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Detection of Fish Passing Through Narrow Path Using Ultrasound

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1. Introduction

Hydroacoustic techniques have been used to observe fish behavior in water, because the fishes can be detected using acoustic signals even in turbid water and low light condition, where visual inspection and underwater video recording are ineffective[1,2]. To detect school of fish, fish finders, sonar, quantitative echo sounder, etc. are used from the ship. These devices and techniques have difficulty to detect each fish and precise behavior of the fish. To observe each fish precisely, high-resolution acoustic camera using multi beam sonar such as DIDSON has been used[3,4]. However, this equipment is very expensive and complicated structure.

In this study, we aim to measure fish behavior with a simple measurement system. As the first step, we examined the effectiveness of fish body detection in narrow path using a pair of transducers. In previous studies, the characteristics of ultrasonic echo from fish bodies have been studied such as target strength[5]. However, most of these studies focused on the echo from the swim bladder, and the echo from other parts have not been studied well. In addition, transmitted waves through the fish body have not been focused on, while the transmitted waves have been used for nondestructive inspection[6-8]. In this report, the property of echoes and transmitted waves from a fish body, from the tail to the head, are investigated to construct fish detection method in narrow path by simple measurement structure.

2. Materials and methods

Experiments were carried out using a circular tank with a water depth of 200 mm. The temperature of the water was 25 °C. One dead Japanese Jack mackerel *Trachurus japonicus* with total length of 174.0 mm, folk length of 151.7 mm, maximum body width of 21.2 mm, and width at caudal fin of 0.4 mm was used. The fish was suspended at 100 mm from the bottom of the tank using fishing lines of 0.37 mm diameter and a rectangle frame with height of 200 mm and width of 300 mm. The suspended fish was covered by plastic bag filled with water. The echoes from the bag were negligibly small.

Two transducers (Olympus, A303S-SU) with aperture of 13 mm were placed on each side of the fish as shown in **Fig.1**. The distance between the transducers *d* were 60 and 100 mm. One transducer transmitted 10 cycle up-chirp signal of 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 the other transducer

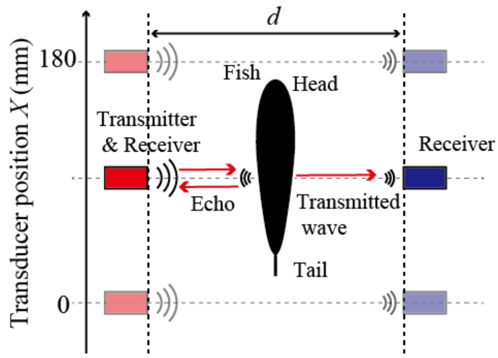

Fig. 1 Experimental condition of fish detection from echo and transmitted wave using ultrasound.

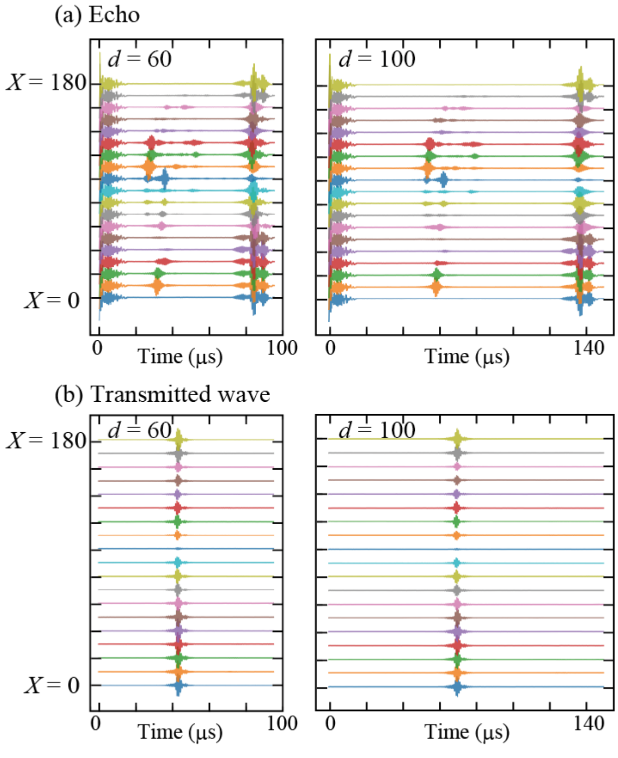

Fig. 2 Waveforms measured at transducers position *X* from 0 mm to 180 mm in 10 mm increments: (a) echo and (b) transmitted waves.

