Tu P6 09

Amplitudes Preservation in 'Non-invasive' Methods of Land Noise Elimination

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SUMMARY

Onshore seismic data processing with task to reconstruct true amplitude relations needs specific approach to land noise elimination. Dedicated procedures and non-standard approach to the removal of land noise is covered.
Advanced methods which eliminate the unwanted waves and leave useful signal untouched are called non-invasive. These methods are remedy in challenging areas where ground roll, guided waves, air waves, side scattered waves and cultural coherent noise, create complex pattern. These interactive and iterative procedures based on the cascade methods and hybrid modeling, allow to obtain noise models in different domains, adaptive adjustment of these models to the real data, and subtraction from input traces. That approach includes for example techniques of building noise models with depth-consistent statics, multichannel enhancement, or kinematic corrections. These methods are frequently the only way to receive unchanged signal in areas where noise occurred and when standard procedures failed.

Introduction

Onshore seismic data processing with task to reconstruct true amplitude relations, in the examined interval, needs dedicated approach to eliminate the unwanted noise. Various types of noise (land-specific) strongly disturb useful seismic signal, so if they are not correctly eliminated then the final product includes residual artifacts. These artifacts are not always being observed on time stacked sections because of the power of the stacking. However they are present in the pre-stack data, consequently influence shapes of post-migration structures, trace amplitudes and signal phase.
The non-invasive (i.e. leaving useful signal untouched) methods of removal coherent or random noise are presented. Such approach allows to remove unwanted waves from seismic data with full preservation of amplitude relations for the horizons covered by high amplitude noise. Non-invasive methods of coherent noise elimination are remedy in challenging areas where ground roll, guided waves, air waves, side scattered waves and cultural coherent noise, create complex pattern of mixture with true reflections. In many cases standard approach to the noise elimination fails and often direct filtration procedures which attenuate high-amplitudes (from land noise) are not AVO friendly because they strongly influence amplitude relations of useful signal.
Dedicated procedures, and non-standard approach to the removal of land noise are covered. That includes techniques of building noise models with depth-consistent statics, multichannel enhancement, or kinematic corrections. The core of this technology are hybrid or cascade methods of obtaining noise model in different domains, adaptive adjustment of these models to the real data, and subtraction from properly scaled input traces.

Description of the method with data examples

Non-invasive methods base on interactive and iterative approach to estimation and extraction of the noise models from recorded seismic wave-field (Fig.1). The noise modeling is being performed step by step with use of cascaded techniques. Frequently, hybrid modeling is applied, especially to incoherent noise. This approach destroys useful signal while noise is enhanced and modeled. It ensures that the useful waves are not present in noise models, especially in case when high-energy of unwanted waves covers true, weak reflections.
When non-invasive methods are applied, a suitable preparation of the seismic data before noise models creation is crutial. The proper trace scaling is being applied individually to each modeled noise, and is time and space variant. The multi-channel processes (e.g.: mixing, FK, Tau-P, CRS, ECP^{GT}) work as much better as amplitudes do not have too large variations. Scaling which does not preserve true amplitude relations is used to model extracted noise. However, when adaptive processes are to be used, the dynamic scaling is removed and noise models are scaled, matched, and shaped to the input data. Scaling procedures influence the whole data processing so incorrect scaling at the beginning of processing, strongly affects the final seismic image. In case of land data, when high amplitude ground roll exists, it is difficult to define proper surface consistent amplitude factors before ground roll is removed. The scaling applied for reconstruction of true amplitude relations must depend only on the unchanged useful reflection signal.

