Blended Source Ocean Bottom Node Seismic Data Acquisition – A Case Study*

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Abstract

Blended or "simultaneous" sources have recently been introduced in land seismic operations with dramatic improvements in both crew productivity and data quality. The application offshore, however, has been relatively limited so far. For towed streamer surveys the firing of more than one source at a time increases the fold of coverage and hence data quality but for ocean bottom seismic (OBS) the use of two or more blended sources can have a dramatic impact on survey duration and hence cost. The challenge has been how to ensure not only no loss of data quality when multiple sources are fired at once but also that technical downtime of the equipment on the seafloor is minimized.

Traditionally the performance of OBS systems has been hampered by the inherent technical downtime experienced by all the contractors operating ocean bottom systems – the terminations, connectors, power distribution and data telemetry components within a traditional ocean bottom cable (OBC) system are inherently prone to failure due to the intrinsic nature of the cable deployment /recovery cycle where the cables are stressed and de-stressed every time they are laid onto/recovered from the seabed. It is akin to recovering the full streamer spread every line change for towed streamer operations.

The desire to improve operational performance was the driving force behind the development of autonomous nodal systems and its extreme reliability has allowed ever larger seafloor spreads to be operated.

Nodal Technology

Since its commercial introduction in 2009, more than 300,000 node deployments have been made in water depths ranging from 20 to 1,200m in the Red Sea, North Sea and Gulf of Mexico. The data recovery from these deployments has been in excess of 98.7%, which is a remarkable figure for seismic equipment reliability; either land or marine but is not altogether surprising since the traditional sources of technical downtime have been eliminated. The greatest benefit of this outstanding technical performance is that we can now focus on improving the overall operational performance of the crew.

Shot Considerations

Shot Effort: With small receiver spreads the duplication of shot effort is very time consuming and hence costly. With high density shot "carpets" – a shot grid with shot locations every 50m in both the x and y directions – some shot point locations will have as many as eight shots. With the larger seafloor spread sizes that the greater reliability of nodal systems affords this replication of shot effort can be significantly reduced (Figure 1).

Shot time: Since we are working with static recording spreads, even with so-called "rolling" geometries where a portion of the receiver spread is moved between successive shot salvos, the time taken to shoot the shots dictates the overall rate of acquisition. There are not many variables that we can control to reduce this if we want to retain high fold although the traditional restriction regarding the speed of the shooting vessel through the water being limited by the required record length no longer applies with the continuous data recording available from the nodes. We can select the record length after the data have been recorded and can even have records that contain more than one shot from the same source vessel. Looking at the very dramatic improvements in source performance that have been achieved onshore using a variety of "simultaneous" vibratory sources, the uplift in OBS survey performance that can be achieved by firing more than one source into an OBS spread drops straight to the bottom line since survey durations can be almost cut in half for a relatively modest increase in daily operating cost resulting from the addition of another source vessel.

The key to this is the ability to separate or "de-blend" the two (or more) shots recorded by each receiver. We have adopted the approach taken by Delft University (Mahdad, et al., 2011) namely to remove from the desired source those incoherent events from the other or un-desired source. Rather than try to synchronize the sources with a defined intra-source time dither as has been done for towed streamer blended source acquisition (Beasley, et al., 2012) we have adopted an autonomous source approach proposed and patented by Apache Corp whereby each source vessel operates entirely independently acquiring source points on a pre-determined pseudo-random spacing and thus the energy from the "other" shots appears as random events in the common receiver gathers for the "desired" shots. Figure 2 shows shot gathers before and after de-blending.

From the continuous recording in each node we extract two (or more for more sources) sets of common receiver gathers, each timed according to their respective shot times (Figure 3). Application of an "incoherent energy" filter and iterative thresholding allows for a high quality signal estimate, which can be mapped to the time and location where that same energy occurs as interference to the other source(s). The only information required to do this is the time and location of each shot, no source signature or water column information – depth, water velocity – are needed. Testing using data recorded in situ in the Gulf of Mexico has indicated that the de-blending process is robust down to extremely close source separation distances of the order or a few tens of meters. This is because the de-blending process in undertaken in the common receiver domain and thus the only attribute that controls the success of the de-blending process is the incoherency of the undesired shots. Subsequent processing is exactly as for non-blended conventional acquisition.

