Effect of Deghosting on Conventional Streamer Seismic Data: A Case Study on data of Western Offshore Basin, India.

Pritam Bera, Srilata Mohapatra;ONGC Ltd., India*

bera_pritam@ongc.co.in

Keywords

Source and Receiver De-ghosting,
Low frequency enhancement.

Summary

Marine conventional streamer data are typically contaminated by the interference from ghosts on both source and receiver sides. New marine processing flows attempt to supress this interference. In this paper, it has been shown that using deghosting technique, the amplitude of source and receiver side ghost has been suppressed, resulted in low frequency enhancement and improvement of quality of data. This deghosting process has been applied on the conventional acquired streamer data of Western Offshore Basin, India.

Introduction

In marine acquisition, the interference of up and downgoing portions of a seismic wavefield at the air/water contact causing both source and receiver side ghost effects. Ghosts closely follow primaries in seismic data with opposite polarity as well as the same polarity, interfere with the primaries (Figure 1). The ghost, which generally refers to the downgoing wavefield that is generated when the upgoing wavefield reflects or scatters off the air-water interface, is problematic in different respects. It introduces amplitude and phase distortions that, for example, attenuate frequencies where destructive interference is significant. Certain frequencies can be totally annihilated at the receiver and are known as notch frequencies. As a result, accuracy, bandwidth and resolution of the data may be limited. The ghost notch depends on the streamer depth and source depth directly. Attenuating the ghost effect results low frequency enhancement and broadens the available frequency band and helps to obtain high resolution images.

Concept/Theory

In conventional marine seismic surveys, sources and receivers are placed at certain pre-defined depths below the sea surface based on several parameters. Figure 1 shows the primary reflection, the source ghost, receiver ghost & ghost reflection recorded due to source and receiver ghost interaction and the reflection time of primary and ghost event.

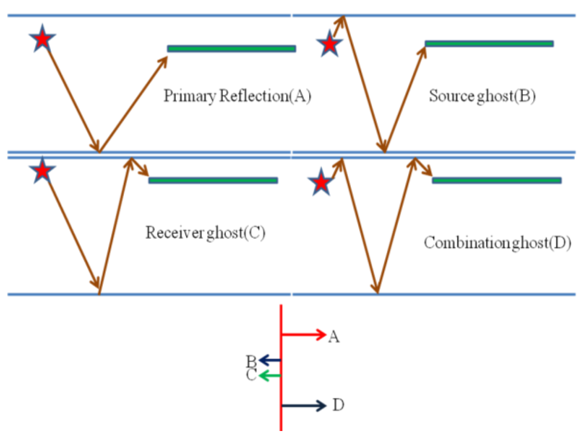

Figure 1: Examples of primary and ghost reflections.

Whenever we see the data with no ghosts, Events look a spike, Data with source ghost, events have large side lobe and Data with source and receiver ghost, events have larger side lobe.
Figure 2 shows the wavelet with source ghost (A) has energy with different polarity just after the primary, the wavelet with source plus receiver ghost (B) shows that it increases the lobe energy and ghost free wavelet(C) shows the minimum lobe energy. All the wavelet has been generated from actual gun signature.