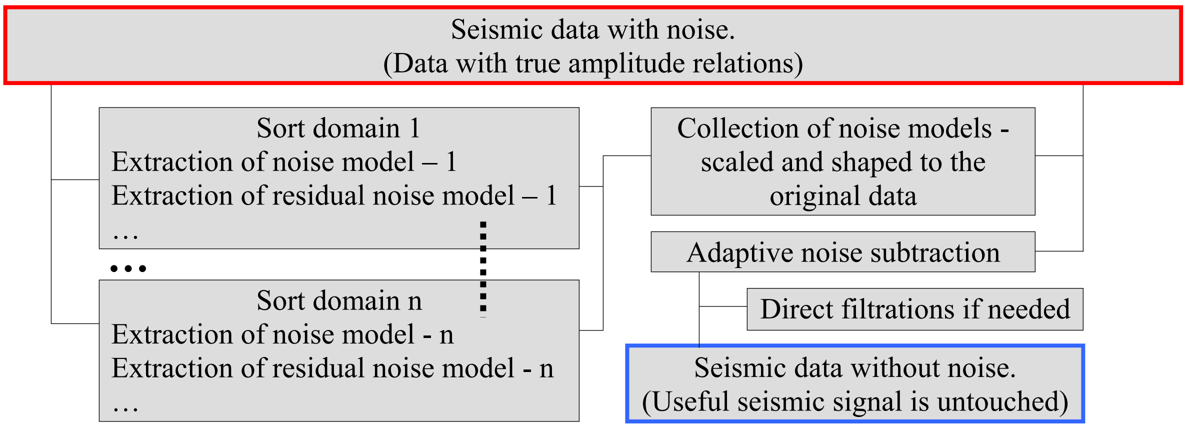

***Figure 1** The non-invasive method idea – diagram.*

Ground roll elimination is presented in Fig.2. Cascade method was applied iteratively, and adaptive subtraction was used twice. Firstly, it was performed in frequency domain and the result was used to generate the first iteration noise model. The obtained noise model included almost whole ground roll but also residual reflections. In the next step the model was improved while residual true reflections were removed. Second iteration of adaptive subtraction was performed in time domain. Residual, high amplitude artifacts were eliminated by direct filtration (advanced de-spiking in time-frequency domain). Residual, aliased waves of the ground roll were removed by adaptive FK filtering in source and receiver domain. In the red boxes in Fig.2, the amplitude spectra were estimated. They are the same before and after noise elimination. The signal shape is the same for the near and far offsets. Trace amplitudes have the same level and similar character. No-invasive method did not destroy the useful seismic signal, and did not change amplitudes along reflections.

