3D seismic survey system with simultaneous shooting by underwater speakers

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Seismic reflection technology has developed as a method to image subsurface structures, especially in the oil and gas exploration industry. It is possible to identify sedimentary structures from the reflection configuration, and faults by offsetting the reflections on the seismic reflection profiles. At present, the use of seismic reflection technology has expanded into other areas, including crustal studies in seismogenic zones for earthquake disaster prevention and carbon capture and storage.

Recently, the use of explosive type of energy sources such as airguns was restricted because of its potential impacts on marine mammal and fish species (IOGP, 2017). This restriction is particularly severe in coastal waters such as Tokyo Bay, where detailed geological structures are still unknown because of a lack of seismic data. Therefore, we are developing an environment-friendly seismic survey system that uses underwater speakers (UWSs) as a non-explosive type of energy source. Explosive sources instantly generate impulsive waves with high sound pressure, whereas non-explosive sources generate non-impulsive waves with low sound pressure over a certain period of time. Using an energy source with low sound pressure, it is possible to conduct seismic surveys with a relatively low environmental impact on marine ecosystems. Another advantage in using non-impulsive seismic sources is the application to 3D seismic survey using single streamer cable, as shown in Figure 1. We report here on a seismic survey system using UWSs, which would enable us to collect 3D seismic data in such a blank zone in seismic survey as Tokyo Bay.

Moreover, seismic surveys in Tokyo Bay are also important for modeling the structures in the surrounding Kanto basin (e.g., Koketsu et al., 2009). Recent seismological studies revealed that shallow geological structures control long-period ground motions, which may cause severe damages to large-scale man-made structures such as high-rise buildings, oil tanks and suspension bridges.

Compared to explosive sources that instantly shoot an impulsive wave with a considerably higher level of sound pressure, non-explosive sources generate non-impulsive waves with relatively smaller level of sound pressure for a certain period of time. By taking the cross-correlation between the non-impulsive wave and an observed record, the observed record is converted into a series of impulsive reflections. This procedure is the same as that used in onshore vibroseis surveys (Yilmaz and Doherty, 1987).

We tested the effect of increasing the signal-to-noise (S/N) ratio by cross-correlation processing. Based on a numerical experiment, the increase in the S/N ratio by cross-correlation processing was about 26 dB. Since the increase in the S/N ratio is equivalent to the effect of increasing the sound pressure level (SPL) of a source wave, the SPL of the UWS used in this study becomes larger by about 26 dB after cross-correlation processing. As a result, the SPL of the UWSs may become larger than that of an airgun although it depends on the frequency characteristics of airgun.

From 2017 to 2019, seismic experiments using UWSs were conducted by T/V Hiyodori of the Tokyo University of Marine Science and Technology in the Tokyo Bay. We would like to demonstrate resulting 2D and 3D seismic reflection data as well as examples of wavefield separation by cross-correlation.

Keywords: underwater speaker, 3D seismic data, environment-friendly