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Investigation of Underwater Acoustic Lens Performance by Geometric Analysis
水中音響レンズの幾何的性能評価法の検討

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1. Introduction

An underwater acousic lens for imaging has to make converging acoustic beams at the image surface. To predict its performance, acoustic field analysis was computed. However, the calculation is needed at every incidence angle, that require considerable time. Then evaluation way of the beam width at converge area was considered [1-3] and approximate equations were also proposed [3]. It discussed only beam width along acoustic axis, because of the studies for a concavity type convergent source. Here, it was necessary to estimate the underwater acoustic lens for imaging not only along the acoustic axis but also off the axis to check an imaging performance over full visual field. It was also necessary to estimate the lens for imaging not only beam width but also aberration which causes an image distortion.

In this study, authors reported introduction of evaluation method of an acoustic lens by geometric analysis which is generally used in optics.

2. Geometric analysis

It is not special in the optical industry that image performance of incident beam into a lens system is evaluated by geometrical analysis. This method can provide an easy way to get aberrations on vicinity of incident acoustic energy convergence position for not only the case (I) entering acoustic wave into the lens along the acoustic axis but also the case (II) entering acoustic wave along oblique angle to the acoustic axis.

Nonetheless the following explanations and the investigations, Author limits it in the case (I) to make discussion simple. Acoustic converging rays through a lens by geometric analysis were shown in Fig.1 (a). It defined that the density of acoustic ray entering into a lens is associated with the density of acoustic energy entering into the lens. That is to say, the energy that one acoustic ray carries is divided into evenly. Then, the density of acoustic ray through a lens shows sound energy distribution at the position without modification.

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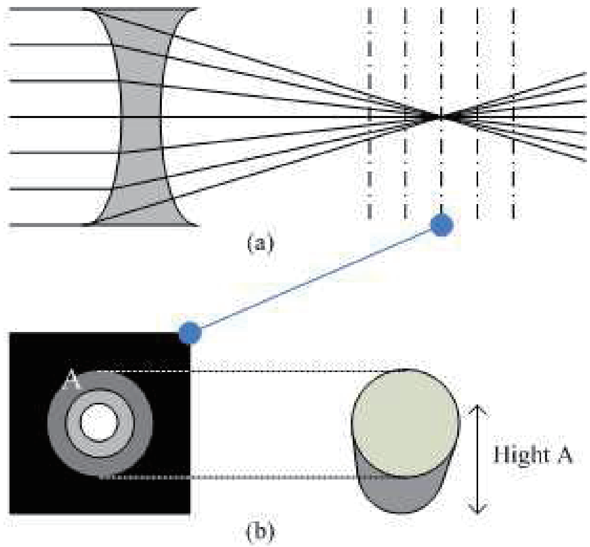

Fig.1 Concept of encircled energy.

On the other hand, measured distribution of acoustic energy can be shown as encircled-energy. In the convergence region of incident beam, one example of acoustic field in an orthogonal section to acoustic axis is shown in Fig.1(b). Contour line A was approximated in a circul. Assuming that the circul is bottom and the the acoustic energy contour line A is hight, volume of cylindrical column is acoustic energy amount within contour line A.

A diameter which enclose 80% energy of the total flux is plotted at each position along the acoustic axis. This was performed both by geometrical analisys and experimental results.

In comparison and examination of results mutually, calculated lens performance expectation and measured results are tried to be associated.

3. Experimental set up

The measurement object was biconcave lens which is made of acrylic resin (Acrylite is made in Mitsubishi Reyon). The effective diameter is 150mm, all view angle is 8°. The sound refractive index was assumed to be n=0.532 [4].

Figure 3 shows an acoustical lens characteristics measurement system in a tank which size is 1.5 m width, 1.5 m length, and 1.0 m depth. The origin of coordinate system is located on a center of stop surface. Each direction is defined in Fig.3. Burst waves of 10 cycles were projected by the transducer (1 MHz center frequency, 25Φ diameter). The waves went through the lens, which was set at 1275 mm apart from a transducer, and then these were received by a hydrophone. The receiver position is set at with 1-mm increments in between from 176mm to 186mm, because converge point was X=181mm[4]. During the experiment, the tank water temperature was constant by 22.6 degrees.

