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Efficiency Improvement of Signal Coding Method for Acoustic Sensing in Occlusion Area Using Super-Directional Sound Sources

効率的な符号化法と超指向性音源を用いた不可視領域空中音響センシング

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1. Introduction

For sensing technology, various kinds of signals such as light, radio waves, sound waves, and lasers are used. In this study, we focused on acoustic sensing in Air and tried to detect an object existing in occlusion area that cannot be detected by visible light (i.e., hidden behind other objects). This method explicitly uses the diffraction phenomenon of sound waves with a long wavelength. **Fig.1** shows an image of an object detection in an occlusion area. And we propose and evaluate efficiency improvement of the signal coding method for object detection in occlusion area.

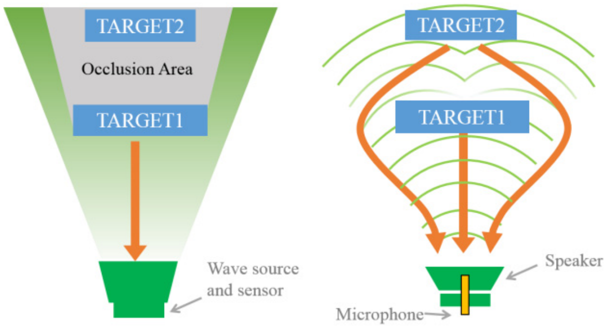


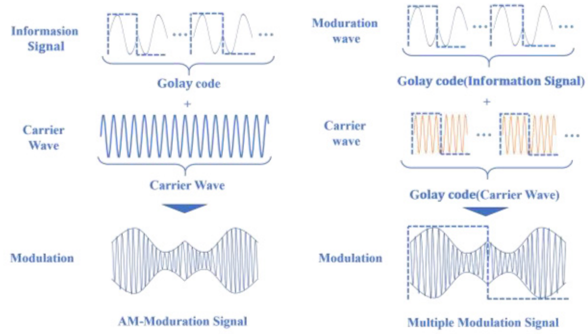
Fig. 1 Image of occlusion area sensing.

2. Proposed Method

The effect of Diffraction is more pronounced at lower frequencies. At the same time, it exerts various adverse effects on sensing. A first difficulty is that the sound wave energy diffuses and the signal-to-noise ratio (SNR) decreases. A second difficulty is that unnecessary reflected waves from obstacles other than the target generate noise and virtual images. So therefore, we attempt to solve these difficulties using a parametric speaker, which can emit sharp directed sound, even at low frequency.

In previous study, we proposed a system that achieves sharp directivity, spatial resolution, and high S/N ratio by using the parametric speaker as a transmitter in air and combining signal processing technologies. And we tried to detect objects in the occlusion area of acoustic sensing in Air by diffraction phenomena [1][2][3].

This study focuses on applying double modulation to the transmitted signal to efficiently detect objects in occlusion area. In the conventional method, only the information signal component of the modulated wave is utilized for sensing. In the new method, the carrier wave is also coded. The results of sensing for occlusion area are compared by each coding method including the use of difference frequency, and we aimed to detect objects in occlusion area more efficiently.



(a)Conventional　　　(b)proposed
Fig. 2 Image of new modulation system.

3. Multiple Modulation

In this study, the Golay code was used as a signal coding method. In the conventional method, when sound waves are emitted by a parametric speaker, the ultrasonic wave is used as just a carrier wave and the coded signal is used as the information signal to detect objects in occlusion area. In this study, we utilized an encoded ultrasound signal for the carrier wave, and we considered if it would be possible to detect objects in the occlusion area efficiently by comparing the results of sensing in the difference frequency and the results of sensing in the ultrasound.

Fig.2 shows the images of the modulation methods of the conventional method and the method proposed in the study. As shown in the right figure in Fig.2, the coding method is applied not only to the difference sound, which is an information signal, but also to the ultrasonic wave, which is a carrier wave. In our experiment, we evaluated the results of this ultrasonic and difference frequency.

4. Experiment

The object detection experiment in occlusion area was conducted at the gymnasium of our university. In the experiment, the microphone and parametric speaker are set at the same position, Target 1 is set at D1 and Target 2 is set at D2. **Fig. 3** shows an image of the experimental environment in which an object is placed in occlusion area. The parameters in this experiment are listed in **Table 1**. In Fig. 4-7, the object is placed at D1 = 5[m] and D2 = 7[m].

