Blended Acquisition – A potential step-change in geophysical flexibility and operational efficiency

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Abstract

The introduction of additional sources in marine seismic acquisition can lead to more versatile geometries including longer offsets and more diverse azimuth coverage. It also has the potential to make some acquisition templates more efficient and reduce the need for infill as well as reducing the technical risk and HSE exposure. To avoid reduction in fold and shot density the sources can be fired simultaneously. The challenge is to preserve the geophysical integrity of the data, in particular in the pre stack domain, through a robust randomization scheme and subsequent de-blending methodology.

Introduction

In seismic exploration, there is continuous drive towards more dense data sampling to better image complex geological structures. Recent advances in acquisition such as Wide-Azimuth, Multi-Azimuth or Rich-Azimuth acquisition can deliver a more diverse range of source, azimuth and offset sampling. To collect such data, multiple source and receiver vessels are deployed, thereby increasing the costs of the survey significantly. In conventional acquisition, there is zero time overlap between shot records, and data are recorded discontinuously. The source domain is often poorly sampled, leading to aliasing.

In simultaneous acquisition, data can be recorded continuously, and temporal overlap between shots is allowed. Consequently, more sources are fired during the same period of acquisition, which greatly enhances the flexibility in survey geometries. As a result, a more densely sampled data set in terms of source spacing, but also azimuth and offset distributions can be obtained. In terms of efficiency, simultaneous acquisition can contribute by reducing survey times, which is of particular value in critical situations where small acquisition time-windows dominate due to severe safety, environmental or economic restrictions. As such, from an acquisition point of view, simultaneous acquisition holds the promise of both efficiency and quality improvements. However, unless source separation can be achieved to a sufficiently high degree, the enormous potential benefits of simultaneous sources remain unrealized.

Method

In simultaneous source acquisition, seismic data is recorded with a temporal overlap between the shots. Better sampled data in terms of source spacing, azimuth and/or offset distributions can be obtained in a much more efficient way. These potential benefits can only be realized if the recorded data, with interfering energy from multiple sources, can be handled properly. Our approach is to apply randomized time-delays to the sources during the acquisition of the data. As a result of using randomized firing schemes, coherency measures can be utilized to actively separate the recorded data over the individual sources. Baardman et.al. (2013) have demonstrated that optimized randomization schemes, introducing “pseudo randomization”, instead of using random time-delays, can benefit the performance of the source separation. Such a scheme ensures that consecutive shots when looked at in the common receiver domain do not have similar or almost identical delays. Figure 1 shows a generic example of such a pseudo random scheme.

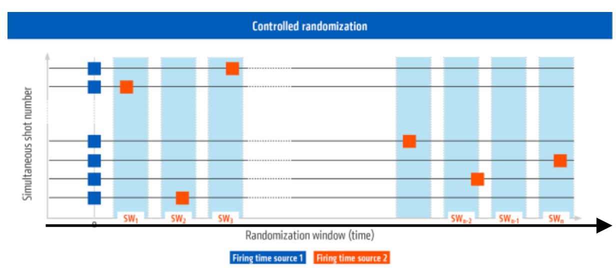

Figure 1 – *Pseudo randomization scheme; The first source is fired at time 0 and the second source is fired at a random time in a randomly chose sub-window. For the next shot the previously chosen sub-window is eliminated and can only be chosen again after a certain number of shots.*

Deblending strategies have always been formulated as an optimization problem with the aim to preserve signal Berkhout 2008). The differences are mainly in the type of constraints used for the unknown source (van Borselen and Baardman, 2012) or the type of solver used in the inversion (Kumar et. al, 2015). On the other hand, the performance of the signal preservation is highly depended on the domain and the bases used for the data reconstruction.
A slightly different approach takes its inspiration from compressional sensing. Recent rank-minimization based deblending method (Kumar et. al, 2015) performs deblending in each monochromatic frequency slice where

an explicit low-rank assumption is made on some spatial domain.

Simultaneous Long Offset (SLO)

Continuous long offset (CLO) acquisition combines a dual-vessel operation using only short streamers with a smart recording technique involving overlapping records (van Mastrigt et al., 2002). The dual-boat operation effectively doubles the streamer length, thus obtaining very long offset ranges. A compromise is that the effective inline shot spacing is doubled in comparison to single vessel operations. A revised configuration referred to as simultaneous long offset (SLO) acquisition is similar to the CLO configuration but involves simultaneous shooting of the forward and rear source vessels thus halving the inline (CLO) shot spacing and making it identical to a conventional setup with double the streamer length. It is thus possible to acquire surveys with total offset in the range 12-16km with only 6-8km streamer length deployed. A generic illustration of this acquisition template is shown in Figure 2.

