Exorcising the Ghosts – the New Streamer Technology La

PGS claims to have built a marine seismic streamer that is capable of removing receiver ghosts, thereby enhancing frequency bandwidth and seismic resolution. If proven by full-scale field tests, this could be a major break-through in seismic acquisition.

Lasse Amundsen is Chief Scientist, Geophysics, at Statoil. He is adjunct professor at the Norwegian University of Science and Technology (NTNU) and at the University of Houston, Texas.

Martin Landrø is professor in Applied Geophysics at the Norwegian University of Science and Technology (NTNU), Department of Petroleum Engineering and Applied Geophysics, Trondheim, Norway.

In conventional marine acquisition, with towed streamers containing pressure sensitive hydrophones, the streamer depth controls the frequency content and hence seismic resolution of the recorded data.

Two conflicting issues need consideration when deciding upon streamer depth. On one hand, towing the streamers at shallow depths gives the high-end frequency content needed for resolution but attenuates the low-end frequency content required for deep penetration and to undertake more detailed stratigraphic interpretation. Shallow towing also makes the seismic data susceptible to swell noise. On the other hand, deep towing of streamers enhances the low frequencies, but attenuates the high frequencies. The swell and ambient noise problem is reduced.

The so-called 'receiver ghost' causes the frequency bandwidth problem described above. The receiver ghost is that part of the signal that reflects off the sea surface, before being recorded on its way down when passing the streamer. It is the receiver ghost that attenuates the low-end frequencies for shallow towing and high-end frequencies for deep towing. Therefore, seismic de-ghosting has been an old and longstanding, but as yet unsolved, data processing challenge in exploration geophysics,

PGS Cable

unched by PGS

where the objective is to broaden the bandwidth of the seismic hydrophone recordings.

Since the receiver ghost has proved difficult to eliminate through data processing, geophysicists over decades have looked for acquisition techniques that might exorcise this ghost. The most recent attempt, presented at the EAGE annual exhibition in London in June by PGS, does seem to have the potential to be a major step forward for the seismic industry.

An Old Idea

Geophysicists have long known that the pressure field recorded by hydrophones and the vertical component of the particle-velocity recorded by geophones on the seabed benefit the suppression of receiver ghosts and associated water-layer reverberations.

J. Ed White, in his textbook "Seismic Waves", pointed out as early as 1965 the possible usefulness to geophysical prospecting and oceanographic research of deploying a composite detector on the sea floor: "The output of a *pressure detector* near the solid interface can be combined with the output of a *particle-velocity detector* in such proportions that waves arriving ... from the fluid will create no net output, whereas ... waves from the solid will be detected."

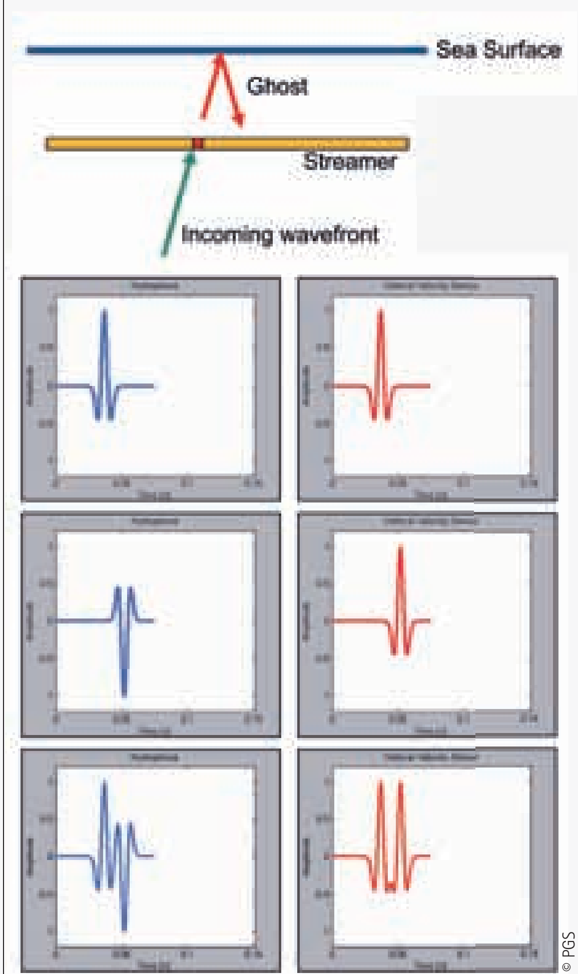
In spite of this, the use of a *dual sensor* did not become a full-scale practice until the late 1980's. By that time, marine 3D streamer seismic was acknowledged as a necessity for detailed reservoir imaging. However, over fields obstructed by production platforms marine 3D seismic could not be acquired without large gaps in coverage. To circumvent this problem, Rigsby et al (1987) introduced, in shallow-water areas, the bottom-cable technique to collect pressure data where conventional streamers could not be towed. It was soon realized that such data experienced the destructive effects of the receiver ghost and subsequent water-column reverberations, producing holes or notches in the frequency spectrum, thus limiting seismic resolution.

