Dual Sensor Towed Streamer: From Concept to Fleet-Wide Technology Platform

M.T. Widmaier* (Petroleum Geo-Services) & A. Day (Petroleum Geo-Services)

SUMMARY

Introduction

The launch of dual-sensor towed streamer technology in 2007 was probably the most important milestone in the seismic industry during the last 10 years. The launch kicked off huge interest and demand for broadband seismic methods and their benefits. It also triggered the development of new acquisition and processing technology on both the source and receiver side. Broadband benefits and the ability to accurately separate dual-sensor recordings into up- and down-going wavefields have been exploited throughout the entire seismic value chain.

Since the first 2D dual sensor applications in 2007, PGS has steadily converted its seismic fleet from conventional to dual-sensor streamers and will complete the fleet-wide roll-out during 2015. This paper will revisit the key learnings during the technology roll-out and discuss acquisition and processing technology that has been adapted in order to fully utilise the system.

Wavefield separation

Ghost reflections from the sea surface have limited the bandwidth of towed streamer data in the past. The introduction of dual-/multi-component streamers has enabled the industry to overcome the receiver ghost problem (Carlson *et al*., 2007, Caprioli *et al*., 2012). Particle motion sensors with complementary ghost response functions compared to pressure sensors are utilised to remove ghost reflections in an accurate and robust way (Figure 1). The removal of the receiver ghost increases the seismic bandwidth and thus provides better resolution for interpretation. The ability to remove the ghost accurately allows the streamers to be towed deeper. The signal-to-noise ratio is improved by deeper tow, especially at the low frequency end of the seismic bandwidth. Improved low frequency content enhances the quality and accuracy of seismic inversion and reservoir characterisation (Kroode *et al*., 2013).

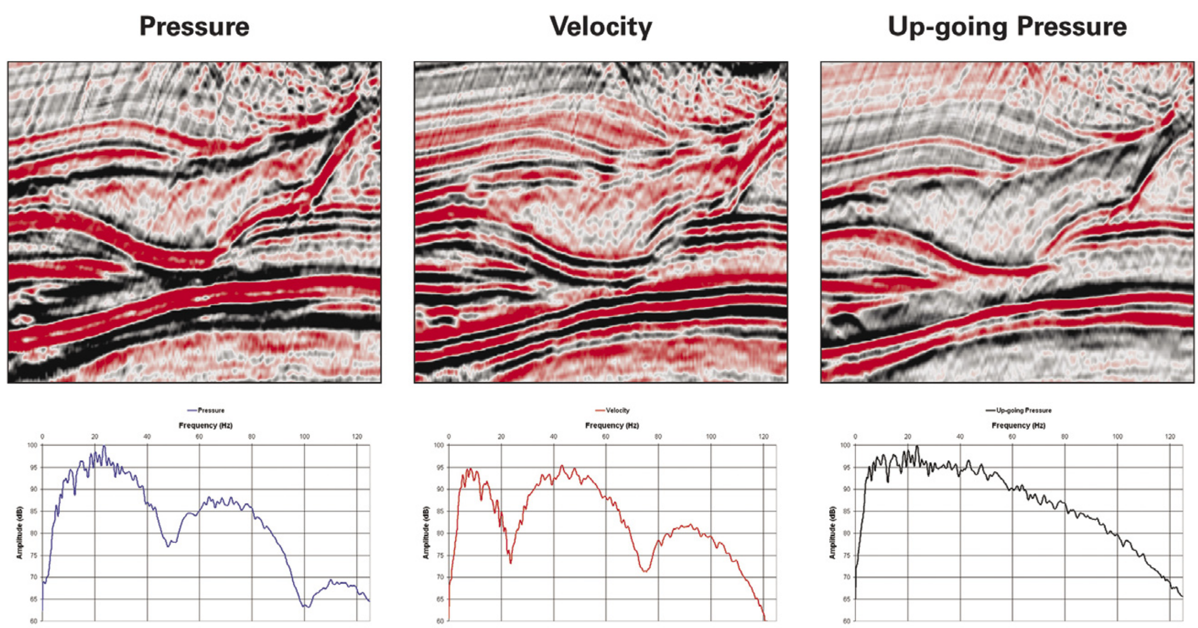

Figure 1 *Unmigrated stack comparison as shown in Carlson, et al (2007). Note the complementary amplitude spectra for pressure vs. particle. The images are from left to right, the pressure-only result, the (vertical) velocity-only result, and the up-going (de-ghosted) pressure wavefield derived from the pressure and velocity wavefields. The data shown in the example was acquired in 2007 with a streamer depth of 15m.*

