Increasing the Efficiency of Acquisition in a Busy North Sea Season - Dealing with Seismic Interference

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SUMMARY

This paper describes a new method for on-line evaluation and acceptance of seismic interference (SI). The project was split into three phases. The first phase utilized existing data with SI issues and was aimed at removing these, while at the same time defining a fixed processing flow that could be used on-board for on-line acceptance of SI noise. The second phase was a shorter field verification trial, aimed to test and verify findings from phase 1 – would the flow work and were we able to acquire good seismic data within close proximity to each other (<50 km between active seismic vessels) and still get good data? The final phase of the project was the acquisition of two larger exploration programs whilst not having to shut down for SI. The project was a success. We were able to monitor and remove SI noise – during production and to such a degree that the two vessels could reduce the distance between themselves down to ~40 km whilst still acquire good seismic data. This allowed the two vessels to optimize the acquisition such that only a few hours of downtime for time-sharing were incurred over a period of 5 weeks simultaneous acquisition.

Introduction

This paper describes a new method for on-line evaluation and acceptance of seismic interference (SI), thereby reducing both time-sharing and cost for all involved parties. The project was split into three phases, where the first part took place prior to any field activity. This utilized existing data with known seismic interference issues and was aimed at removing these, and at the same time to define a fixed processing flow that could be used on-board for on-line acceptance of seismic interference noise. The second part was a shorter field verification trial, in the area of the larger seismic acquisition program, aimed to test and verify findings from phase 1 – would the flow work and were we able to acquire good seismic data within close proximity to each other (less than 50 km between active seismic vessels) and still get good data? The third and final phase of the project was the acquisition of two larger exploration programs whilst not having to shut down for seismic interference. The project was a success. We were able to monitor and remove seismic interference noise during production and to such a degree that the two vessels could reduce the distance between themselves down to approximately 40 km whilst still acquire good seismic data. The minimum distance of 40 km allowed the two vessels to optimize the acquisition plan such that only a few hours of downtime for time-sharing were incurred over a period of 5 weeks simultaneous acquisition.

Background

Exploration for oil & gas in the North Sea region is in high demand. Recent large discoveries illustrate the potential in the region and oil companies have been quick to raise their activities to new levels. During a typical July summer month of 2011 and 2012, more than 20 seismic vessels operated simultaneously in the North Sea, see Figure 1. This dense population of seismic vessels and active air-gun sources represents a challenge when it comes to dealing with seismic interference and sharing of acquisition time.