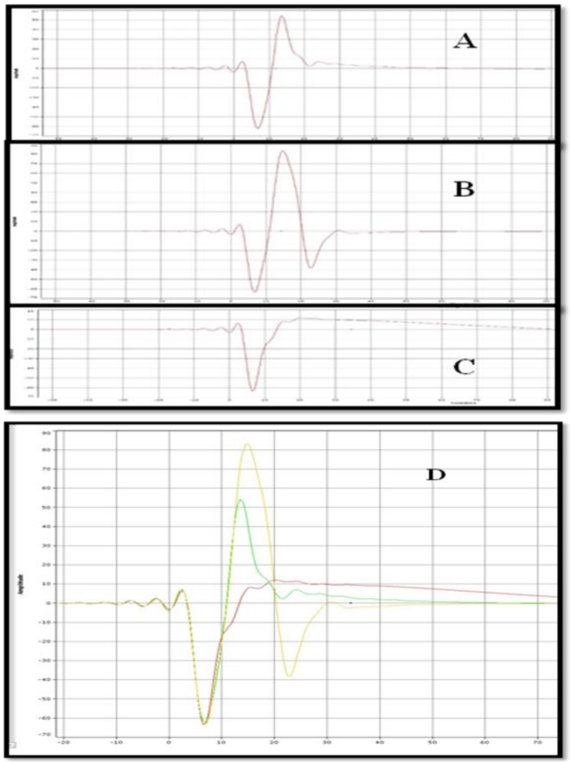

Figure 2: Wavelet with source ghost (A) and source +receiver ghost (B) & ghost free wavelet(C).Overlay of three wavelet (D; Red-ghost free, Green- wavelet with source ghost, Yellow- wavelet with source +receiver ghost).

The notch in the frequency spectrum created by the surface ghost due to placing the source and receivers below a sharp discontinuity, which is the water/air contact in marine acquisition.

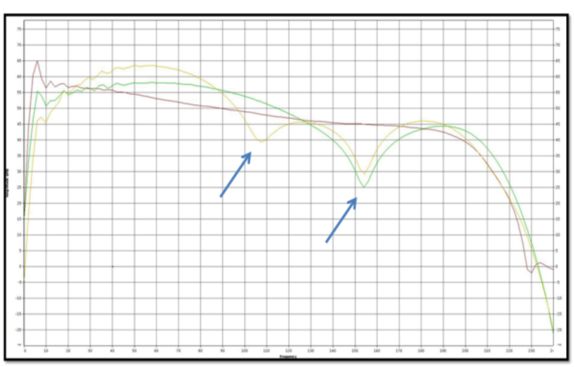

Figure 3: Spectrum of ghost free wavelet (Red) and Receiver ghost included wavelet (Green) and Receiver + Source ghost included wavelet (Yellow).Notches are due to source and receiver ghost.

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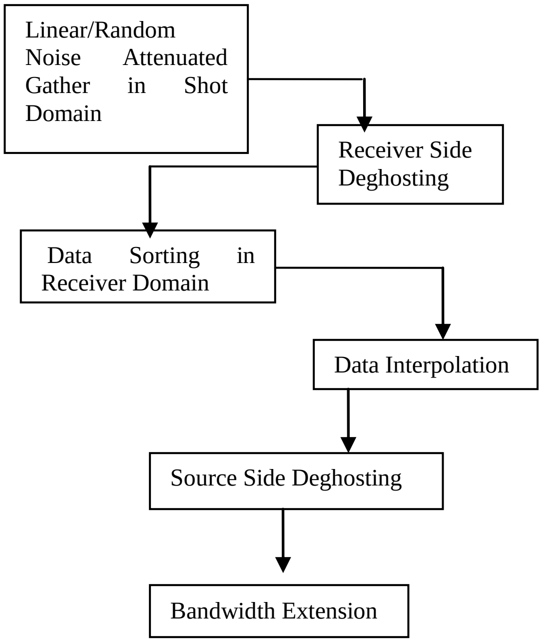
Ghosts on seismic data is not only impacting higher frequencies by introducing notches but also causes loss of amplitudes at the lower frequencies(Figure 3). The impact of two ghost reflections, one for the source side and one for the receiver side further complicate the spectrum that by adding notches in the spectrum at the appropriate harmonics.

Deghosting technique is used to attenuate the receiver and source ghost of data, as a result low frequency enhancement and a flatter spectrum. The recorded data set is a combination of the upgoing and downgoing pressure on a streamer in space and frequency domains. In processing, we ideally want the upgoing pressure at a defined depth with minimal ghost response. It is difficult to relate downgoing wave field or total wave field in TX domain, it is necessary to use an indirect relationship by performing the wavefield separation in different domain where a forward model of the upgoing and downgoing wavefield has been generated at zero depth. At this depth, the downgoing wavefield is now reverse polarity of the upgoing. Following this, the upcoming and downgoing wavefields are redatumed to a specified constant depth. To make the transform more stable, constraints are applied such as coloured noise and a variable reflection coefficient with frequency. To improve the quality of deghosting , process has been done in fine spacing.
Normally, before Deghosting, linear an direct arrival noise should be attenuated. All the process prior to deghosting are carefully applied so that they do not modify the ghost information. That's why, normally zero phasing is applied after deghosting.