One point to note is that we can apply this de-blending methodology to other sources. If we know the precise shot times and approximate geographical locations of the undesired/interfering shots these can also be "de-blended." Thus, we can remove the impact of Seismic

Interference (SI) as long as the SI is incoherent with the energy from the desired shots. This also applies to the second shot from a given source that will appear if a record length is selected after acquisition that is longer than the acquisition shot interval.

"Super Crew" Configuration

In order to maximize the operating performance when utilizing large channel count spreads on the seafloor we have incorporated a dual function or "hybrid" vessel which is equipped with both receiver node deployment and operating equipment as well as a seismic source (Figure 4).

This allowed us to both reduce the vessel count on the crew, excluding support/chase vessels, to three and also to deploy and recover the 4,200 nodes we are shooting into, equivalent to 210km of spread, using two-node handling systems. At sustained node deployment and recovery rates of 100 nodes/vessel per hour this means we were able to both deploy and recover the entire 52.5km^2 area receiver patch in less than one day. The shot/receiver effort for each patch is shown in Figure 5.

The 12 x 17.5km receiver lines, spaced at 250m, are laid N-S and the shot-lines are E-W. To further reduce shot effort the survey is being shot "single-sided" i.e. all the shots outside the receiver area in the cross receiver line direction (E-W) are only shot to the east of the spread. This reduces the source effort by almost a factor of two, which has significant survey duration and cost implications. Inline shot offsets of 9km are required for deep target imaging whilst the cross-line shot offset is 6km. Thus, the shot area for each patch is 35.5 km x 9 km, almost 320km^2. With a shot-line spacing of 250m and a shot spacing of 37.5m the number of shots per patch is over 34,000 with each source vessel nominally acquiring ~17,000 shots each. The operation begins with one source vessel commencing at the southwestern corner of the receiver area and the second source vessel mid-way "up" the receiver area at an offset of almost 18km. Each vessel then shoots wholly independently until the entire shot area is covered.

Conclusions

By employing such a large spread – initially 4,200 active receiver locations but later increased to 5,200 – and using blended sources the 2,200km^2 survey was acquired in less than one year with obvious economies of scale. This was only possible due to the reliability of the nodes. If such a large-scale survey were to be attempted with OBC systems, the ensuing technical downtime would render the whole operation commercially unviable. Blended source acquisition demonstrably affects survey duration/costs and is expected to become de rigueur for 3D OBS surveys. Whether or not it will have application for 4D will depend on the nature of the 4D signal being sought and will have to be evaluated on a case-by-case basis.

Acknowledgements

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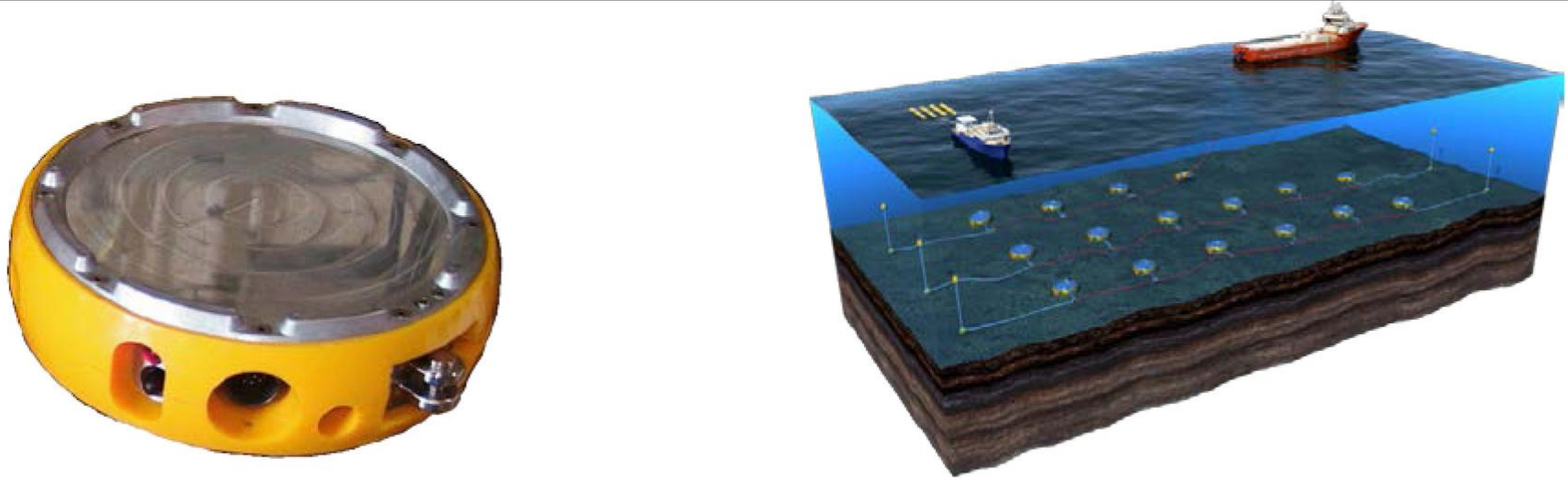

