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Basic Study on High Frequency Ultrasound Imaging of Shellfish in Sediment

高周波超音波を用いた内生二枚貝音響可視化のための基礎的検討

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1. Introduction

Asari (*Ruditapes philippinarum*) is a shellfish of a few centimeters in size, which lives in relatively shallow layer in sediment. The shellfish is not only an indispensable aquatic resource for humans but also important species which has purification function in underwater ecosystem. In Japan, the shellfish has greatly decreased in recent years [1]. Thus, it is necessary to establish a resource management method and a system for monitoring their lifecycle. However, sediment makes it difficult to survey the shellfish efficiently. In general, digging is used for the survey, however, the method requires huge effort and time. In addition, it always destructs a survey site. Therefore, an efficient and non-destructive survey method is required.

Acoustic sensing has been applied to detect buried objects in sediment as one of the efficient methods. Buried wooden shipwrecks under the seabed were detected by using chirp signals with 1.5-13 kHz swept pulse [2]. Mizuno *et al.* visualized aquatic plant's root in sediment as three-dimensional acoustic image using transducer that transmits a pulse with a center frequency of 100 kHz [3]. Thus, in most cases, wavelengths are much longer than grain sizes. However, in the case of detection of the shellfish, it is required to use high-frequency ultrasound which provides a wavelength closer to grain size. In addition, the shellfish lives in sediment with various grain sizes. The difference in grain size dramatically changes sound velocity and attenuation [4]. The different velocities deform pulse waves and a high attenuation deteriorates the contrast of acoustic images. Therefore, it is necessary to develop an effective acoustic visualizing method by using high-frequency ultrasound.

The objective of this paper is to improve the visibility of acoustic image deteriorated by changing sound velocity and attenuation with different grain sizes. We observed reflected waves from an aluminum square pillar and a shellfish buried in glass beads (GB) with different grain sizes.

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2. Methods and Materials

Experimental set-up is illustrated in Fig. 1. Acoustic focus probe 25 mm in diameter with a focal length of 32 mm (JAPAN PROBE CO., LTD.) was used. The probe transmitted a square pulse with a central frequency of 1-MHz. An acrylic case was filled with the water-saturated glass beads and set in the water tank. Then, water and water-saturated glass beads were boiled to remove air. Two types of targets (an aluminum square pillar, a shellfish filled with silicone rubber) and eight types of glass beads with different grain sizes (GB0.046–GB0.855: 0.046 mm–0.855 mm) were prepared. The probe scanned along x axis at an interval of 1 mm and the backscatters were recorded in a computer.

Based on the spectrum analysis of reflected waves from a square pillar, the BPFs were designed and applied to reflected waves from the shellfish. The widths of passband were set to twice full width at half maximum of a peak in the amplitude spectrum. In addition, the pulse waves, which were elongated by velocity dispersion, were corrected. In this study, curved phase component of reflected waves was replaced with linear phase component (phase correction).

