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Estimation of Acoustic reflection characteristics of human target

空中超音波による人ターゲットの音波反射特性の評価

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1. Introduction

The acoustic sensing in the air is thought as a method which can acquire various information about an object, such as its position, surface configuration, and the movement[1)-4)]. We reported a sensing system that enables indoor measurements for the application to the autonomous movement type robot and object monitoring. The human body is a very important acoustic target when the acoustic sensing is used in the living space, so it is necessary to understand the acoustic reflection characteristics of human body. In this paper, we present measurement results of the angle dependence of amplitude and the fluctuation in time of reflected wave from the human body.

2. Method

The experiment was conducted in an indoor environment. Measurement configuration is shown in **Fig. 1**. We placed the target at the distance of 2000 mm in front of the source and receiver. The distance between the source and the receiver is 80mm. The sound wave was transmitted from the speaker (Pioneer PT-R4) and reflected wave from a target was received by microphone (B&K 4939). In this measurement, the phase modulated M-sequence signal, centered at 25 kHz, was used.

3. Results and discussion

First, we measured the angle dependence of the amplitude of reflected wave from a torso (half body mannequin). Directions of 0° , 90° and 180° for a body were defined as shown in **Fig.1**. **Figure 2** shows the amplitude of reflected wave from the torso. We changed a direction of the torso every 15 degree. **Figure 3** shows the amplitude of reflected wave from the human every 45 degree. The angle dependences of the torso and the human body agree with each other. Next, the change in time of the reflected wave was examined. We measured the reflected waves from the front and the rear faces of volunteers' human body at the same time. **Figure 4** shows the change of reflected waves from the rear

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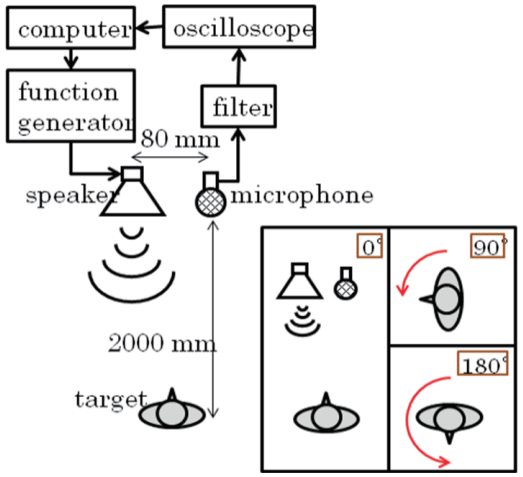

Fig.1: Measurement configuration

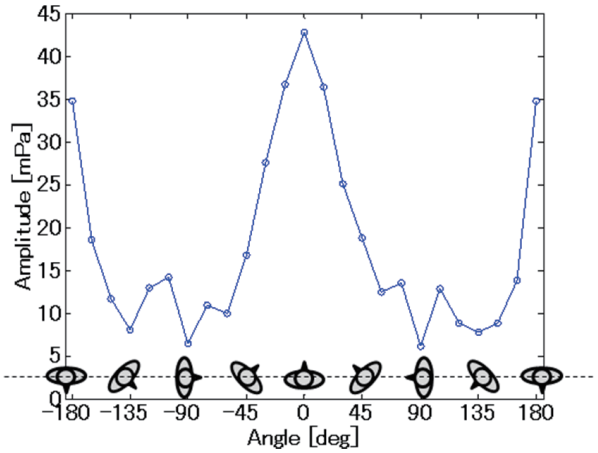

Fig.2: The angle dependence of the amplitude of reflected wave from a torso

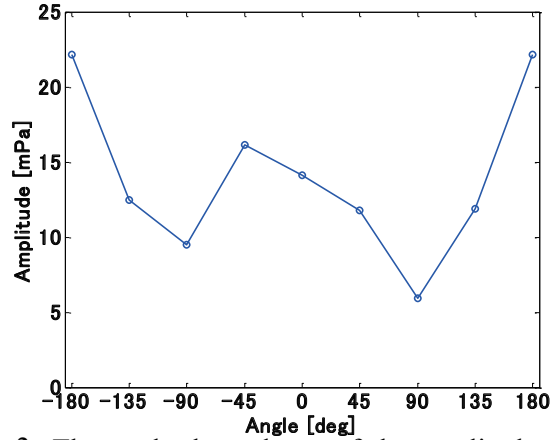

Fig.3: The angle dependence of the amplitude of reflected wave from a human body

faces of human body. In **Fig. 4**, a horizontal axis corresponds to time and the vertical axis corresponds to measurement interval. We can see travel times of reflected waves are changing with time. It means the front and rear faces of human body are moving back and forth slightly.