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on opposite side received transmitted wave through the fish body. The transducers were scanned 180 mm in 1 mm increments and the fish body were measured from the tail to the head.

3. Results and discussion

Figure 2 shows the received waveforms after pulse compression at d = 60 and 100 mm in the experiment. Echoes from the fish body were observed as shown in Fig. 2(a). Single echo was observed from the tail, while multiple echoes were observed from the body. The amplitude of transmitted waves around the center of the fish body decreased compared with that at other body parts as shown in Fig. 2(b). These tendencies were almost same regardless of the distance between the fish body and the transducers.

Figure 3 shows the profiles of echoes from the fish body. High amplitudes of echoes were observed at the tail part and the center of body contains swim bladder compared with other parts as shown in Fig. 3(a) and (b). Time-of-flight (TOF) in Fig. 3(c) shows the time when the maximum amplitude was observed in the echo at each transducer position X. Deviation in TOFs at each X shows that the fish has some strongly reflective parts, such as swim bladder, vertebral column, and caudal fin.

Figure 4 shows the profiles of transmitted waves through the fish body. Lowest amplitude of transmitted wave was observed at the center of the body compared with other parts as shown in Fig. 4(a) and (b). Reduced amplitudes were also observed in transmitted waves through the fish body parts other than swim bladder, while small reductions were observed in the transmitted waves through the caudal fin. ΔTOF in Fig. 4(c) shows the difference of the TOF between transmitted waves with and without fish body. Decrease of TOFs were observed at the fish body and the amount of decrease seems to be correlated with body width of the fish at each X.

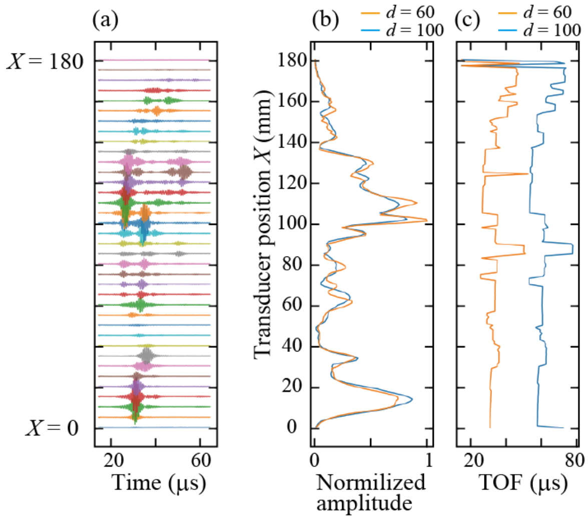

Fig. 3 Profiles of echoes from fish body; (a) waveforms of echo at distance between transducers d = 60 mm and transducers position X from 0 mm to 180 mm in 5 mm increments, (b) maximum amplitudes of echoes, and (c) TOF of echoes.

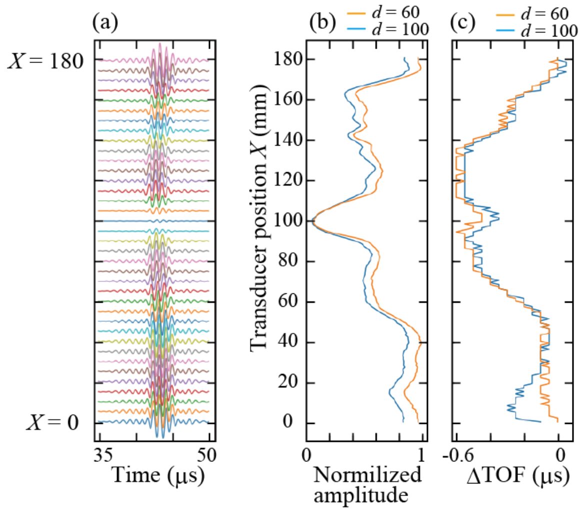

Fig. 4 Profiles of transmitted waves through fish body; (a) waveforms of transmitted wave at distance between transducers d = 60 mm and transducers position X from 0 mm to 180 mm in 5 mm increments, (b) maximum amplitudes of transmitted waves, and (c) difference of TOF in transmitted waves.

4. Conclusion

In this study, we investigated the property of echoes and transmitted waves from a fish body. From the echoes, the outline of the fish was observed. High amplitudes of the echoes from swim bladder and caudal fin were observed. From transmitted waves, low amplitudes in transmitted waves from body parts include swim bladder were observed. The combined use of the echo and transmitted waves may increase the accuracy of fish detection compared with the use of only the echoes.

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