Study to reduce the size and weight of an underwater acoustic imaging system

Imaging experiment using frequency controlled beam steering transmitter and receiver array

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***Abstract*— To reduce size and weight of our underwater acoustic video camera 4-DWISS, we proposed new transmission and reception method that was the advanced frequency controlled beam steering method with new receiver array. The new receiver has a bank of elements configured to inverse the polarization axis adjacent of element, the electrodes are common, which is as same transmitter. Because the method is an acoustic lens less. Then the acoustic imaging experiment in a tank was conducted by using the method. We got an appropriate two-dimensional acoustic image. New method for lightweight achieved a two-dimensional acoustic imaging.**

Keywords—frequency controlled beam steering method; acoustic imaging; lensless;

I. INTRODUCTION

We developed an underwater acoustic video camera, Four-dimensional Wide-angle Imaging and Surveying SONAR (below, 4-DWISS), which not only visualize three-dimensional space in real time but also survey the space with post-processing [1]. But the underwater part of 4-SWISS is heavy at 130kg. Therefore, it is due to the simple operation, be reduced in size and weight has been desired.

Then, visibility performance is not dropped, it was the goal of size and weight of the system. We gave up a heavy physical acoustic multiple lens. Then, it was examined to replace with a new transmission and reception method.

The method is as follow. Transmitting is the usual frequency controlled beam steering method [2]. The transmitter had a bank of elements configured to inverse the polarization. Using LFM pulses you'll achieve a beam steering with single driving signal. On the other hand, the receiver was applied to the same method of the transmitter, many receivers were arrayed in the vertical direction. Received signals were synthesized by using beamforming to obtain two-dimensional acoustic images.

This new method is reported in comparison with the original frequency controlled beam steering method.

In addition, two-dimensional images were shown at each delay time, means the three-dimensional image. Then, a three-dimensional image was updated sequentially, means the four-dimensional image. Both three-dimensional and four-dimensional imaging has been studied by 4-DWISS development. Then this paper only mentioned two-dimensional imaging.

II. TRANSMITTER AND RECEIVER ARRAY

A. Transmitter

The structure of the transmitter is shown in Fig. 1 that is based on frequency controlled beam steering method. The transmitter has a bank of elements configured to inverse the polarization axis adjacent of element, the electrodes are common. When an AC signal of frequency f drive for the array, the sound will be driven in the direction. Since θ is determined by eq. 1, it depends on frequency. Where θ, λ, d are transmitting phase, wavelength, element pitch, respectively. In other words, using an LFM pulse you can achieve beam steering with single driving signal.

$$\theta = \sin^{-1}\left(\frac{\lambda}{2d}\right) \tag{1}$$

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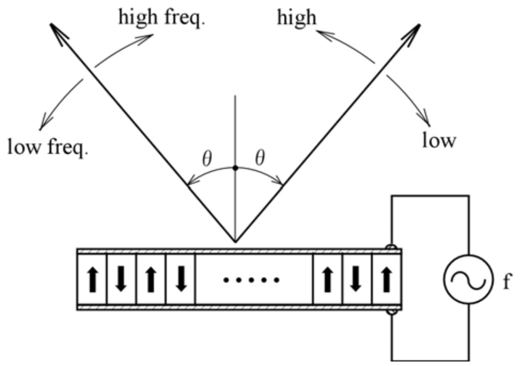
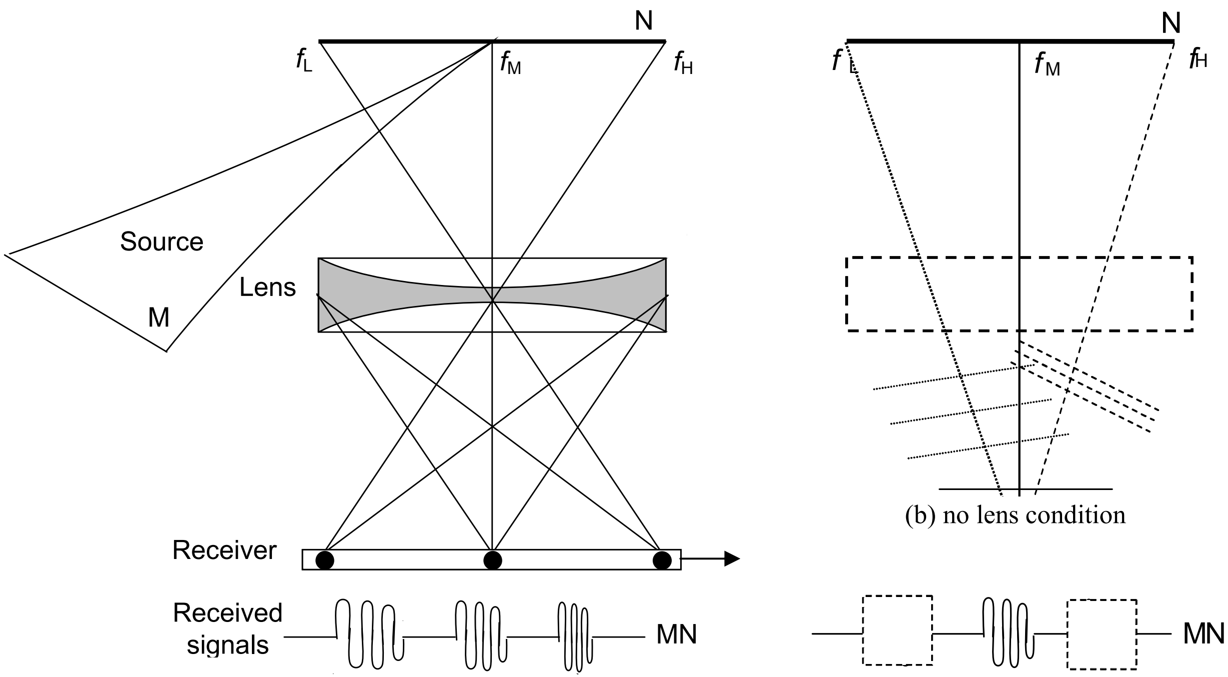


