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Measurement of breathing and heart rate in the standing position with clothes using airborne ultrasound
空中超音波を用いた立位・着衣状態の人の呼吸・心拍計測

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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. We have examined the reflection characteristic of human body, and showed that breathing and heart rate in the supine position can be measured [2]. We also measured basic acoustic characteristic of clothes, and evaluated noncontact measurement system using M-sequence, MTI filter and phase tracking [3) 4)].

In this paper, we present effect of clothes and posture in the measurement using noncontact acoustic system to measure breathing and heart rate in the standing position with clothes.

2. Measurement system

To measure breathing and heart rate, body surface movement was measured by analyzing the reflected signal from the body. Transmitted signal was the 9^{th}-order M-sequence-modulated signal centered at 25 kHz. Transmission and receiving of the signal were repeated 300 times at intervals of 0.1 s.

To improve SN ratio, received signal was processed by pulse compression. Then, using ith and $(i+1)$th signal, $a_i(t)$ and $a_{i+1}(t)$, we calculated phase difference, $\arg\left(a_{i+1}(t)\right) - \arg\left(a_i(t)\right)$. Movement was estimated by tracking phase difference.

3. Measurement in the supine position
3. 1 Measurement configuration

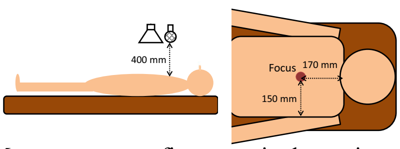

Fig. 1 Measurement configuration in the supine position

First, the experiment of measuring breathing and heart rate in the supine position was performed. Measurement configuration is shown in **Fig. 1**. A speaker and microphone were located above a volunteer lying on a bed. To evaluate the effect of clothes, measurement was performed without clothes and with a T-shirt that thickness is 0.6 mm. A heart sound sensor was also attached to the volunteer to compare a result of measurement using ultrasound.

3. 2 Result

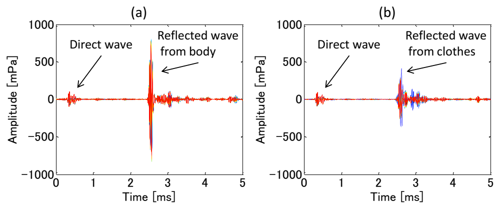

Fig. 2 Received signal in the supine position (a) without T-shirt (b) with T-shirt

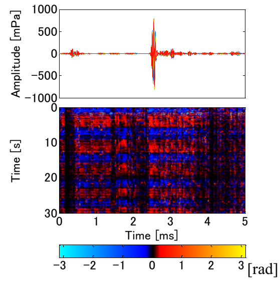

Fig. 3 2D plot of phase difference

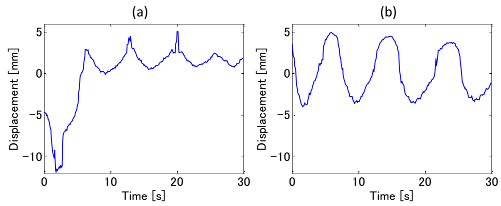

Fig. 4 Measurement of movement caused by breathing in the supine position (a) without T-shirt (b) with T-shirt

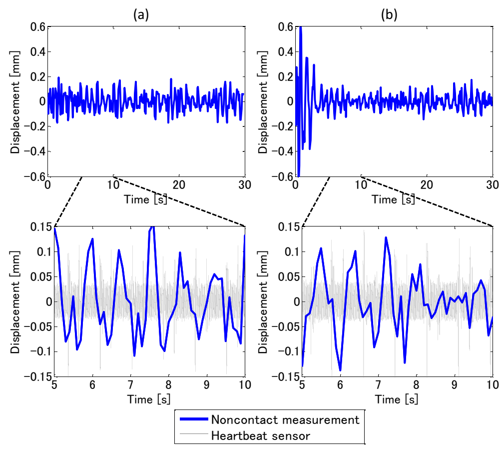

Fig. 5 Measurement of movement caused by heartbeat in the supine position (a) without T-shirt (b) with T-shirt

