Proceedings of Symposium on Ultrasonic Electronics, Vol. 31 (2010) pp. 327-328
6-8 December, 2010

Measurement of human surface movement using airborne ultrasound

空中超音波を用いた人ターゲット表面の振動計測

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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. We obtained the change of reflected waves from the front and rear faces of a human body and observed very small movements supposed to be caused by breathing. In this paper, we present measurement results of the fluctuation in time of reflected wave from the human body in a supine position.

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 650 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.

The change in time of the reflected wave from the human body in a supine position was examined. We transmitted the acoustic signal targeting to the epigastrium on the healthy volunteers in a supine position, and measured the reflected wave.

The heart sound sensor is placed on left ventricular apex position of a volunteer and heart sound is measured synchronizing with the ultrasound transmission to examine the relation between a small movement measured by the ultrasound and the heart beat. The volunteer stopped breathing for 40 seconds from beginning of the measurement.

We demodulate the reflected wave from the target into complex signal $c_i(t)$ ($c_i(t)=a_i(t)\exp(j\phi_i(t))$). The reflected wave from the target, amplitude of the wave($a_i(t)$), phase of the wave($\phi_i(t)$) and enlarged

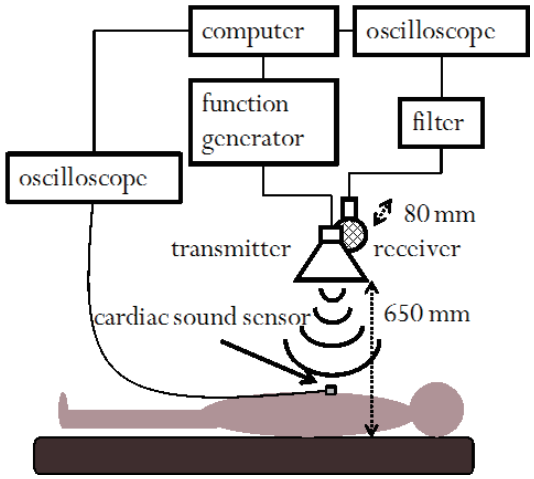

Fig.1: Measurement configuration

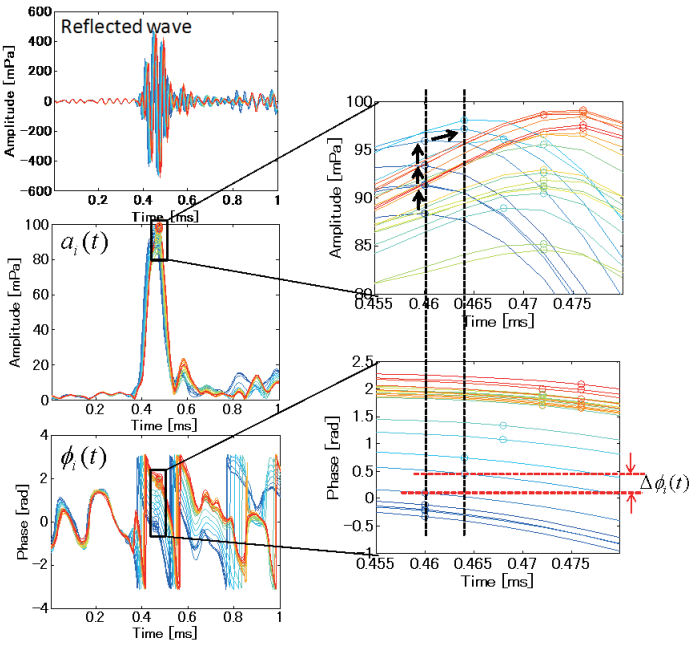

Fig.2: Analysis method of vibration on human surface

figures of $a_i(t)$ and of $\phi_i(t)$ are shown in **Fig. 2**. The phase fluctuation in time of reflected wave from target $\Delta\phi_i(t)$ is given by

$$\Delta\phi_i(t)=\phi_{i+1}(t)-\phi_i(t)$$

In this experiment, the change in phase is calculated at the time when the amplitude

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becomes the maximum in each receiving signals. Human surface movement is estimated by this phase change.

