Increased temporal bandwidth using hydrophone only recording and conventional airgun arrays – why not?

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Summary

Usable bandwidth is determined by the signal to noise ratio rather than just signal. Modern streamers have superior noise performance compared to older versions and this reduction in noise seems to have been overlooked in the search for greater temporal bandwidth. Above approximately 2Hz the noise floor is determined by environmental issues such as swell noise and cable jerk rather than noise inherent to the equipment. Tests show that a usable temporal bandwidth of at least 3-90Hz can be obtained using a conventional airgun array and modern hydrophone only recording when a) the sea surface is not a perfect mirror and b) the streamer is towed in a deep, quiet environment.

Introduction

Theory tells us that when a hydrophone records a receiver ghost reflection whose polarity has been reversed by reflection at the sea surface then constructive and destructive interference lead to enhanced signal strength at certain frequencies and reduced signal strength or notches at other frequencies. If the sea surface is a perfect mirror then perfect cancellation can occur at the notches in the amplitude spectrum. If the sea surface is rough, and hence not a perfect mirror, the cancellation is imperfect and the notches become broader and shallower.

However, usable bandwidth is determined by both signal and noise not just signal. If the signal strength is above the noise floor, then that signal is usable. There are many sources of noise when recording seismic data but it is clear that if we can reduce the noise levels then we can also increase the usable temporal bandwidth with just hydrophones. Modern recording equipment has sufficiently reduced inherent noise levels that, if towed in a quiet environment, the overall S/N levels can be low enough to allow recovery of a fully usable bandwidth from at least 3 – 90Hz provided the sea surface is a less than perfect mirror.

Experiment and results

In July 2011, we recorded a 2D test line in deep water, offshore NW Africa. The line was first recorded with a conventional towing geometry of 8m source depth and 9m cable depth. The line was then repeated with the only change being that the cable was dropped down to 32m depth. The airgun source array was not modified to enhance low frequencies. The line was recorded by the Artemis Atlantic with the low cut recording filter out. Both passes were recorded in a wave height of approximately 1.5m

Figure 1 shows a sample shot record both raw and with a low cut filter applied for both the 9m cable depth and the 32m cable depth. Not surprisingly, it is immediately apparent that there is a high level of coherent, low frequency noise on both raw data sets but even on the raw data we can see more signal on the 32m record than on the 9m record. On the low-cut filtered data, we see that towing at 32m has reduced the environmental, swell noise considerably and boosted the overall S/N ratio although there is an increase in cable-jerk coherent noise at both the near and far offsets. We expect this to be overcome with improvements to the rigging.

Various low pass filters were also applied to test the lowest usable frequency for both datasets. For example, figure 2 shows usable signal on the 32m cable depth data after applying a 3.5Hz low pass filter. A 5Hz low pass (not shown) reveals a S/N ratio of approximately 1 on the 9m cable whereas the S/N is considerably higher when the data is recorded at 32m.

Depending on the water velocity, a cable at 32m has theoretical notches at approximately 24Hz, 48Hz, 72Hz etc. The S/N levels in these higher frequency notches were also examined and estimated to be above 1 down to several seconds below the water bottom. The S/N is strongest at the lower of these notches but as shown in figure 2 (right) there is still coherent signal down to approximately 2s below the water bottom even in the 72Hz notch.

If we have recorded usable S/N within the 'normal' 4ms bandwidth but also increased the low frequency limit, it should be possible to obtain migrated images with approximately 3-90Hz bandwidth. Although not shown here, migrated images with 3-90Hz bandwidth have been obtained with careful processing.

