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Detection of free-swimming fish passing through narrow passage using MHz-band ultrasound

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1. Introduction

To detect school of fish in water even in turbid or low light condition, hydroacoustic measurement devices such as fish finders, sonar, quantitative echo sounder, etc. are used[1)]. These devices have difficulty to detect each fish and precise behavior of the fish because of the use of kilohertz-band ultrasound. To observe each fish precisely, high-resolution acoustic camera such as DIDSON with acousitc lenses using megahertz-band ultrasound has been used[2)]. However, this equipment is very expensive and complicated structure.

To construct a measurement method for fish behavior with a simple structure, we have examined the effectiveness of fish body detection in narrow path using a pair of transducers with megahertz-band ultrasound[3)]. This previous study investigated the property of echoes and transmitted waves from a fish body, and showed that the combined use of the echo and transmitted waves may increase the accuracy of fish detection compared with the use of only the echoes. However, this study used dead fish as a measurement sample, and validity of the measurement for free-swimming fish has not been verified.

In this study, the validity of free-swimming fish detection using a pair of transducers with megahertz-band ultrasound are evaluated in small shallow water tank. To increase robustness of fish detection, we also focused on the backwall echo, which have been used for nondestructive inspection[4)], in addition to echo from fish and transmitted wave through fish as investigeted in previous study[3)].

2. Materials and methods

Experiments were carried out using a rectangular acrylic tank (x-y-z dimensions 100×200×50 mm) with a thickness of 2 mm and a water depth of 25 mm. The temperature of the water was 25 °C. One goldfish *Carassius auratus* with total length of 56 mm swam freely in the tank. Two transducers (Olympus, A303S-SU) with aperture of 13 mm were placed on both sides of the center of the long side of the rectangular tank as shown in **Fig.1**. The outside of the tank is also filed with 25 mm of water, and the transducers were in the water. One transducer transmitted 10 cycle up-chirp signal of

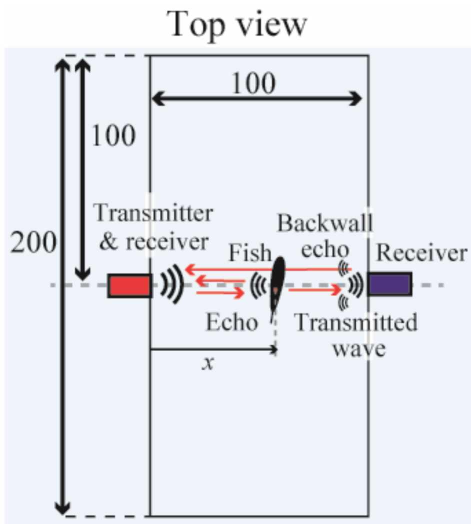

Fig. 1 Experimental condition of free-swimming fish detection using echoes from fish and backwall, and transmitted wave of ultrasound.

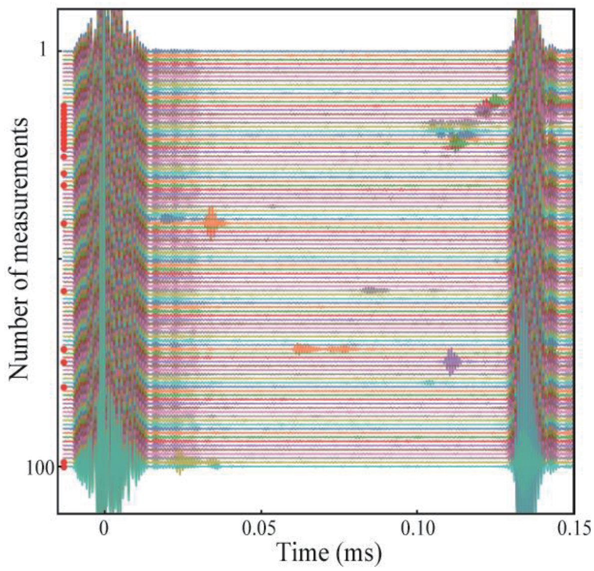

Fig. 2 Waveforms of echoes for each measurement after pulse compression.

0.5-1.5 MHz using a function generator (Agilent, 33120A) and an amplifier (R&K, AA290-0S). The transducer received echo from the fish and backwall through diplexer (RITEC, RDX-6). The other transducer on opposite side received transmitted wave through the fish body. These received signals were acquired by a digitizer (National Instruments, USB-5133) at a sampling frequency of 100 MHz.

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The transmission of the up-chirp signal per one measurement was performed 5 times every 0.15 s, and this set of measurement was performed 100 times every 2.5 s. The swimming behavior of the fish was also recorded using digital video camera (Kodak, PIXPRO WPZ2) from above the water tank. The position of the head and tail fin of the fish was obtained from the recorded video using DeepLabCut[5], and whether the fish was between the transducers at the time of each measurement were analyzed by the obtained position.