From **Fig.4,** it can be seen that the SNR at 7 m was improved. It is thought that this improvement is due to the fact that the information signal of the double-modulated signal is generated in the air as a difference frequency, which enables us to detect objects in occlusion area.

Fig.5 shows the results of autocorrelation of the carrier wave in the double-modulation. Since ultrasonic waves are used, the objects in occlusion area are not detected. By comparing Fig. 4 and 5, we can see that there are objects in occlusion area as well as in the visible area.

In **Fig.6**, the information signal of the AM modulated signal was generated as a difference frequency and the sound wave was processed by autocorrelation. As in Fig. 4, the SNR at the 7m position was improved and the object in the occlusion area was considered to be detected.

5. Conclusion

In this study, we demonstrated that the carrier wave can detect objects in the visible region, while the information signal is self-demodulating in the air and can detect objects in occlusion area by using double modulation. Therefore, we were able to detect objects in the invisible region efficiently.

As a future task, we will consider effective selection of signals based on factors such as spatial resolution and signal frequency.

Table1. Parameter of Transmission Signal

	Modulation Type	Signal Type	Frequency
Fig.4	Multiple Modulation	Information Signal	1470Hz
Fig.5	Multiple Modulation	Carrier wave	44100Hz
Fig.6	AM Modulation	Information Signal	1470Hz

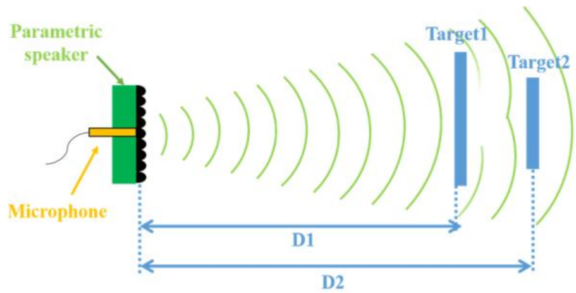


Fig. 3 Experiment environment

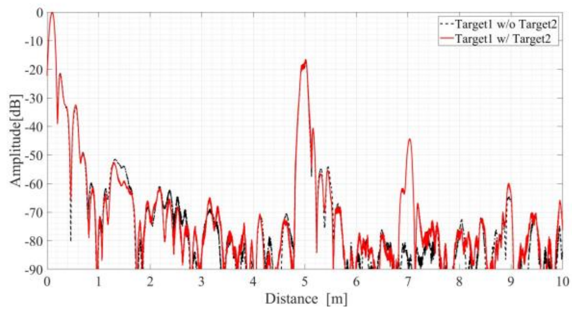


Fig. 4 PCT result of difference frequency (double-modulation; information signal frequency: 1470Hz)

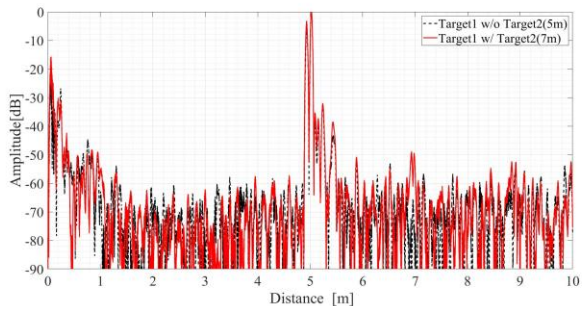


Fig. 5 PCT result of carrier frequency (double-modulation; carrier wave frequency: 44100Hz)

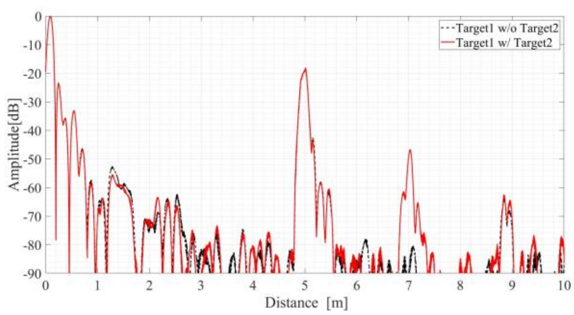


Fig. 6 PCT result of difference frequency (AM-modulation; information signal frequency: 1470Hz).

References

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