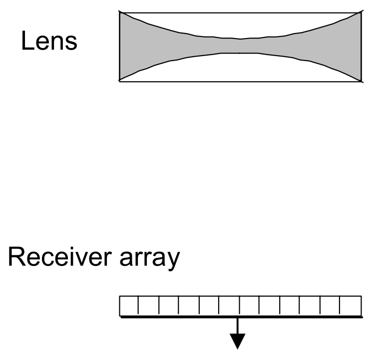
Fig.1 Schematic illustration of transmitter by using frequency controlled beam steering method.

B. Reciever array

The receiver has the same structure as the above-described wave transmitter, which is arranged vertically. In other words, it was a one-dimensional array. In reception, the equation (1) is satisfied. When sound come from the θ direction, the receiver will only receive the signal of frequency f.



(a) horizontal direction



(c) vertical direction

Fig. 2 Receiving image of original frequency controlled beam steering method. (a) is along horizontal direction, (b) no lens condition, and (c) is along vertical direction.

III. THE TRANSMISSION AND RECEPTION BEHAVIOR AND TWO-DIMENSIONAL DIVISION OF THE IMAGE

A. Simple method (original frequency controlled beam steering method)

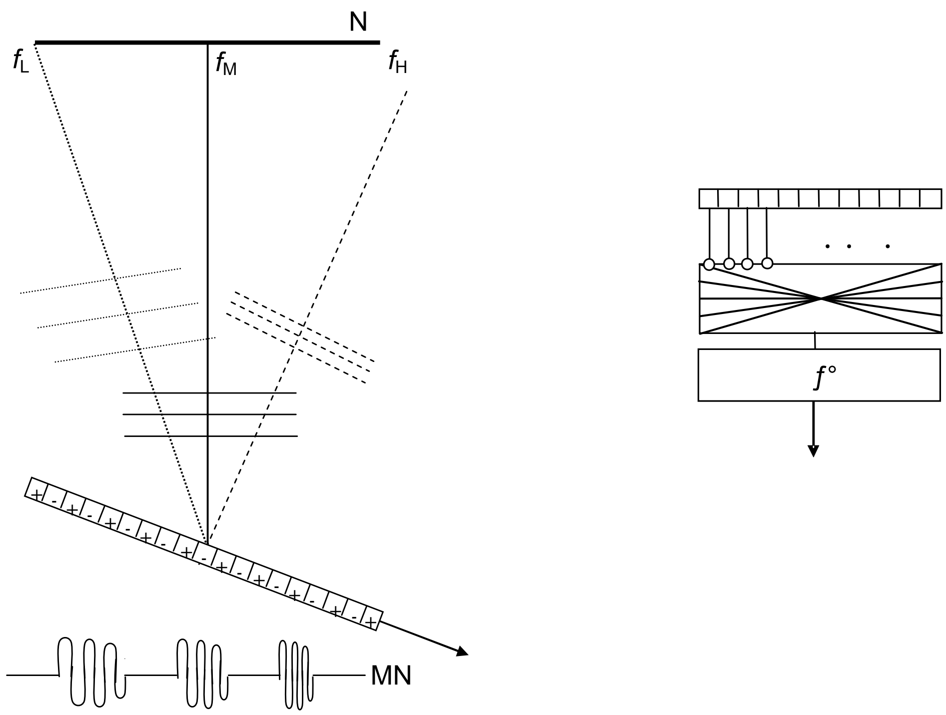
The receiving behavior of simple method is shown in Fig. 2. In both (a) simple method (original frequency controlled beam steering method) and (b) no lens condition for comparison are described along the horizontal direction. And the source is the same as Fig.1 in these figures. In (c) simple lens with a simple receiver array is described along the vertical direction.

In Fig.2 (a), the oblong receiver is arranged in the horizontal direction. The receiving signals were focused on the receiver array by the lens. Then these signals along the vertical direction were also divided by the lens into three packets of frequency f_H, f_M, f_L. It is equivalent to integrating the signals, for each frequency. The received signals are rearranged in order of frequency by using FFT analysis. In other words, it is possible to divide in the horizontal direction. From the above, in a simple method, sound waves are divided into two-dimensional.