Figure 5 shows the movements of the target which is calculated from a phase at the time when the amplitude becomes the maximum in each receiving signals. The front and rear face movements, $f(t)$ and $b(t)$ are shown in solid and dotted lines, respectively. **Figure 6** shows $d(t) = f(t) - b(t)$, that is out-phase movement. In other words, the movement $d(t)$ means the change of thickness of the human body. By high SN ratio measurement using M-sequence signal, we can measure the slight movement stably. **Figure 7** shows the result of frequency analysis of $d(t)$ $(= f(t) - b(t))$ and $s(t)$ $(= f(t) + b(t))$. Fourier transforms of $d(t)$ and $s(t)$, $D(f)$ and $S(f)$ are shown in solid and dotted lines, respectively. The main frequency component of the out-phase movement of the body , $D(f)$ is 0.125Hz. This frequency agrees well with the frequency of breath, so we can observe breath movement of the human target. The in-phase movement means the whole body movement. Its frequency component concentrates under 0.1Hz.

4. Conclusion

The human body is a very important acoustic target in indoor measurement. We measured the fluctuation in time and the angle dependence of amplitude of reflected wave from the human body.

The amplitudes of reflected waves from the front and rear faces are larger than the amplitudes of reflected waves from side faces of a human body. Next, We obtained the change of reflected waves from the front and rear faces of a human body. Using the phase tracking of received signals, we can observe very small movements of the front and rear faces of human body. This movement is supposed to be caused by breathing. Main frequency component and the amplitude of thickness change are 0.125 Hz and 2.5mm.

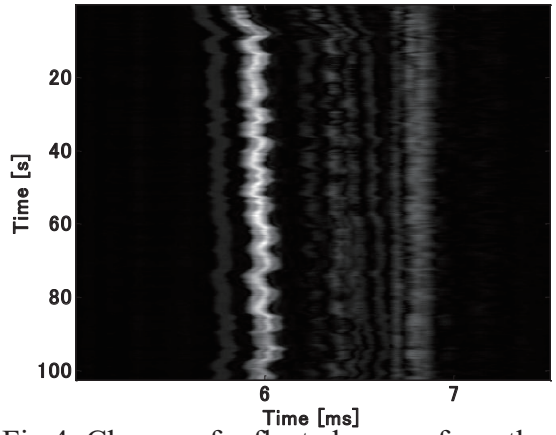

Fig.4: Change of reflected waves from the rear face of human body

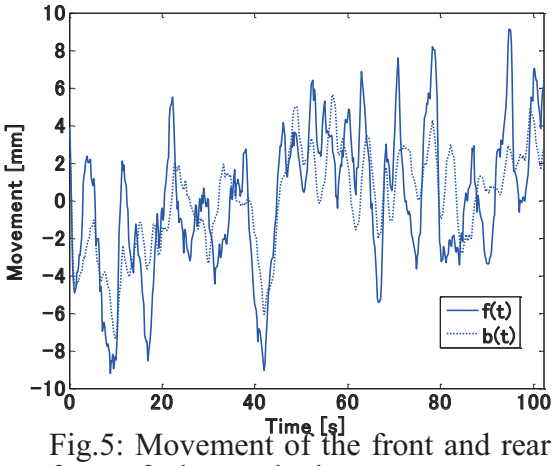

Fig.5: Movement of the front and rear faces of a human body

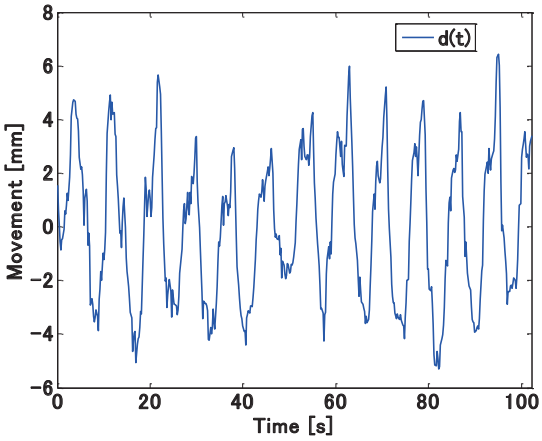

Fig.6: Difference of front and back movement

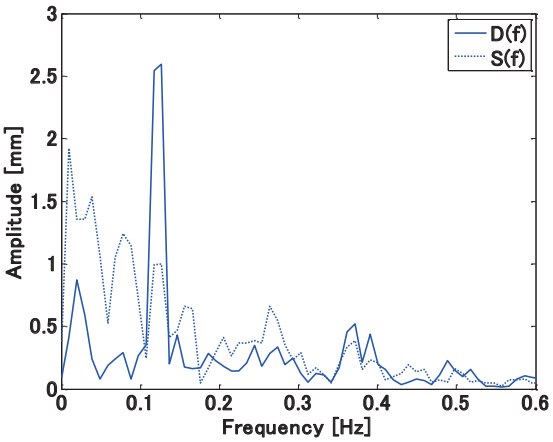

Fig.7: Frequency analysis of human movement

References

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