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Acoustic measurement of small movement on objects behind cloths
布背後の物体表面の微小振動の計測

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1. Introduction

Acoustic sensing in the air has the potential to obtain various information about a surrounding object such as its position, shape, material and movement. Hence, the advance of acoustical measurement techniques is required. We have developed acoustic imaging techniques of a small target and showed that the human breath and heart rate in the supine position can be measured [1)-4)]. To realize acoustical monitoring the breath and heart rate as biometric signal at upright position, we measured acoustic transmission characteristics of cloths and detectability small movement on objects behind cloths.

2. Acoustic measurement of small movement

2. 1 Measurement configuration

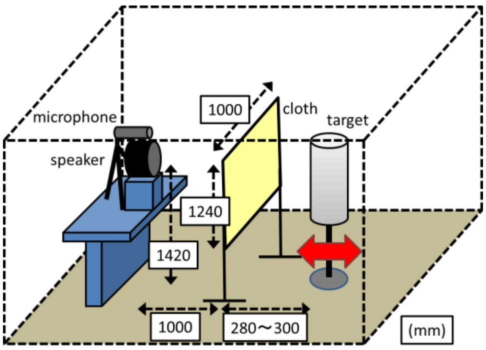

Fig.1 Measurement configuration

Measurement configuration is shown in **Fig. 1.** Acoustic signal was transmitted from a speaker (Pioneer PT-R4), passed through a canvas fabric, was reflected at the target, passed through cloth again and was received by a microphone (B&K 4939) adjacent to the speaker. The graded number of the canvas fabric is No.11 (309.5 g/m^2). A cylindrical foamed polystyrene of 200 mm in diameter reciprocated along a distance of 20 mm at a speed of 6 mm/s to simulate a breathing movement. Transmitted signal was the phase modulated 9-th M-sequence signal centered at 25 kHz. Transmission and receiving of signal were repeated 500 times at intervals of 0.2 s to measure a small movement.

2. 2 Transmission characteristic through cloth

We measured the attenuation of sound waves passing through the canvas fabric. **Table. 1** shows thickness and area density of canvas fabric used in the measurement. Canvas fabric is classified by a graded number system. The numbers run in reverse of the weight so a No. 11 canvas is lighter than No. 4 shown in **Table. 1**. **Figure 2** shows measurement results of the attenuation. Sound attenuation tends to increase with area density and increases with frequency. Sound attenuation at 25 kHz by passing back and forth through the grade No. 11 canvas fabric is 27.4 dB.

Table.1 Classification of canvas fabric

	Thickness [mm]	Area density [g/m^2]
No.11	0.60	309.5
No.10	0.80	393.6
No.9	0.85	486.7
No.8	1.05	433.1
No.6	1.20	596.0
No.4	1.40	760.1

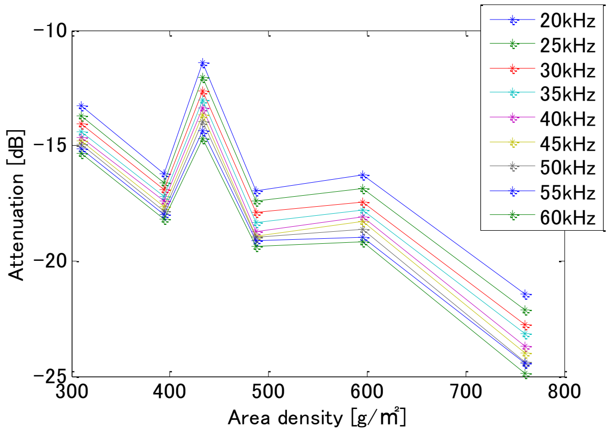

Fig.2 Attenuation passing through canvas

2. 3 Movement measurement

Received M-sequence signal was correlated with discrete M-sequence, and processed by a moving target indicator (MTI) filter. MTI filter is a filter intended to reject reflected signals from stationary objects and improve detectability of reflected signal from moving object. In this measurement, a MTI filter is implemented by the difference between temporally adjacent received signal samples. Using i th and $(i+1)$ th received signals, $a_i(t)$ and $a_{i+1}(t)$ at interval 0.2 s, we calculated phase difference, $\arg(a_{i+1}(t)) - \arg(a_i(t))$ to obtain a movement of objects. Then we tracked a position of the target by integrating phase difference of reflected signal from the target.

2. 4 Measurement results

Figure 3 shows measurement results of a moving target. **Figures 3(a)-(e)** show received signals after correlation processing, signals after MTI processing, 2-D plot of phase difference using a colormap, phase difference at tracking peaks and tracking position of the target. Although reflected signals from the target can't be detected before MTI processing (**Fig. 3(a)**), reflected signals are well detectable after MTI processing (**Fig. 3(b)**). Target movement can be well observed in two-dimensional plot (**Fig. 3(c)**).