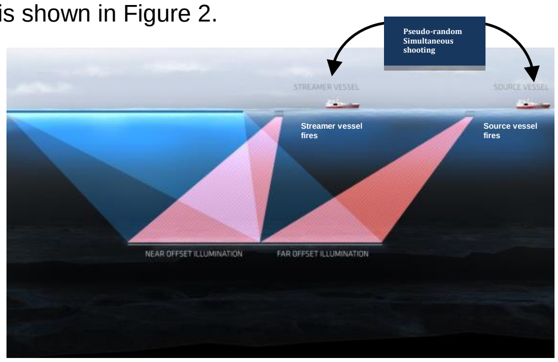

Figure 2 – *SLO (Simultaneous Long Offset) comprises two vessels; Front source vessel providing the long offsets and streamer vessel with source providing near to medium offsets.*

There are obvious operational benefits with shorter streamers and they include in sea maintenance, work boat exposure (HSE) as well as less exposure to barnacles in areas where this is a challenge. Infill can be reduced because of less feathering combined with the face that one can shoot for coverage with both streamer and source vessel. An example of modelled infill for a conventional 12km by 12 streamer scenario compared to the similar SLO configuration is shown in Figure 3.

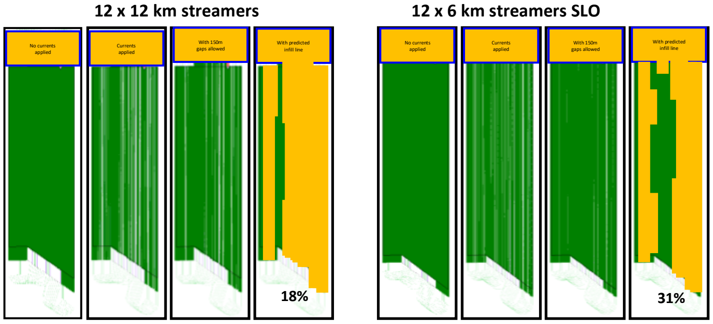

Figure 3 – *Modelled infill for a conventional 12 km by 12 streamers configuration compared to the similar SLO configuration. (Current data from West Africa)*

Blended and deblended gathers from an SLO acquisition are shown in Figure 4. The long offset source and the near offset source has been well separated. Another example of the power of source separation is shown in Figure 5. Here an SLO configuration with 8km streamers providing a total of 16km offset. In addition one experienced fairly strong SI which has been well separated as well due to the natural dithering between the interfering vessel.

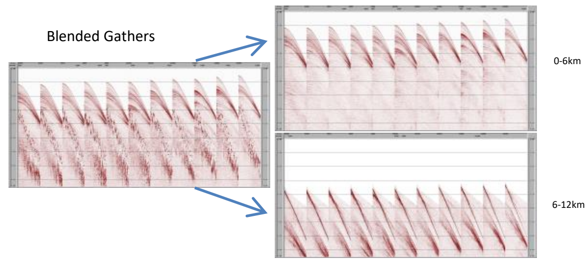

Figure 4 – *Blended gather to the left containing both long offset source and near offset source overlapping. To the right separated gathers containing the near offset range on to and the long offset gathers bottom right.*

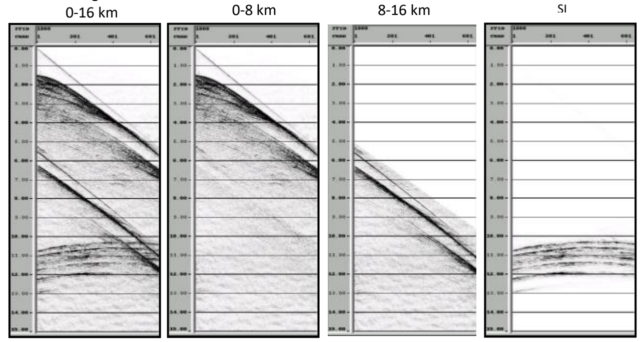

Figure 5 – *Blended gather to the left containing both long offset source and near offset source overlapping in addition to seismic interference (SI). In the middle the near offset gathers and the long offset gathers separated. To the right is the separated and subtracted SI.*

Simultaneous Wide Offset (SWO)

With the success of blended acquisition to provide long offsets one may contemplate to use the blended acquisition concept to improve acquisition concept to improve acquisition efficiency. Such an acquisition template applies to a deep water scenario where near offset information is not compromised to any considerable degree. The setup comprises again a source vessel and a streamer vessel but this time put side by side to double the subsurface coverage per sail-line. If sources were fired sequentially, either in dual source mode or in single source mode it would lead to loss of 50% fold. However with simultaneous shooting of both source vessel and streamer vessel source, the fold will not be compromised. This acquisition template is illustrated in Figure 6.

