Z-99 Solid streamers and single hydrophones

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Summary

Solid streamers are less sensitive to weather-related noise than liquid streamers. Hence, with the solid streamers the operational weather window can be extended. In addition solid streamers can be towed shallower without a prohibitive increase in noise.
The application of noise filters on single hydrophones in a solid streamer only yields marginal improvements over application of the same filters on hydrophone groups. These improvements do not justify the introduction of single hydrophone recording.
For reduction of weather noise a hydrophone spacing of 3 m may be adequate for solid streamers. However, the reduction from 16 to 8 hydrophones per 12.5 m groups shows an increase in flow noise. This flow noise will further increase with only 4 hydrophones at 3.125 m per 12.5 m group.

Introduction

There is a continuous push towards better signal-to-noise ratio and broader bandwidth for mapping the finer details in the subsurface. Similarly, time-lapse (4D) studies require not only an accurate repetition of the monitor surveys, but also good seismic data quality. Although the signal bandwidth can be improved with a shallower depth of the streamer, the signal-to-noise ratio may not improve due to the higher level of sea-state related noise for a shallow streamer. Hence, it seems essential to address this type of noise. In the late 90-ties a single hydrophone recording system was introduced by WesternGeco in order to allow for dedicated noise filtering of these single hydrophones before forming them into 12.5 m groups. At the same time Thales introduced a solid streamer system.

Late 2001 SERCEL conducted an experiment with a solid streamer system, which amongst others included a section with single hydrophones at an interval of 1.5 m. CGG together with SERCEL performed additional tests in 2003 in an operational environment for the duration of 2-3 months. Shell UK as operator for these surveys, allowed the insertion of some sections with single hydrophones in one of the deployed streamers. The duration of this field experiment allowed for exposure to any weather condition including the acquisition of seismic data with the operational qualification Not To Be Processed (NTBP). The field geometry allowed for direct comparison of the single hydrophones with groups in the solid section in front and with groups in the liquid section just behind, and with solid and liquid groups in the adjacent streamers.

Field experiment 1 – Solid streamers and liquid streamers

CGG acquired seismic data offshore Morocco using traditional liquid Syntrak streamers and full offset solid streamers. This allowed for comparison of signal and noise and operational performance of both streamer systems. In a good weather period the movement of the streamer through the water controls the minimum broadband noise level. This flow noise was measured at 5 microbar (with 3 Hz low-cut) for the solid streamer and 3 microbar for the liquid streamer. The increased flow noise in the solid streamer is caused by the reduced number of hydrophones per 12.5 m group (8 instead of 16), the location of the hydrophones closer to the skin, a reduced hydrophone aperture and the smaller streamer diameter.

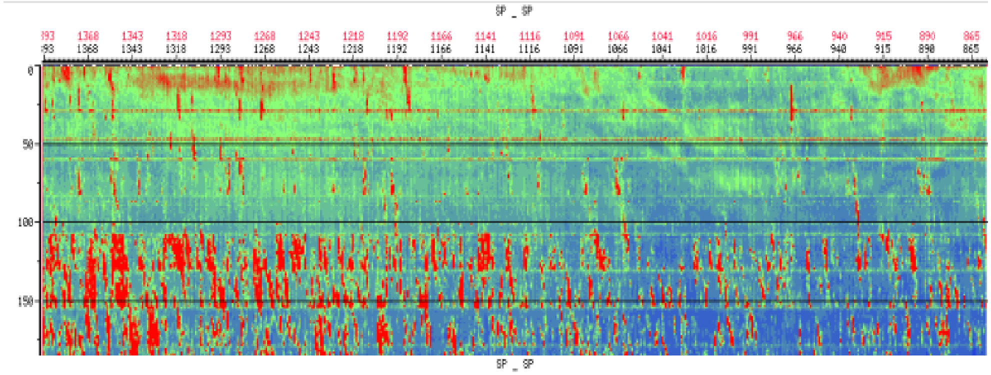


Figure 1 – RMS noise per channel along a profile (hybrid streamer solid+liquid)

