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Improvement of Communication Quality by a Parabolic Acoustic Receiver Pointing at a Transmitter
送信機を指向するパラボラ音響受信機による通信品質の向上

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1. Introduction

Underwater acoustic (UWA) communication is an essential technology to network underwater drones and sensors for more efficient underwater exploration. In UWA communication, omnidirectional transducers are typically used to cover large areas where the exact location of the transmitter and receiver is unknown. However, the use of omnidirectional transducers requires massive transmission power and complicated signal processing1). On the other hand, the use of directional transducers is attracting considerable attention recently, since it has the potential to achieve low-power and simple communication2,3).

In this paper, we evaluate the possibility of UWA communication using the parabolic reflector as a directional transducer. Specifically, we design a directional transceiver using a parabolic reflector. Different from existing directional transducers (*e.g.*, single transducer with a large aperture and array of multiple transducers), parabolic reflector with a small number of transducers has a potential to achieve directional signal transmission and reception without the need for large transducers or complicated signal processing. We have found that the use of the reflector can improve communication quality by simulation4,5). However, performance evaluation by experiment has not been performed yet. Hence, in this paper, we perform preliminary experiments in air to evaluate the performance of UWA communication using directional transducer.

2. Design of Directional Transducer Using Parabolic Reflector

A parabolic reflector used in this experiment is shown in **Fig. 1**. The directional transducer consists of the reflector and three microphones. The reflector is a paraboloid of rotation5). The aperture diameter of the paraboloid is 3.0×10^{-1} m and the focal length is 7.5×10^{-2} m. The material of reflector is duralumin. The aperture surface and the focal point lie on the same plane, where a microphone is placed at the focal point.

3. Experiments in an Anechoic Chamber

Experiments were conducted to verify the effectiveness of the designed directional transducer. **Figure 2** shows the experimental environment. The experiment was conducted in an anechoic chamber, where the effect of sound reflection from the wall and floor can be ignored. The transmitter consists of a PC with software (MATLAB, MathWorks), digital-to-analog converter (USB-6363, National Instruments), a power amplifier (AMP1: AP05, FOSTEX) and a speaker (PT20K, FOSTEX). The receiver consists of a microphone (C9767, DB products), an operational amplifier (AMP2: OPA344), and analog-to-digital converter (USB-6363). First, the impulse response between the speaker and the reflector was calculated. Specifically, a chirp signal (center frequency; 18.8 kHz and bandwidth; 2.3 kHz) was transmitted from the speaker. The angle of the reflector θ was changed from 0° to 90° (θ = 0° when the speaker and the reflector were facing each other). The center of rotation is located 1.5×10^{-1} m behind the microphone. The signal was received by the microphone and the impulse response of the

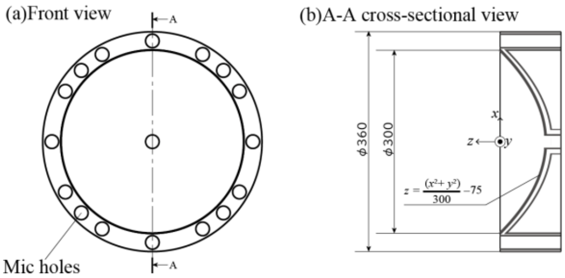

Figure 1: Designed parabolic reflector.

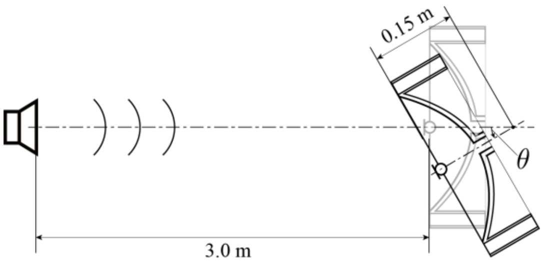

Figure 2: Experimental environment.

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channel was obtained by calculating the cross-correlation function between the transmitted and received signals. Here, the speed of sound and frequency of the chirp signal used in this experiment was determined from room temperature so that the wavelength is the same as that of the signal used in the simulation [speed of sound; 1,482 m/s, and frequency; 75 - 85 (kHz)].

We next evaluated a relationship between incident angle θ and communication performance. **Figure 3** shows a block diagram of the transmitter and receiver. The chirp signal transmitted from the speaker was received by the microphone and the impulse response was calculated. The ratio of mean square value of each received signal with chirp signal and silence is defined as the input signal-to-noise ratio (ISNR). The transmitted signal was calculated using single-carrier modulation (training sequence; 100 symbols, message; 200 symbols, modulation; QPSK, carrier frequency; 18.8 kHz, and signal bandwidth; 1.1 kHz). The signal was received by the center microphone while the angle of the reflector θ was changed from 0° to 90°. White Gaussian noise was then added to the received signal. Finally, the receiver performed demodulation and equalization using a single-channel RLS-DFE equalizer (FF; 41 taps, FB; 40 taps, and forgetting factor; 0.98). The output signal-to-noise ratio (OSNR) was used to evaluated communication quality.

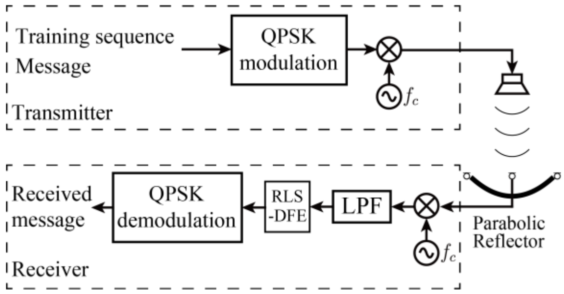

Figure 3: Block diagram of the transmitter and receiver.

Figure 4 shows the experimental results. We first focus on the relationship between incident angle θ and ISNR. As shown in the figure, the ISNR with the reflector (solid line) is larger than the that without the reflector (dotted line) when θ is less than 25°. We next focus on the relationship between θ and OSNR. From this figure, we found that the OSNR with the reflector outperformed that without the reflector when θ is less than 70°. The reason why the SNR was not maximum at 0° was probably because the speaker and the reflector were not facing each other or the speaker was not on the central axis of the reflector.

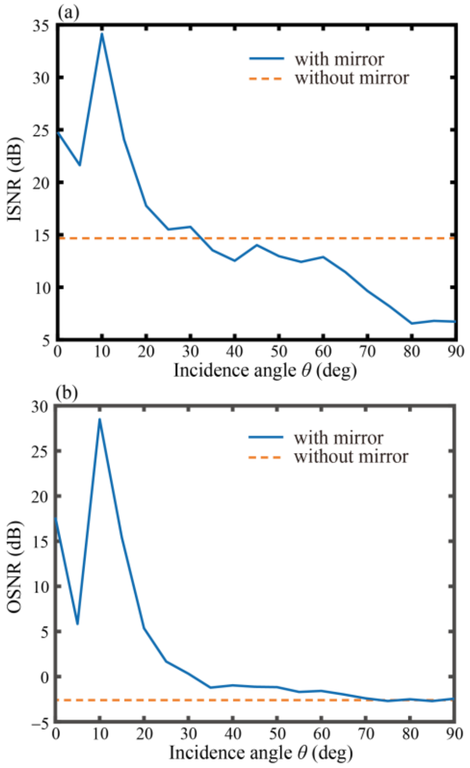

Figure 4: Experimental results; relationship between incidence angle θ and (a) ISNR, and (b) OSNR.

4. Conclusions

The communication using parabolic reflectors was evaluated by experiments. As results, we found that UWA communication using parabolic reflector can become a viable alternative to achieve low-power and simple communication.

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