B028

Improved Marine 4D Repeatability Using an Automated Vessel, Source and Receiver Positioning System

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SUMMARY

A new automated and integrated, vessel, source, and receiver control system has been developed to improve the accuracy and repeatability of 4D surveys. The new control system replaces operator intervention with automated updates to vessel, source, and streamer steering devices from positioning information from all in-sea equipment. This has lead to a step change in the accuracy of source repeatability (2.5-m repeat accuracy for 95% of shotpoints), and has also improved the ability to repeat receiver positions.
Introduction
Source and receiver repeatability is one of the most critical aspects for time-lapse seismic acquisition. In this paper, we describe a new automated marine field positioning system for achieving improved source and receiver repeatability. The system has gone through several stages of testing, and the most important repeatability test results are given. The test results have since been confirmed through several successful 4D surveys in the North Sea during the 2007 season, and also during wide-azimuth surveys in the Gulf of Mexico.

Integrated vessel, source, and streamer steering
A new integrated steering controller, called Q-Pilot, has been developed. Q-Pilot will automatically steer the vessel, the sources, and the streamers to achieve the best possible 4D position match. The combined control system, source steering, and streamer steering is called dynamic spread control (DSC). In the development of the system, three important features were identified: 1) Automation – it is not possible for an operator to accurately predict the behavior of the towed spread and the vessel in a changing current environment. 2) Independent source steering – very tight specifications on source position repeatability are not possible to achieve even with optimal and automated vessel steering. Controlling the source position independently is a vital ingredient and this means that the vessel may be steered to position the front end, which improves the receiver repeatability. 3) Planning and QC – Planning the 4D survey acquisition is more involved and requires more care than planning a regular exploration 3D survey. Hence, dedicated software was developed to provide an optimized navigation plan (NavPlan) for each 4D monitor survey. These three key items formed the basis for defining the system requirements.

The NavPlan contains the desired source and receiver positions. NavPlan positions are simply subtracted from the measured real-time positions from the navigation system and run through independent controllers for the streamer steering devices, winches (for source steering), and vessel. In addition, several feed-forward controllers are used to improve the system performance.

The vessel controller can be set up in several different ways. The basis for the vessel steering is the track point. Figure 1 shows an example where the track point is set up to be the streamer front ends. The vessel is moved to starboard because the current is pushing the entire spread to port.

At the same time, the winches control the sources so that both the streamer front ends and the sources are positioned correctly.

Accuracy of source positioning
In a recent test in the North Sea, we performed source repeatability tests by matching to a predefined NavPlan. The plan called for matching a dual source configuration to a non-straight line, thus increasing the difficulty of achieving the necessary accuracy compared to straight preplot line shooting. The test result showed source positioning error to be less than
2.5 m for 95% of the shotpoints (Figure 2). This level of accuracy is an order of magnitude better than some conventionally acquired 3D surveys.

In another test in the Gulf of Mexico, in an area with stronger and more rapidly varying ocean currents, the same excellent source repeatability results were achieved. This test was done during a wide-azimuth survey, where two streamer vessels were equipped with identical spreads and exposed to the same environmental conditions. One streamer vessel (dark blue) had the DSC system installed and the other streamer vessel (dark red) was manually steered. In this way, a true apple-to-apple comparison was achieved. The vessel with the DSC system achieved 4-m error or less relative to the preplot for 95% of the observations, while the manually steered vessel achieved 14-m error or less. The results were consistent for the duration of the test, which lasted for a few weeks. Also seen on the graph is that the source positioning results for the source vessels is somewhere between the two streamer vessels. A source vessel is not towing a large seismic spread and is much easier to maneuver than a streamer vessel. However, not even the easy-to-control source vessels can match the performance of the DSC-controlled vessel.

**Accuracy of receiver positioning**

As described in the previous paragraphs, the DSC system can, for all practical purposes, eliminate source positioning errors. This level of source repeatability is important for 4D binning. During the same North Sea test that was mentioned previously, we also tested the ability of the system to repeat receiver positions accurately.