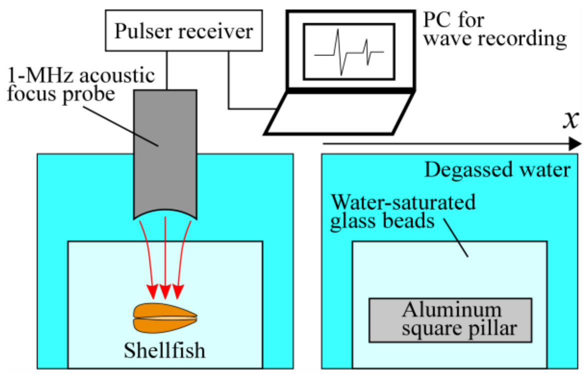

Fig. 1 Experimental set-up

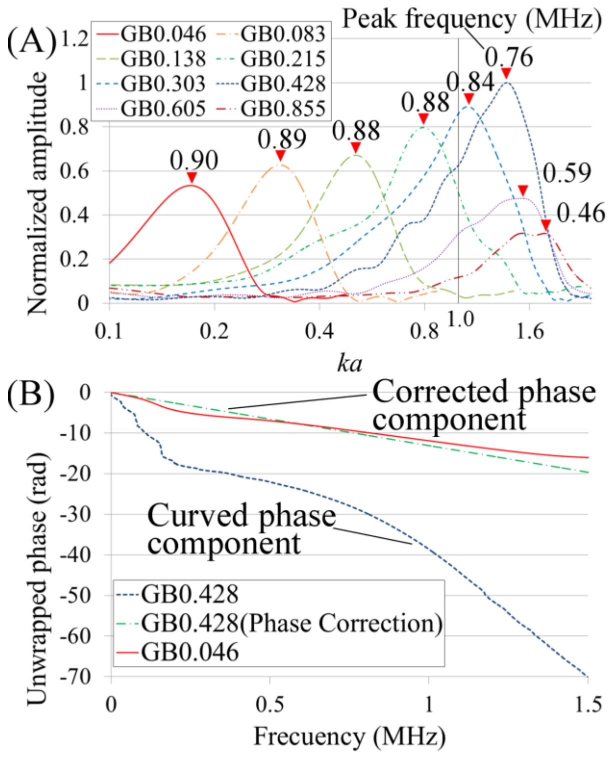

Fig. 2 (A) Amplitude spectra as a function of *ka* and peak frequencies. (B) Phase spectra of reflected waves from an aluminum square pillar in water-saturated glass beads. (A) shows results of eight types of glass beads. (B) shows two types of the glass beads (GB0.428, GB0.046) and corrected phase spectrum of GB0.428.

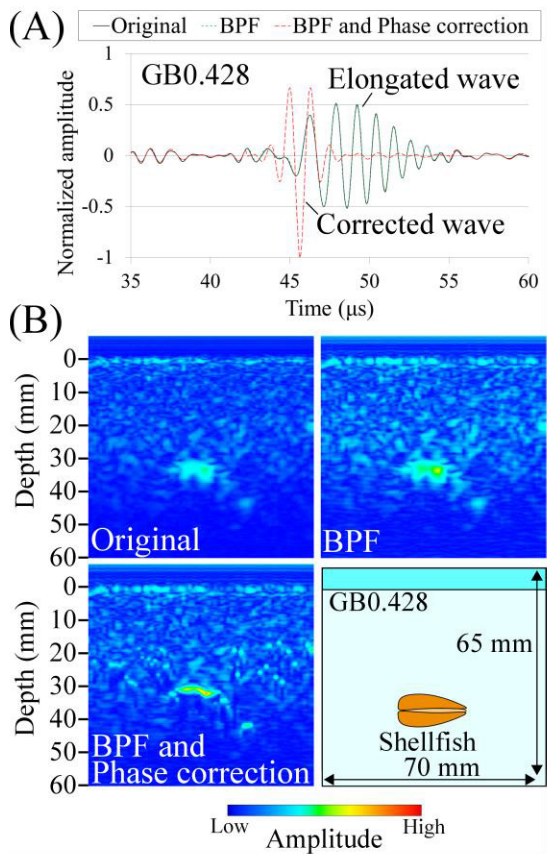

Fig. 3 (A) Reflected-waveforms from an aluminum square pillar and (B) acoustic images of a shellfish in water-saturated glass beads (GB0.428) at each stage of signal processing.

3. Results and Discussion

Two remarkable attenuation characteristics are found with the spectrum analysis, as shown in Fig. 2 (A). One is rapid reduction of amplitude spectrum components in a region of $1 < ka$ (k: wavenumber, a: diameter), mainly caused by the multiple scattering attenuation. The other is gentle reduction in a region of $ka < 1$, mainly caused by the viscous attenuation. The result indicates the amplitude component greatly changes in the range of transition from $ka < 1$ to $1 < ka$. In terms of phase spectrum, in contrast to the linear phase component of GB0.046, that of GB0.428 is curved like a FM signal, as shown in Fig. 2 (B). The pulse wave without dispersion usually has linear phase component. However, in high-frequency region, it is shown that phase spectrum is curved due to velocity dispersion, and that causes elongated waveform. Figure 3 shows that the BPF removes weak amplitude spectrum components and keeps strong ones, resulting in emphasis of strong reflection from the target. Furthermore, velocity dispersion was corrected by phase correction, as shown in Fig. 3. It's clear that the phase correction improves the sharpness of acoustic image. This signal processing enables us to visualize a shellfish clearly in sediment while reducing the influence of velocity dispersion.

4. Future work

This study indicates that proposed signal processing methods can contribute to an efficient shellfish visualization system. However, sediment usually consists of various grains with different sizes, densities, and shapes. In addition, the porosity of sediment also changes. This various and changeable property makes it difficult to visualize shellfish clearly. Thus, we are going to develop a robust visualization system by combining signal processing, image processing, and with three-dimensional visualization. The system would be greatly useful in the field of fishery and hydrobiology.

References

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