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Examination of Arrangement of facing ultrasonic transducer arrays for design of omnidirectional loudspeaker

無指向性スピーカー設計のための対向型超音波トランスデューサアレイの配置について

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1. Introduction

Omnidirectional sound sources have been studied for a long time.[1] And they have been used for various purposes, for example, loudspeakers for indoor voice announcement.

Ultrasonic transducers are used and studied in a wide range of applications such as ultrasonic sensors and parametric array speakers with sharp directivity, due to its flexible installation given by their size and lightness[2-4].

In previous study, we investigated an omnidirectional sound source using an ultrasonic transducer array[5]. By arranging ultrasonic transducer arrays that face each other and emit ultrasonic waves of different frequencies from both sides, an audible sound with a difference frequency between input ultrasonic signals can be generated over a wide range. The directivity is improved more omnidirectional by changing the array shape to a completely circular. In addition, by using an acoustic camera, it was visualized that a sound source was generated between the arrays. In that study, the ultrasonic transducer array used drove all the transducers in the same phase, and there was insufficient consideration of phase management.

In this study, we designed and made a new array. It can radiate ultrasonic waves on different phases from an array. We investigated how the acoustic characteristics such as frequency amplitude characteristics and directivity can be changed by inverting the phase of some oscillators.

2. Experimental method

The new array is designed to allow phase control for every circular part. Fig.1 shows (a) an ultrasonic transducer array and (b) facing ultrasonic transducer array. 169 ultrasonic transducers (UT1oo7Z325R, SPL) were used in each array. And the diameter of this array is 17.4 [cm]. In the previous array we used 91 transducers, and its diameter was 10.5 [cm] [5].

Because of the center frequency of the ultrasonic transducer array is 40 kHz, for the experiment, we used input signals with frequencies

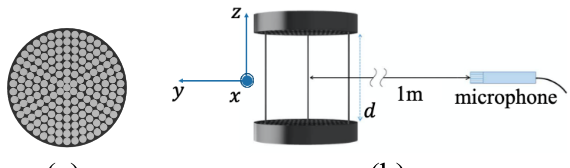


Fig. 1 (a) Ultrasonic transducer array. (b) Facing ultrasonic transducer array.

varying from 30[kHz] to 50[kHz] [5]. The distance *d* between the arrays is could be set to a range of 10[cm] to 40[cm].

As shown in Fig. 1, for the measurement of the frequency–amplitude characteristics and directivity, a microphone (4939, BK) was placed 1 m from the center of the facing ultrasonic transducer array, set at the height of the intermediate position of the array. Here, the input voltage was set to 25[Vp-p] in all measurement.

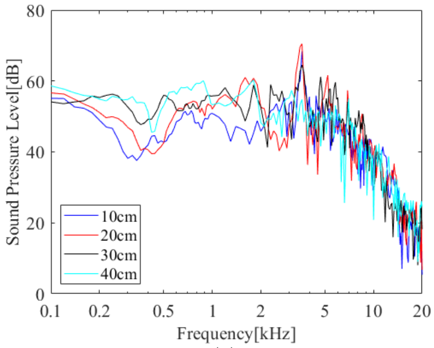
To measure the frequency–amplitude characteristics, sinusoidal signals with different ultrasonic frequencies were used as inputs, so that the difference frequency ranging from 100[Hz] to 20[kHz] was generated by nonlinearity.

The directivity was measured by rotating the ultrasonic transducer arrays. The directivity we measured is the directivity in the horizontal plane (x–y plane in Fig.1(b)).