Processing Steps & Data Preparation

The data has been acquired with channel spacing of 12.5m and shot spacing of 25m flip-flop (50m for single shot). Streamer depth is 7m and Source depth is 5m.



Firstly, Different types of linear noise, random noise and direct arrival have been attenuated. Debubling has been done before deghosting. For this technique we take only one streamer data. Then receiver side ghost has been removed. Data has been sorted in receiver domain. As shot interval is big, data has been interpolated in fine spacing (50 m to 12.5m). Then source side ghost has been removed.
Finally we go for energy decay compensation and bandwidth extension (Inverse Q amplitude and phase).

Examples & Discussion

The following example is from Western Offshore Basin, India. Firstly, if we go through the spectrum of ghost free signature and ghost included signature, low frequency has been enhanced and there is certain drop of amplitude in higher frequency which is due to the decay of energy in the subsurface (Figure 3).

Figure 4 indicates that in receiver and source deghosting, side lobes have been reduced. Similarly autocorrelation shows the same scenario (Figure 6).

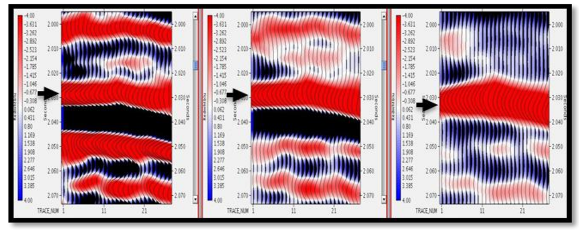


Figure 4: Gather- Input vs After Receiver Deghosting vs After Receiver+ Source Deghosting

In Figure 5, it has been shown in the first step the receiver ghost and lobe has been reduced and then in second step the source ghost has been reduced. It gives spike trace.

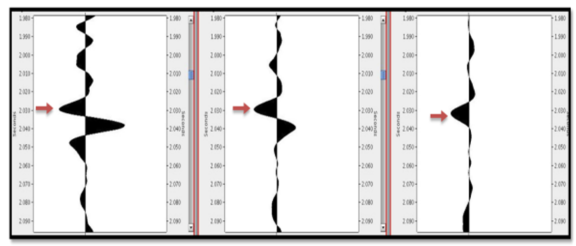


Figure 5: Single Trace- Input vs After Receiver Deghosting vs After Receiver+ Source Deghosting.

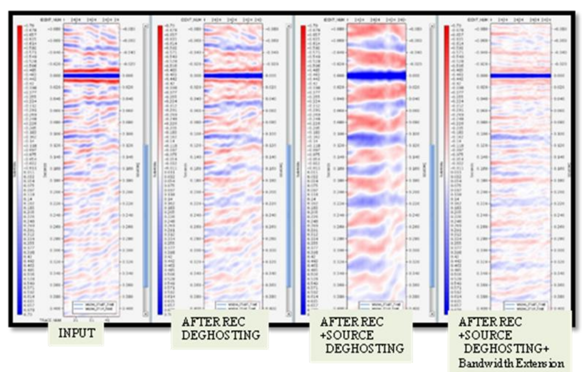


Figure 6: Auto-Correlation of Gathers in different stages

Whenever the ghost has been removed from data, low frequency has been enhanced (Figure 7), but there is drop in higher frequency as the spectrum of signature shows same (Figure 3).

