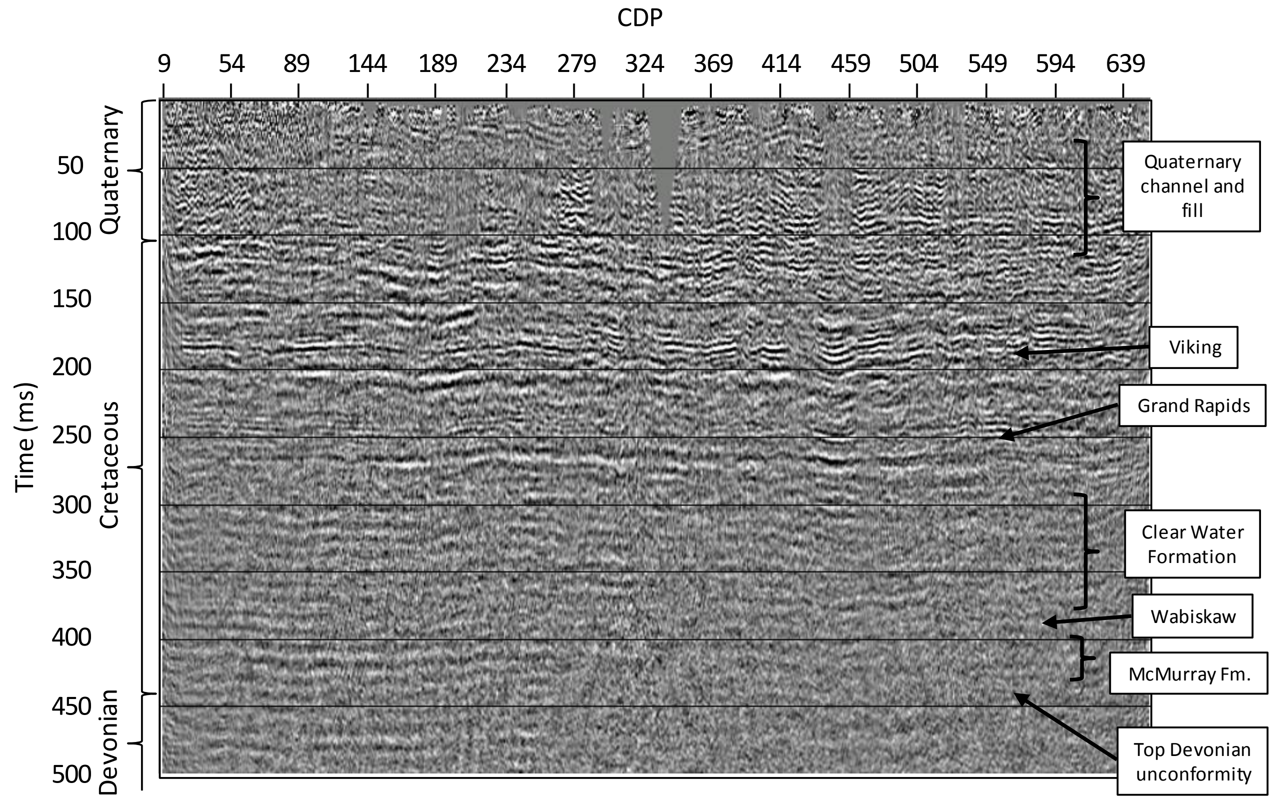

Figure 4. The second harmonic (H2) correlated processed seismic image with annotation

Conclusions

Using the second harmonic as the correlation operator decomposed from each sweep point in a test survey, we were able to show that thin shallow reflections between 50 and 100 ms, appear to be better imaged than using the industry standard pilot as correlation operator. Further investigation is warranted to assess the validity of these possible near surface reflectors.

Acknowledgements

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References

Harrison, C. B., Margrave, Gary F., Lamoureux, Michael P., Siewert, Arthur, Barrett, Andrew (2011). Harmonic decomposition of vibroseis sweeps using Gabor analysis. Geoconvention 2012. Calgary.

Lebedev, A. V., and Beresnev, I. A. (2004). "Nonlinear distortions of signals radiated by vibroseis sources." Geophysics **69**(4): 968-977.

Walker, D. (1995). "Harmonic resonance structure and chaotic dynamics in the earth-vibrator system." Geophysical Prospecting **43**: 487-507.

Wei, Z., and Hall, M.A. (2011). "Analyses of vibrator and geophone behavior on hard and soft ground." The Leading Edge **Feb**: 132-137.