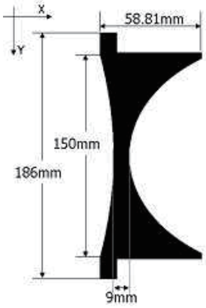

Fig2 Underwater acoustic lens

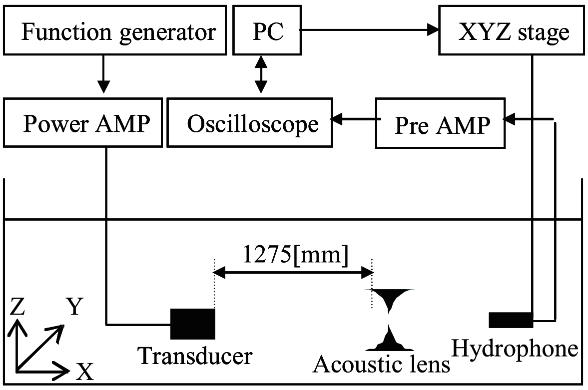

Fig3 Experimental setup.

4. Results and discussions

One of the measued results is shown in Fig.4, which is YZ plane at X=181mm convercence point. Conter lines in the figure described muximum enrgy dividing into ten equal parts. The other ten figures also described in the same way. Those figures said that conters area became smaller with change in X from 176mm to converg point and then became larger with change in X from converg point to 186mm.

Next following a procedure shown in Fig.1(b), a radius showing 80 % of energy was decided in each figure. The result showed solid line in Fig.5. The curve shows convex below and minimum position is on X=181mm. A doted line, which is a result by the geometry analysis, shows not only convex below but also seep. Cause of the difference may include an aberration of the lens or in corresponding to conditions between the measurement system and the geometry analysis.

5. Conclusive remarks

To evaluate lens performance circumstantially, introduction of a geometry analysis which is

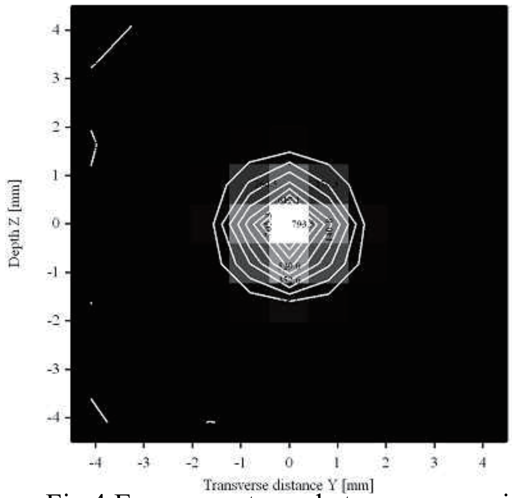

Fig.4 Energy contoured at converge point.

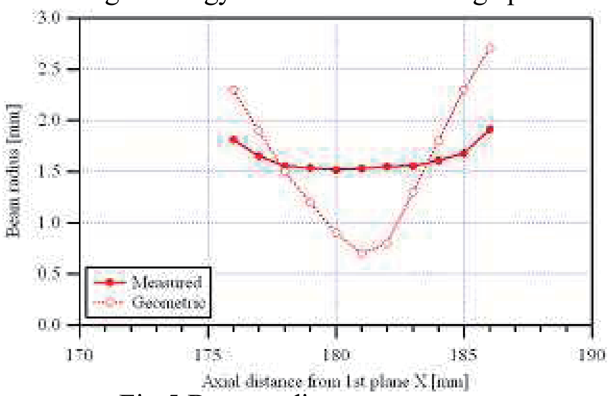

Fig.5 Beam radius at converge area.

generally used in optics was examined. Comparison geometric and measured encircled energy said that both results showed the same tendency. In the future, to increase degree of coincidence between both results the investigation will be continued.

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