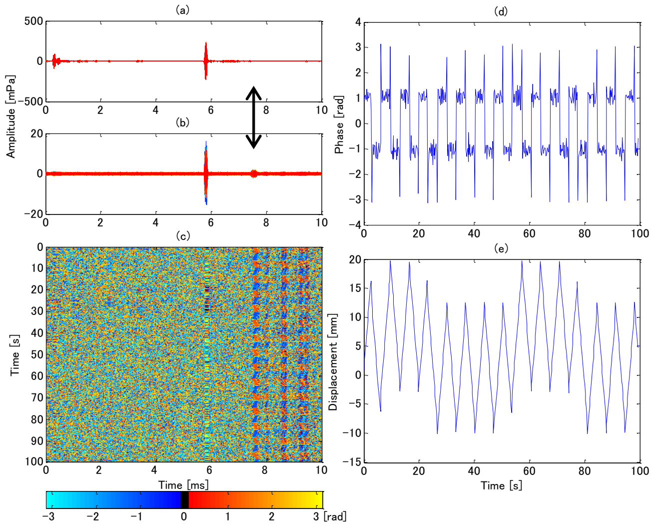

Fig.3 Measurement results of tracking the target

3. Detectability estimation

In these measurements, a detectability of the target depends on speed of the target. We tried to measure the target movement with changing speed of target from 0.6 mm/s to 6.0 mm/s. **Figure 4** shows the results. Speeds of target are **(a)** 6.0 mm/s, **(b)** 3.6 mm/s, **(c)** 1.8 mm/s, **(d)** 0.6 mm/s. Down-pointing arrows indicate the location of reflected signals. Signals are well tracked (**(a) -(b)**). In contrast, it is difficult to track a signal at a speed of 0.6 mm/s **(d)**. Measurement accuracy decreases with decreasing speed of the target. **Figure 5** shows the relationship between speed of the target and SN ratio after MTI processing. In this processing procedure, tracking of the target is possible until the SN ratio after MTI processing decreases a few dB.

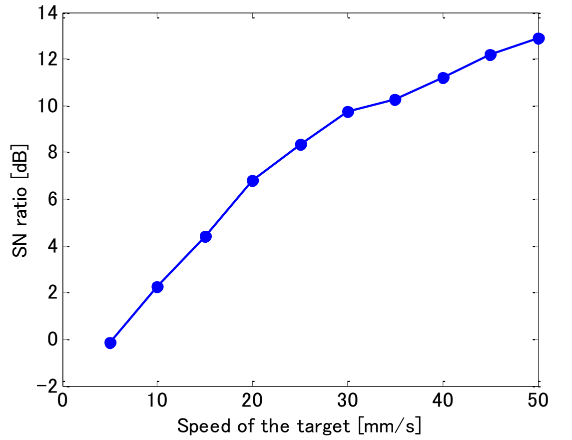

Fig.5 Relation between speed of the target and SN ratio

4. Conclusion

We tried to measure small movement of the target behind cloths by using M-sequence, MTI filter, tracking phase difference. Acoustic attenuation of cloths and detectability of target movement at various speeds were estimated. We obtained basic data to detect small movement on human in a standing position with high accuracy.

References

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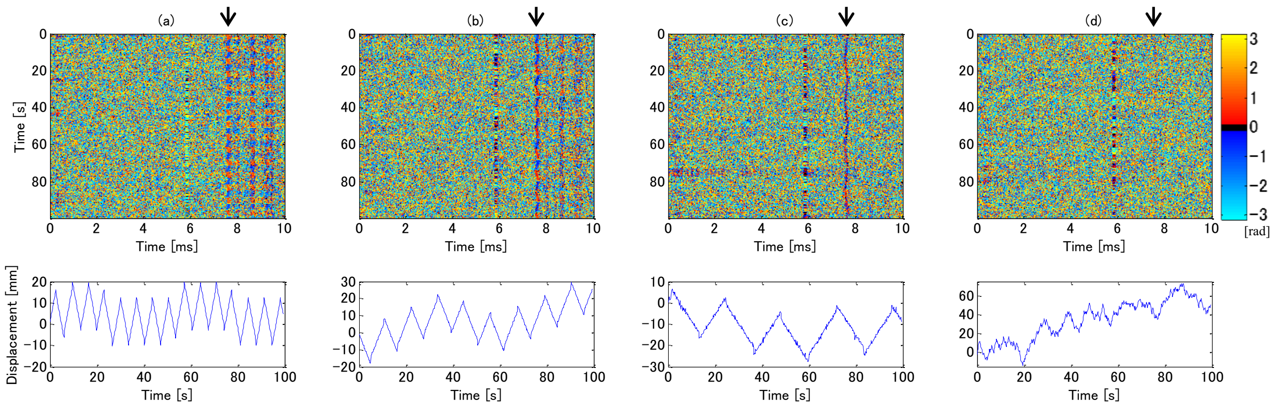

Fig.4 Estimation of displacement (a)6.0 mm/s (b)3.6 mm/s (c)1.8 mm/s (d)0.6 mm/s