A Case Study in adaptive deghosting a 2D conventional streamer

Markos T. S. Sourial,
WesternGeco Geosolutions, Canada

Introduction

The recorded seismic data bandwidth is the result of the convolution of source signature, earth attenuation, the various types of external environmental noises, and the free surface ghosts in marine acquisition. A great deal of effort has been undertaken in the seismic industry to deliver an improvement and expansion to the seismic bandwidth in both acquisition and signal processing, and with particular emphasis towards the low frequency end of the spectrum. This is essential for many exploration objectives such as imaging deep targets and targets beneath absorptive overburdens. It is also very important for those applications that follow seismic processing – such as pre stack inversion of the data. Interest in obtaining an uplift in deghosting has extended quickly from deghosting newly acquired acquisition to reprocessing of legacy streamer datasets.

In marine acquisition, the depth of streamer and source determine the amount of swell noise recorded by the streamer, and also the position in the spectrum of the free surface ghost notch. Both of these elements in turn affects the characteristics of the seismic bandwidth. A deeper tow is typically quieter than a shallow streamer, as a deeper tow insulates the streamer from the majority of the effects of the sea state. However, the deeper streamer will have the first receiver side ghost notch occur at a lower frequency than the shallower streamer. These ghost reflections cause a loss in frequency content through destructive interference of the down-going wave with the upgoing wave (figure 1). It is useful to narrow their effects to obtain a broadband spectrum by having a higher signal to noise ratio across a broader range of frequencies.

Hence, in signal processing, we strive to narrow both source and cable notches and maximize the usable frequency range of the spectrum by using deghosting algorithms. In this case study, the deghosting is performed adaptively for a single streamer dataset in the processing sequence as a pre-stack process.

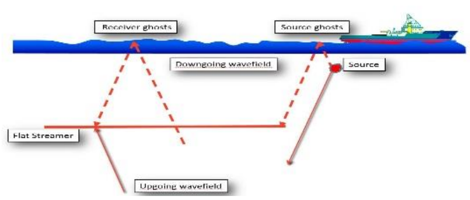

Figure 1 *The flat cable towing with source/receiver ghosts (schematic).*

Method

In the method followed in this case study, deghosting the recorded seismic data is performed on a shot-by-shot basis. In this case study, we follow the philosophy that this should ideally be applied early in the overall processing flow, before any de-multiple or velocity analysis processes, in order for those subsequent processing steps to be able to leverage the uplift given by the deghosting process. The Adaptive deghosting used here is a 2D angular spectral reconstruction inversion operator in the shot domain. The algorithm reads the real cable depth headers to initiate the inversion process and can adapt for detector depth perturbation and water velocity to give more accurate ghost model. The method is applicable to hydrophone only data, whether towed at a flat constant tow depth or in a slanted configuration, and thus is suitable for deghosting legacy seismic data.

Example

In this study, the adaptive deghosting process was applied to the very early stage pre-stack data during the reprocessing of a typical 2D marine dataset with flat-towed streamer - acquired on Canada's east coast in 1999. It is one cable/one shot dataset that was acquired with a streamer depth of 10m and source depth of 7m. Due to the age of the acquisition, there is an expected uncertainty in the streamer depth due to the limited accuracy with which these could be recorded at that time.

However, assuming a streamer depth of 10m, we expect the first non-zero Hz ghost notch to appear at 75Hz, and the first non-zero Hz source notch to appear above 100Hz.

The 2D lines have a varying water bottom depth from very shallow of 100ms to very deep of 4000ms. This dataset showed the stability of adaptive deghosting results on shallow and deep water. The adaptive deghosting was selected as the tool to handle the deghosting, as the adaptivity of the method should be able to compensate for to the above mentioned uncertainty in detector depths.).

Prior to deghosting, de-bubble and noise attenuation were first applied to the data. Deghosting was applied to narrow both source and receiver ghosts. The process was applied to calculate the receiver ghost model first and then the source ghost. The comparison between shots and stacks (figure 2 through 6) before and after deghosting for both shallow and deep water shows the uplift in signal. Additionally, a migrated stack comparison between adaptive deghosting and conventional 1D deghosting (figure7 and 8) enables us to see more geological details.