3. Results and discussion

Figure 2 shows the averaged received waveforms of echoes for each measurement after pulse compression. Red dot indicates that the fish was between the transducers at the measurement. Echoes from the fish were observed when there is a fish between the transducers.

Figure 3 shows the profiles of echoes, transmitted waves, and the fish position *x*. The position *x* of the fish as shown in Fig. 3(b) seems to be correlated with time-of-flight (TOF) of echoes from the fish as shown in Figs. 3(a) and 3(c) when the fish was between the transducers. When the amplitude of the echoes was small as shown in Fig. 3(d), the TOF was calculated as smaller value as expected from the position *x* because the amplitude of the echo becomes smaller than the reverberation generated on the wall of an acrylic tank near the transmitter. The amplitudes and TOF of backwall echo and transmitted waves were also affected by the existence of the fish between the transducers as shown in Figs. 3(e) and 3(f). In some measurement, the effect of the fish can be observed in the backwall echoes and transmitted waves even when the echo from fish is small.

4. Conclusion

In this study, the validity of free-swimming fish detection using a pair of transducers with megahertz-band ultrasound are evaluated in small shallow water tank. The fish swimming between the transducers can be detected from the echoes from the fish and backwall, and transmitted waves through the fish.

Acknowledgment
This work was supported by JSPS KAKENHI Grant Number JP23K14005.

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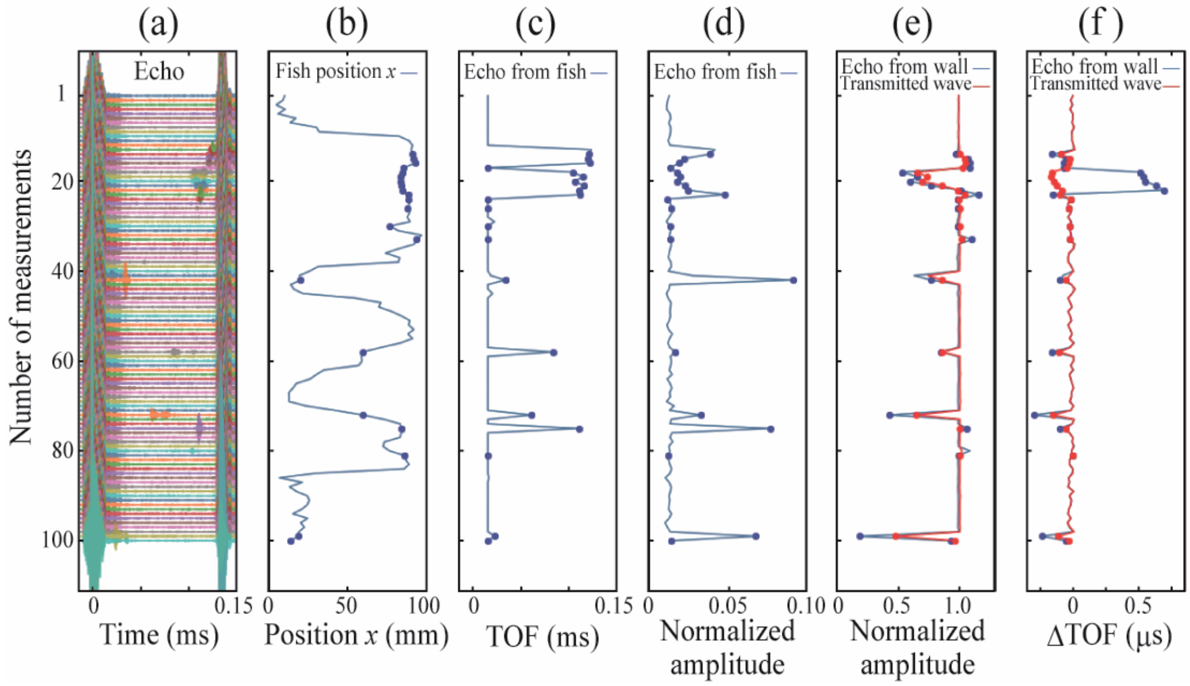

Fig. 3 Profiles of echoes and transmitted waves, and fish positions for each measurement; (a) waveforms of echoes, (b) fish positions *x*, (c) TOFs of echoes, (d) maximum amplitudes of echoes, (e) maximum amplitudes of echoes from backwall and transmitted waves, and (f) difference of TOF in echoes from backwall and transmitted waves. Dots indicate that the fish was between the transducers at the measurement.