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Short Cluster Airgun Array for Shallow to Deep Crustal Survey

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A seismic airgun source should be designed under several conditions which depend on geological targets. For the shallow-targeted survey as in standard oil and gas exploration, we should take into consideration that the source has a wide frequency band and a high primary-to-bubble ratio (P/B). The deeper the target or longer the offset, the more crucial the amplitude in the lower frequency range becomes. As expected, the primary-peak amplitude should be raised. The P/B is still important in deep-penetration surveys for accurate seismic imaging. However, it is usually difficult to obtain such features along with a conventional or bubble-tuned airgun array. Thus we propose a new short airgun array that can meet these demands by using a closely spaced linear cluster technique.

INTRODUCTION

Recently, as offshore oil and gas exploration goes into deeper-water and more complex geological regions such as the sub-salt or sub-basalt layer, the low frequencies of seismic exploration become much more important. The seismic source feature that is composed of airguns is essential for imaging deep or complex geological targets. The low-frequency component of a few Hz up to 25 Hz in source energy is especially crucial for deep crustal penetration.

With respect to academic experiments, all kinds of unveiled geoscientific objects lie under the sea from shallow water to the deepest trench (11 km), and many of the major geological interests are in the deeper part of the crust, sometimes several tens of km beneath the seafloor, such as seismogenic faults, plate boundaries, igneous rocks and the Moho. The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has been conducting seismic experiments for deep crustal studies with low-frequency-rich sources through the last decade. The basic approaches for understanding the earth's crust are as follows:

• A seismic reflection survey with a long streamer imaging geological structure down to the Moho and constructing the sedimentary layer's velocity model.

• A seismic refraction survey combined with over 100 Ocean Bottom Seismometers (OBS) to build an entire crustal velocity model.

Both approaches require high-output and low-frequency-rich seismic energy in order to make the survey penetrate far down into the crust. These studies always demand better sources and sensors so as to distinctly catch the seismic waves from deeper in the earth.

For a further integrated and detailed understanding of the earth's crust from shallow to deep, studies with a highly resolved structural image and more accurate velocity model construction are vital. These require a new seismic source which accommodates various features of geological interest, such as depth, horizontal extent, structural complexity and rock property, all of which affect the specifications of seismic acquisition.

The airgun-array signature is designed by 4 factors: gun depth, air pressure, air volume and geometrical arrangement. These are defined depending on the target by optimizing the frequency content, wavelet shape, output power and directivity. However, it is difficult to make an airgun array suit a variety of targets because of some tradeoff on such desired source features. In addition, unlike the oil and gas exploration industry, many of whose seismic vessels furnish large-scale airgun arrays and multistreamer systems, a large-scale seismic system may not be practical for an academic institute. Contrary to scientific needs, an academic research vessel lacks enough seismic system, which is not dedicated to seismic exploration but also to a variety of scientific experiments.

Therefore, desiring an excellent seismic source that is applicable to the various scientific interests, we designed a new short airgun array to satisfy the demands of shallow to deep seismic studies, an airgun array preferably small enough to be installed on the limited deck space.

KEY OF AIRGUN SIGNATURE

Frequency Content

The airgun is the most reliable source that emanates a low-frequency-rich and high-energy elastic wave for marine seismic exploration. The typical dominant frequency of the airgun signature for oil and gas exploration is 10 Hz to 80 Hz. In order to improve temporal resolution, wide bandwidth is important. Just having low or high frequencies does not improve temporal resolution (Yilmaz, 1987). Usually an airgun array employs a number of guns in different sizes which can generate seismic energy in different parts of the amplitude spectrum, although the spectra of the different guns overlap (Stoffa and Ziolkowski, 1983). The most important factor is the ghost-notch effect which determines the frequency range. This is caused by the reflection from the water surface which destructively interferes at around the specific frequencies given by $V/2D$, where V is the velocity of sound in the water, and D the depth of source. (The receiver ghost is given by the same formula.) For example, if we put the array in 6-m water

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