Adaptive Vector Filters for Ground Roll Reduction

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CSEG Geophysics 2002

Summary
A method of ground roll reduction in three component seismic data using adaptive filters is presented. Recognition that ground roll exhibits an elliptical retrograde particle motion dictates that energy will arrive in both vertical and horizontal components of a three component receiver. Furthermore, the polarized nature of the ground roll allow us to differentiate it from other signals and/or noise that may also correlate between horizontal and vertical components. The problematic nature of ground roll arises from its slow velocity combined with large amounts of dispersion. These factors combine to make removal of ground roll in processing troublesome. Adaptive filtering allows us to apply single receiver station filters using correlation between components to identify and remove noise with non-stationary filters. The polarized, band limited nature of ground roll allows us to differentiate it from other signals in the station components to aid in designing optimal filters. Results are presented that show significant ground roll reduction without any dependence on spatial sampling or receiver arrays.

Introduction
Ground roll is one of the most familiar types of noise to a geophysicist, and its slow velocity requires strict spatial sampling requirements if it is to be eliminated using traditional filtering approaches such as FK. Also, this slow velocity means it reaches our receivers at the same time as the body waves containing information about deeper subsurface geology. One traditional approach to ground roll attenuation is to use geophone arrays, but arrays are only partially successful at ground roll elimination in a wide azimuth 3C 3D survey. This combination of factors leads one to search for alternative approaches to attenuate ground roll.

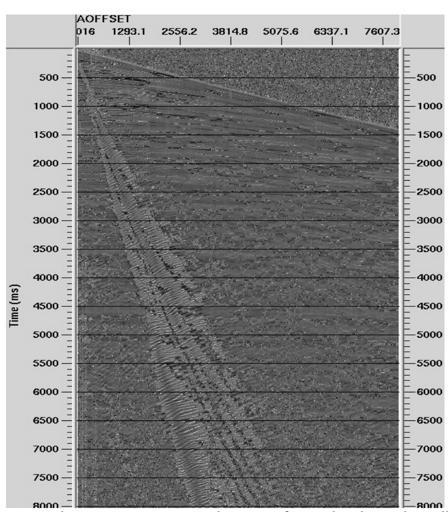
Polarization filters are the broad category of filters that rely on detection and separation of ground roll due to its elliptical particle motion. Several polarization filters have been presented (Tatham, R. H., McCormack, M. D., 1991). These have met limited success because of the dispersive nature of ground roll as well as the invalidation of many assumptions due to local geologic conditions. Our approach attempts to overcome some of these limitations by adapting our filter coefficients on a sample-by-sample basis as our estimate of the noise changes.

Adaptive systems are generally characterized by the ability to adjust performance in a time-varying fashion using a dynamic noise estimate input (Widrow, B., Stearns, S. D., 1985). We recognize that the ground roll presents itself in both the vertical and horizontal components, and has similar amplitude characteristics in both of these components. We choose to do our filtering on vertical and radial components. In addition to the similar amplitude characteristics, the elliptical motion allows us to differentiate ground roll from other forms of energy (Rene et al., 1986) by its phase polarization. This allows us to produce a time-varying, offset-windowed filter that reduces ground roll on a station-by-station fashion without any dependence on spatial sampling or receiver arrays. We may also choose to band limit the frequency content of the filter.

We present results that show successful application of the filter on data from Alberta, Canada. The approach requires two steps. The first is filter design where we define offset dependent application windows based on instantaneous phase differences (Rene et al., 1986) between vertical and radial components. We also choose a frequency band if desired. The second step is to apply the LMS Adaptive filter algorithm (Widrow , B., Stearns, S. D., 1985) to only the data within the offset window, time tapering in and out of the window.

Filter Design
When ground roll is of sufficient amplitude to be a concern in our seismic data, it is clearly visible within a shot record as a high-amplitude, low-frequency, dispersive noise train. However, there are also other wave types, such as pure shear refracted arrivals and Love waves that can arrive at nearly the same time and masquerade as ground roll. Our filter design goal is to isolate the ground roll in time as well as frequency to apply our filter to only the seismic data clearly contaminated with ground roll.