Further progress

To solve this notch problem (i.e. to remove the hole in the frequency spectrum), Fred Barr and Joe Sanders (1989) at Halliburton Geophysical Services took advantage of White's insight and introduced an ocean bottom cable (OBC) equipped with both hydrophone sensors (measuring pressure) and verti¬cal geophone sensors (measuring particle velocity), leading to improved resolution by proper combination of the hydrophone and geophone signals in processing.

The basic principle is that when the two sensors are calibrated relative to each other, the ghost on the hydrophone recording and the geophone recording will exactly cancel each other. The ocean bottom dual sensor cable technique has been successfully applied in the Gulf of Mexico.

In the mid-1980's, a few years before the Barr-Sanders de-ghosting solution for shallow water ocean bottom cable surveying, Geco-Prakla introduced and tested the over/under towed streamer acquisition concept as a de-ghosting solution for towed streamer data. In the over/under configuration, data are acquired with streamers towed in pairs at two different streamer depths, with one streamer above the other. As is well known, the Geco-Prak-



An upgoing reflection event from the subsurface is recorded on the streamer, then travels to the sea surface where it is reflected downwards. The downward traveling event measured on the streamer is referred to as the ghost. The lower part of the figure shows that the hydrophone measuring pressure and the geophone measuring particle velocity see the upgoing event with the same polarity but the downgoing event with opposite polarity. In data processing, signals from the hydrophone and geophone are simply added together, and the ideal response without any receiver ghost is obtained.

The Problem
Every recorded reflection wavelet from conventional marine hydrophone streamers is accompanied by a ghost reflection from the sea surface. The ghost produces unwanted notches (zeros) in the seismic frequency band. The resulting filter effect on the recorded data restricts streamer towing depths to a range of about six to nine meters.

The solution
The "Next Generation Streamer" adds particle velocity sensors to the pressure sensors to create a dual-sensor towed marine streamer - overcoming the limitations of hydrophone-only acquisition systems.

How
By recording data from co-located, properly scaled pressure and velocity sensors receiver ghost events due to the sea surface can be cancelled. The hydrophone and geophone measure the upgoing reflection signal from the subsurface with same polarity but the ghost with opposite polarity. When the two recordings are summed, the receiver ghost thus cancels. The signal-to-noise ratio is increased and more high and low frequencies are recorded.

© PGS

The noise level is reduced when the towing depth for a streamer is changed from 7 to 15 and 20 meters.