A baseline test line was acquired first without any active streamer steering. This test line is shown in dark blue in Figure 4. It had a streamer feather that varied from almost -6° to +3° – i.e., a variation of 9° over the entire line. For the shotpoint range shown in the graph, the
variation is 4°. Once the baseline was established, three different attempts were made to repeat the baseline streamer feather (green, red, and cyan lines).

The left part of Figure 4 shows the streamer feather relative to the straight line preplot, calculated from the P1/90 navigation data. A very good feather match is obtained for the range of shotpoints shown. The right part of Figure 4 shows the estimated streamer feather calculated from the measured ocean current as dotted lines. The solid green and blue lines on the right graph are the same as the left graph, i.e., the streamer feather calculated from the navigation data while the red and cyan lines are omitted for clarity. A linear relationship is assumed – i.e., streamer feather is estimated as the angle between the measured vessel speed and the crossline component of the measured ocean current. This simple principle is illustrated in Figure 5, where \( \phi \) is the estimated streamer feather. The estimate can be quite noisy, so in Figure 4, the estimate is filtered before plotting.

As shown in the right part of Figure 4, the estimated feather appears to be reasonably good when compared to the true measured streamer feather from the baseline line (dark blue). Also, the green shows that, in this case, the currents were too strong for the streamer steering to be able to compensate. During this line, the streamers are steered with maximum available force towards the baseline line for the entire line, but because the streamer steering devices are only able to compensate for roughly 3° of streamer feather, a good feather match is never obtained. For the other two lines it is further observed that the natural feather (assuming that the estimated feather from the current meter data is a reasonable approximation to natural feather) is quite different from the baseline line. No attempts were made to match the tidal cycles on these test lines and, with careful planning of line start times in regions where the currents are mainly tidal driven, it should be possible to achieve very good results with this system.

**Benefits for survey efficiency and design**

Having shown that source repeatability error can be reduced to almost zero, we can now envisage more efficient survey designs. While the system has been designed to benefit 4D
applications, there are other situations where source repeatability is important, e.g., wide-azimuth surveys. The recent implementation of wide-azimuth towed-streamer surveys, mainly in the Gulf of Mexico, has lead to acquisition of surveys with a much higher density of traces. This presents challenges to data processing in terms of cost and efficiency. However, the survey designs call for repeating shotpoint positions many times. If these shots can be repeated to sufficient accuracy, then they can be merged to form supershots with a dramatic reduction in data processing time and cost.

In 4D applications, the need for combined source and receiver repeatability has been demonstrated: see, for example, Calvert (2005) and Smit et al. (2005). Reducing the source repeat positioning errors to almost zero allows control of the final repeatability solely by the receiver repeat positioning errors. Goto et al. (2004) demonstrated the use of streamer steering to improve receiver repeatability and other attempts to improve repeatability include the use of streamer overlap, although the latter reduces the survey efficiency by deploying more in-sea equipment (streamers and associated devices). Of course, there is no reason why both streamer steering and overlap cannot be used simultaneously.

The use of an automated vessel, source, and streamer steering facility improves the repeatability of the 4D survey, which feeds through into ultimately more efficient surveys. The additional level of control also allows the possibility of acquiring “antiparallel” surveys (adjacent swaths are acquired in opposite azimuths), which have superior geophysical attributes in terms of azimuth sampling (Vermeer, 2002). An added benefit to acquiring 4D surveys in “antiparallel” mode is that higher streamer feather differences can be tolerated before the combined source and receiver position errors fall outside 4D repeatability specifications.

Conclusions
We have documented a new automated and integrated vessel, source, and streamer positioning system called dynamic spread control that can be used in 4D applications to improve significantly the accuracy of repeat surveys. The DSC system is able to provide accurate feather match for lines with dynamically changing feather, provided that the current strength is less than the operating capability of the streamer steering devices. The DSC system produces a step change in source position accuracy. A major part of this improvement comes from the automation, thus removing the need for frequent operator intervention.

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References
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