Figure 1. a) Z700 node; b) nodes in operation.

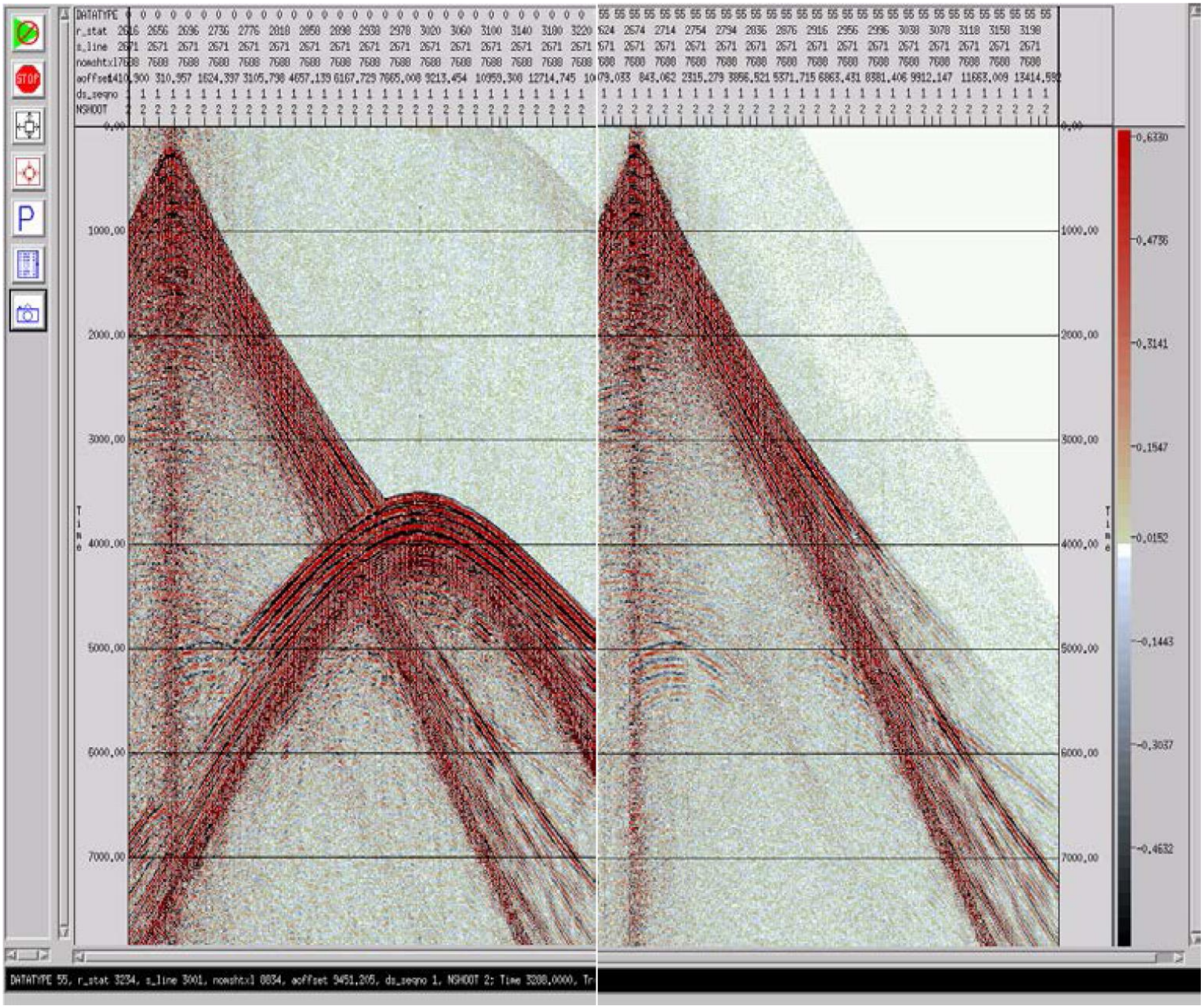

Figure 2. a) Common shot gather - blended shots; b) common shot gather - de-blended shots.