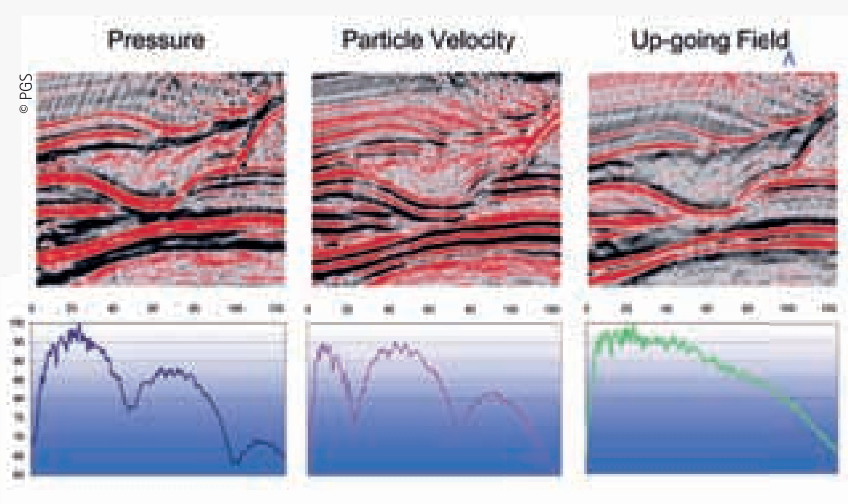
la attempt was not successful, because the two streamers at that time could not be kept vertically paired. However, through recent developments of steerable Q-marine streamers, today the over/under streamer technique is commercially available from WesternGeco (see GEO ExPro v. 3, no. 1, 2006).

Motivated by the Barr-Sanders solution, initiatives were later taken to construct a marine streamer equipped with vertical geophones in addition to hydrophones. No attempt was successful, however, until PGS launched their new streamer, presented at this year's EAGE annual convention in London. PGS themselves call this the "Next Generation Streamer" and the company claims it has the potential to revolutionise seismic acquisition. If it is also a "step change in technology", we will soon know.

Their field example does, nevertheless, show encouraging results, and later this year a 2D vessel will be equipped with the new streamer and tested at various locations in a number of different geological settings. PGS plans to equip a minimum of one 3D vessel with the new streamer technology in 2008.

Works for all Depths?

The major challenge for geophone recordings in a marine streamer is to attenuate the noise caused by water motion close to the streamer, and it is especially difficult to achieve high quality recordings of the vertical particle velocity field. Therefore, one should expect that these ghost-attenuating technologies would work best for shallow seismic data; the deeper we want to image, the weaker the seismic signal will be, and hence the more difficult it will be to obtain a clean vertical geophone signal.



© PGS

Field example showing seismic stack sections of hydrophone data (left), geophone data (middle) and de-ghosted hydrophone data (right). Below: Frequency spectra of the same datasets, clearly demonstrating that the de-ghosted data set (lower right) has no notches in its spectrum, in contrast to the spectra of the hydrophone and geophone data.

PGS is, however, of the opinion that it has the ability to de-ghost signals and to optimize data quality, not just for one target depth, but also for all depths - shallow to deep.

The hydrophone signal is less influenced by local water movements close to the streamer, since it measures pressure vari¬ations and not particle velocity.

A hydrophone measures the pressure and this is a robust measurement, since it is a scalar field (the same value in all directions). To measure the particle velocity in the water is harder since we need to measure a vector component, i.e. the vertical component of the particle velocity field. Furthermore, such measurements will be more sensitive to noise created by small eddies or flow patterns associated with non-seismic activity close to the streamer. Even for hydrophone data, we observe that increased noise level can be measured close to devices mounted directly on the streamer. This applies, for instance, to the 'birds' that are used to control the depth of the streamer.

Future prospects

As soon as the new streamer technology has been fully verified through several case studies, demonstrating that it can deliver data with larger frequency bandwidth for various geophysical objectives, we can foresee cost benefits and several areas of applications:

When a streamer can be towed at arbitrary depth without any significant loss in seismic data quality, the weather window for seismic acquisition can be extended. The noise level will be significantly lower for deeper towing depths. This will lead to reduction in acquisition costs and more efficient seismic surveys.

Improved high-end signal frequency content yields enhanced resolution, allowing for a more detailed stratigraphic interpretation.

As soon as improved low-end frequency content can be documented, deeper signal penetration is expected, thereby improving seismic imaging in areas of complex geology, such as below basalts and salt. Furthermore, advanced seismic inversion methods require low frequencies to work.

The new acquisition technology will probably improve the performance of advanced seismic multiple attenuation algorithms.

For time lapse seismic data acquisition, the new streamer technology holds the potential to improve repeatability between two seismic surveys, since the data are less influenced by variations in sea surface roughness between two surveys.

You will find more information about the new technology at www.pgs.com [Next Generation Streamer - A Clearer Image]. Here you can also download an animation that describes the new cable in simplified terms.