Blended Shooting and Multiple Sources – Improved Efficiency and Data Quality, Reduced Exposure

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Abstract

The ability to effectively deblend overlapping shot energy in processing has made dense shot and multiple source acquisition viable. This has opened up considerable flexibility in the survey design process, with significant increases in trace density resulting from each source added to the towing configuration. The benefits include the ability to acquire 6.25 m x 6.25 m bin high resolution seismic, substantially greater productivity for reduced project time and cost, and reduced HSE exposure for crew and equipment. This all comes without any additional capital or operational expenditure as no extra equipment is required offshore. The means by which this is achieved includes built in data quality safe guards to mitigate against any potential risks present in deblending through tailored survey design. This combination of data quality and efficiency upside, reduced HSE exposure, and debending risk mitigation through survey design has resulted in the steady growth in popularity of the Polarcus' dense shot, multiple source offering.

Introduction

Dense shot geometries create significant data quality and efficiency gains in marine towed streamer seismic. The use of multiple source acquisition to maximize subsurface sampling for a given towed streamer configuration is one well known example. Multiple sources require reduced shot intervals to achieve sufficient signal to noise and to allow pre-processing routines to be effective when applied to inline offset and midpoint gathers. Deblending in processing then becomes necessary to achieve the depth of investigation necessary to image deeper targets when reduced shot intervals are used. Because the significant benefits and continued potential of overlapping shots has long been recognized by the industry, there continues to be rapid progress in the field with new methods such as Seismic Apparition being introduced. Still, the potential risks are well known and it is crucial that any acquisition geometry that harnesses the benefits of dense shot acquisition also mitigates against potential or perceived risks of currently available deblending routines. Polarcus has combined the use of dense shotpoint acquisition, multiple sources, and deblending in processing to capture the efficiency and data quality gains, while mitigating against potential risks to the final product through its XArray™ offering.

Method

The number of inlines per vessel pass is equal to the product of the sources and streamers being towed. Historically, streamer spreads have grown to keep pace with increasing demands for productivity and cost reduction. Sources were limited by the combination of inline sampling requirements on midpoint and offset gathers, and overlapping shot energy making more streamers the natural choice. Had it been a technically viable option at the time to grow source arrays to the extent that streamer arrays did, we might have seen quite different geometries today. Instead of the current industry default 12 streamer, dual source configuration, a 5 source - 5 streamer setup might have been the go-to configuration of choice providing comparable subsurface coverage and efficiency. Undoubtedly a configuration of such magnitude would have come at greatly reduced cost and exposure for service providers and ultimately operators. Nonetheless, the fact that streamer spreads have gotten so large, and multi-source acquisition is now technically viable, means that each extra source added to the configuration results in drastic increase in trace density. On a 12 streamer spread, the number of CMP lines increases from 24 to 36, by adding and extra source to a dual source configuration. When the cross-line bin dimension between these two geometries is maintained, the triple source geometry achieves 50% more coverage per vessel pass than the dual source geometry. If instead the streamer separation is maintained, the crossline bin size is 1/3 smaller resulting in improved spatial sampling and data quality. Undoubtedly there is great flexibility gained here and the number of sources, the number of streamers, and the streamer separation can be tailored to achieve the data quality fit for project geophysical objectives, and efficiency to minimize project cost.

Figure 1 below plots efficiency and data density for some common conventional and XArray™ geometries. On the maximum efficiency end of the spectrum, modern deflector and front-end drag reduction technology means that line intervals of 1km wide can be achieved with a 2 km wide streamer spread. Polarcus averaged 180 km^2 of acquisition per day for over 12,000 km^2 of proprietary work offshore Myanmar in 2016 by using a spread of this width. To give an idea of magnitude, *Figure 2* shows a picture of the Polarcus Amani and her port side deflector while acquiring that survey. While some suggest that ultra-wide spreads may not be suited to shallow water and certain types of geology, there are certainly great benefits in cases of budget constraints, tight shooting season, substantial pre-commits, or as a high quality alternative to basin-wide 2D.

