3P6-6

Proceedings of Symposium on Ultrasonic Electronics, Vol. 37 (2016)
16-18 November, 2016

Numerical Analysis for Estimating Scattered Waveform from Complex-Shaped Object in Water
数值解析による水中複雑物体からの散乱波形の推定

Shunichi Fujii [1], Takenobu Tsuchiya[1†], Hironori Mori[1], and Nobuyuki Endoh[1] ([1]Dept. of Eng., Kanagawa Univ.)
藤井 俊一 [1†], 土屋 健伸 [1], 毛利 裕則 [1], 遠藤 信行 [1] ([1] 神奈川大 工)

1. Introduction

Scattered waves from objects in water change depending on the size, shape, and posture of the objects. In the field of fish acoustics, studies have been done on the effect of a posture angle and a shape of the air bladder of fish on the amplitude of scattered waves[1)], which are used for estimating target strength (TS) and fish type. Reflection characteristics of arbitrary shapes have also been reported[2)]. Recently, numerical analysis has made it easier to obtain the scattered waves from objects in water owing to the high-speed CPU and GPU. Accordingly, we aim to obtain new knowledge in scattered waves from objects in water by conducting propagation analysis by a finite-difference time-domain (FDTD) method and with consideration for the characteristics of the propagation path.

In this study, as a preparatory step for the analysis of scattered waves from the objects with arbitrary shapes in water, we conducted the analysis of scattered waves using a spheroidal model as the shape of fish. We obtained the change in the amplitude of the scattered wave due to the receiving angle, which occurred when the posture angle of the spheroid changed.

2. Analysis method

Figure 1 shows the model diagram of the spheroid. The target spheroid has its rotational axis along the major axis, and its shape was a = 103 mm along the major axis (z axis) and b = 35 mm in the minor axis (x- and y-axes).

Figure 2 shows a model for the analysis of scattered waves. We conducted a 3-dimensional analysis in this simulation, and the analytical domain was 490 mm in each direction. We assumed the following characteristics for the domain: speed of sound 1,500 m/s, density 1000 kg/m^3, and being filled with water without attenuation. We used a FDTD method as the analysis method. The location of the center of the object was at z = 294 mm from the sound source, and its x and y coordinates were same as those of the sound source. We varied the posture angle θ of the spheroid from 0˚ to 90˚. Pulse waves were generated from the sound source with a central frequency of 100 kHz and a pulse width of 40 μs. The receiving point for the scattered wave was at 105 mm from the center of the object. The receiving point on the line segment connecting the center of the object and the sound source was defined as 0˚, and the range of the receiving angle was the front of the object, i.e., ϕ = ±90˚. The scattering cross section of the object becomes minimum for a posture angle of 0˚ and maximum for 90˚. The analysis time was 375 μs (1500 time steps). Also, we assumed the spheroid to be a perfectly reflecting object in this analysis.

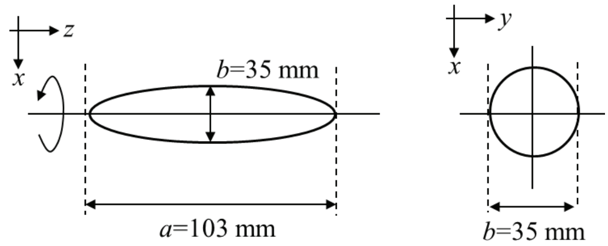

Fig. 1 The model diagram of the spheroid.

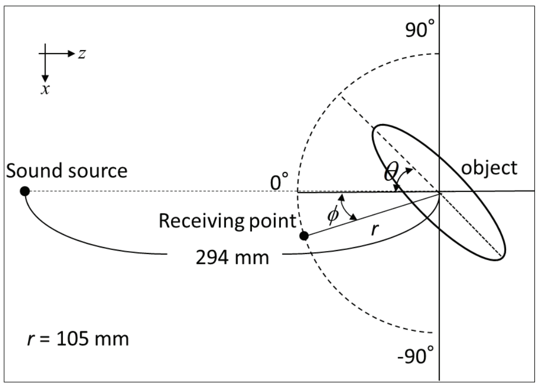

Fig. 2 The model for the analysis of scattered waves.

3. Results

Figure 3 shows the analysis results of the received waveform for a posture angle of θ= 0˚ and a receiving angle of ϕ= 0˚. The figure shows two types of wave: a direct wave reached directly from the sound source and a scattered wave received as reflection from the object. We then applied a time window on the results in Fig. 3 and obtained the

