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Experimental Evaluation of High Intensity Ultrasound Source System using Acoustic Waveguide for Calibration of Hydrophone

ハイドロホン校正のための音響導波路を用いた高強度超音波音源システムに関する実験評価

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1. Introduction

In recent years, high intensity focused ultrasound higher than 40 MPa[1] has been used for cancer treatment, etc., in medical field,, and high intensity ultrasound is also used for applications such as ultrasound cleaners or ultrasound dispersers in industrial field. Requests for evaluation of the high intensity acoustic field and non-linear calibration has been increasing. Therefore, hydrophone which receiving sensitivity is calibrated in high intensity acoustic field is required for the acoustic field evaluation. The hydrophone sensitivity calibration is performed by using the absolute calibration system[2] with a polyethylene terephthalate (PET) membrane, a laser interferometer, and the comparative calibration system with a reference membrane type hydrophone. The acoustic pressure at the measurement position should be measured precisely in order to calibrate the sensitivity of the reference membrane type hydrophone. Vibrating velocity on the surface of a gold deposited PET membrane set in the far field of a transmitting ultrasound source transducer should be measured with a laser interferometer, and the sound pressure should be calculated by using the above measured vibrating velocity. For example, the sensitivity calibration of hydrophone is performed in the range of 450 mm to 525 mm from a 1 MHz flat disk type ultrasound source with 25.4 mm diameter in NPL (B.K.), and sound pressure is from 12.0 kPa to 13.4 kPa[3]. However, the hydrophone for measurement of the acoustic field of HIFU treatment device or ultrasound cleaner should be calibrated in the higher intensity acoustic field.

Therefore, it is necessary to develop an ultrasound source to transmit more high intensity ultrasound plane wave, and to calibrate a hydrophone for measuring high intensity acoustic field. Accordingly, we should develop the original ultrasound source which can form the high intensity acoustic field with similar spatial distribution of sound pressure as the acoustic field formed by the conventional flat disk type ultrasound source.

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2. Ultrasound source system using an acoustic waveguide

We proposed an ultrasound source system for formation of the high intensity ultrasound field with similar spatial distribution of sound pressure as the ultrasound field formed with the conventional flat disk type ultrasound source. Our proposed ultrasound source system can form the high intensity ultrasound field, by using a spherical concave type ultrasound transducer and a hollow cylindrical type (pipe shaped) acoustic waveguide, by not only application of higher voltage to the piezoelectric element. We proposed our original ultrasound source system for formation of the similar shaped high intensity ultrasound field as the ultrasound field formed with the conventional flat disk type ultrasound source. When the focal point of the focused ultrasound field from a spherical concave type ultrasound transducer is set at the center of one aperture surface of a hollow cylindrical acoustic waveguide, the similar shaped high intensity ultrasound field that with the flat disk type transducer can be formed by ultrasound waves irradiated from the other aperture surface of the hollow cylindrical acoustic waveguide. Our proposed source system is shown in **Fig. 1**.

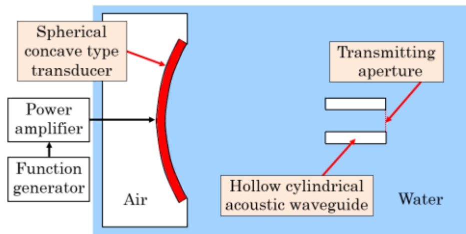


Fig. 1 Ultrasound source system using a hollow cylindrical acoustic waveguide and a spherical concave type transducer.

3. Construction of the experimental ultrasound source system

It was shown by axisymmetric acoustic field

3D simulation based on the finite element method that the acoustic pressure distributions of our proposed system were higher intensity than those of the same diameter flat disk type transducer [4].

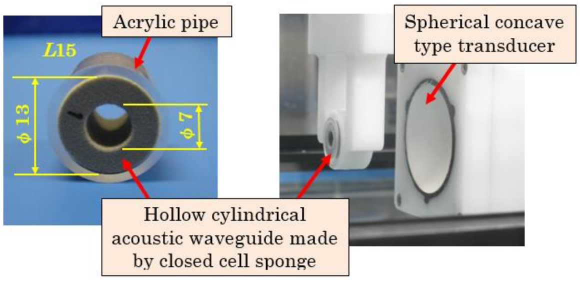


Fig. 2 Experimental ultrasound source system using hollow cylindrical acoustic waveguide made by closed cell sponge and spherical concave type transducer.