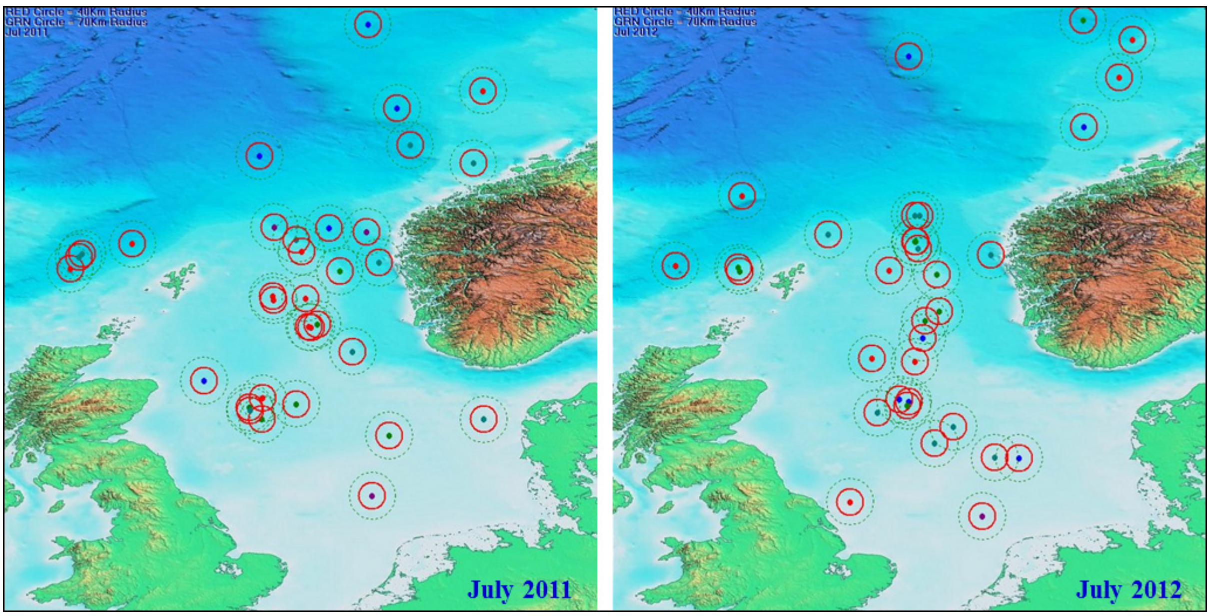

Figure 1 *Seismic vessel locations in the North Sea region for the two summer months, July 2011 and 2012. The red circles represent 40 km distance from center of the survey areas. Dotted circles represent 70 km distance. Overlapping circles indicate areas where the vessels had to time-share with each other due to excessive SI noise (source NPF).*

Historically one has assumed that within a distance of less than 70-100 km one has to time-share as the SI levels would otherwise be too high and the resultant data quality would suffer. In the scenario above – where more than 20 seismic vessels are operating simultaneously in the North Sea – smarter solutions and possible acceptance of higher seismic interference noise levels are sought after.

Method for removal of seismic interference

Several methods are available for removal of seismic interference, see Yu (2011) or Gulunay (2008). This paper does not intend to revisit these – but is instead focused on using a robust method that can handle SI for most cases without the need for much testing or tweaking. One such method, which is available from most seismic processing companies, is the "*tau-p-common-p*" approach, illustrated in Figure 2. This uses a linear-radon transform from shot domain *time-offset* to shot domain *tau-p*. After a whole seismic line of shots has been transformed, individual *p-traces* are sorted into *p-ensembles*, where a noise detection process is applied to detect and remove the seismic interference spikes. The zeroed samples are then reconstructed using FX prediction. After detection, removal and interpolation, the data are transformed back to *time-offset* domain and the SI noise can be removed (using least-squares subtraction) from the raw input data again – if one wants to avoid transforming the complete dataset. The power of this method is that it only relies on the SI noise being random from shot to shot. After transformation and sorting into *p-ensembles*, the geology will be continuous and any seismic interference will appear as random "spike" noise. The method can handle very large amounts of SI – and also any number of SI elements, as long as they are random from shot to shot within common *p-traces*. Since the method relies on transforming single shots via a linear radon transform – heavy swell noise contamination can be a problem. It is important to remove such random swell noise – prior to addressing the SI noise.