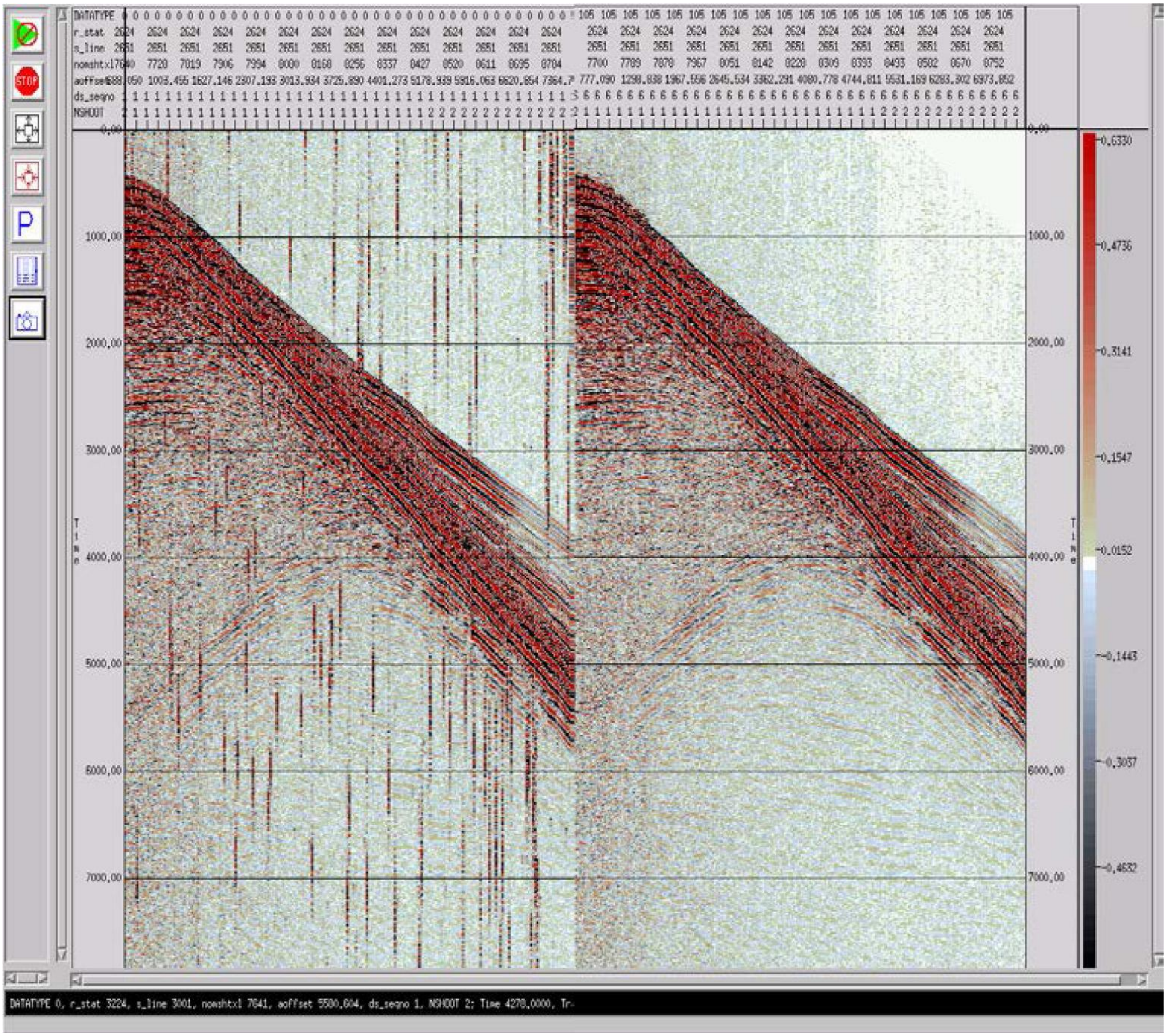

Figure 3. a) Common receiver gather - blended shots; b) common receiver gather - de-blended shots.