We fabricated the above proposed ultrasound source system using the 1 MHz spherical concave type transducer with aperture diameter of 40 mm, the curvature of 40 mm, and the hollow cylindrical acoustic waveguide made by a closed cell sponge with inner diameter of 7 mm and length of 15 mm as shown in **Fig. 2**.

4. Measurements and results

Block diagram of experimental system and configuration parameters of spatial acoustic pressure distribution measurements are shown in **Fig.3**. One end of the acoustic waveguide is placed at the measured focal position of the spherical concave type ultrasound transducer, and anti-cavitation hydrophone is scanned on the central axis of the transducer. Appearance of the experimental system are shown in **Fig.4**.

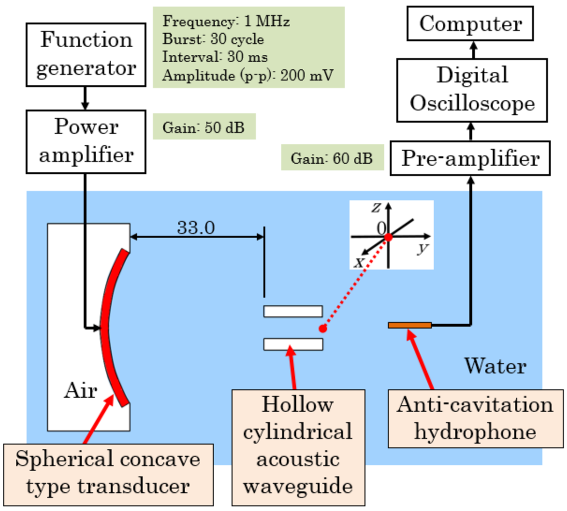


Fig. 3 Block diagram of experimental system for spatial acoustic pressure distribution measurements by anti-cavitation hydrophone.

Experimented and simulated results of the relationship between central axis and normalized acoustic pressure are shown in **Fig. 5(a)**. Experimented and simulated results of the relationship between transversal position (x direction and z direction in **Fig. 3**) and normalized acoustic pressure at the position of y =30 mm from the transducer are shown in **Fig.5(b)**.

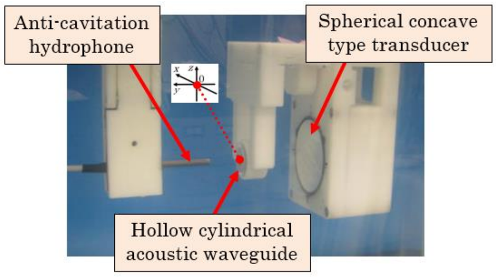
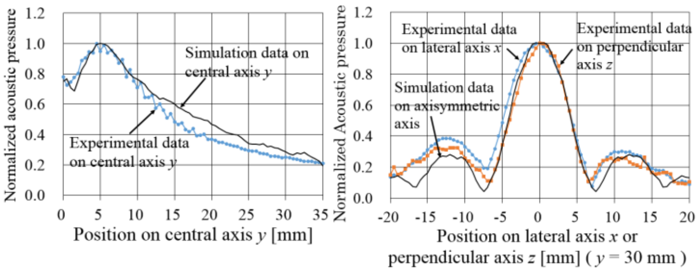


Fig. 4 Appearance of the experimental system for spatial acoustic pressure distribution measurements.



(a) Central axis y (b) Lateral axis x and perpendicular axis z at y = 30 mm

Fig. 5 Comparison of the center normalized spatial acoustic pressure distributions of the experimental data with the simulation data.

As results, experimented data are almost coincides with the simulated data, especially, the experimented -6 dB main beam width is matched to the simulated data within 10 % as shown in **Tabe 1**.

Table 1 Evaluation of -6 dB main beam width at y = 30 mm of the experimented data and the simulated data.

Simulated data BW_0 [mm]	Experimented data BW_A [mm]		Ratio of -6dB beam width BW_A / BW_0	
	Lateral axis x	Perpendicular axis z	Lateral axis x	Perpendicular axis z
8.46	9.30	8.30	1.10	0.98

5. Conclusion

We proposed and fabricated high intensity ultrasound source system using acoustic waveguide, and measured spatial acoustic pressure distributions. As the result, we confirmed that experimented data are almost coincides with the simulated data, spatial acoustic pressure distributions are formed the similar main beam with a flat disk type transducer.

References

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