2Pa2-3

Evaluation of reflected waveform from obstacles on the road surface

Yuki Tan[1†], Shinnosuke Hirata[2], and Hiroyuki Hachiya[1] ([1]Tokyo Tech., [2]Chiba Univ.)

1. Introduction

The airborne ultrasound is widely used to acquire target information such as position and motion. In order to detect objects using the pulse-echo method, it is necessary to understand the reflection characteristics of the object.

In this paper, we investigated the basic characteristics of reflection from an object, targeting steps on the road surface and floor surface. To examine the reflection characteristics, we carried out a simulation by the two-dimensional FDTD method (Finite-difference time-domain method) and an experiment using a metal block. We will explain the factors that generate the reflected wave from a stepped object and the change in the reflected wave when the size of the object and the curvature of the edge change.

2. Method

Simulations by using the FDTD method and experiments using the metal block were carried out.

In the simulation, the arrangement of the transmitter/receiver and the object was set, as shown in **Fig. 1**. As the transmission signal, a 12-wave sine-burst signal is used, and the center frequency is 33.3 kHz (period 30 ms). The speaker, which is the transmitter, is 0.5 m in height, and the ten microphones, which are the receivers, are arranged vertically on the upper side of the speaker at intervals of 2.5×10^{-3} m which is about 1/4 wavelength. The calculation area of the simulation is 1.5 m in front of and behind the speaker, 0.5 m between the speaker and floors, and 0.7 m between the speaker and ceiling, and the grid size is 0.25×10^{-3} m. The walls and ceiling are absorbing boundaries.

In the experiment, three sine-burst waves were used as the transmission signal, the center frequency was 33.3 kHz, which is the same as one in the simulation, the height of the speaker was 0.65 m from the floor, and the distance to the metal block (10 cm(W) × 10 cm(H) × 5 cm(D)) was 3 m.

Accurate detection of the reflected signal from the top edge, which reflects less than the bottom edge, is essential for estimating the location and size of obstacles on the road surface. In this study, two methods, simulation, and experiment, are used to

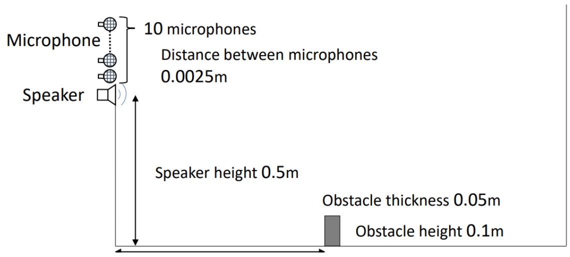


Fig. 1 Configuration of FTDT simulation.

evaluate the response of reflection characteristics due to the change of the obstacle's top edge shape. This time, two kinds of edge shapes were examined: one with a right angle (r = 0 m), which is the same as the metal block, and the other with a radius of curvature r = 0.02 m at the top edge.

3. Simulation and experimental results

Figure 2(a) shows the reflected signal when the upper edge of the object on the road surface is at a right angle (r = 0). The horizontal axis represents time [ms] and the vertical axis represents amplitude [V]. The positions and colors of the broken lines in **Fig. 2(a)** are the arrival times of the signals corresponding to the paths of the colored arrows in the reflection path diagram of **Fig. 2(b)**, respectively.

The red arrow indicates the path of reflection from the bottom edge of the obstacle, the blue arrow indicates the path of edge wave at the top edge of the obstacle, and the light blue arrow indicates the path of specular reflection of the signal after edge reflection at the top edge of the obstacle on the floor.

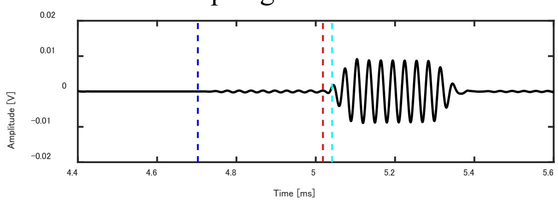
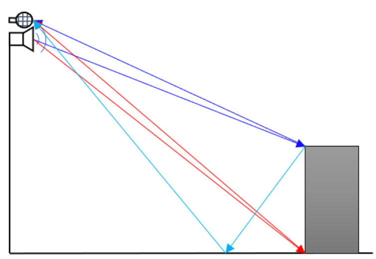


Fig. 2(a) Reflected signal from the object (h=0.1, r=0).



tan@us.sc.e.titech.ac.jp, hachiya@sc.e.titech.ac.jp

Fig. 2(b) Reflected signal paths (r=0).

Figure 3 shows the result of the simulation performed by changing the height of the obstacle by 0.2 m. In comparison with **Fig. 2(a)**, it can be seen that the position of the bottom edge reflection of the obstacle is not moving, so there is little change in the RF signal, and the arrival time is displaced according to the change in the top edge position.