Figure 1 shows the RMS noise in marginal weather. The colours represent the RMS noise level after a low cut of 3 Hz for consecutive shot points along the horizontal axis and for all channels along the vertical axis. Near offsets with solid sections are at the top and far offsets with liquid sections at the bottom of the graph. One can clearly see, that the sea state does not affect the solid streamer sections as badly as the liquid streamer sections, despite the fact that there are 8 hydrophones in a group against 16 hydrophones in the liquid groups. This yields potentially an extension of the weather window and an improvement of the signal-to-noise ratio. Although the limitation of weather statistics does not justify a general conclusion, the acquisition with the solid streamers in this survey showed a significant improvement in the operational efficiency. Generally the noise decreases with offset. This explains the position of the solid sections at the front and close to the towing arrangement.

Field experiment 2 – Initial single hydrophone test with solid streamer

The single hydrophone part of SERCEL's field experiment in 2001 was of limited value for the analysis of weather-related noise, since all tests were done under a relatively good weather condition. As part of this experiment single hydrophones were mounted at 1.5 m interval in two 90 m long sections.

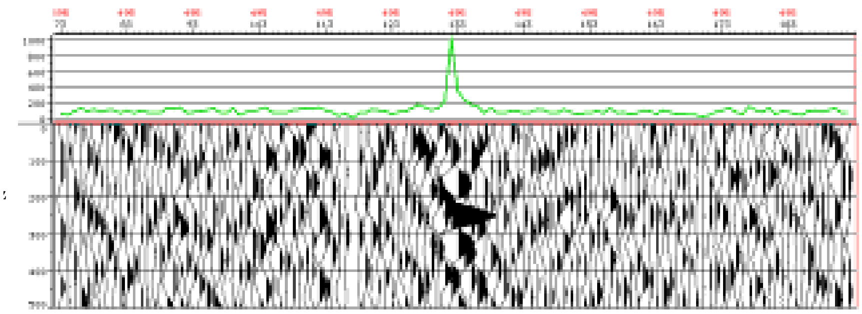


Figure 2 – Single hydrophone cross-correlations in the solid streamer

In figure 2 the noise recording of the hydrophone in the middle of one section was cross-correlated with these of all other hydrophones after application of a 3 Hz low cut filter. The horizontal axis corresponds with the horizontal distance between these hydrophones for each of the cross-correlations with the auto-correlation in the middle of the figure. The lower graph shows the cross-correlation functions, while the upper green curve shows the maximum cross-correlation value. The autocorrelation in the middle is obviously 100%. At large separation between the two hydrophones the measured noise is not showing any relevant correlation and the value is approximately 10%. Due to the limitation of the time window for the analysis and due to the limitation in frequency band, the cross-correlation will never become 0%. The interesting information in the figure is the width of the cross-correlation peak in the green curve. This width is approximately 3 – 4 m. The spatial filter to remove this noise should be 3 – 4 m wide. In this test with 1.5 m hydrophone spacing this corresponds with a spatial filter with 3 filter points. With a hydrophone spacing of 3 m, this would be a 2-point filter, justifying just a straight sum.

Field experiment 3 – Solid single hydrophones in production environment

This production acquisition extended over two surveys with different streamer depth. The data with the shallower streamer deployment at 6 m was obviously of most interest. The streamer spread consisted of 8 streamers at 100 m separation. All streamers had solid SEAL sections in the front and liquid SEAL sections at larger offsets. The outer streamer 8 had 96 groups of 12.5 m solid SEAL, 132 single hydrophones at 1.5 m interval solid SEAL and longer offset groups of 12.5 m liquid SEAL. Streamer 7 contained 108 groups of 12.5 m solid SEAL and longer offset groups of 12.5 m liquid SEAL. Sequences with low and high vessel speed and with good, marginal and bad weather (NTBP) were selected for further analysis.

