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Noncontact measurement of breathing and heart rate using airborne ultrasound
空中超音波を用いた呼吸・心拍の非接触計測

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1. Introduction

Acoustic sensing in air has the potential to obtain various information about a surrounding object such as its position, shape, material and movement. In previous paper, we have examined the reflection characteristic of human body [2], and proposed a noncontact measurement technique of human surface movement to obtain vital information using airborne ultrasound [3]. We also measured basic acoustic characteristic of clothes to measure body surface movement with clothes [4].

In this paper, we present the measurement results of body surface movement of several volunteers in the standing position with clothes.

2. Experiment

2. 1 Measurement configuration

Body surface movement is measured by analyzing the reflected signal from the body. **Figure 1** shows measurement configuration. Signals was transmitted from speakers and reflected signals from the body was received by the microphones. Speakers and microphones were set apart from front and back side of the volunteer. Thickness movement of body was detected by summing the movement of front and back of the body [1]. To evaluate the effect of clothes, measurement was performed without clothes and with T-shirt with a thickness of 0.6 mm. A cardiac sensor attached to the volunteer to compare a result of measurement using airborne ultrasound.

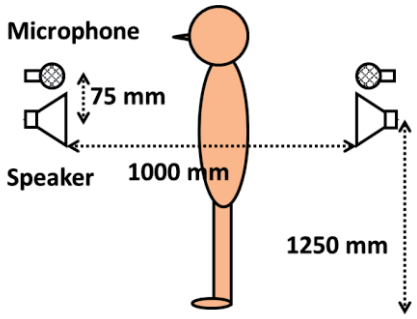

Fig. 1 Measurement configuration in the standing position

2. 2 Measurement system

When target moves, propagating time of signal also changes. In this system, movement of the target was estimated by using propagating time difference.

To improve signal-to-noise ratio (SNR), the 8th-order M-sequence-modulated signal centered at 40 kHz was used for the transmitted signal. The SNR of received signals is increased by pulse compression. The amount of SNR improvement using 8th-order M-sequence-modulated signal is 24 dB. Transmission and receiving of signals were repeated at intervals of 50 ms.

After processing by pulse compression, using ith and (i+1)th signal, $a_i(t)$ and $a_{i+1}(t)$, phase difference was calculated by $\arg\big(a_{i+1}(t)\big) - \arg\big(a_i(t)\big)$. Movement was estimated by tracking phase difference. Measurement using phase difference is expected to have higher resolution than using time of flight.

2. 3 Results

Movement by breathing could be measured easily because of large displacement. **Figure 2** shows measurement results of movement by heartbeat of four volunteers. **Figure 2 (a)** shows the results in case of the measurement without clothes and **(b)** shows the results in case of the measurement with T-shirt. **Figure 2 (i)** shows received signals by the microphone in front of the body. In all cases, the amplitude of the reflected signal when volunteers wore T-shirt is lower than the amplitude when volunteers did not wear T-shirt. Amplitude with T-shirt was about half the amplitude without T-shirt. **Figure 2 (ii)** shows the results of position tracking of body surface or clothes when volunteers held the breath and **(iii)** shows outputs of cardiac sensor measured at the same time. To extract the movement by heartbeat, results of position tracking was processed by high-pass filter. In case that measurement performed without clothes, we can see a periodic movement that the displacement is less than 1 mm. This movement and outputs of cardiac sensor are synchronized. Then it is found that the measured movement was caused by heartbeat. In case that measurement performed with T-shirt, even though measured movement was not clear than the measurement without clothes, we can see a periodic movement synchronized with cardiac sensor. It is considered that body surface movement caused by heartbeat propagates to clothes and periodic movement by heartbeat could be measured by tracking movement of clothes. In the result, the validity of proposed measurement system was confirmed.

3. Conclusion

We performed the measurement of body surface movement caused by heartbeat in the standing position with several volunteers. It is confirmed that the noncontact measurement can be done using airborne ultrasound.

References

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3) K. Hoshba *et al*: Jpn. J. Appl. Phys. **52** (2013) 07HC15.