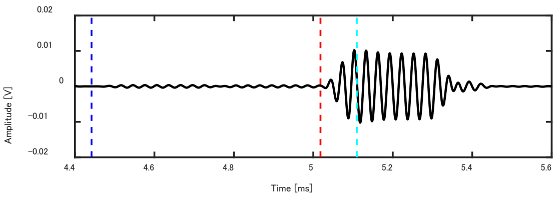


Fig. 3 Reflected signal ($\mathbf{h} = \mathbf{0.2},\ \mathbf{r} = \mathbf{0}$).

Figure 4 shows the experimental result of measurement using the metal block. In this example, the size of the obstacle is $30\ \mathrm{cm(W)} \times 20\ \mathrm{cm(H)} \times 5\ \mathrm{cm(D)}$.

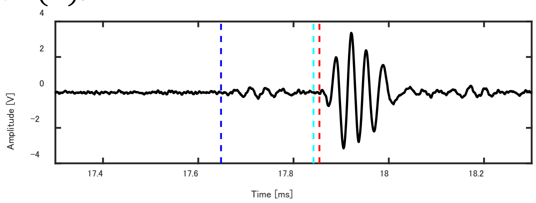


Fig. 4 Measured reflected signal ($\mathbf{h} = \mathbf{0.2},\ \mathbf{r} = \mathbf{0}$).

Next, the top edge shape was changed from a right angle (r = 0) to a rounded edge of $r = 0.02$ under the conditions of the simulation shown in **Fig. 2(a)**, and the simulation was carried out. The results are shown in **Fig. 5(a)**, and the reflection paths are shown in **Fig. 5(b)**.

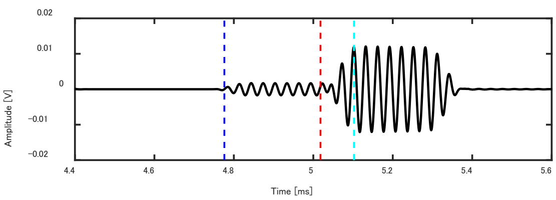


Fig. 5(a) RF signal at $\mathbf{h} = \mathbf{0.1},\ \mathbf{r} = \mathbf{0.02}$.

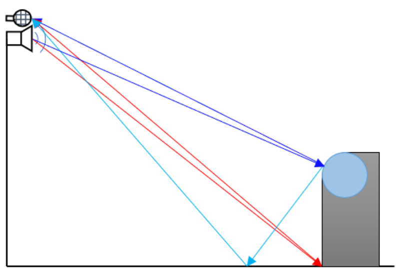


Fig. 5(b) Reflected signal paths at $r = 0.02$.

From the wave propagation movies of FDTD simulation, it was confirmed that reflection similar to specular reflection occurred on the edge because there was a vertical reflection surface with respect to the transmitter by changing the shape of the top edge of the obstacle. As a result, in addition to the path of the blue arrow in **Fig. 5(b)**, it is considered that the reflection intensity of the path of the light blue arrow is increased.

From the amplitude information of the RF signal in **Fig. 2(a)** and **Fig. 5(a)**, the average of the reflection amplitude from the bottom edge at 0.1 ms after the light blue dashed line and the reflection amplitude from the top edge at 0.1 ms after the blue dashed line are plotted in **Fig. 6**. As shown in Fig. 6, it can be confirmed that the shape of the top edge of the obstacle also affects the intensity of reflection from the bottom edge.

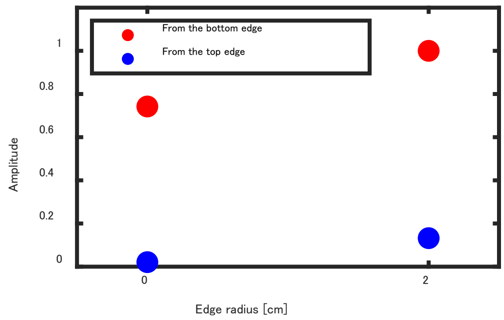


Fig. 6 Average amplitude of reflected signals from the top and bottom edges per radius.

4. Conclusion

We presented the basic characteristics of reflection from an object, targeting steps on the road surface and floor surface. The reflection characteristics were examined by using the FDTD simulation and the experiment using a metal block.

The curved surface at the top edge of the obstacle increases the reflection intensity of the signal from the top and bottom edges.

We will quantitatively evaluate the effect of the shape on the reflected wave by changing the shape of the obstacle.

References

1) Y. Ikari, S. Hirata, and H. Hachiya, Jpn. J. Appl. Phys. 54, 07HC14 (2015).
2) K. Yamanaka et al., Jpn. J. Appl. Phys. 55 07KC09 (2016)
3) S.Hirata et al. Account. Sci. & Tech. 37(6), pp. 322-325(2016)