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Design and Development of Omnidirectional Sound Source Using Facing Ultrasonic Transducer Arrays

対向型超音波トランスデューサアレイを用いた無指向性音源の設計と開発

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1. Introduction

Omni-directional sound sourse have been studied for long time. They have been used as playback devices, for example, speakers for indoor voice announcement and measurement of room acoustic characteristics[1].

On the other hands, ultrasonic transducers are being studied for acoustic sensing transmitters / receivers and array parametric speakers. In the research using this parametric speaker, much research has been conducted on the control of directivity[3-5]. In addition, ultrasonic transducers are expected to be used in a variety of applications in the future by the flexibility of installation due to size and lightness[6-9].

Therefore, in this study, we have investigated an omnidirectional sound source using an ultrasonic transducer array in which ultrasonic transducers are arranged in an array. In our elementary study, it was found that when arrange ultrasonic transducers face to face in a straight line and radiate different ultrasonic frequency from each array, the audible sound with differential frequency of ultrasonic sound is emitted with wide directivity. However, in the previous studies, when we make ultrasonic transducer arrays, ultrasonic transducers arranged in a quadrangle or a hexagon. Therefore the directivity was not completely omnidirectional[10].

This time, we examined improvement of the directivity by making the shape of the array completely circular (central point symmetrical) and measuring the acoustic characteristics. We designed and manufactured a facing ultrasonic transducer array using an array of ultrasonic transducers arranged like a circle, measured its characteristics, and examined the feasibility as an omnidirectional speaker.

2. Experimental method

We designed and fabricated the ultrasonic transducer arrays arranged facing each other in straight line as shown in **Fig. 1**. 91 ultrasonic transducers, UT1007-Z325R (SPL) are used per array. Since the center frequency of this ultrasonic transducer array is 40[kHz], the experiment mainly uses 30[kHz] to 50 [kHz] as an input frequency. We measured the frequency-amplitude characteristics and directivity of the facing array sound source.

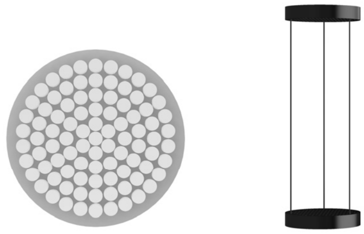

Fig. 1 Ultrasonic transducer array and facing ultrasonic transducer arrays.

The distance between the arrays is changed from 10 [cm] to 40 [cm] and measured. In the measurement of the frequency-amplitude characteristics and directivity, the measuring microphone (4939, BK) was set at a distance of 1[m] from the facing ultrasonic transducer array and the height of the microphone was set at the intermediate position of the facing ultrasonic transducer array.

3. Frequency-amplitude characteristics

Countinius sine waves of different ultrasonic frequencies were output from both sides so that the difference sound frequency became 100[Hz] to 20[kHz] centering on 40[kHz], and the sound pressure of the generated difference sound frequency was measured.

We compare the frequency-amplitude characteristics when the distance between the ultrasonic transducer arrays is changed and when the input voltage is changed.

Fig. 2 shows frequency-amplitude characteristics when the distance between arrays is changed. The input voltage is 25[Vp-p]. From this figure, it can be seen that the low frequency characteristics under about 2[kHz] are flat when the distance between arrays are 10[cm], 20[cm], 40[cm]. The output also becomes smaller as the frequency becomes higher. This trendency is similar to the frequency characteristic of the ultrasonic transducer.

Next, **Fig. 3** shows frequency-amplitude characteristics when the input voltage is changed to 5[Vp-p], 15[Vp-p], and 25[Vp-p]. Here, the distance between arrays is 20[cm]. It can be seen that the characteristics under 5[kHz] are almost flat, when the input voltage is 25[Vp-p], 15[Vp-p], and 5[Vp-p]. From this result, it is found that the shape of the amplitude characteristics does not change with the input voltage.

4. Directivity

Directivity was measured by rotating the facing ultrasonic transducer arrays. The ultrasonic frequency was set as 40 ± 0.5, 40 ± 1, 40 ± 1.5, and 40 ± 2[kHz] so that the differential frequency was 1, 2, 3, and 4[kHz]. Here, the input voltage is set at 25[Vp-p].

Fig. 4 shows that the directivity of the audible sound measured when the distance between arrays are 10 and 20[cm]. From Fig.4, it can be seen that audible sound waves are radiated almost omni-directionally at any frequency. Furthermore, even when the distance between the arrays was changed, the directivity was not greatly disturbed, and the sound waves are radiated omni-directionally.

From the result of the directivity measurement, it can be said that the sound source of the facing ultrasonic transducer arrays has directivity characteristics close to omni directionality.

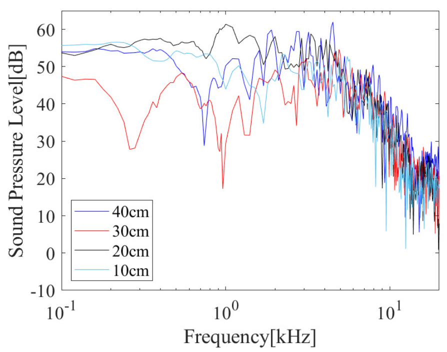

Fig. 2 Frequency-amplitude characteristics when the distance between arrays is changed (input voltage: 25[Vp-p]).

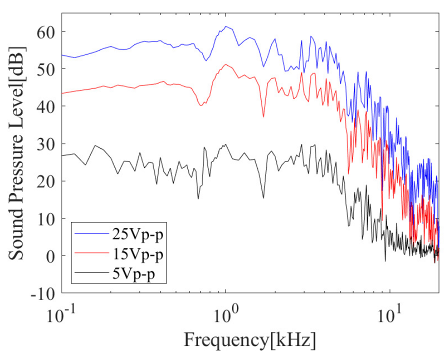

Fig. 3 Frequency-amplitude characteristics when input voltage is changed (distance between arrays: 20[cm]).

5. Conclusion

We present a new omni-directional sound source using facing ultrasonic transducer arrays. From the measurement of directivity, it was experimentally found that the sound was radiating non-directionally by using facing arrays of ultrasonic transducers arranged like a circular (central point symmetrical) shape.

This result suggests that it is possible to produce simpler, smaller, and light-weighted omni-directional loudspeakers with higher design like a ring and polyhedron by using this facing ultrasonic transducer array.

References

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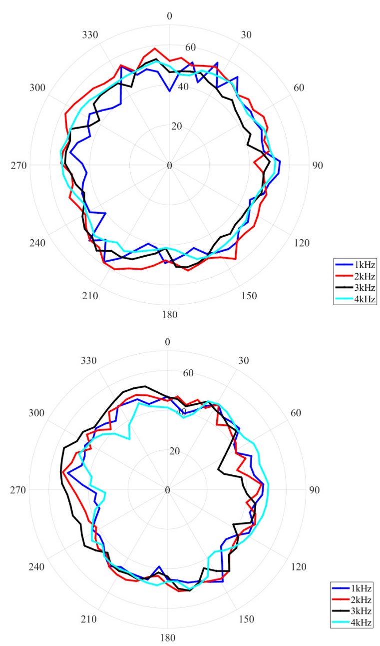

Fig. 4 Measured results of directivity at each distance of arrays (upper: 20 [cm], lower: 10 [cm])