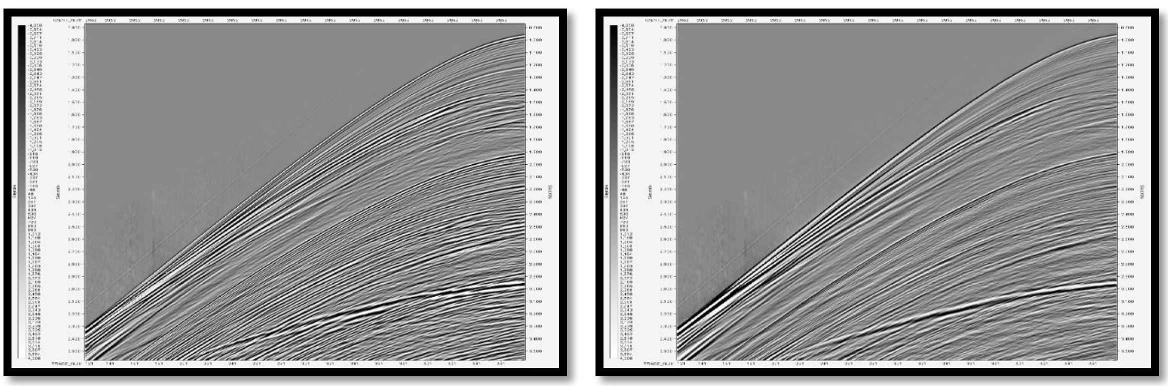

Figure 2*. Shallow water Shot gather (left: input, right: after deghosting)*

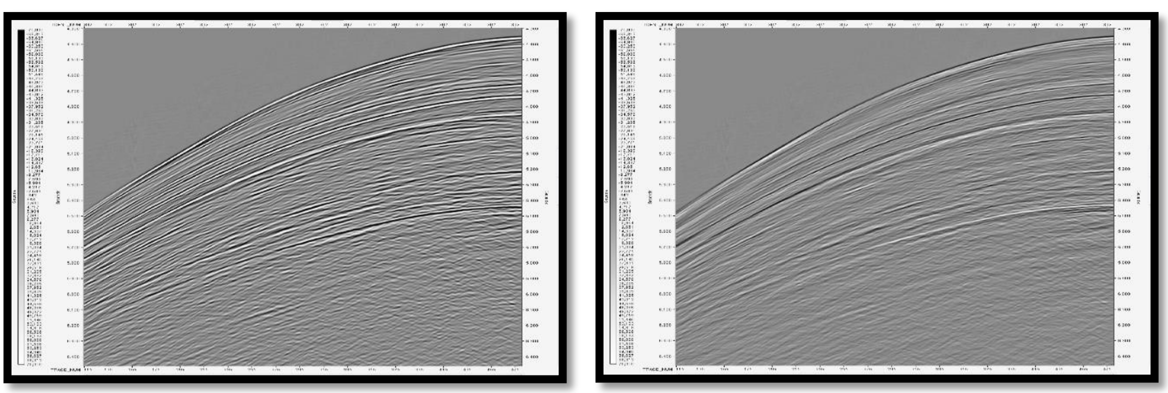

Figure 3*. Deep water Shot gather (left: input, right: after deghosting)*

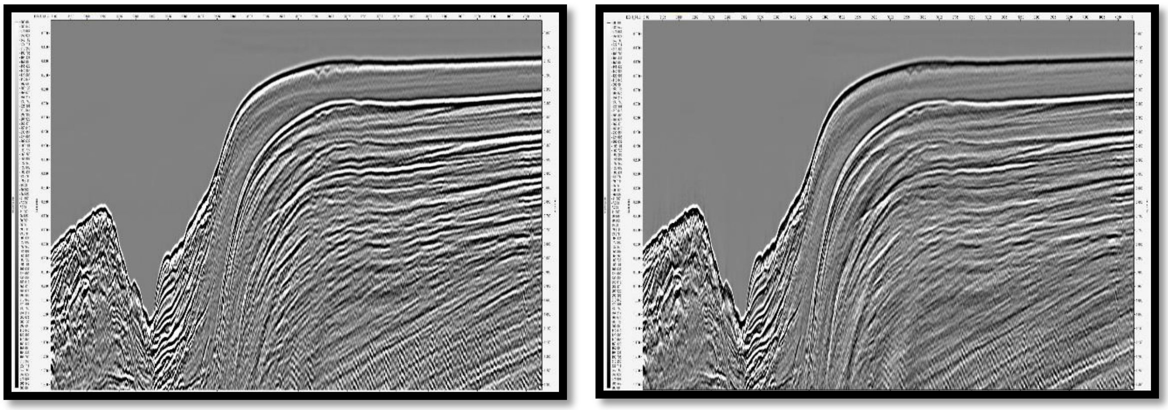

Figure 4*. Shallow water Stack section (left: input, right: after deghosting)*

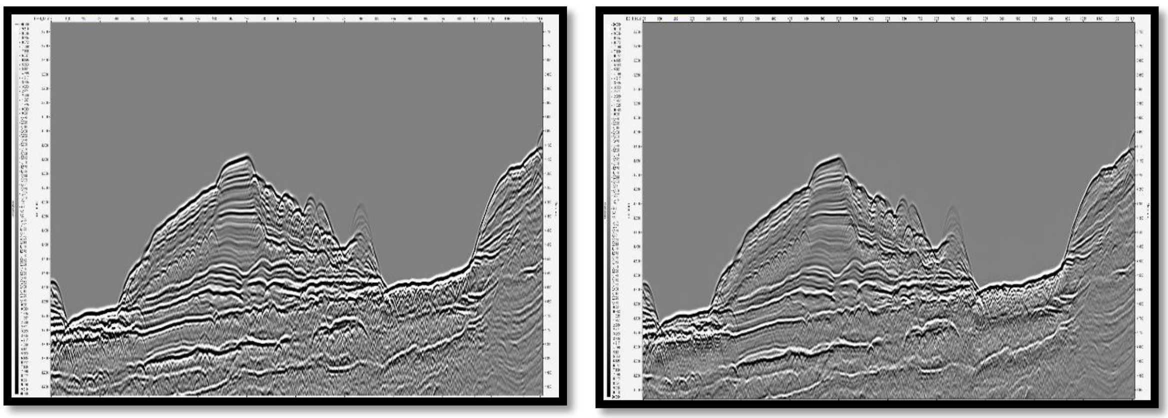

Figure 5*. Deep water Stack section (left: input, right: after deghosting)*

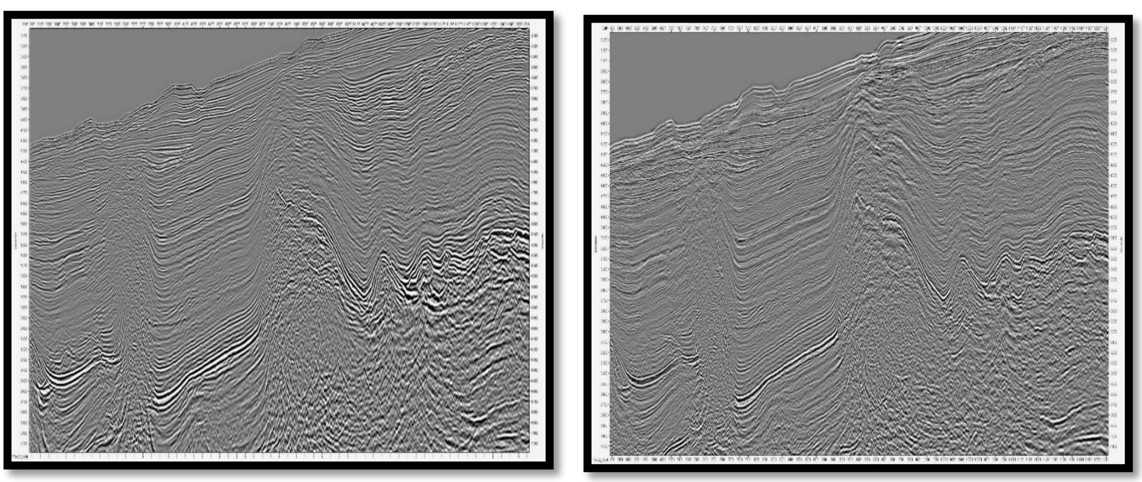

Figure 6*. Deep water KPrSTM Stack section (left:Conventional, right:Adaptive Deghosting)*

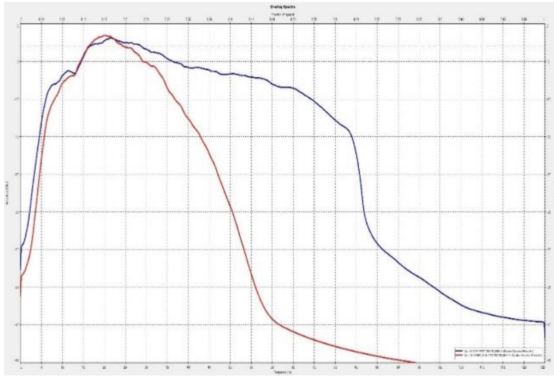

Figure 7. *Amplitude spectra for KPrSTM (figure 6) comparison between conventional (red) and adaptive deghosting (blue)*

The amplitude spectrum in figure 8 show that the bandwidth of the data over which we have usable signal to noise has been significantly extended. Having extended the usable bandwidth, there remains the potential to further shape the spectrum as appropriate and as desired for interpretation.

Conclusion

The source and receiver ghost notches attenuate the amplitude in the non-deghosted data, at around 73Hz and also at the very low frequency end - due to the destructive interference of the upgoing and downgoing wavefields. The adaptive deghosting narrows the ghost notches even in the presence of some uncertainty in the cable depth. The deghosted dataset has sharper wavelets and better resolution which should improve the inversion results and the usable low frequencies for Full Waveform Inversion (FWI) in the future. In conclusion we observe that the seismic bandwidth of legacy marine data, such as that used in this case study, and acquired off the East Coast of Canada in 1999, can be considerably extended by recently developed deghosting techniques. The extended bandwidth can then be leveraged in the data processing flow to deliver data with additional value for future interpretation and further processing.

Acknowledgements

The author would like to thank WesternGeco management for their encouragement and their full support during the different stages of the processing and the Multiclient Team for the permission to publish this paper. The authors also would like to thank Peter Watterson (WesternGeco), Juan Paulo Perdomo Tellez (WesternGeco) for providing the technical support during testing.

References

Rickett, J., "Success and challenges in 3D interpolation and deghosting of single-component marine-streamer data", SEG Technical Program Expanded Abstracts 2014: pp. 3599-3604.

Rickett, J., van Manen, D. J., Loganathan, P., and Seymour, N., "Slanted-streamer data-adaptive deghosting with local plane waves", EAGE Expanded Abstracts 2014: Broadband Acquisition and Processing II, doi: 10.3997/2214-4609.20141453.