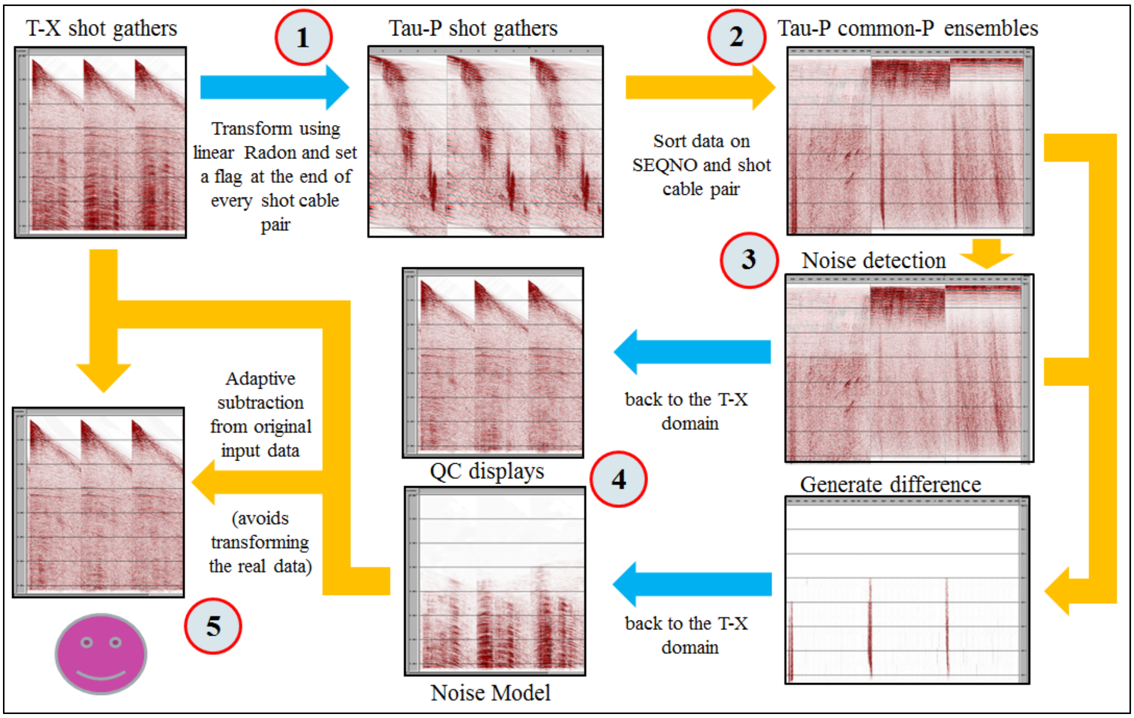

Figure 2 *Illustration of the workflow for the "tau-p-common-p" SI removal method. Going from top-left to lower-left corner; 1) Transform the whole shot line from t-x space to tau-p. 2) Sort the tau-p shots into p-ensembles. 3) Run a noise detection process and then 4) transform the noise back to t-x space. The last step 5) is to subtract the SI noise from the raw input data again.*

A real field trial

In the early months of 2011 it became apparent that two seismic surveys (see figure 3) were going to be shot in close proximity to each other in the same time period by two different vessels. Both vessels were from the same seismic company – so it was deemed appropriate to start an investigation into seismic interference, to possibly assess the impact that SI would have on the two operations as well as a detailed analysis into what can be done to reduce time-sharing to an absolute minimum.

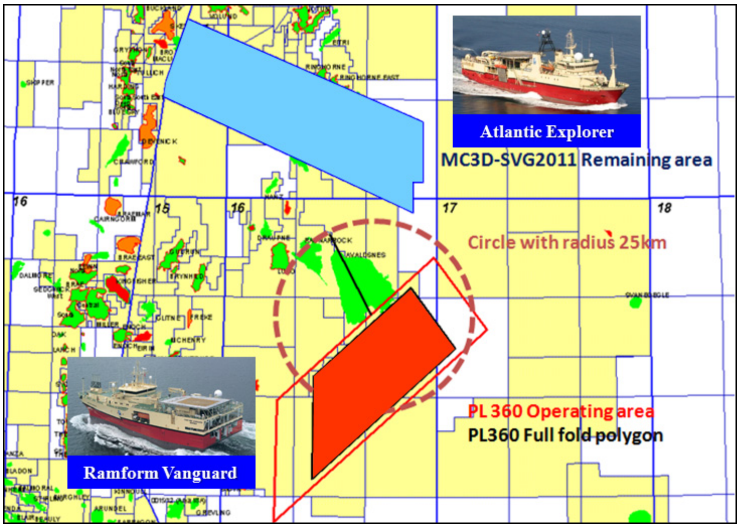

Figure 3 *Map showing the two seismic survey outlines and distance between them. The minimum distance between the two surveys is less than 20 km so it was expected that quite a lot of time could be spent in lieu of time-sharing.*

The project was split into three main phases. Phase 1 was a pre-study to demonstrate the SI removal toolbox and define a plan and procedure including a set processing flow for onboard processing to evaluate and eliminate SI whilst keeping up with production. The "*tau-p-common-p*" method was the chosen one – and detailed flows and instructions were then passed to the onboard crews for utilization during the actual seismic acquisition. The 2nd phase was a short field trial, at the start of the seismic programs – where one line was shot twice – first with SI and the 2nd time without any SI contamination from the second vessel. Results from phase 1 were utilized to demonstrate that the SI encountered could be removed to an acceptable limit. A lot of work also went into determining such SI limits both in terms of microbars, distance and direction. The 3rd and final phase of the project was the acquisition of the two large seismic programs simultaneously utilizing all the learning's and minimizing the time-sharing.

One major outcome of the pre-study phase and the field trial phase was a number of QC plots used to determine the acceptability criteria for SI noise levels. A selected number of these plots are shown in figure 4, where the test line is displayed and analysed for acceptance of SI removal. Similar plots were generated for each sequence as the large acquisition projects commenced.
As more and more data was acquired it became apparent that the SI removal method chosen would be able to handle SI levels of roughly 40 microbars in this specific area. This level was reached at approximately 40 km distance between the two seismic vessels – the rule of thumb became a 40/40 rule - maximum 40 microbar SI noise which should occur at roughly 40 km distance. It is worth mentioning that this specific rule is expected to vary from survey to survey and as such is not uniformly adoptable. Using these simple criteria, the two vessels were able to optimize the production plan such that during 5 weeks of simultaneous acquisition, only 8 hours of SI standby time was incurred. After completion of both surveys it was estimated that this new method for online acceptance of SI noise saved 3-4 days of production time for each vessel.

