Enhancing the Signal-To-Noise Ratio of Sonic Waveforms by Interferometric Stacking

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Abstract

Sonic logs are essential tools for reliably identifying interval velocities which, in turn, are used in many seismic processes. One problem that arises, while logging, is the scattering of the transmitted sonic energy caused by borehole irregularities due to washout zones along the borehole surface. The scattering of energy hence weakens the signal recorded by the receivers, and masks the first breaks by noise. Our objective is to extend the theory of super-virtual seismic refraction interferometry to enhance the signal-to-noise ratio of refracted P-wave arrivals in sonic waveforms. The super-virtual interferometric stacking is based on the cross-correlation and convolution of waveforms, in which the waveforms act as natural wavefield extrapolators. We also propose a modified super-virtual interferometric stacking to mitigate the effect of the spurious artifacts in the super-virtual waveforms, which are caused by the cross-correlation datuming step.

The theory of super-virtual interferometric stacking is composed of two redatuming steps, each followed by a stacking operation. The first one is of correlation type, where waveforms are cross-correlated with each other to obtain virtual waveforms with the sources datumed to the refractor. The second one is of convolution type, where the virtual waveforms are convolved with the recorded ones to de-datum the sources back to their original positions. The stacking operation following each datuming step would enhance the signal-to-noise of the super-virtual waveforms. Nevertheless, these waveforms suffer from spurious events, known correlation artifacts, due to the cross-correlation datuming step. The cross-correlation and stacking are smoothing operators, which could reduce the resolution of the super-virtual sonic waveforms.

To alleviate these problems, we replace the correlation-type datuming step by a deconvolution-type one. This method would suppress the spurious artifacts, enhance the temporal resolution, and deconvolve the source wavelet in the super-virtual sonic waveforms. We tested our proposed method on both synthetic and field data examples. The results show a remarkable enhancement of the signal and the suppression of the correlation artifacts. We conclude that the application of the proposed method could help enhance the signal-to-noise ratio of the waveforms.