Deeper tow, controlled and uncontrolled depth variations

While deeper tow enables the recording of more low frequency signal energy, it can increase operational complexity at the same time. Increasing and maintaining deep streamer front-ends in a 3D spread is challenging. Deeper front ends typically require additional downward forces and create higher drag. As the wavefield separation for dual-sensor and multi-component streamers is based on recordings from collocated complementary sensors, there is no theoretical requirement to tow the streamer flat. Streamer depth profiles can be designed and deployed in order to optimize seismic data quality without sacrificing acquisition efficiency. E.g., nominal tow depths of 25m or 30m can be achieved without pushing the front-ends beyond depths that have been routinely deployed for dual-sensor streamers in the past (15m-20m). Streamer steering devices can be utilized to mildly increase the tow depth over the near offset range until the nominal tow depth is reached (Lesnes *et al*. 2014).

Technical specifications for conventional hydrophone-only surveys usually only allow, e.g., streamer depth tolerances up to +/- 1m relative to nominal tow depth. The flexibility of streamers with complementary particle motion and pressure sensors makes this specification obsolete. Uncontrolled cable depth variations can now be dealt with in a geophysically correct way.

Impact of the rough sea surface

Towing streamers deep also means that the seismic measurements are made further away from the sea surface, i.e., the recordings are less exposed to weather and rough sea-surface-related noise. Thus, if the streamer is located deeper than the wave base, data with good signal-to-noise can be acquired also under marginal weather conditions. Consequently, weather related downtime has been reduced compared to conventional towed streamer acquisition (Osnes *et al*., 2010). Seismic operations with dual-sensor streamers in worsening weather conditions are usually not stopped due to high noise levels but for operational safety reasons.

A receiver ghost is the result of an up-going wavefield being reflected downwards at the sea surface. The ghost reflections, i.e., the down-going wavefield, carry an imprint of the sea surface shape above the streamer at the time of the seismic recording (Figure 2). Imprints of rough sea surfaces can be clearly observed, e.g., in hydrophone recordings of the total pressure field. Such imprints can be problematic especially for 4D, as the effects of a rough sea surface are not repeatable. Wavefield separation techniques that use recording from complementary sensors can remove sea surface effects that are associated with the receiver ghost without making assumptions about the condition of the sea surface.

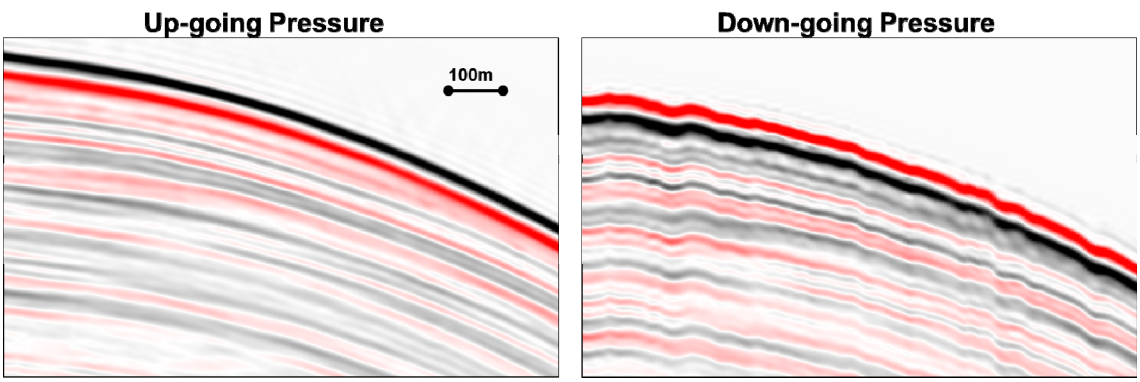

Figure 2 *A receiver ghost is the result of an up-going wavefield (left) being reflected downwards at the sea surface. The ghost reflections, i.e., the down-going wavefield (right), carry an imprint of the sea surface shape above the streamer at the time of the seismic recording. Imprints of rough sea surfaces on the ghost reflections can be clearly observed. The example is a shot gather from Offshore Brazil.*

Mitigating noise

The integration of particle motion sensor (either particle velocity sensors or accelerometers) into a seismic streamer has led to new requirements for noise mitigation and onboard QC. Particle motion sensors are more sensitive to mechanical vibrations and turbulence along or in the vicinity of the streamer compared to pressure sensors (hydrophones). Peripheral units like steering devices, acoustic devices, compasses, retrievers which are traditionally attached to seismic streamers can cause such undesired vibrations and turbulence. These devices have been re-engineered during recent years in order to meet requirements for state of the art streamer technology (Figure 3). The new devices are now integrated in the streamer as much as possible through connector units (Hillesund *et al*., 2012).