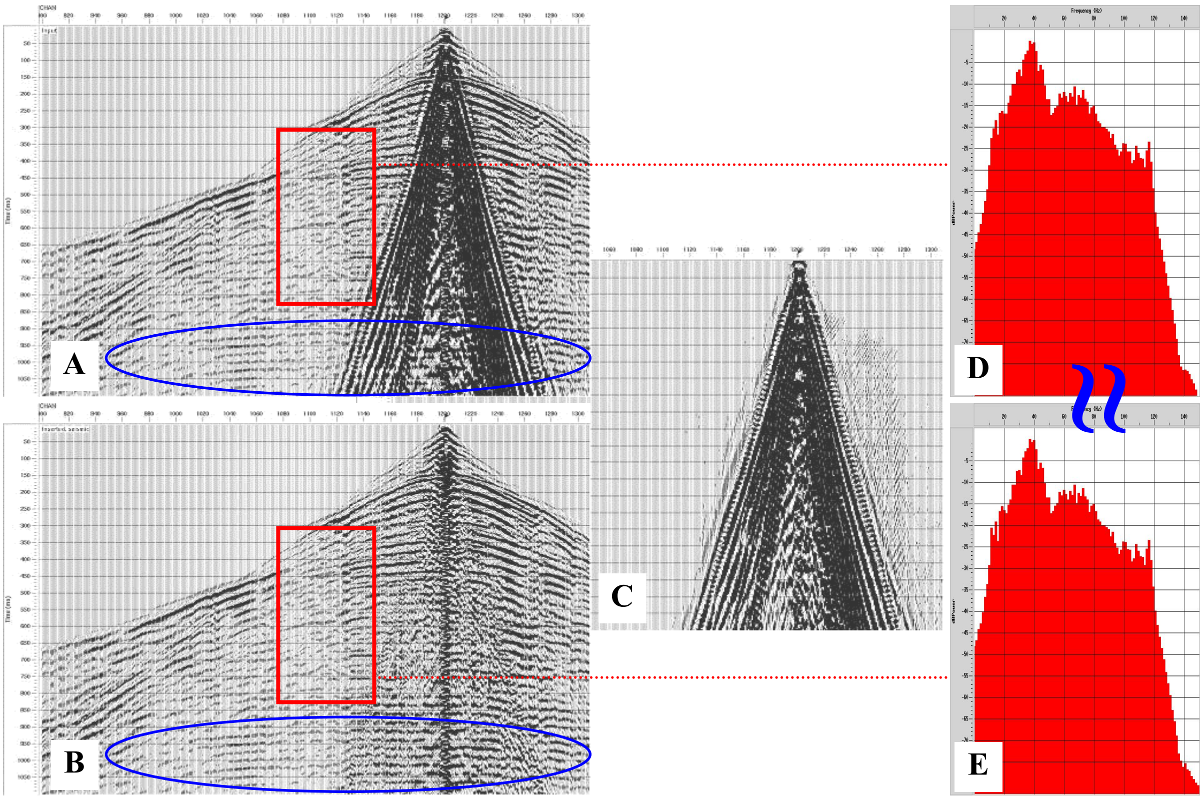

Figure 2 *Effectiveness of ground roll elimination - raw source record with application of divergence correction. A) original data, B) data after noise elimination, C) difference between data from before and after noise elimination, D) amplitude spectra marked in red box before ground roll elimination, E) amplitude spectra marked in red box after ground roll elimination.*

Guided waves (reflected refractions) is another type of land coherent noise which significantly deforms seismic image and disturbs amplitude relations. The guided waves have almost the same directions as true reflections and almost whole offsets are covered by such noise. It is difficult to remove just the noise without destruction of true reflections if direct filtrations are being applied. The low frequency components are vulnerable to destruction in such approach. The wavelet is getting narrow and character of signal is strongly changed. Non-invasive methods allow to remove such noise with preservation of low frequency component. The effectiveness of the guided waves removal is presented on Fig.3. Cascade method with hybrid modeling and adaptive subtraction was used. Six independent noise models were created in source and receiver domains. Source records on Fig.3. show efficiency of that approach. Low frequencies of the true reflections were preserved (red arrows), while noise was eliminated. Comparison of the stacked sections proves effectiveness of the guided waves elimination. Horizons, originally covered by guided waves, are well visible after noise elimination, and have the same character as horizons outside noisy zone.