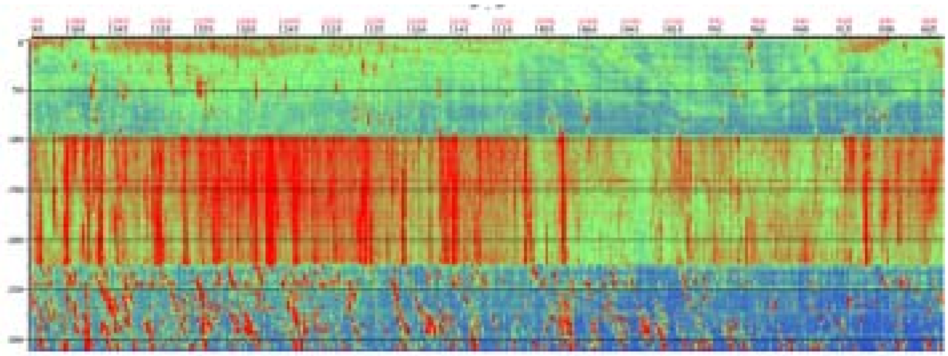


Figure 3 – RMS noise in solid groups, solid single hydrophones and liquid groups

The measurement on streamer 8 in figure 3 was made simultaneously with that on streamer 7 in figure 1. Both are in marginal weather condition. The noise in the single hydrophones is not attenuated by the combination of 8 hydrophones and is appears as dominantly red in the figure. The weather-related noise seems to extend over the full length of the single hydrophone sections, i.e. approximately 200 m. However, this does not necessarily mean, that this noise has a spatial coherency over that distance.

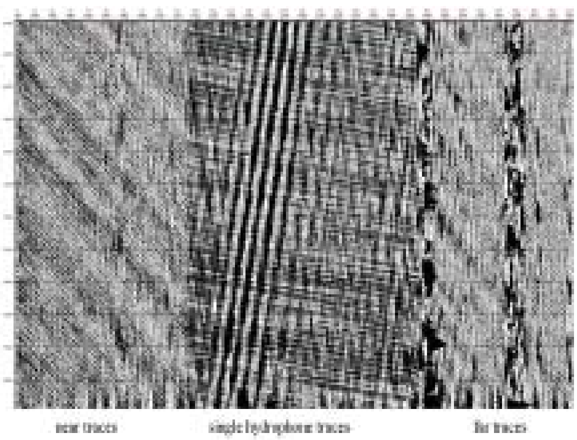
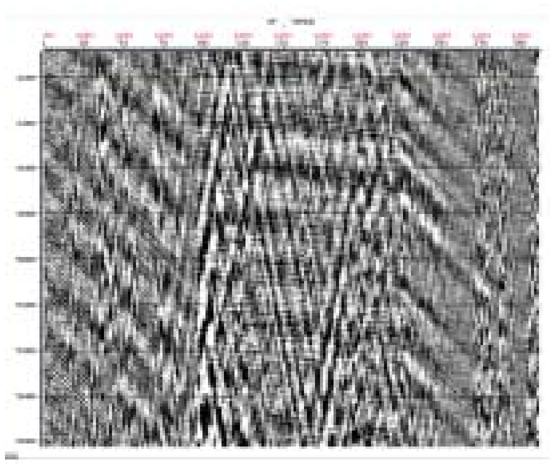