3. Results and discussion

In **Fig. 3**, 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 surface of human body is moving slightly. **Figure 4** shows the movements of the target which is calculated from a phase. The frequency analysis result of the human surface movement while the subject is stopping breathing (0 ~ 40 s) is shown in **Fig. 5**. The amplitude of movement is about 0.08 [mm] and frequency is about 1 [Hz], then this signal is compared with heart beat. The human surface movement observed by measurement with ultrasound (10 ~ 30 s) and the heart sound with heart sound sensor (10 ~ 30 s) are shown in solid and dotted lines, respectively in **Fig. 6**. The human surface movement given by analysis of reflected wave is in good agreement with the timing of heart sound, so we can observe heart beat movement of the human target using ultrasound.

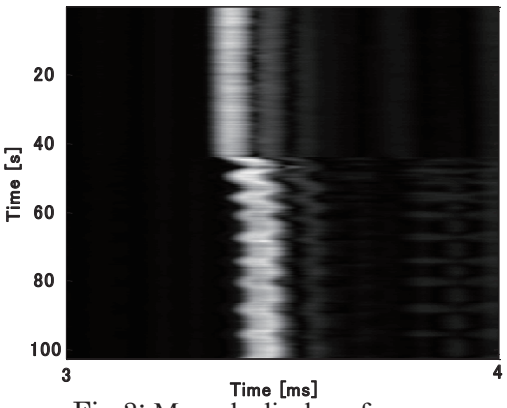

Fig.3: M-mode display of received signal from the

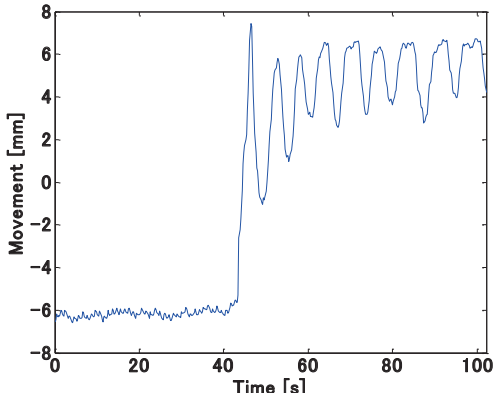

Fig.4: Measurement of human body movement

4. Conclusion

We measured the fluctuation in time of reflected wave from the human body in a supine position and compared the human surface movement observed by ultrasound measure with heart sound by heart sound sensor. Using M-sequence signal and the phase tracking of received signals, we can observe very small movements of human surface. This movement is supposed to be caused by heart beat. Main frequency component and the amplitude of this movement are 1 Hz and 0.08 mm.

We will gather on measurement data of volunteers and evaluate effect of cloths and change in position.

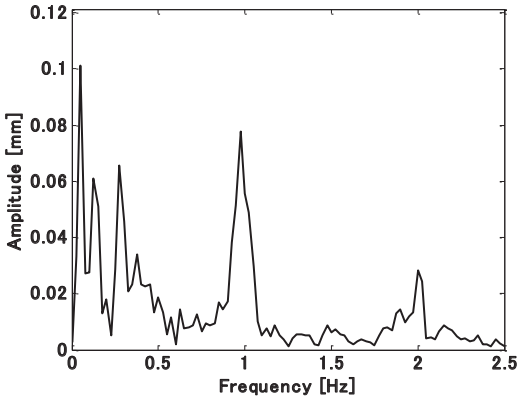

Fig.5: Frequency analysis of movement of human body (No breath)

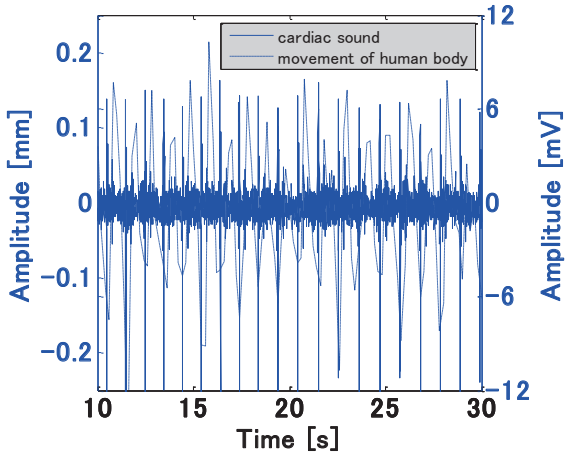

Fig.6: Comparison between cardiac sound and movement of human body

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