Forming and controlling audible spot including wide frequency band with two parametric speakers

二つのパラメトリックスピーカによる広帯域の周波数を含む局所的可聴領域の形成と制御

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1. Introduction

A parametric speaker is used for transmitting audible sound to the particular direction because of its high directivity [1]. Forming audible spot is also studied using some parametric speakers [2]. However, the area of audible spot changes when the frequency of the sound is changed. Then, we have proposed sound pressure control method for forming stable audible spot [3]. In previous work, proposed method was evaluated by forming audible spot including a single frequency.

In this paper, proposed control method is evaluated by forming audible spot including wide frequency band.

2. Method

2.1 Modulation method

To play audible signal from ultrasound, single side band (SSB) modulation [4] was used. Career signal v_c and audible sound v_s are defined as follows:

$$v_c(t) = A_c \sin 2\pi f_c t \quad (1)$$
$$v_s(t) = A_s \sin 2\pi f_s t. \quad (2)$$

A_c and A_s are amplitudes of a career signal and audible sound, f_c and f_s are frequencies of them, t is the time. SSB modulation is a kind of amplitude modulation. Modulated signal by SSB is given as follows:

$$v_{ssb}(t) = A_c \sin 2\pi f_c t + \frac{A_s}{2} \sin 2\pi (f_c - f_s) t. \quad (3)$$

The first term is a career signal and the second one is side band signal. In this paper, for forming audible spot, a career signal and a side band signal are transmitted from two parametric speakers, respectively. Audible sound is played as the difference tone between a career signal and a side band signal, and audible spot is formed at cross point of their transmitted directions.

2.2 Sound pressure control

When the frequency of audible signal f_s is changed, the amplitude of a side band signal $\mathrm{A_s}/2$ changes because of the frequency characteristics of the speaker. In case of that, the area of audible spot also changes, and forming stable spot is difficult. Then, sound pressure is introduced to a side band signal. Using frequency - sound pressure characteristics of the speaker which transmits a career signal F_1 and another speaker which transmits a side band signal F_2, $\mathrm{A_s}/2$ is controlled as follows:

$$\frac{\mathrm{A_s}(f_c - f_s)}{2} = \frac{F_2(f_c - f_s)}{F_1(f_c)} \cdot A_c \quad (4)$$

By introducing this control, amplitudes of a career signal and a side band signal is equalized at any f_s, and forming stable audible spot is expected.

3. Evaluation experiment

3.1 Experimental configuration

To evaluate proposed control method, evaluation experiment was performed. Fig. 1 shows experimental configuration. Two parametric speakers were placed at the distance of 500 mm from microphone. They are placed at the angle of 90 degrees. The career signal and the side band signal were transmitted from the speaker No.1 and No.2. f_c was 40 kHz, and to play audible sound including wide frequency band, f_s was set from 1 to 1.1 kHz. That is, the side band signal includes the component at the frequencies from 38.9 to 39 kHz. Fig. 2 shows frequency - sound pressure characteristics of each speaker F_1 and F_2 in Sec. 2.2. Using this F_1 and F_2, transmitted signal was controlled. Fig. 3 shows frequency spectra of transmitted signal. In this experiment, it was verified whether the amplitude of formed audible sound is stable at each frequency by proposed method.

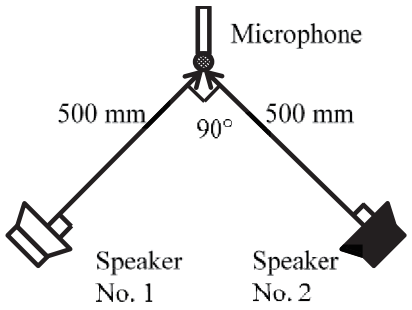

Fig. 1 Measurement configuration.

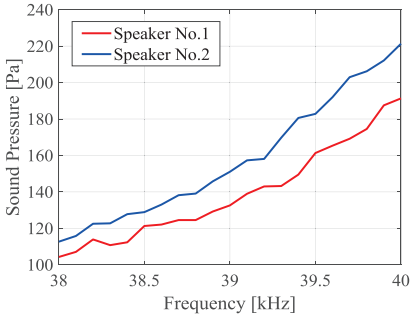

Fig. 2 Frequency - sound pressure characteristics of parametric speakers.

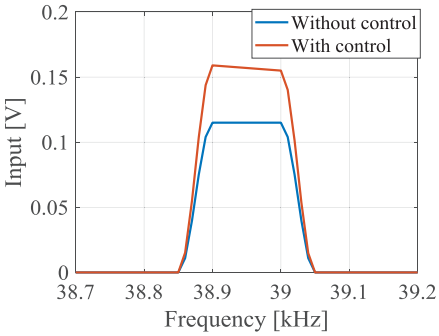

Fig. 3 Frequency spectra of transmitted signals.

3.2 Results

Fig. 4 and Fig. 5 show frequency spectra of received signals. Fig. 4 shows ultrasonic range and Fig. 5 shows audible range. Blue lines represent results without control and red lines represent results with control. As shown in Fig. 4, the career signal at the frequency of 40 kHz and the side band signal at the frequency around 39 kHz can be seen. Comparing results without control and with control, the amplitude of the career signal was 21.9 Pa, and that of uncontrolled and controlled side band signals were 17.7 and 22.8 Pa. As the result, it is found that the difference of the amplitude between the career signal and the side band signal can be reduced. As shown in Fig. 5, the amplitude of audible signal formed by controlled signal is also higher than that by uncontrolled signal. However, the effect of stabilization cannot be seen well. This reason is assumed that frequency range was not enough for evaluation. In future work, we will evaluate proposed method with wider frequency band.

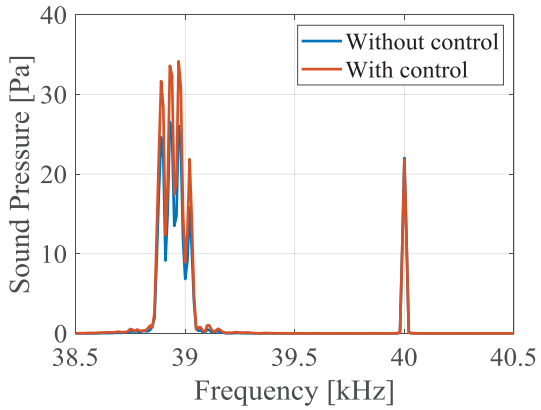

Fig. 4 Frequency spectra of received signals at ultrasonic range.

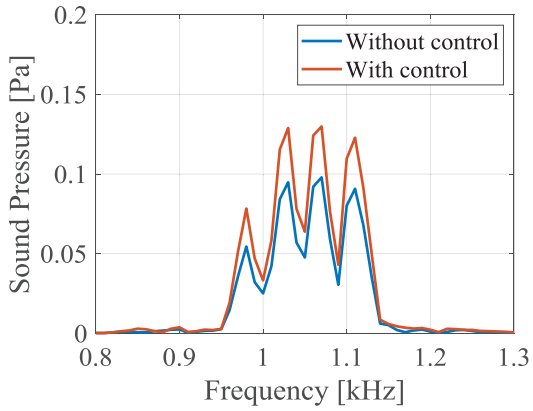

Fig. 5 Frequency spectra of received signals at audible range.

4. Conclusion

In this paper, proposed sound pressure control method for forming stable audible spot with two parametric speakers was evaluated by forming audible spot including wide frequency band. As the result, the difference of the amplitude between the career signal and the side band signal could be reduced. However, it was found that evaluation with wider frequency band is necessary.

References

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