B. Advanced frequency controlled beam steering method with the receiver array

The receiving behavior of advanced method is shown in Fig. 3. In this method, both source and receiver are the same as Fig.1.

As mentioned in Section 2, when a sound comes from θ direction the receiver will catch the signal of frequency 'f'. In this situation the equation (1) is also satisfied. In other words, the lens effect of the simple method was replaced by the receiver of the advanced method along horizontal direction. On the other hand, the sound wave division in the vertical direction was realized by phase matching processing. The process achieves the convergence effect without lens. From the above, sound waves are divided into two-dimensional by using in the advanced method.



(a) horizontal direction

(b) vertical direction

Fig. 3 Receiving image of advanced frequency controlled beam steering method with the transmitter array.

IV. ACOUSTIC IMAGE IMAGING EXPERIMENT IN A TANK

A. Experiment

Figure 3 shows the block diagram of the measurement system for an imaging experiment. Fig. 3 (a) shows a side view of the water tank, and (b) shows a top view of them. The transmitter installed on the X-Y axis at the same location and same angle as the transmitter. The targets were two spherical buoys, which is 0.1m diameter, lined up in the Z-axis direction. The source frequency, voltage and the number of burst wave are from 800 to 910 kHz, 20 Vp-p, 20 cycles, respectively. The received signals were averaged 1,000 times on the digital oscilloscope. And the transmission frequency was varied in increments of 5 kHz to obtain similar data in the above range.

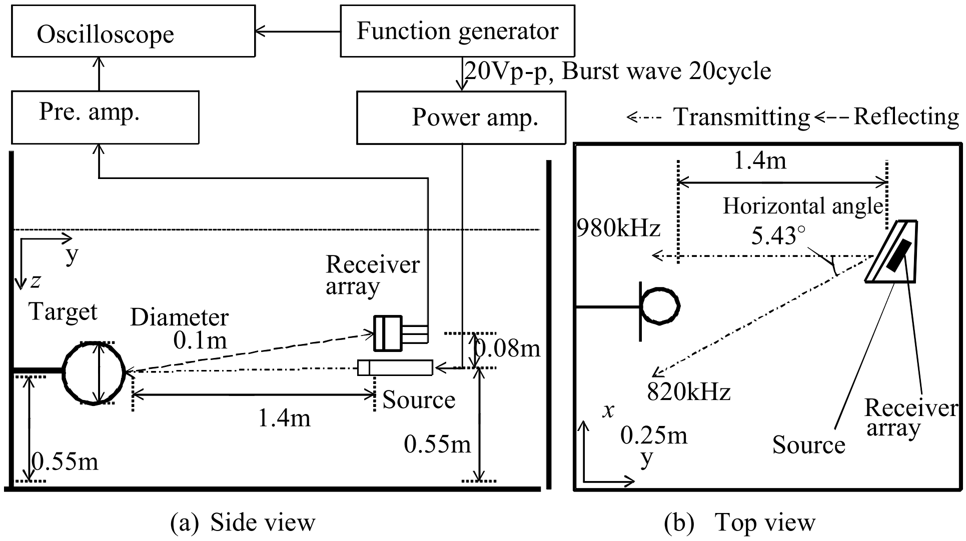


Fig.3 Setup for tank experiment.

B. Result

Fig. 4 shows the results of two-dimensional acoustic images. The characteristics of the transmitter and receiver are corrected. Fig.4 has a visual field of 20° in the vertical direction and 5.43° in the horizontal direction, and the length of view region is about 50 cm vertically and about 10 cm horizontally. When the target was two spherical buoys lined up in the vertical direction, the two images are shown in figure. And these images completely separated.

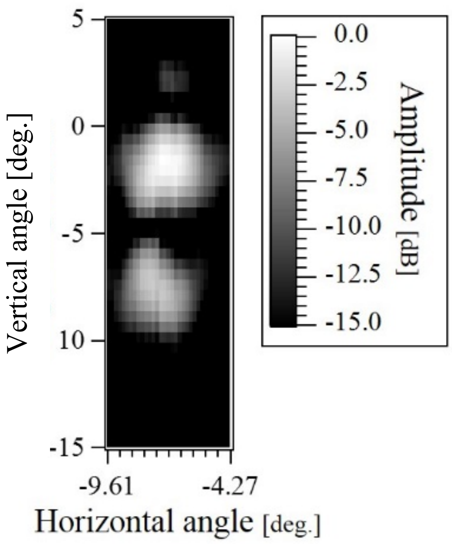


Fig.4 Two-dimensional acoustic images.

V. SUMMARY

In this paper, to reduce size and weight of our acoustic video camera 4-DWISS, we proposed new transmission and reception method that was the advanced frequency controlled beam steering method with the receiver array. Then the acoustic imaging experiment in a tank was conducted by using the method. We got an appropriate two-dimensional acoustic image. New method for lightweight achieved a two-dimensional acoustic imaging.

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