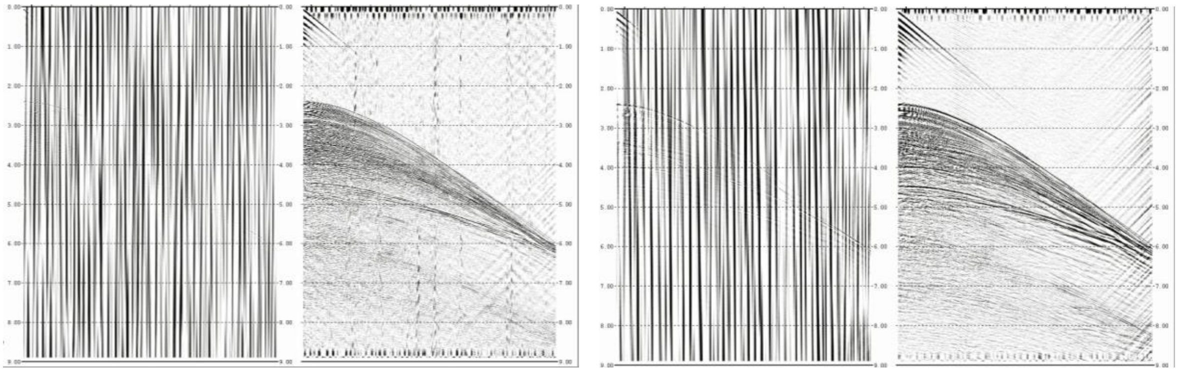

Figure 1 *Shots recorded at 8m cable depth (left) and 32m cable depth (right) both raw and after a 2Hz low cut filter. At 32m we see an overall boost to S/N on the raw data plus a reduction in environmental swell noise after the low cut filter. However, there is an increase in cable- jerk, coherent noise caused by a sub-optimal towing configuration.*

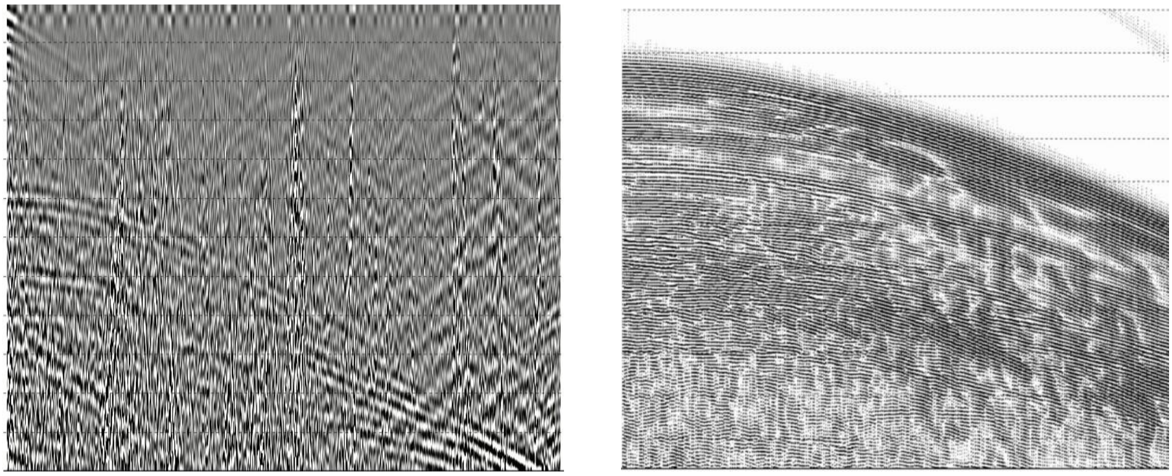

Figure 2. *Left: 3.5Hz low pass of shot at 32m cable depth showing usable signal. Right: Notch filter around high frequency notch at approximately 72Hz showing usable signal to approximately 2s below the water bottom*

Conclusions

A conventional airgun array has been shown to emit energy below 5Hz with sufficient energy to be recorded in a low noise level environment with conventional hydrophone equipment. Moreover, under the assumption that the sea surface is not a perfect reflector, modern hydrophone-only recording equipment has inherent noise levels low enough to allow recording of usable signal in at least a 3-90Hz temporal bandwidth if towed deep enough to avoid near surface swell noise.