Seismic operations in temperate waters like, e.g., offshore West Africa or Brazil are exposed to barnacle growth along the streamers. Streamer drag can be increased significantly by rapid barnacle growth. Barnacles also generate noise. Manual cable cleaning and scraping is very often the only effective measure to mitigate barnacle related problems. In recent years, automated in-sea streamer cleaning units have been engineered that allow for continuous proactive barnacle mitigation. These devices are nowadays also operated while recording.

On-board workflows for quality control have been extended to monitor not only the noise levels of hydrophone recordings but also the quality of the particle motion data and data deliverables like the up-going wavefields (i.e., wavefield separated/de-ghosted data). The wavefield separation process is usually executed on-board while a survey is ongoing.

Figure 3 *Picture from one of the qualification tests of dual-/multi-sensor streamer steering. The inline design of the steering device produces less towing noise than conventional birds (Hillesund et al., 2012).*

Acquisition footprint removal based on separated wavefields

3D towed streamer acquisition in shallow water can lead to illumination holes at swath boundaries due to a lack of near offset data. The lack of data not only creates a footprint in the image, but also limits the ability to quality control migration velocities based on flatness of the gathers, and also hinders AVO/AVA type studies. It has been demonstrated recently that the concept of virtual source imaging (Wapenaar et. al, 2010) can be extended to multi-sensor streamer acquisitions to utilize sea surface reflected (downgoing) wavefield energy that provides the missing near-surface information. Recent case studies, e.g., Long *et al*. (2013) and Rønholt *et al*. (2014), demonstrate how separated up- and down-going wavefields from dual-sensor systems can be used to image the overburden, and to remove the acquisition footprint that is evident if only the primary reflections are used.

Conclusions

New streamer technology has provided a step change in seismic data quality. The increase of the natural frequency content of seismic data as well as the ability to accurately separate seismic data into up- and down-going wavefields has resulted in benefits throughout the entire value chain. The rollout of the new towed streamer technology has been accompanied with changes to operational aspects of seismic acquisition as well as quality control. Data quality objectives have been successfully combined with the requirements for safe and efficient operations.

Acknowledgements

The author thanks Petroleum-Geo Services (PGS) for permission to publish this abstract.

References

Caprioli, P.B.A., Özdemir, A.K., Özbek, A., Kragh, J.E., van Manen, D.J., Christie, P.A.F. and Robertsson, J.O.A. [2012] Combination of Multi-component Streamer Pressure and Vertical Particle Velocity - Theory and Application to Data. *74th EAGE Conference and Exhibition 2012*.

Carlson, D.H., Long, A., Söllner, W., Tabti, H., Tenghamn, R. and Lunde N. [2007] Increased resolution and penetration from a towed dual-sensor streamer. *First Break*, 2007.

Hillesund, O., Day, A. and Fjellstad, O.E. [2011] Multicomponent Streamer Steering. *73rd EAGE Conference and Exhibition 2011.*

ten Kroode, F., Bergler, S., Corsten, C., de Maag, J.W., Strijbos, F. and Tijhof, H. [2013] Broadband seismic data— The importance of low frequencies. *Geophysics*, **78**(2), WA3WA14.

Lesnes, M., Day, A. and Widmaier, M. [2014] Increased streamer depth for dual-sensor acquisition – Challenges and solutions. *SEG Technical Program Expanded Abstracts 2014*, 143-147.

Long, A., Lu, S., Whitmore, D., LeGleut, H., Jones, R., Chemingui, N. and Farouki, M. [2013] Mitigation of the 3D cross-line acquisition footprint using separated wavefield imaging of dual-sensor streamer seismic. *75th EAGE Conference & Exhibition*.

Osnes, B., Day, A., Widmaier, M., Lie, J.E., Danielsen, V., Harrison-Fox, D., Lesnes, M. and El Baramony, O. [2010] First 3-D Dual-sensor Streamer Acquisition in the North Sea – An Example from the Luno Field. *72nd EAGE Conference and Exhibition*.

Rønholt, G., Lie, J.E., Korsmo, O., Danielsen, B., Brandsberg-Dahl, S., Brown, S., Chemingui, N., Valenciano Mavilio, A. and Whitmore, D. [2014] Broadband velocity model building and imaging using reflections, refractions and multiples from dual-sensor streamer data. *76th EAGE Conference & Exhibition.*