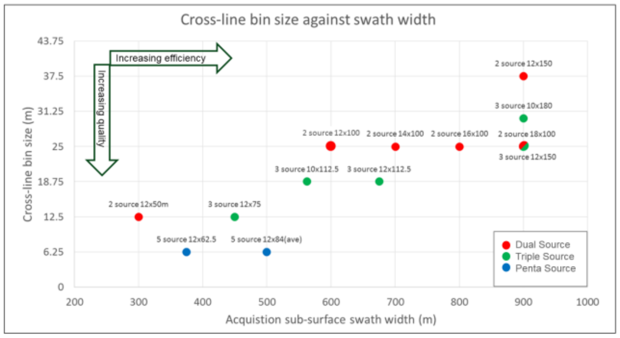

Figure 1: Productivity versus data quality plotted for commonly used dual source, and XArray™ triple and penta source geometries.

Referring again to *Figure 1*, an ultra-wide spread with dimensions comparable 10 x 200 m would require 18 streamers to achieve the same 25 m crossline bin size that is achieved with 12 streamers and triple source. This has knock-on implications for capital outlay needed to purchase and host large volumes of equipment offshore, operational expenditure associated with acquiring with that many streamers, and the HSE exposure both due to the additional 50% in-sea equipment and the time required to maintain it via workboat missions and deployment and retrieval.

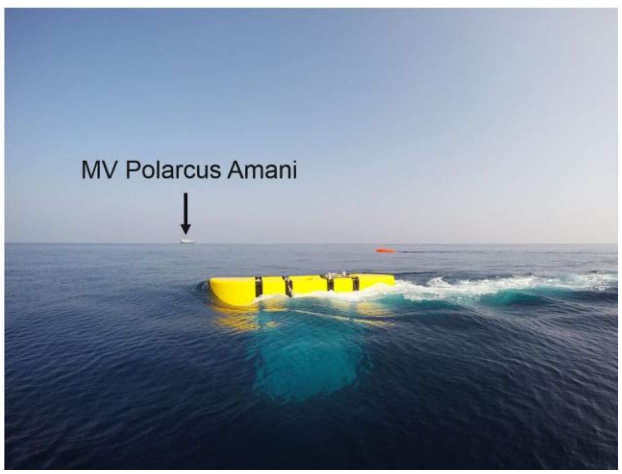

Figure 2: The Polarcus Amani is shown in the background, over 1000 m away from her port side deflector. This picture was taken while acquiring a natural line interval of 1000 m offshore Myanmar.

On the high density end of the XArray™ spectrum, 6.25 x 6.25 m bins can be achieved with reasonable efficiency through the use of 5 sources in the Penta Source configuration as described by Hager et al (2015). Improved spatial sampling of the seismic wave field in the crossline direction has a number of benefits for acquisition and processing. The first and most notable is the increase in maximum unaliased frequency recorded in the crossline direction as shown in *Figure 3*, making broadband products viable in the crossline direction. This results in improved temporal and spatial resolution, especially in the presence of steeply dipping events such as diffractions off of faults or complex salt bodies. It stands to reason that higher trace density results in better attenuation of multiple and high frequency noise as these are properly sampled as opposed to being aliased and redistributed during migration. Higher resolution sampling, combined with more effective multiple and high frequency noise attenuation means that complex overburden is more accurately imaged. Indeed this is of great benefit in salt provinces where deeper targets need accurately modelled overburdens to avoid imprinting and distortion of pre-salt targets.

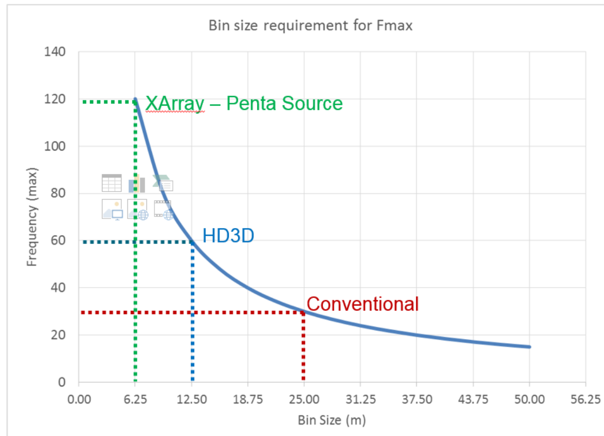

Figure 3: Bin size required to record maximum unaliased frequency indicated by the solid blue curve assuming water velocity and 30^0 dip.

