

Enhanced Low Frequency Signal-To-Noise Characteristics of an Airgun Technology Based Source

J. Brittan¹, P. Farmer², N. Bernitsas², T. Dudley²

¹ ION; ² ION

Summary

In facing the challenge of imaging complex three-dimensional structures with high impedance contrast boundaries, geophysical theory tells us that we need data with long offsets, rich azimuthal content and as high as bandwidth as possible. In particular, the importance of the information carried by low frequencies has been highlighted as critical in such diverse geological situations as sub-basalt imaging and GOM sub-salt imaging. While modern ocean-bottom nodal based acquisition has made the acquisition of long offsets and rich azimuths operationally and economically feasible, it is still common for OBS exploration surveys to be carried out with sources and receivers that are not optimised for low-frequency data acquisition.

In this paper, we report on a survey we recently carried out in the Western Gulf of Mexico using a source that was optimised to provide an uplift in signal to noise at low frequencies. This source may be characterised as a pneumatic seismic source as it is based on airgun technology. The new source, while designed to optimise the signal to noise ratio at frequencies less than 4 Hz, also provides significant signal across the full seismic bandwidth typically used in modern imaging projects.

Introduction

In facing the challenge of imaging complex three-dimensional structures with high impedance contrast boundaries, geophysical theory tells us that we need data with long offsets, rich azimuthal content and as high as bandwidth as possible. In particular, the importance of the information carried by low frequencies has been highlighted as critical in such diverse geological situations as sub-basalt imaging (Ziolkowski *et al.*, 2003) and GOM sub-salt imaging (Brenders *et al.*, 2018). While modern ocean-bottom nodal based acquisition has made the acquisition of long offsets and rich azimuths operationally and economically feasible, it is still common for OBS exploration surveys to be carried out with sources and receivers that are not optimised for low-frequency data acquisition.

In this paper, we report on a survey we recently carried out in the Western Gulf of Mexico using a source that was optimised to provide an uplift in signal to noise at low frequencies. This source may be characterised as a pneumatic seismic source as it is based on airgun technology. It is therefore more akin to the tuned-pulse source described by Chelminski *et al.* (2019) than the large variable-frequency resonator described by Brenders *et al.* (2018). Unlike, the variable-frequency resonator, the new source, while designed to optimise the signal to noise ratio at frequencies less than 4 Hz, also provides significant signal across the full seismic bandwidth typically used in modern imaging projects. At high frequencies (150 Hz and upwards) the amplitude levels output by the new source are considerably less (15 dB or more) than that of a conventional air-gun array, which means the new source has considerably smaller behavioural threshold distances for marine mammals than conventional sources. In a companion paper (Brittan *et al.*, 2020) we show how the enhanced signal-noise in the low frequencies enables the recovery of complex, high impedance-contrast boundaries when utilising a time-shift based full-waveform inversion algorithm.

Low Frequency Sources

As a result of the need to support modern inversion methods such as FWI, there has been considerable recent interest in improving the signal-to-noise output at low frequencies from airgun based sources. The output energy of such a source is a function of the product of the final pressure of the source chamber and the volume of the chamber (Watson *et al.*, 2016). The spectral output of this energy is controlled by oscillations of the source-created bubble, which are significantly controlled by the volume of individual sources. The far field output of the source depends on the source's basic signature interacting with the ghost energy reflected from the sea surface (Amundsen *et al.*, 2017).

Data Examples

The survey was conducted using a sparse (1km x 1km nominal spacing) array of ocean-bottom nodes in a mean water depth of approximately 2km. A comparison of the spectra from a conventional array and the new source (shot into the same ocean bottom nodes) can be seen in Figure 1. The key differences are that the peak frequency for the new source is around 3.5 Hz (as opposed to 7.5 Hz for the conventional array) and that the signal-to-noise ratio in the range 1.5-4.5 Hz is considerably increased (up to 20 dB).

Conclusions

The data collected with the new source has shown that modified air-gun technology can provide an increase in signal-to-noise ratio in the key frequency range 2-4Hz over conventional multi-gun air gun arrays.. In a companion paper, we show that these new source concepts fully support modern inversion methods.

