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P - 354

A Step Change in Marine Seismic – A Dual Sensor Towed Streamer

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Introduction

PGS has been developing an entirely new towed marine streamer concept for about five years. The project objective was to engineer a streamer that is capable of recording both the scalar pressure field and the vertical component of the vector particle velocity field. PGS' Next Generation Streamer has accomplished these objectives, and is a step change in streamer technology. This technology overcomes the limitations of hydrophone-only acquisition systems, and allows PGS to separate the up-going wavefield incident upon the streamer from the down-going-wavefield that is reflected from the sea surface. It is thus possible to remove the receiver ghost from the data, at all depths, and thereby recover significant low and high frequency amplitudes normally missing from marine seismic data. It is no longer the case that E&P decision makers must parameterize streamer surveys to maximize data quality at one target depth, whilst sacrificing image quality at shallower or deeper targets.

The PGS Next Generation Streamer uses an extremely quiet, ruggedized solid streamer design to provide enhanced resolution, better penetration, and improved operational efficiency. In fact, the towing depth is typically quite deep, thus increasing the operational window in poor weather or environmental conditions that no other system can handle. PGS experience demonstrates that the technology can deliver deghosted data not just for one depth, but for all depths – in one pass, using one streamer depth. It is also a no-risk technology – PGS can use the dual-sensor information to duplicate the parameters of any existing survey, thus allowing 4D matching plus the benefits of improved image clarity.

PGS has assembled a full acquisition and data processing product range for the Next Generation Streamer. 2D commercial operations are planned to begin in late-2007, followed by 3D commercial operations in 2008.

The Receiver Ghost

Unfortunately, a hydrophone in a towed streamer always records two wavefields that constructively interfere with each other. The up-going pressure wavefield propagating directly to the hydrophone from the earth below, and the down-going pressure wavefield reflected downwards from the "free air" sea surface immediately above the streamer. As the reflection coefficient of a relatively calm sea surface is close to -1, the down-going pressure wavefield has equal amplitude to the up-going pressure wavefield, but opposite polarity. The consequence is that a series of "ghost" notches are introduced into the frequency spectra, and the reflection wavelet is undesirably elongated, reducing temporal resolution. In contrast, velocity sensors are directional, so the down-going velocity wavefield is measured as having equal polarity to the up-going velocity wavefield. Furthermore, the peaks and notches in the amplitude spectra for pressure data are complementary to those for velocity data. Thus, the summation of pressure and velocity data will cancel the amplitude of the ghost event trailing each primary event, and the notches in the amplitude spectra will be removed. This is the case for all angles of incidence and for all source-receiver offsets.

Figure 1 is a simple synthetic example that demonstrates summation of zero-offset stacks for pressure and velocity data. The receiver ghost that complicates interpretation of relatively thick intervals has been removed, and an extremely clear image results.

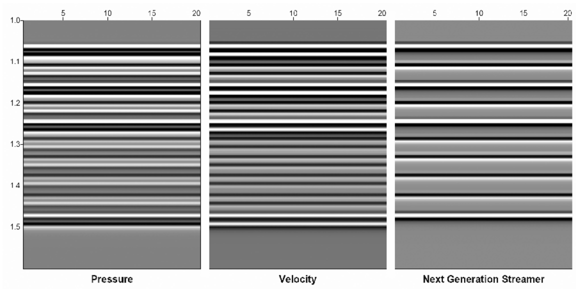

Figure 1. Conceptual synthetic zero-offset stacks for pressure-only, velocity-only, and summation of pressure+velocity. Summation cancels the receiver ghost present in the pressure and velocity data.

It follows from simple theory that if the vertical component of particle velocity is known, the total measured seismic wavefield can be decomposed in data processing into the up-going and down-going pressure and velocity wavefields. As the velocity could never historically be measured on towed streamers, however, it was necessary to pursue an estimate of the vertical pressure gradient. One operationally challenging approach to estimate the vertical pressure gradient is to tow two streamers at different depths. It is of course better if the vertical component of the particle velocity can be directly measured – achieved now by PGS.

Next Generation Streamer Operations and Opportunities

The commercial Next Generation Streamer architecture uses densely sampled groups of collocated pressure and velocity sensors in a low-noise solid-fill streamer. An ethernet telemetry system minimizes power consumption for the Next Generation Streamer architecture. The Next Generation Streamer is typically towed at a depth of about 15 m in a quiet and stable environment.

Data processing is relatively straightforward to yield the deghosted and decomposed pressure and velocity wavefields. These wavefields can then be extrapolated to any desired towing depth, if required. Thereafter, the data are passed on to a "conventional" processing flow, modified of course to exploit and preserve the improved frequency and signal-to-noise content of the signal.

Towing a deep Next Generation Streamer allows PGS to operate in a longer weather window, sometimes in scenarios where conventional operations would be shut down. Developmental experience over the past few years demonstrates that weather and operational noise is typically reduced by 3 to 7 dB, dependent upon survey conditions. Efficient acquisition follows from only having to tow all streamers at one depth, exploiting the full streamer width capacity of the vessel, and easily controlling all streamer behaviour.

An advanced implementation of Surface Related Multiple Elimination (SRME) is possible with the Next Generation Streamer. Multiple prediction is based on the up-going pressure wavefield and the down-going velocity wavefield. The key advantage of using the down-going velocity wavefield is that any variations in the sea surface level and reflection coefficient are implicitly included in the implementation. In addition, the use of a velocity field automatically incorporates angle-dependent scaling into the prediction process.

Field Data Example

Figure 2 presents data acquired with a 6100 m Next Generation Streamer towed at a depth of 15 m. Note the significant improvements for the up-going pressure wavefield in terms of event resolution and frequency content on stacked data.

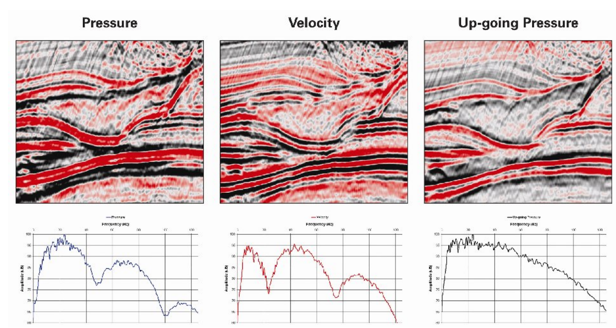

Figure 2. Unmigrated stack comparison. **Left:** Pressure-only result. **Middle:** Velocity-only result. **Right:** Up-going pressure wavefield, derived from the summation of the pressure and velocity wavefields.