The efficiency and data quality benefits of multiple sources through dense shot acquisition are undeniable, however to ensure its continued success and growth in popularity, it is important to address areas of possible concern through mitigating risk. Willen et al (2015) describe three areas of possible concern as: interference that finds its way through the processing flows into the final image or angle gathers, signal attenuation during deblending, and unplanned fluctuations in the source-receiver geometry stemming from the randomized shot schedule. Berkhout et al (2008) distinguishes blended shooting from simultaneous shooting as the continuous recording of multi-source responses that overlap in time, where delay times between shots may be large (up to seconds). In XArray™, delay times are greater than 3.5 seconds on average and typically vary about 5.5 seconds in the most common case of 12.5 m shotpoint intervals. Blended shooting as described by Berkhout et al (2008), and implemented in XArray™ allows for several benefits and protections to be incorporated into the acquisition design while still achieving improved inline shot density. Firstly, a regularly spaced grid of preplot shotpoints can be used in acquisition as the randomness of shot times needed for effective deblending is achieved from the natural variation in time taken for the vessel to travel between preplotted shotpoint locations. This removes the need for a system generated random time dither, and avoids the 4D repeatability issues (unplanned fluctuations in source-reciever geometry) described by Willen et al. Secondly, when a regularly spaced shotpoint grid is used, the shotpoint interval is chosen in the survey design exercise to achieve the required inline fold, while at the same time ensuring that the primary targets fall within the “clean” zone between consecutive mudline reflections. This is the means by which crosstalk in the final image is mitigated against for example, where there is no prior experience in a particular geologic setting. Aaron et al (2016) describe how a risk analysis using these principles was performed prior to acquisition of the second phase of a conventional dual source program to ensure suitable protection of primary target zones when using triple source for improved efficiency.

400 km^2 of XArray™ penta source data were acquired in 2015 for Quadrant energy off the west coast of Australia, achieving 6.25 x 6.25 bin size in a deep water setting. An additional 50 km^2 area was then reacquired using conventional dual source acquisition with 6.25 m x 25 m natural bin size. Both datasets were taken through equivalent processing sequences PSTM for fast track, and PSDM for full onshore processing. *Figure 4* below shows the comparison of convention vs penta source for fast track PSTM and full processing PSDM. The uplift in image resolution is clearly apparent between conventional dual source and penta source images.

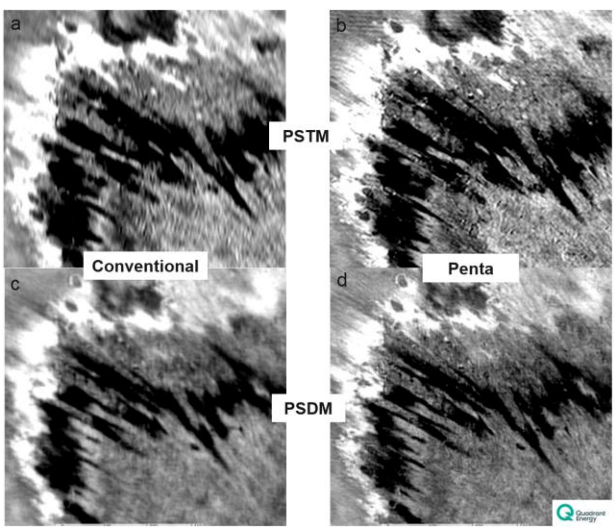

Figure 4: An equivalent time slice comparing penta source and dual source datasets over the Baxter field acquired for Quadrant Energy in 2015. Conventional images are on the left, with Pena Source on the right. Fast track PSTM are above, and full processing PSDM are below.

Conclusions

Productivity gains in terms of reduced survey duration and cost, as well as data quality incentives and reduced HSE exposure make the use of multiple source acquisition and dense shotpoints an appealing proposition. Polarcus has acquired over 40,000 km^2 of dense shot, multiple source data under the XArray™ banner since 2015, with another 30,000 km^2 already booked for 2017 and 2018 projects. Part of the appeal of the method is its use of blended shot acquisition allowing for primary target protection, facilitating entry into previously untested geologic settings. Its regular grid of preplot shotpoints makes it a viable 4D solution. These benefits are achieved with no extra in-sea equipment requiring additional capital or operational expenditure and HSE exposure.

References

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