Figure 4. European supporter – hybrid node handler/source vessel.

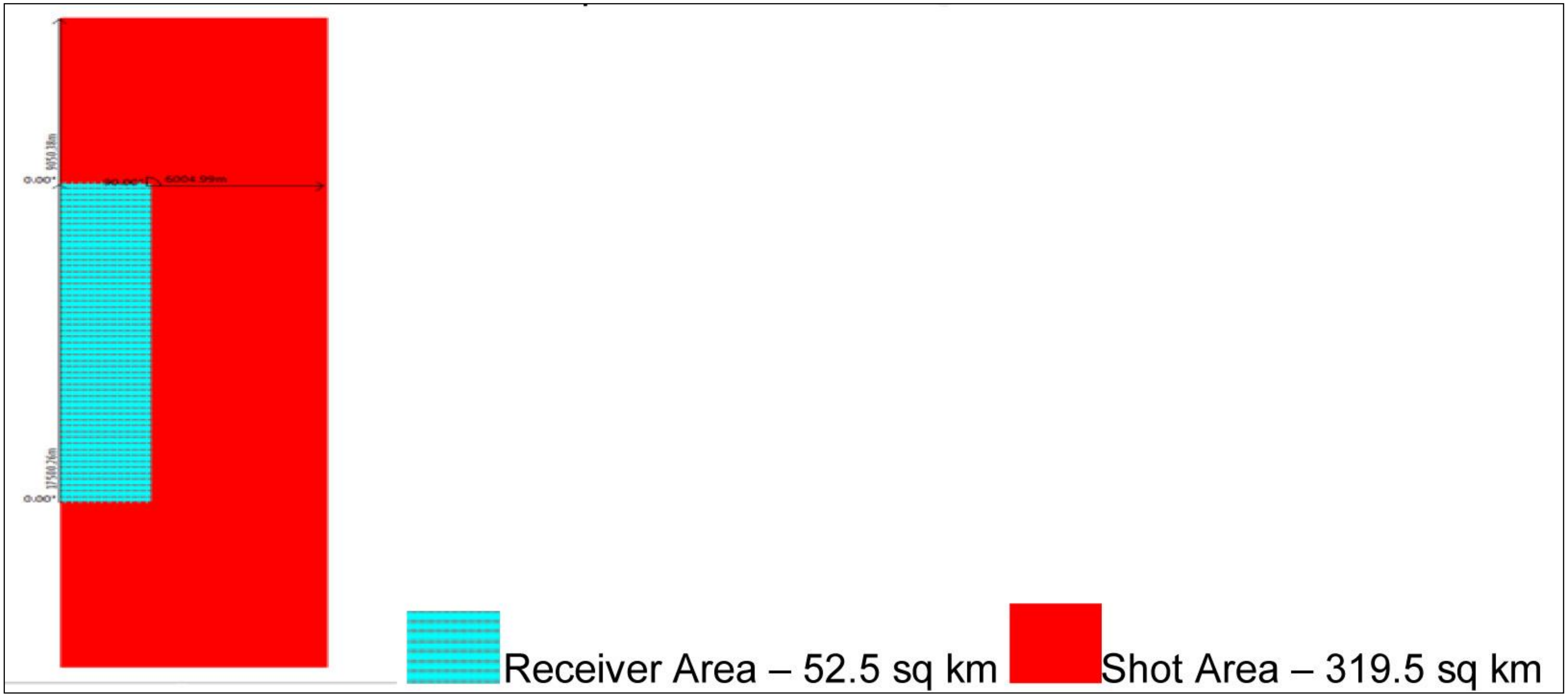

Figure 5. Super Crew acquisition geometry.