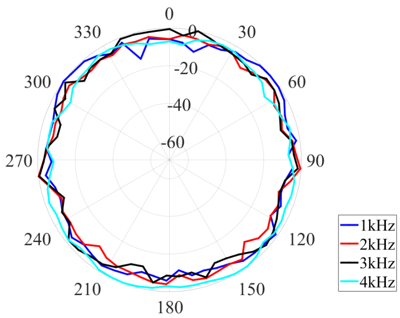
3. Acoustic characteristics

First, Fig.2(a) shows the frequency amplitude characteristics and directivity when all ultrasonic transducers are driven in the same phase. The distance between arrays are 10[cm], 20[cm], 30[cm] and 40[cm]. From this figure, it was found that the larger the distance between the arrays, the greater the sound pressure in all frequencies. The appropriate distance between arrays is larger than that of previous arrays. From this, it is considered that the appropriate distance between arrays can change as the size of the array changes.

And Fig.2(b) shows the radiation pattern when the distance arrays is 40cm. The ultrasonic frequency was set that the difference frequencies were 1, 2, 3, and 4[kHz]. As shown, the directivity is almost



(a)



(b)

Fig. 2 (a) frequency amplitude characteristics when all ultrasonic transducers are driven in the same phase. (b) radiation pattern when the distance between array is 4o[cm].

omnidirectional at all frequencies.

Based on these result, we inverted the phases of some circular parts in the array whose distance between arrays is 40[cm], and measured how the frequency amplitude characteristics and directivity changed.

The phase of the ultrasonic transducer is inverted for 3 or 4 circular parts from the outside of the array. The two inversion manners are called method 1 and method 2, respectively. (See Fig.3) In method 0, all ultrasonic transducers are driven in the same phase.

In Fig.4 (a), it shows that the frequency amplitude characteristics when the state of phase is method 0, 1 and 2. From this result, it was found that when the number of oscillators to be inverted exceeds half of the number of oscillators in the entire array, the output becomes larger than when all oscillators are in phase, at the low frequencies. Therefore, it was expected that the frequency-amplitude characteristics can be controlled by inverting the input phase of ultrasonic transducers.

In addition, the radiation pattern for method 0 and method 2 is shown in Fig.4 (b). Directivity is almost omnidirectional even when the phase is inverted.

4. Conclusion

In this study, we made a new array that can radiate ultrasonic waves of different phases from one array and measured the acoustic characteristics. From this result, it was found that the frequency-amplitude characteristics can be controlled by inverting the input phase.

In the future, it is expected the performance as an omnidirectional sound source can be further improved by adequately controlling the driving part and the phase of the transducers of the array.

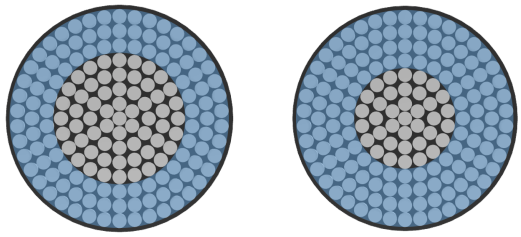
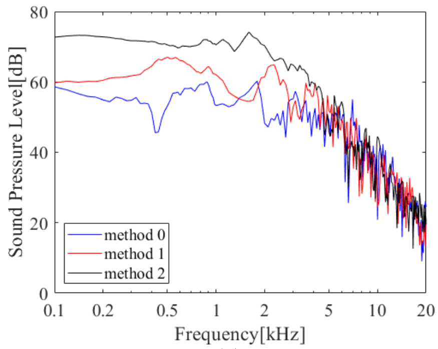
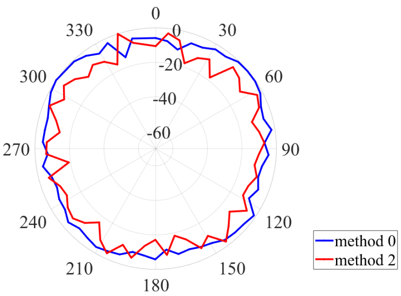


Fig.3 The part that inverts the phase of the transducers in method 1 (left) and method 2 (right).



(a)



(b)

Fig. 4 (a) frequency-amplitude characteristics in method 0, 1 and 2. (b) directivity for method 0 and 2.

References

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