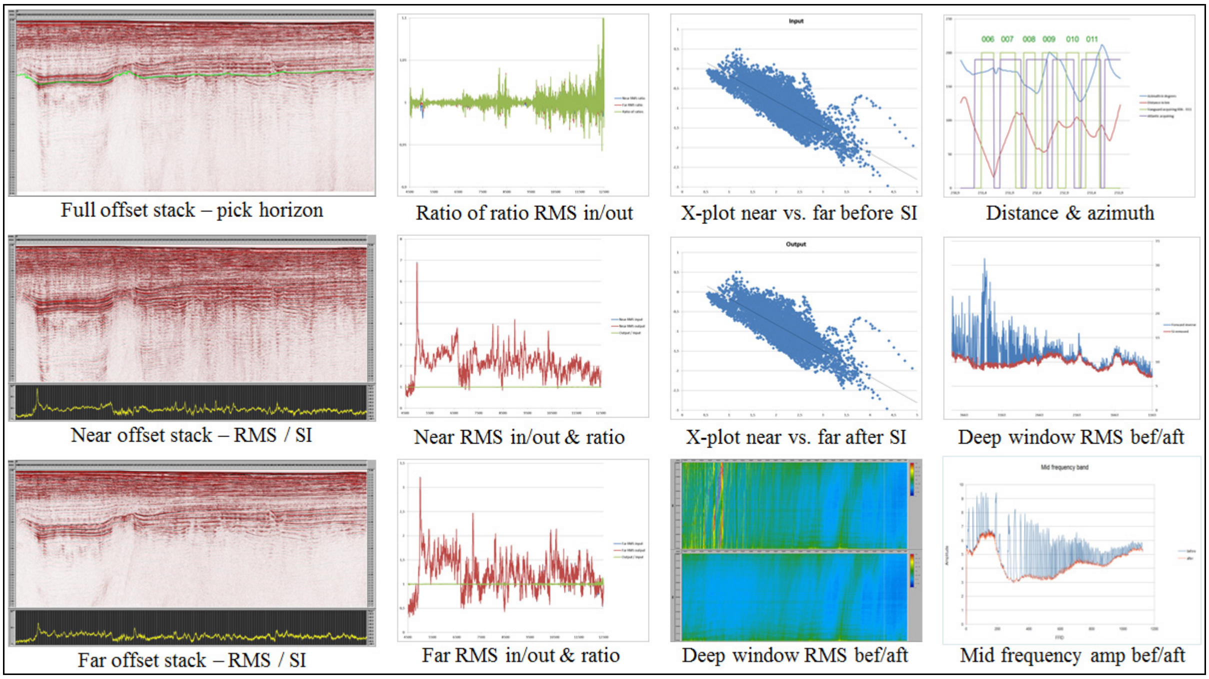

***Figure 4** Seismic interference QC plots from the test line acquired as phase 2 of this project. The line is displayed as a full offset brute stack – then various analyses (RMS, near vs. far, x-plots and distance & azimuth) of the data are shown before and after SI removal. The plots demonstrate that the SI removal does not affect the signal content or amplitude behaviour of the real data, but only removes the SI noise.*

Conclusions

The *tau-p-common-p* SI removal flow has been demonstrated to be very robust for elimination of SI noise. The method uses no a-priory information and can handle SI from several sources at the same time. From this case study we were able to demonstrate that the method has no discernible effect on attributes of the data, such as high and low frequencies or AVO response. Through proper planning, testing and evaluation, two seismic surveys were shot in close proximity to each other – with simultaneous acquisition for 5 weeks, only incurring 8 hours of standby time for SI. Experiences from the full processing of the two datasets were that swell noise removal prior to the SI removal is important. Proper QC of the data after SI removal is also vital. Overall one should expect to use somewhat more time in processing, when the data is contaminated by SI. Both swell noise and SI were handled successfully in these projects and final data quality is excellent.

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