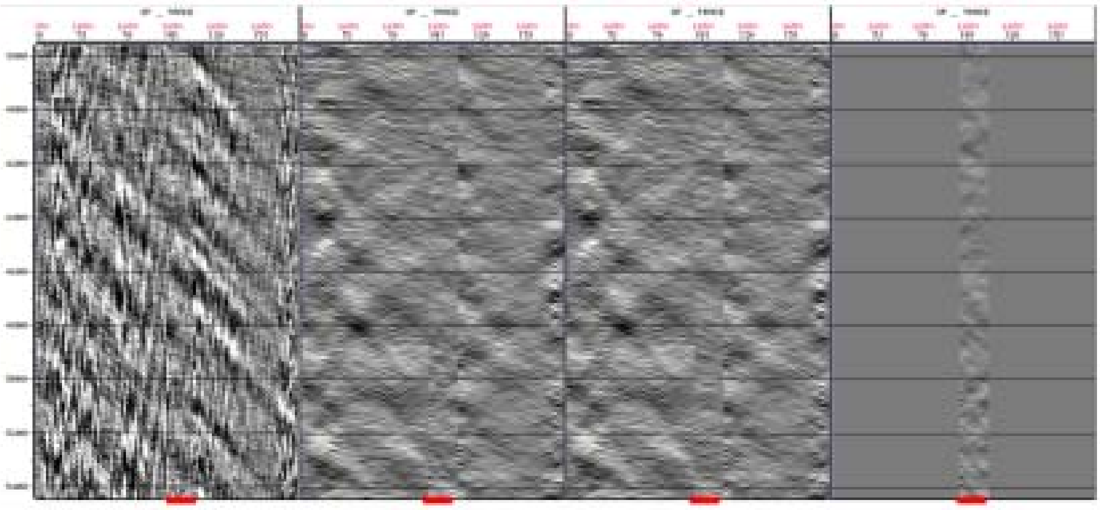
Figure 4a – Shot record in marginal weather



4b. – Shot record in marginal weather

A shot record of a marginal weather sequence is shown in figure 4. The solid near groups are on the left, the solid single hydrophones in the middle and the liquid groups on the right. The cause of the high frequency noise train in the solid groups on the left has not been investigated further. Obviously, this noise train appears more horizontally in the single hydrophone segment due to the shorter spatial distance between the channels. In the liquid sections some noise bursts can be seen; they affect several groups. In the solid groups on the left this is less pronounced. The single hydrophones show the spatial coherency of this noise as very low frequent steep noise trains with a constant and very low apparent velocity. In Figure 4b the very low velocity noise train stops at the front-end boundary with the solid groups. This indicates that this steep noise train seems to be effectively attenuated by the summation of the 8 hydrophones forming these solid groups.

Various dedicated noise filters have been designed to reduce the noise trains in the single hydrophones. Surprisingly, a simple FK-filter was quite effective. Due to its very low frequency this noise is apparently not severely aliased after spatial sampling by the 12.5 m groups. The special FK-filter was applied equally on the single hydrophones before the group forming and the solid and liquid groups (figure 5b). In the next experiment the FK-filter was applied after the group forming of the single hydrophones and on the original solid and liquid groups (figure 5c).



a.: input *b.: filter + summing* *c.: summing + filter* *d.: difference b - c*

Figure 5 – Noise filter on single hydrophones and groups; bad weather (NTBP)

The difference between filtering before and after group forming is shown in figure 5d. For these NTBP data there is a difference between filtering before or after group forming. However, it is claimed that this difference does not justify the additional complication and costs of single hydrophone recording.

The filtering of figure 5 was repeated with the use of alternate hydrophones, simulating a spacing of 3 m. Similar results were obtained.

Conclusions

1. Solid streamers are less sensitive to weather-related noise than liquid streamers. Hence, with the solid streamers the operational weather window can be extended. In addition solid streamers can be towed shallower without the prohibitive increase in noise.
2. Single hydrophone recording may help in demonstrating some coherence in this noise organization. However, the hydrophone group recording efficiently attenuates this noise.
3. The application of noise filters on single hydrophones in a solid streamer yields only marginal improvements over application of the same filters on hydrophone groups. Such improvements do not justify the introduction of single hydrophone recording.
4. For reduction of weather noise a hydrophone spacing of 3 m may be adequate for solid streamers, but the reduction from 16 to 8 hydrophones per 12.5 m groups shows an increase in flow noise, and this would be further increased with only 4 hydrophones at 3.125 m per 12.5 m group.

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