Fundamentals of Wavelet Processing of Land Seismic Data, Part 1

Peter W. Cary - Sensor Geophysical Ltd.

Abstract

Noise has a big impact on the choice of wavelet processing flow for land seismic data since both random and coherent noise have a significant effect on the ability of deconvolution to perform correctly. Textbook studies of the effect of noise on deconvolution tend to use only small amounts of random noise, which is not realistic for land data. The purpose of this paper (Parts 1 and 2) is to illustrate how the types of noise that are typically present on prestack land seismic records affect the wavelet that ends up being embedded in the final seismic section. A prestack wavelet processing flow that consists of surface-consistent deconvolution followed by trace-by-trace spectral whitening (preferably time-variant) is illustrated, explained and justified in Part 1. In Part 2, a poststack wavelet processing flow that consists of poststack spectral whitening (again, preferably time-variant) and f-x decon is also illustrated, explained and justified. The final wavelet that is produced by this flow will typically have a broad, flat amplitude spectrum and a non-zero phase spectrum.

The effects of each step in the wavelet processing flow are illustrated with a single shot gather generated from a sonic log from the Berland River region of Alberta. Realistic types of noise (random noise, ground roll, back-scatter, Q) are added in a step-by-step manner, and the effect of each step is monitored by convolving the operator with a spike, as well as with the true wavelet, at the bottom of each trace, as shown in Figure 1. Trace-by-trace deconvolution produces wavelets with highly irregular amplitude and phase spectra because of trace-to-trace variations in the noise. Surface-consistent deconvolution produces wavelets that also have the wrong phase, but at least the phase is consistently wrong, which is considerably better than the inconsistently wrong phase that trace-by-trace deconvolution produces. Ground roll can have a large impact on the phase of the seismic wavelet, so it is best to try to keep it out of the deconvolution design gate. It is hard to avoid the influence of all coherent noise, however. Errors in the estimate of the low frequencies of the wavelet due to low frequency noise can have a surprisingly large effect on the phase of the final wavelet.

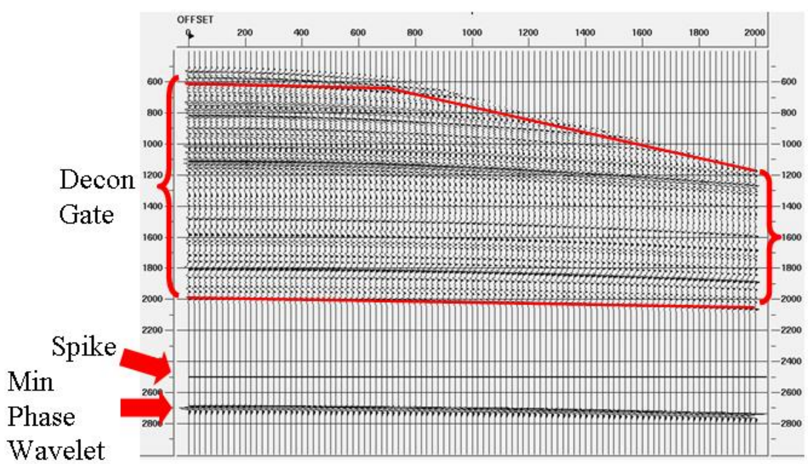

Figure 1. Synthetic seismograms (before addition of noise) used in the study. The spikes and wavelets at the bottom are used to monitor the effects of each step in the wavelet processing flow.

Spectral whitening (zero-phase decon) is applied to prestack traces mainly as a noise attenuator, but it also attempts to further whiten the amplitude spectrum of the signal. Time-variant spectral whitening produces virtually identical results to zero-phase decon within the decon design gate, but superior results above and below the gate. Since spectral whitening is applied on a trace-by-trace basis after surface-consistent deconvolution, it produces wavelets with consistent phase, but uneven frequency content, as shown in Figure 2. The trace-to-trace variations in the wavelets' frequency content produced by spectral whitening are clearly an undesirable effect if AVO analysis or time-lapse studies are the final goal. Nevertheless, spectral whitening remains a favoured processing tool because of its ease of use and superior performance at attenuating coherent noise on the final stack compared to multichannel processes like F-K or Radon transforms.

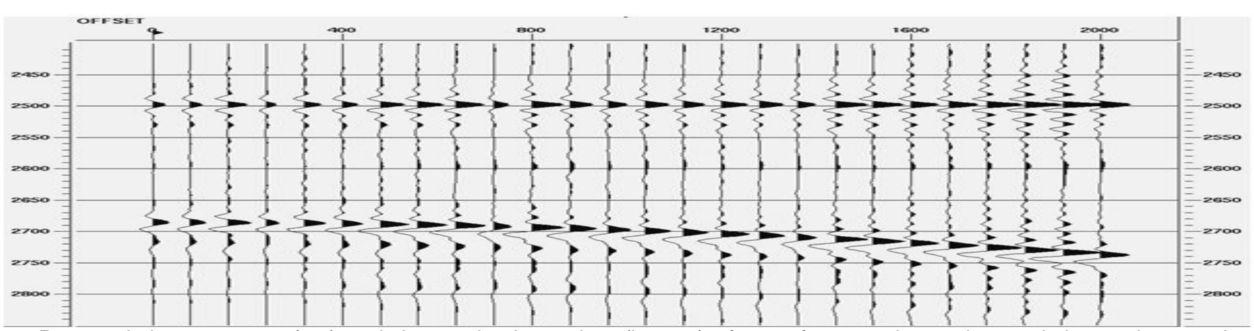

Figure 2: Deconvolution operators (top) and deconvolved wavelets (bottom) after surface-consistent deconvolution and spectral whitening when realistic noise is present. The phase is constant for all these traces, but the frequency content changes from trace to trace.