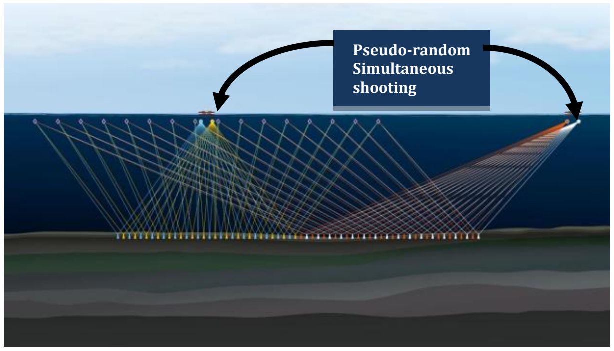

Figure 6 – *Simultaneous Wide Offset (SWO) for deep water acquisition.*

One should caution that a feasibility study is needed to make sure that survey objectives are met, given target and a given complexity of the velocity model including anisotropy.

Triple Source

Triple source has been proposed as a way to either improve subsurface cross line sampling with a given streamer separation or similarly improved acquisition efficiency with a given cross line bin size. Increasing the number of sources from 2 to 3 means that the in line source spacing is will increase by 33% unless overlapping records are used. With the overlap comes the need for the best possible way to separate the source contributions. The obvious way to solve this problem is to adopt active blending with controlled randomization of every shot and application of deblending techniques mentioned earlier in this paper. In addition going from 2 to 3 sources will reduce the source strength since one is forced to go from 3 to 2 subarrays per source. In the table below we summarize a number of possible acquisition scenarios.

Acquisition Parameters	Dual Source	High Density Dual Source	Triple Source	High Density Triple Source	P-Cable Single Source	High Density Triple Source
Streamer Spread	12x75m	18x50m	12x75m	18x50m	16x12.5m	16x37.5m
Crossline Bin Size	18.75m	12.5m	12.5m	8.33m	6.25m	6.25m
Sail Line Separation	450m	450m	450m	450m	100m	300m

Among the various tradeoffs one can mention that a high resolution survey with a relatively shallow target in moderate water depth seems represents a sweet spot for triple source acquisition. No overlap for primary target depth combined with the fact that attenuation is limited, signal to noise is good and therefore one can acknowledge the need for dense cross line spacing. Deeper targets which tend to put more emphasize on source strength, penetration and less need for the tight cross line bin space due to loss of higher frequencies. In a situation like that a triple source acquisition is not an optimal solution.

Broad Band Source

The source notch may limit the usable high frequency content of a marine seismic source. One way to overcome this and remove the source notch is to employ the over under principle and chose depths for the sub sources that creates maximum complementarity between ghost functions (Parkes et.al 2011)

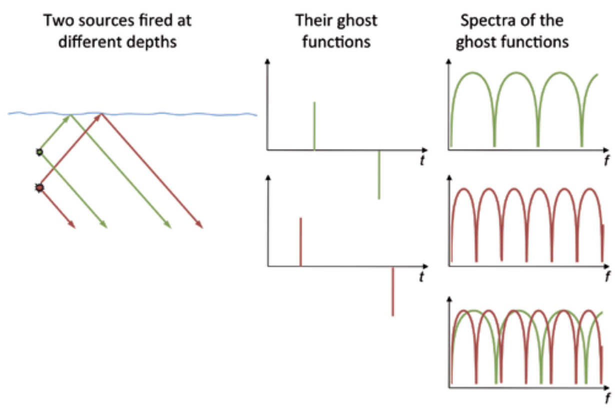

Figure 7 – *Schematic illustration of complementary ghost functions from sources deployed at two different depths.*

If the two sources were not fired simultaneously they would not be co-located and hence the Posthumus principles would not apply (Parkes et.al 2011). A ghost free source is yet another illustration of how blended acquisition has the potential to impact data quality. Figure 8 shows a data example where broadband source and dual sensor streamer are combined.

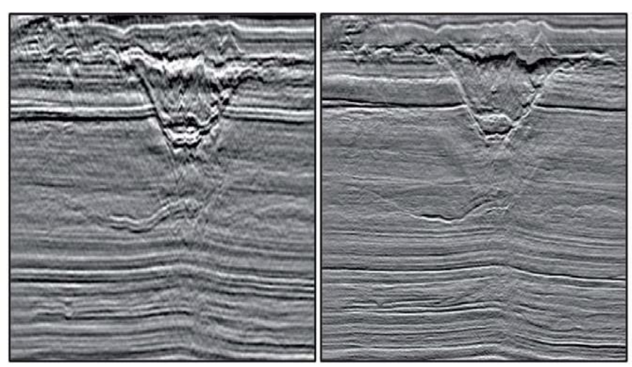

Figure 8 – *Left hand panel; Hydrophone only with conventional source. Right hand panel; Degosted data on both source and receiver side,*

Conclusions

Blended acquisition combined with a sophisticated and robust deblending technique can impact both quality and efficiency. We have demonstrated this through a range various applications. With a growing need for longer offsets, broader bandwidth and rapid turnaround these techniques hold the promise to deliver on these challenging requirements.

Acknowledgments

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