kenshin@kanagawa-u.ac.jp

maximum amplitude for the scattered waves. **Figure 4** shows the change in the amplitude for posture angles of $\theta = 70^\circ$ and 90° to the receiving angle ϕ. Fig.4 shows that, for a posture angle of $\theta = 90^\circ$, the maximum amplitude is obtained at $\phi = 0^\circ$, and there are also other extrema. For a posture angle of $\theta = 70^\circ$, however, there is only one extremum, at which the receiving angle with the maximum amplitude is $\phi = -50^\circ$. The amplitude is almost same as for a posture angle of $\theta = 90^\circ$. The above findings indicate that the receiving angle ϕ at which the maximum amplitude is obtained changes with the posture angle θ. In order to study the effect of the posture angle on the amplitude of the scattered wave, we obtained the maximum amplitude and receiving angle for the given posture angles. **Figure 5** shows the maximum amplitude for posture angle θ. Fig. 5 shows a monotonic increase in the amplitude for posture angle θ from 0° to 50°. **Figure 6** shows the receiving angle ϕ for the posture angle θ. Fig. 6 shows that, for θ from 0° to 50°, the receiving angle ϕ is almost constant. This is because the reflected wave itself did not travel toward the receiving point but instead traveled toward the back of the object. Based on this finding, the reason for which the amplitude monotonically increases for the posture angle θ from 0° to 50° in Fig. 5 is that the maximum amplitude, which was behind the receiving angle -90°, approaches the receiving angle $\phi = -90^\circ$ due to the object's rotation. Also, for the posture angle θ beyond 50° in Fig. 4, there was no significant change in the amplitude, and it is more or less constant. In Fig. 5, for the posture angle θ beyond 50°, the receiving angle monotonically increases. This is because the object rotates such that the surface where the strongest reflected wave is generated is rotating so that the wave can be reflected toward the receiving point, so the maximum amplitude is almost constant, and the receiving angle ϕ changes towards 90°.

4. Conclusions

In this report we obtained the angle dependence of the scattered wave from a perfectly reflecting object simulating the shape of fish. As a result, the amplitude increased as the scattering cross section of the object broadened towards the propagation direction of the wave from the sound source. Also, the amplitude was almost constant for a posture angles of 50° and beyond. Based on the above findings, we understood the characteristics of the reflected wave from a spheroid in the transmitting direction of the wave. In the future, we are planning to model the condition of fish with a bladder and bones and study the angle dependence of the scattered waves.

References

1. Y. Fukuda *et. al.*: J. Marine Acoust. Soc. Jpn. **40** (2003) 138. [in Japanese]
2. M. Ogushi, M. Harazono: Proc. IEICE-ESS Conf. IEICE '10 (2010) 133. [in Japanese]

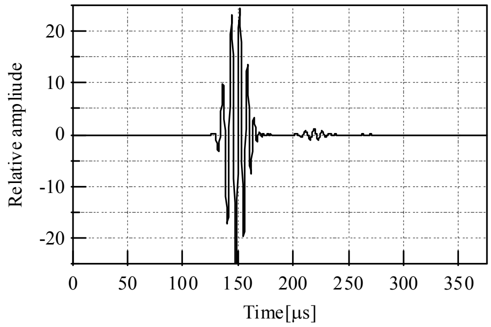

Fig. 3 the received waveform for a posture angle of $\theta = 0^\circ$ and a receiving angle of $\phi = 0^\circ$

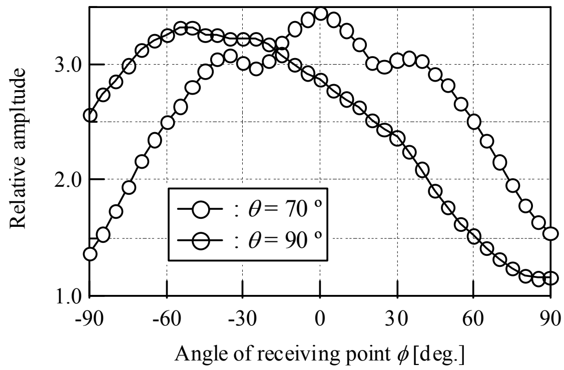

Fig. 4 The change in the amplitude for posture angles of $\theta = 70^\circ$ and 90° to the receiving angle ϕ.

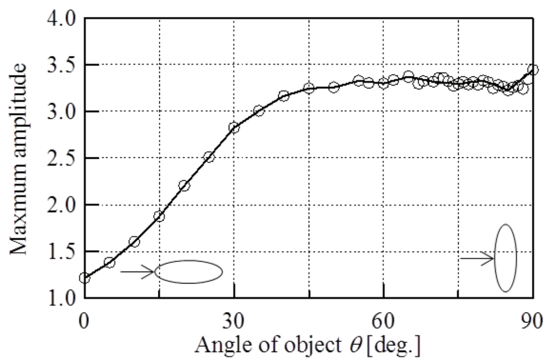

Fig. 5 The maximum amplitude for posture angle θ.

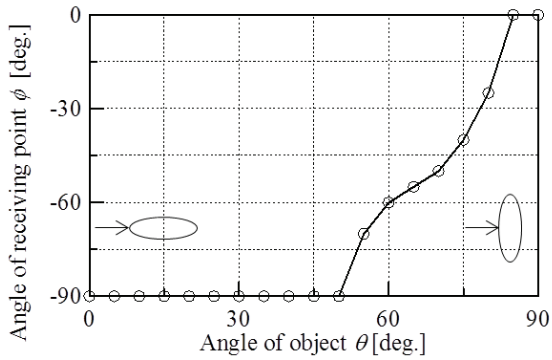

Fig. 6 The receiving angle ϕ for the posture angle θ.