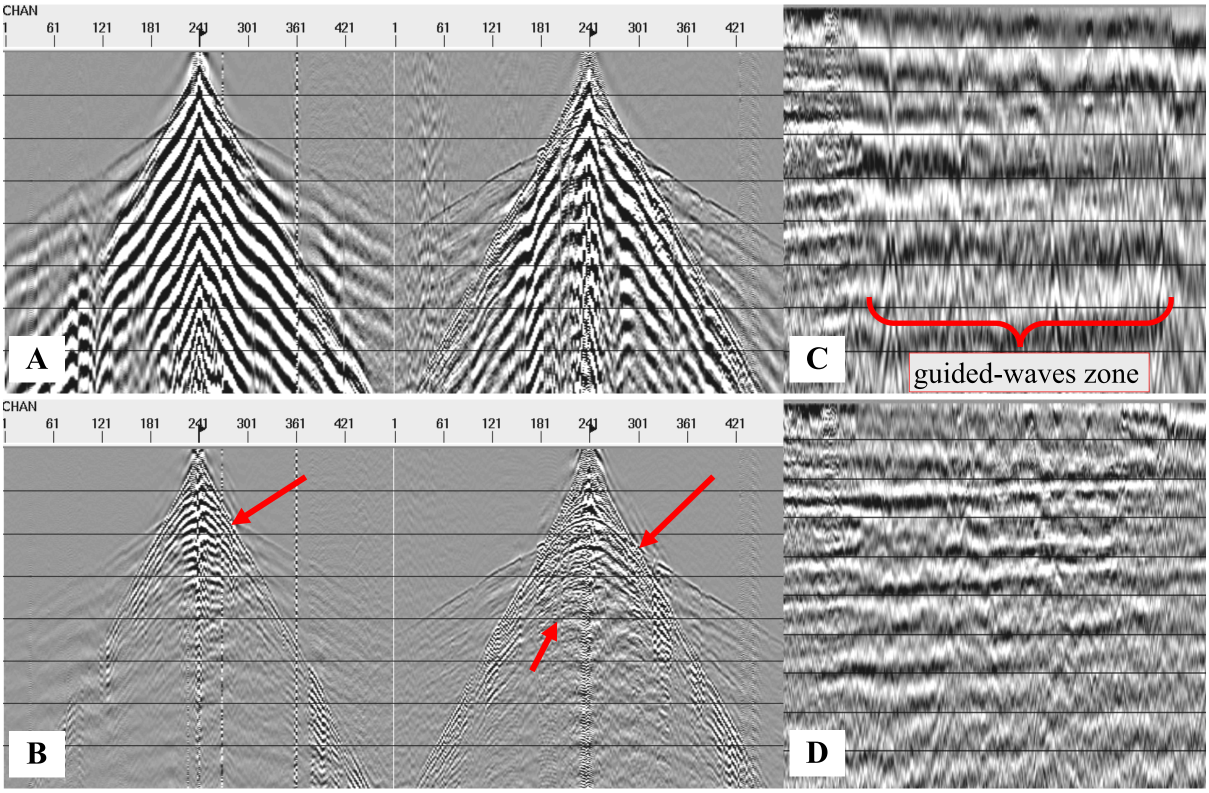

Figure 3 *Effectiveness of guided waves elimination - source records and part of stacked section. A) original data, B) data after noise elimination, C) stacked section before noise elimination with scaling which preserves true amplitude relations, D) stacked section after noise elimination with preservation of true amplitude relations.*

Airblast is a specific noise which always occurs when vibrators are used for land acquisition. Whole amplitude spectra of such noise fits in the same frequency range as the useful signal spectra. If airblast is not properly removed (just attenuation by rescaling) then it influences to the migration results and amplitudes. The coherency of airblast is frequently disturbed, so direct procedures are inefficient. Non-invasive method is the solution. In such approach, coherency of noise can be repaired by application of noise-targeted residual static corrections and iterative noise extraction. Fig.4 shows airblast elimination. Modeling was performed in radon domain after correction of airblast coherency. Adaptive subtraction was used to subtract models from the original data.