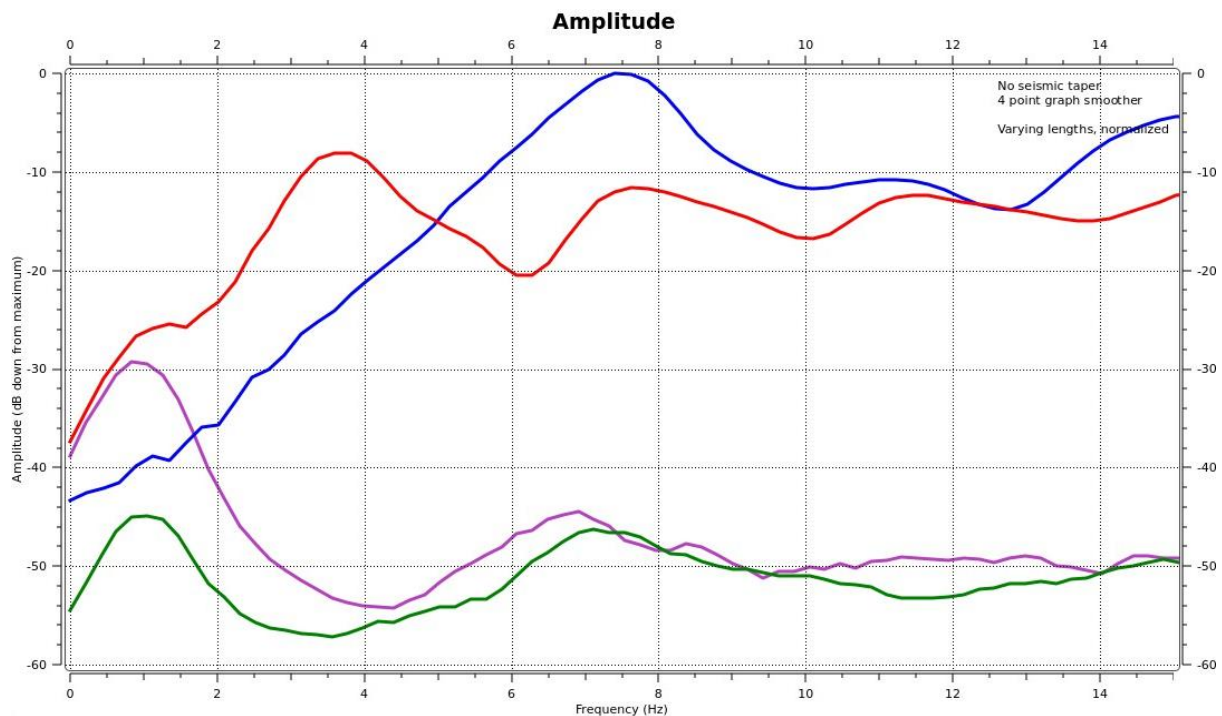


Figure 1. The low-frequency (<15 Hz) part of the amplitude spectra for a conventional air-gun array and the new source. Measured background noise spectra for good and bad weather situations during the survey have also been plotted. Note that a filter has been applied below 1 Hz which accounts for the roll-off in all spectra close to 0 Hz. The noise signals at <1 Hz are considerably higher than those from either source. These spectra have been measured on the same ocean-bottom instruments which were not moved between measurements.

Acknowledgements

The authors wish to thank BHP for permission to publish the data and ION for permission to publish this paper.

References

- Amundsen, L., Westerdahl, H., Pederson, A-S., Thompson, M and Landrø, M., 2017. On firing an air gun very shallow. *Geophysics*, **82**, A25-A29.
- Brenders, A., Dellinger, J., Kanu, C., Li, Q. and Michell, S., 2018. The Wolfspar® field trial: Results from a low-frequency seismic survey designed for FWI. *SEG Technical Program Expanded Abstracts*.
- Brittan, J., Cobo, Y., Farmer, P., Wang, C. and Brookes, D., 2020. Model building in complex, high impedance-contrast geological situations using low-frequency data from an optimised airgun technology based source. *Submitted for EAGE 2020, Amsterdam*.
- Chelminski, S., Watson, L.M. and Ronen, S., 2019. Research note: low-frequency pneumatic seismic sources. *Geophysical Prospecting*, **67**, 1547-1556.
- Watson, L.M., Dunham, E. and Ronen, S., 2016. Numerical modelling of seismic airguns and low-pressure sources. *SEG Expanded Abstracts*, 219-223.
- Ziolkowski, A., Hanssen, P., Gatliff, R., Jakubowicz, H., Dobson, A., Hampson, G., Li, X-Y. and Liu, E., 2003. Use of low frequencies for sub-basalt imaging. *Geophysical Prospecting*, **51**, 169-182.