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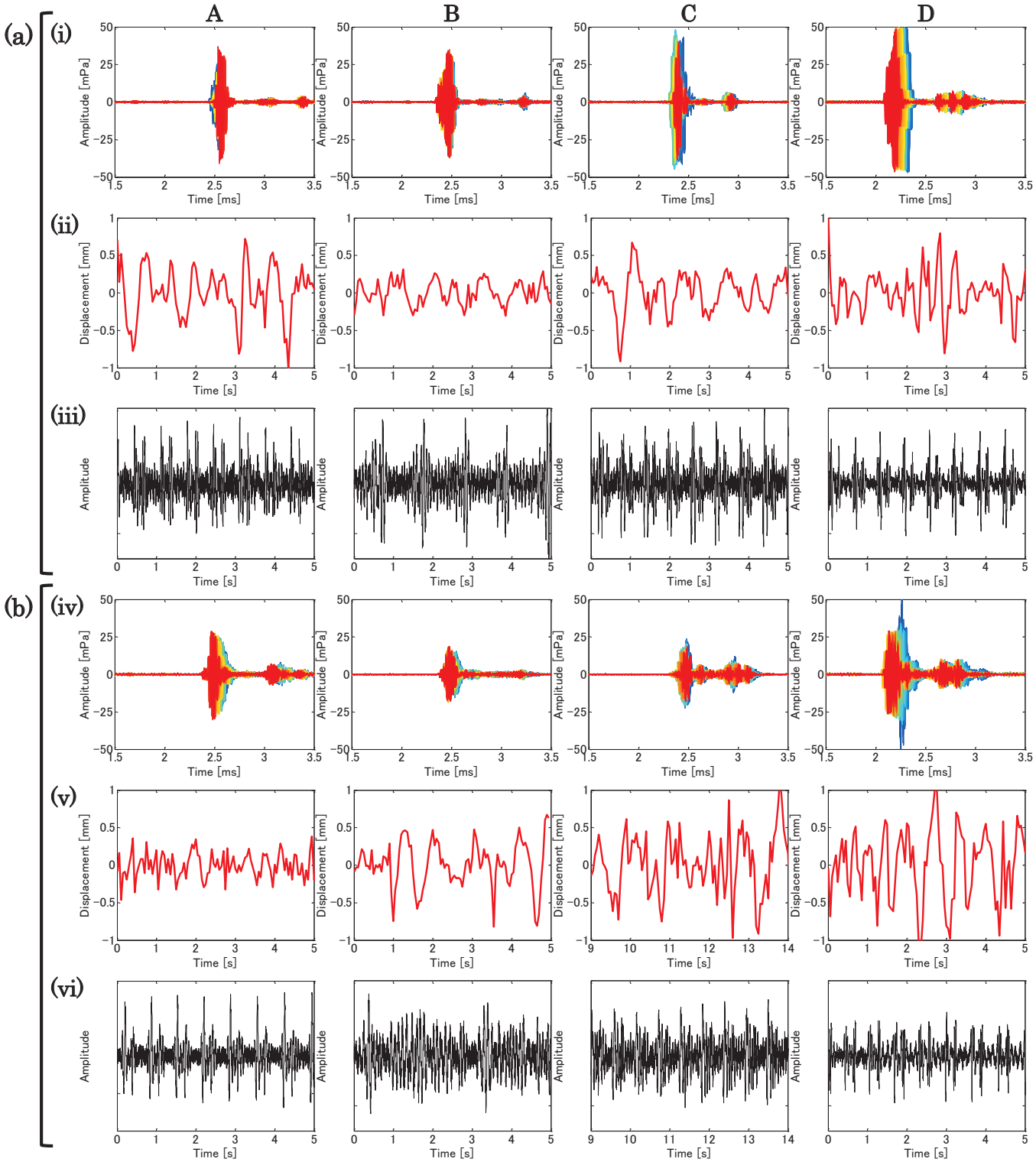

Fig. 2 Measurement results of four volunteers (A~D) in the standing position: (i) Received signal by front microphone, (ii) measured movement caused by heartbeat, (iii) outputs of cardiac sensor. The measurement was performed (a) without clothes (b) with T-shirt.