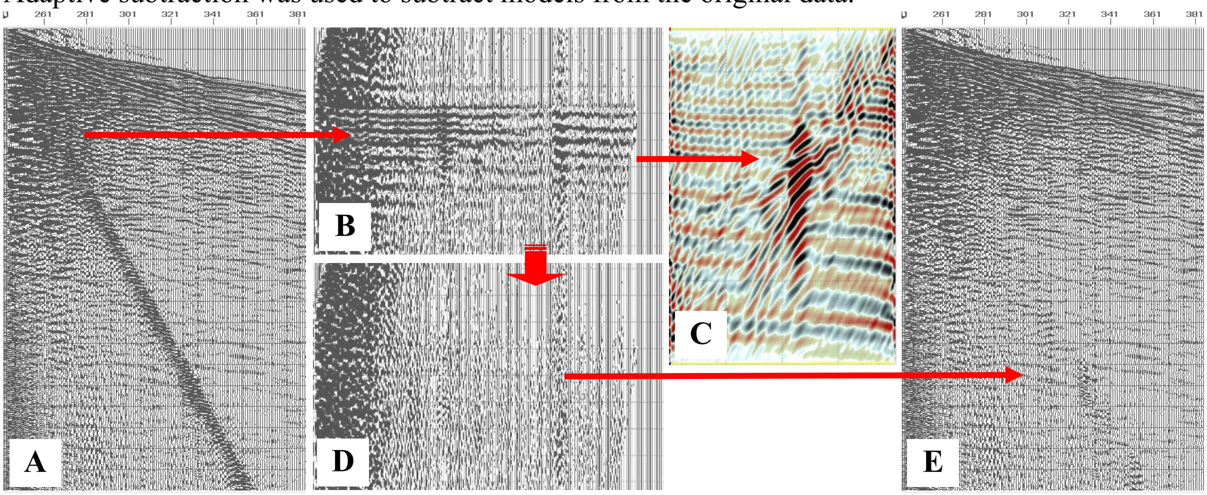

Figure 4 *Effectiveness of airblast elimination - source record with application of divergence correction. A) original data, B) data after noise-targeted flattening, C) modeling of noise in Tau-P, D) data after noise-targeted flattening after subtraction of noise models, E) data after airblast elimination.*

If acquisition is being performed in the urban area, then additional external coherent noise can occur sometimes, and the data quality is changed rapidly. The cultural noise associated with sawmill is presented in Fig.5. The sawmill was working 24 hours per day and generating strong linear noise. Data could not be just removed because of large range of spatial prevalence. Non- standard approach was applied. Proper data scaling and noise models extraction were used. An iterative modeling of waves was applied which employed predictive deconvolution to the noise modeling. Models were stacked and adaptively subtracted from the original seismic data. The seismic signal after noise elimination at the zone where noise previously occurred, is at the same level as the signal where noise was not present. Near offsets were especially difficult to model because of similar curvature of noise to the true reflections.

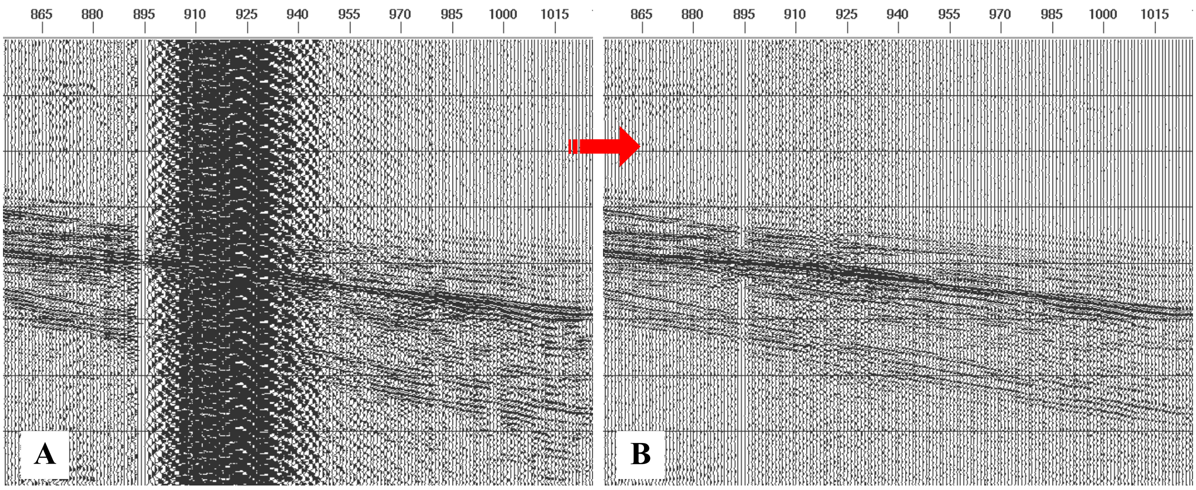

Figure 5 *Effectiveness of cultural noise elimination - part of source record. A) original data, B) data after noise elimination.*

Conclusions

Land seismic data processing with task to reconstruct amplitude relations needs dedicated approach to elimination of unwanted waves. The techniques of noise elimination, which leaves useful signal untouched, are called non-invasive. Interactive and iterative procedures, and non-standard approach based on the cascade methods and hybrid modeling, allow to obtain noise models in different domains, adaptive adjustment of these models to the real data, and subtraction from input traces. This approach includes for example techniques of building noise models with depth-consistent statics, multichannel enhancement, or kinematic corrections. These methods are frequently the only way to receive unchanged signal in areas where noise occurred and when standard procedures failed.

Acknowledgements

The authors thank Geofizyka Torun S.A. for encouraging this work, and for permission to present it.

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