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Exploring the Extent to which Streamer Separation Can Be Relaxed when Using a Multimeasurement Streamer

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SUMMARY

Herein, we explore how we can enable increased efficiency in marine seismic acquisition by using the data recorded by a multimeasurement streamer to allow the relaxation of the usual constraints on crossline streamer spacing - thus, obtaining the desired resolution while towing the streamers farther apart.

Pressure and pressure-gradient measurements acquired by multimeasurement streamers are used to reconstruct the wavefield between the streamers; this is achieved using the generalized matching pursuit (GMP) algorithm. GMP performs wavefield reconstruction and full 3D receiver-side deghosting using multimeasurement data from the streamers, as described by Robertsson et al. (2008).

Although these scenarios can be modelled using synthetic data, it is important to evaluate real seismic data to understand the impact of variables such as acquisition conditions.

In this work, we analyse the results from a field test acquired in the North Sea using multimeasurement streamers. In the field test, a line of data was acquired using a 75m cable separation and then repeated using a 100m streamer separation.

We consider to what extent we can increase streamer spacing and acquisition efficiency without compromising the spatial resolution, concluding that this experiment supports the case for reconstruction at 100m streamer spacing.
Introduction

Efficiency in marine seismic acquisition is, in part, a function of the compromise made in towing a wide acquisition spread, thus giving the vessel a large seismic footprint and still acquiring seismic data of sufficient quality and resolution—specifically crossline resolution—to deliver data that meet acquisition objectives.

In a conventional marine seismic acquisition, where a measurement is made, of the total pressure wavefield alone, data-resolution requirements place a constraint on streamer spacing, and the streamer separation chosen is usually decided in part by a survey design and modeling study. However, inevitably, this decision is also influenced by resource and timing constraints. Hence, with a limited number of streamers, the overall spread width is limited and/or the data spatial resolution is compromised.

However, the pressure and the pressure gradient measurements made by a multimeasurement streamer can be used to reconstruct the wavefield between the streamers, and this is achieved using the generalized matching pursuit (GMP) algorithm. GMP performs wavefield reconstruction and full 3D receiver-side deghosting using multimeasurement data from the streamers (Robertsson et al. 2008).

If the data between the streamers can be successfully reconstructed, the streamer separation can be relaxed without compromising the spatial resolution of the data, as would be the case if only the pressure measurement was acquired. Hence, high spatial resolution can be retained but with a wider acquisition spread, and, therefore, more efficiently.

The benefits of efficient acquisition are well understood; the acquisition duration is reduced, with direct financial savings. Associated benefits include reduced exposure to weather and operational challenges.

The reconstruction will become more difficult as we acquire with larger streamer separations. The most challenging issue for reconstruction is always the point equidistant between two streamers, as this is furthest from the actual measurements. As we increase streamer spacing, we increase the distance of this point from the actual measurements. Hence, we must quantify both at what point the technique will break down, or if it does not break down, then at what point the deterioration in the results is no longer acceptable for the requirements of a particular seismic acquisition.

Vassallo et al. (2012) showed that wavefield reconstruction is easily achieved and accepted with streamer separations up to 75 m. We show that, with a wider separation of 100 m, the wavefield can be efficiently reconstructed, producing equivalent results that are comparable to the accepted 75 m separation results.

Data acquisition and analysis

To investigate the effect of increasing streamer separation on the quality of the reconstruction for real seismic data, a 3D test data set was acquired in the North Sea using a multimeasurement streamer. An initial acquisition was carried out with a streamer separation of 75 m; then, the line was repeated with an increased streamer separation of 100 m over the same pre-plot line.

A standard preconditioning processing flow was applied to the data prior to reconstruction using the GMP technique, primarily to address residual noise on the measurements. The data were then input into the GMP workflow and the wavefield reconstructed on a 6.25-m by 6.25-m surface grid.

As well as visual comparisons in a number of domains, a detailed analysis was carried out post GMP to evaluate the reconstruction of the wavefield acquired with a 100-m separation, compared with the 75-m separation.
In comparing the results, it was important to consider other variables that are inevitably introduced into the experiment when real seismic data are acquired. These include the variability in sea-state conditions between repeat passes of the sail line—even if the acquisition is repeated immediately. Also, inevitably, there is some variation in the streamer positioning for the repeat passes.

**Results**

The data examples in Figure 1 show reconstructed crossline gathers encompassing both the original streamer locations plus all infill locations at 6.25-m virtual streamer spacing. These examples show comparable results for reconstruction of the total pressure wavefield at these two different tow separations, and also reflect the wider acquisition obtained using 100m streamer separation.

Figures 2 and 3 show a selection of time slices of the total pressure wavefield from a reconstructed shot record, again comparing 75-m and 100-m streamer separations. Figure 4 also shows the 100-m reconstructed upgoing wavefield for further comparison.

In addition to standard visual data inspection shown in Figures 1 to 4, a more quantifiable analysis was also conducted, including generating and comparing spectra for the signal and noise components of the recorded data. Figure 5 shows an example of the data analysis where the root-mean-square (RMS) amplitude is measured and compared over a given frequency band and defined time window on shot-domain data following the wavefield reconstruction for both 75-m and 100-m streamer separations. Here, the general amplitude pattern is consistent for both streamer separations and appears to correlate with geological variations rather than reflecting the acquisition cable geometry.

**Figure 1** Comparison of 100- versus 75-m streamer separation reconstruction, as seen on crossline gathers for the upgoing wavefield at 6.25-m spaced virtual streamer locations, for 3 seconds of reflection time. The crossline gather shows the increased trace density achieved following the wavefield reconstruction to 6.25m trace spacing, for both the 75m and 100m streamer separations. Additionally we see the wider acquisition achieved by using 100m streamer separation, without obvious compromise to data quality.
Figure 2 Time slices of reconstructed total pressure wavefield for a shot record acquired with 8 streamers, 3 km in length, with a 75-m cable separation. Anticlockwise from top left, time slices are extracted at 0.3, 0.9, 1.5, 2.1, 2.4, and 2.7 s.

Figure 3 Equivalent Time slices of reconstructed total pressure wavefield for a shot record with 100-m cable separation showing increased subsurface coverage and a similar image.
Figure 4 Equivalent time slices of reconstructed upgoing pressure wavefield for a shot record with 100-m cable separation.

Figure 5 RMS amplitude maps from reconstructed shot-domain data, measured over a defined 2-s window over the area of interest; on the left for a 75m streamer separation, and on the right for a wider 100m streamer separation.

Conclusions

Analysing this experiment’s results demonstrates that the reconstruction quality was comparable for both 75-m and 100-m streamer separations. This provides confidence that, it is possible to relax the streamer separation, specifically from 75 m to 100 m, and still reconstruct the wavefield to the finer crossline sampling to a quality that is acceptable for seismic exploration applications.

Hence, the multiple measurements of pressure and pressure gradient allow more efficient (and safer) acquisition configurations without compromising crossline sampling. This remains an area of open investigation, and additional data points, including wider separations, are required to fully explore the limits of the reconstruction techniques and to determine the limit at which the technique breaks down. This extends to further analysis to establish criteria for exploration seismic measurements vs. appraisal and development seismic acquisition, should different criteria be necessary.

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References

