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Low-frequency vibroseis acquisition experiment in Saudi Arabia

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ABSTRACT

Recent studies in seismic processing and interpretation have emphasized the important role and the benefit of low-frequency content in the data (2 to 3 Hz) for processes such as Amplitude Versus Offset (AVO) analysis and Full Waveform Inversion (FWI). In this study we successfully record low frequencies down to 3 Hz from the data acquired with a newly designed vibrator during a field experiment conducted onshore Saudi Arabia. Further amplitude recovery for frequencies below 10 Hz was achieved by applying a geophone inverse filter. We also show the benefits of this low frequency recording in the velocity model building with FWI.

The enabler for such low frequency data recording is a new generation of low frequency vibrators that was designed to start sweeping at frequencies as low as 1.5 Hz and to reach a full drive level at 5.4 Hz. A further boost of energy, emitted to the ground in the low frequencies, was obtained by designing an optimal sweep that follows the mechanical and hydraulic constraints of the vibrator.

To assess the capability of generating low frequency signals with the new source and custom sweep, several tests were carried out with frequencies ranging from 1.5 Hz up to 200 Hz and sweep length from 4 s to 24 s. The resulting shot gathers show good enhancement of frequencies from 3 to 6 Hz with custom sweep. The average gain in amplitude is around 10 dB compared to the equivalent linear sweep. For further amplitude recovery from the data recorded by the 10-Hz geophone, we apply the inverse filter of the geophone, to compensate for the amplitude damping below the natural frequency. Results on the shot gathers show a significant boost of amplitude up to 20 dB at 3 Hz, 10 dB at 6 Hz and 3 dB at 10 Hz. A low frequency seismic line was acquired specifically for full waveform inversion. Excellent quality low frequencies were acquired using 10 vibrators per shot point, and sweeping for 24 s from 1.5 Hz up to 125 Hz. Starting from a simple 1D model, velocity estimated with full waveform inversion resulted in a reliable depth velocity image down to about 4 km depth.

The combination of improved vibrator mechanics, customized sweep design and receiver damping compensation has helped to improve the bandwidth of the recorded data, in particular at the lower end of the frequency spectra. The extended bandwidth increases the resolution and fidelity needed for reservoir imaging and characterization processes.