Figure 2 (a) shows the reflected signal in case of the measurement without clothes and **(b)** shows the signal in case of the measurement with clothes. The reflected signal from the body and clothes can be seen at 2.5 ms in each figure. The amplitude of the reflected signal from the cloth is about half the amplitude of the signal from the body. **Figure 3** shows 2D plot of phase difference. Red and blue color corresponds to positive and negative velocity. The changes of velocity caused by breathing can be seen. **Figure 4** shows a result of position tracking of body surface and clothes when a volunteer was breathing. The displacement of body surface by breathing is approximately 2 mm, and that of clothes is approximately 8 mm. It is considered that clothes was strengthened by movement of body surface. In addition, **Fig. 5** shows a result of position tracking when the volunteer was not breathing. Lower panel of **Fig. 5** shows the enlarged view and measuring result of the heart sound sensor. There is no significant difference of the displacement, 8 mm. In the enlarged view, measured movement and result of the heart sound sensor are synchronized. Then it is found that the measured movement was caused by heartbeat. Therefore, it is considered to be able to measure movement by breathing and heartbeat with clothes if clothes are thin.

4. Measurement in the standing position

4. 1 Measurement configuration

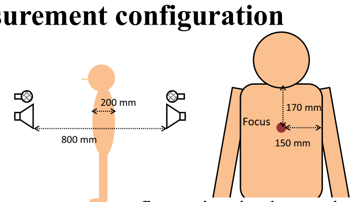

Fig. 6 Measurement configuration in the supine position

Next, we tried to measure breathing and heart rate in the standing position. Measurement configuration is shown in **Fig. 6**. Speakers and microphones are were set apart from front and back side of the volunteer. Then thickness movement of body was detected by summing the movement of front and back of the body [1].

4. 2 Result

Figure 7 (a) shows the reflected signal in case of measurement without clothes and **(b)** shows that in case of measurement with clothes. The reflected signal from the body and clothes can be seen at 2 ms of each figure. **Figure 8** shows a result of position tracking of body surface and clothes when the volunteer was breathing. Despite a large noise than the results in the supine position, the breathing cycle could be measured. In addition, **Fig. 9** shows a result of position tracking when the volunteer was not breathing. Lower panel of **Fig. 9** shows the enlarged view and measuring result of the heart sound sensor. Measured movement was not clear when the measurement was performed without clothes. However, the breathing cycle could be observed when the measurement was performed with clothes. It is considered that measurement of movement by heartbeat without clothes in the standing position is difficult because movement of front or back direction of the body is large, but measurement with clothes was possible because movement of clothes was strengthened by movement of body surface and displacement became large. Therefore, it is found that movement by heartbeat can be measured in the standing position with thin clothes.

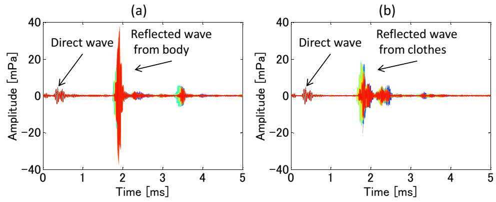

Fig. 7 Received signal in the standing position (a) without T-shirt (b) with T-shirt

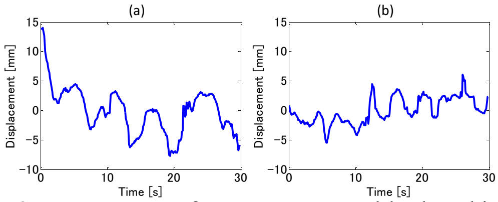

Fig. 8 Measurement of movement caused by breathing in the supine position (a) without T-shirt (b) with T-shirt

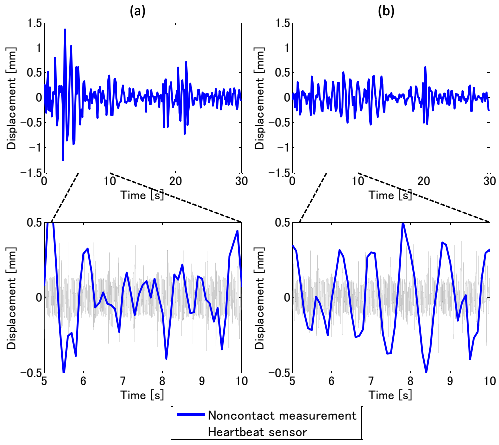

Fig. 9 Measurement of movement caused by heartbeat in the supine position (a) without T-shirt (b) with T-shirt

5. Conclusion

We tried to measure small movement of body surface by breathing and heartbeat using airborne ultrasound, and evaluated the effect of clothes and posture. Body surface movement could be measured in the standing position with clothes. In future work, we will examine how the movement of body surface propagates to clothes on the assumption that measurement is performed with clothes.

References

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4) K. Hoshiba *et al*: Proc. of autumn meeting of ASJ (2013), 1313-1314.