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Radiated sound waves by ultrasonic source with complex type reflective plate attached to circular transverse vibrating plate

円形たわみ振動板に複合型反射板を設置した音源による放射音波

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1. Introduction

A technique is needed to achieve high far-field acoustic pressure with narrow directivity, the latter being necessary to obtain the former[1,2]. For this purpose, we have examined attaching a truncated-cone reflector to a source of aerial ultrasound equipped with a circular transversely vibrating plate[3]. Previous results indicate that this source is well suited to emitting aerial ultrasound with narrow directivity.

In this study, we establish a small conical reflector in addition to this source and compare it to the previous type of reflector.

2. Aerial ultrasonic source

Figure 1 shows the aerial ultrasonic source schematically. It comprises a bolt-clamped Langevin-type ultrasonic transducer, an exponential horn (made of duralumin; amplitude expansion ratio: 5), a resonance rod (made of duralumin; diameter: 8 mm) with screws, and a rigid-wall integral-structure circular transversely vibrating plate attached to the tip of the rod. The circular plate (made of duralumin; thickness: 1 mm; inner diameter: 76 mm; outer diameter: 96 mm) has a resonance frequency of 26.5 kHz. An annular block with a square cross section (made of duralumin; inner diameter: 76 mm; outer diameter: 96 mm; thickness of section: 8 mm; width: 10 mm) and the vibrating plate combined with a rigid wall attached to the rod tip are connected with bolts and nuts to form a rigid wall.

Figure 2 provides a cross-sectional view of the complex reflector installed on the circular rigid-wall integral-structure circular transversely vibrating plate.

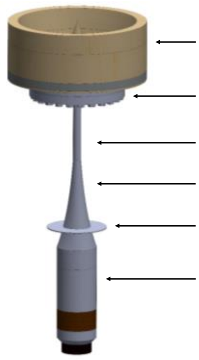

Fig. 1. Outline of an ultrasonic source.

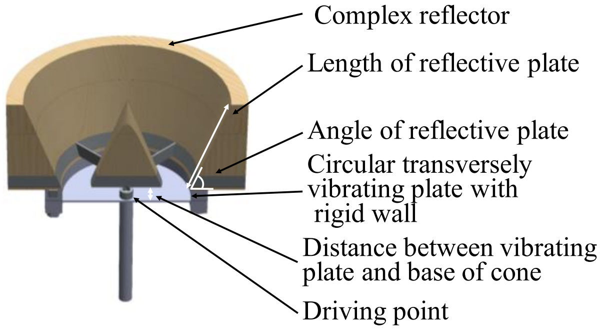

Fig. 2. Outline of vibrating plate and complex reflector.

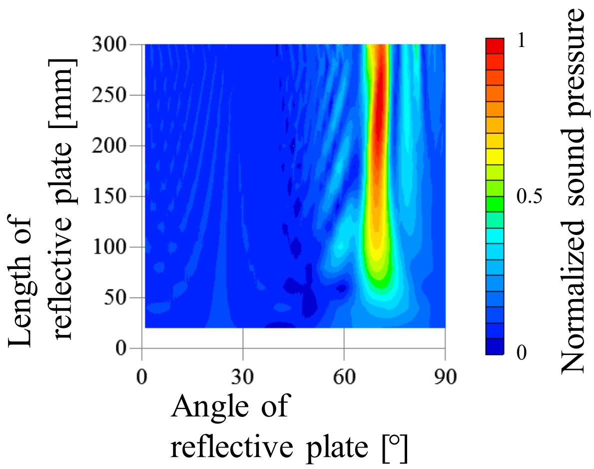

Fig. 3. Relationship between reflector angle and normalized sound pressure.

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3. Angle and length of complex reflector

To obtain narrow directivity, the angle and length of the conical reflector were analyzed using simulation software (COMSOL Multiphysics) based on the finite-element method. The dimensions of the rigid wall, the vibrating plate, and the resonance rod were the same as those of the sound source used in the present study.

Figure 3 shows analysis results for the acoustic pressure at a position 1.5 m vertically along the center axis of the vibrating plate, where the horizontal axis represents the angle of the reflector and the vertical axis represents the length of the reflector. The color map in Fig. 3 represents the pressure normalized by the maximum resulting acoustic pressure; dark blue represents the minimum value and dark red represents the maximum value.

From the results in Fig. 3, high acoustic pressure is obtained when the angle of the truncated-cone reflector is 70°. Based on this investigation result, a complex reflector was designed by the same simulation method. From the result of Fig. 3, the angle of the inner and outer reflective surfaces of the complex reflector was taken as 70°, and the length of the cone and the outer reflective plates were analyzed. From that analysis, the distance between the vibrating plate and the bottom of the conical reflective surface was taken as 10 mm, the length of the outer reflective surface was taken as 64 mm, and the length of the inner reflective surface was taken as 53 mm. As such, the newly designed complex reflector is smaller than a conventional truncated-cone reflector but nevertheless can emit strong sound waves over long distances.

4. Directional characteristics of radiated sound waves

A conventional truncated-cone reflector and a composite reflector were produced based on the results of Fig. 3, and the directional characteristics of the sound waves radiated with each reflector were examined and compared. The distance from the sound-emitting surface (the tip of the reflector) was always 2 m, and the acoustic pressure in each radiation direction was measured using a microphone. The electrical input power of the sound source was held constant at 1 W.

Figure 4 shows the results, where the circumferential axis represents the angle and the radial axis represents the acoustic pressure. High

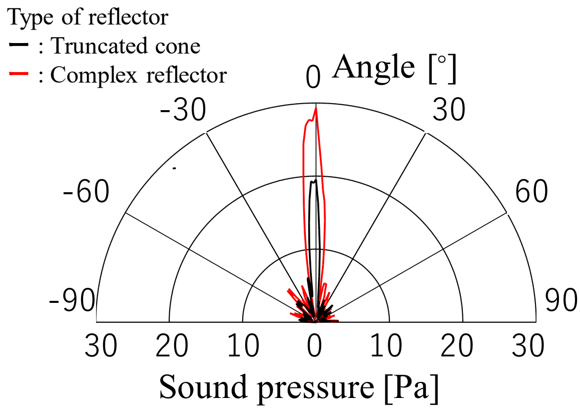

Fig. 4. Sound wave directivity using complex reflector.

acoustic pressure appeared in the 0° direction (perpendicular to the vibrating plate) in both cases, and the radiated sound waves had narrow directivity. With the truncated-cone reflector, the maximum sound pressure (that in the 0° direction) was 19.5 Pa (the sound pressure level 120 dB) and the half-value angle was 10°. With the complex reflector, the maximum sound pressure (again that in the 0° direction) was 29.4 Pa (the sound pressure level 123 dB) and the half-value angle was again 10°. Therefore, the maximum sound pressure with the complex reflector was roughly 1.5 times that with the truncated-cone reflector.

5. Conclusion

In this study, two types of reflectors, namely, a truncated-cone reflector and a complex reflector, were made for the sound waves radiated from a circular transversely vibrating plate, and the emitted sound waves were examined. The results show that the complex reflector gives rise to a higher acoustic pressure than does the truncated-cone reflector. Currently, the maximum acoustic pressure with the former is 29.4 Pa at an electrical input power of 1 W.

Acknowledgment

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