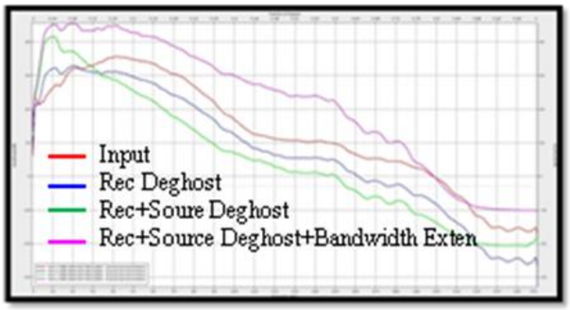


Figure 7: Amplitude Spectrum in different stages

Similarly if we go through the stack, side lobes have been reduced after receiver and source deghosting (Figure 8). Autocorrelation shows the same result (Figure 9).

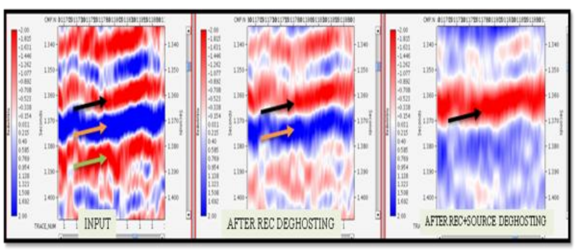


Figure 8: Stack- Input vs After Receiver Deghosting vs After Receiver+ Source Deghosting

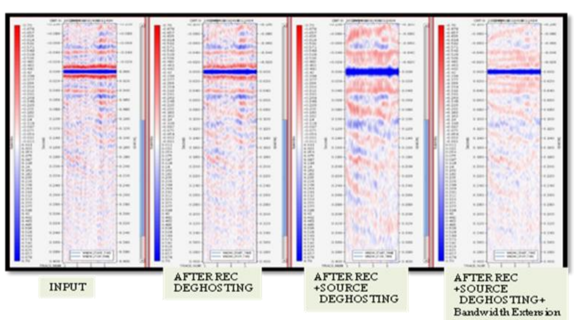


Figure 9: Auto-Correlation of stack in different stages

Figure 10 is the comparison of PSTM stack of deghosting data and without deghosting data. PSTM stack image clearly shows the improvement in terms of event clarity, resolution with respect to without deghosting data.

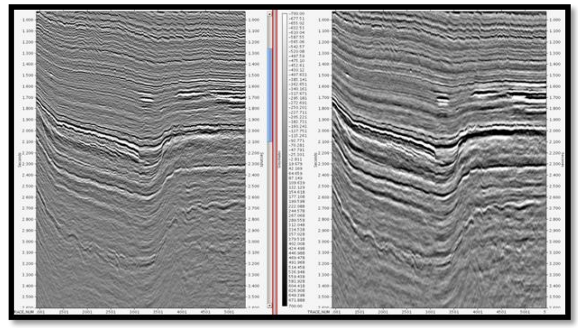


Figure 10: Migrated Stack without Deghosting vs with Deghosting

If we go through the spectrum, there is enhancement of low frequency (Figure 11). Normally source decay compensation and bandwidth extension (Inverse Q amplitude and phase) have been applied in deghosted data. In Figure 11, it has been shown that using bandwidth extension we can recover the higher frequencies.

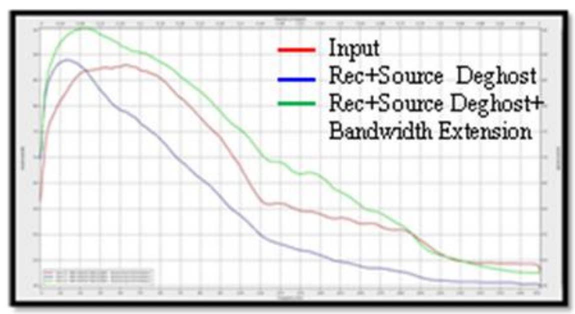


Figure 11: Spectrum of Migrated Stack with and without Deghosting

Conclusion

Resolution of marine seismic data may be significantly degraded by the presence of source and receiver side ghosts and reduces the resolution of seismic data. The greatest impact of the ghost reflections is in the low frequency part of the wavelet. In this paper, it has been shown that using deghosting technique, side lobes has been reduced, resulting low frequency enhancement and improvement in terms of event clarity and resolution which improves the interpretability of geologic features and also can help in prestack inversion and reservoir characterisation studies.

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