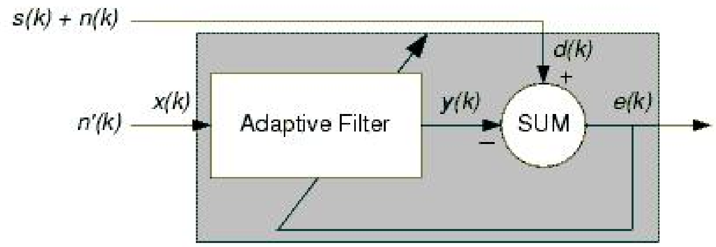
Differentiation of ground roll is done by displaying difference plots between instantaneous phase of vertical and radial data from a single three component station. The resulting difference section allows us to easily identify the polarized noise.



Difference between instantaneous phase of vertical and radial components

Filter Application

Application requires two input signals, one containing the signal and noise, and the second contains the estimate of the noise. The filter is applied in a station-by-station fashion. The following graphic illustrates a general adaptive filter.

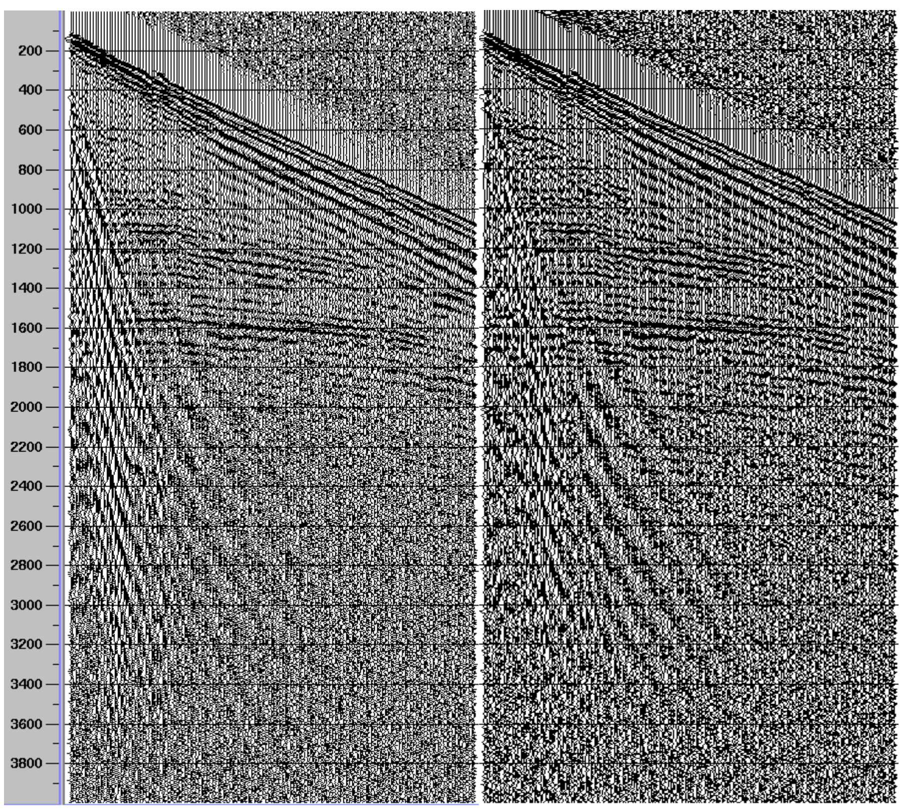


General Adaptive Filter

Our implementation involves inputting the vertical trace as s(k) + n(k) and the radial trace as n'(k). Also, we chose to optionally band limit the filter to only those frequencies present in the ground roll.

Results

The following graphic shows one shot record before and after filter application. The filter is only applied to data within the user specified window, and only with the user defined frequency content.



Unfiltered (Left) and Filtered (Right) ground roll contaminated record

Conclusions

We have presented an adaptive vector filter that is specifically designed to filter ground roll on a station-by-station basis. Its desirable features include independence from spatial sampling and its ability to only attenuate desired frequencies within a window that exhibits consistent phase differences between vector components. Its weaknesses include a fair amount of user guidance and is only applicable to three component data (vector data). Future research directions for optimizing the filtering include analysis of techniques that will allow us to further optimize the results of the filters. These may include trace balancing, further phase analysis, and deconvolution.

Acknowledgments

We would like to express our gratitude to PanCanadian Petroleum Ltd. for the use of the seismic data examples and Veritas DGC Land for the acquisition of some of the seismic used it this paper. We would also like to express our thanks to all our colleagues who have graciously given of their time to discuss and review the work presented in this paper, including Jon Tessman, Bob Brook, Steve Roach, and many others.

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