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Performance Improvement of Compound Eye Underwater Acoustic Lens Using Partition

複眼水中音響レンズの隔壁による性能向上

Yuji Sato[1†], Tadashi Ebihara[1], Koichi Mizutani[1], and Naoto Wakatsuki[1]
([1]Univ. Tsukuba)
佐藤裕治 [1†]，海老原格 [1,2]，水谷孝一 [1,2]，若槻尚斗 [1,2] ([1] 筑波大院・シス情工，[2] 筑波大・シス情系)

1. Introduction

Recently, the network of multiple underwater vehicles gets much attention to obtain a glimpse of the underwater world efficiently [1]. Underwater acoustic (UWA) communication is one of the techniques to establish the network. However, the use of UWA communication among multiple vehicles is still challenging since the collision of packets from multiple transmitters leads to performance degradation. Thus, multiple access techniques (e.g., time-, frequency-, code- or space-division multiplexing) or packet scheduling algorithms have been attracted many researchers.

As an alternative, we propose an UWA communication with space-division multiplexing using an acoustic lens or mirror. The use of an acoustic lens has the potential to achieve simple UWA network since it allows transmission and reception of multiple beams simultaneously without a complicated circuit. To achieve multi-user communication, a compound eye acoustic lens with a wide angle of view is effective[2]. However, the crosstalk occuers under specific angle condition.

In this paper, we design an improved compound eye lens system to address the crosstalk problem by introducing partitions between each lens and hydrophones segment.

2. Design of Lens System

Figure 1 shows a schematic view of a compound eye lens system consists of 6 aplanatic lenses. Each aplanatic lens is designed based on [3], with a refractive index of n = 0.56, thickness of d = 5 mm and back focus of f_b = 91.5 mm. The lens axes of each lens cross at 30°, thus the angle of view is expected as 180°. The radius of curvature of lens array is 200 mm. The focused sound is received by a convex hydrophone array whose radius of curvature is 115 mm. The center of array corresponds with the cross point of lens axes. The array consists of 18 hydrophones whose diameter is about 11 mm. Thus, 1 lens and 3 hydrophones construct one segment. A large absorber is set behind the hydrophones to reduce reflections between the lens and hydrophones and thin absorbers as partitions are set between each segment to devide focused sound fields.

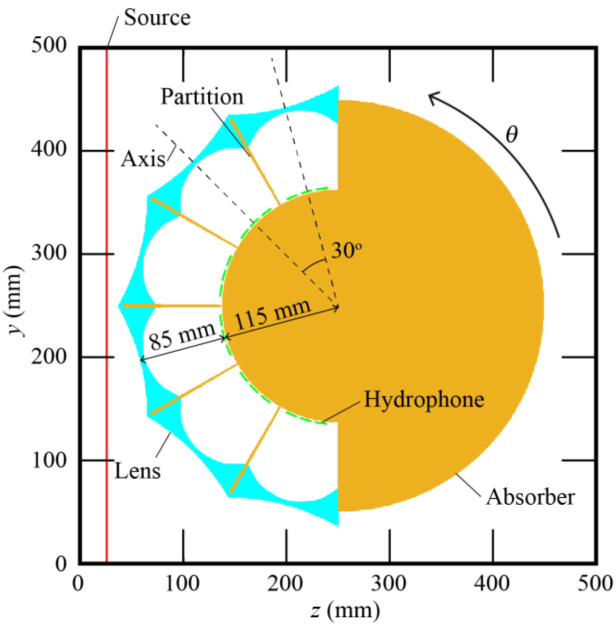

Fig. 1 Schematic views of compound eye lens system.

3. Simulation

3.1 Simulation Environment

An impulse response of the compound eye lens system is calculated with the 2D FDTD method. The calculated field is the same as Fig. 1. In the simulation, the discretization steps were set as Δt = 0.125 μs in time and Δs = 0.5 mm in space. The size of the simulation field and calculation time was set as 500 × 500 (mm^2) and 6.2 ms, respectively.. A chirp signal (center frequency and bandwidth: 100 kHz) is emitted from a line source at z = 25 mm. The lens system is rotated virtually to change the incidence angle θ. The center of rotation corresponds with the cross point of axes of lenses.

The impulse response on the receiver was calculated by a cross-correlation function between the transmitted and received signals, from θ = -90° to θ = 90° at intervals of 2°. Then the received communication signal on each hydrophone is calculated by convoluting a communication data block and the impulse response.

The communication signal is calculated by modulating data block consisted of training

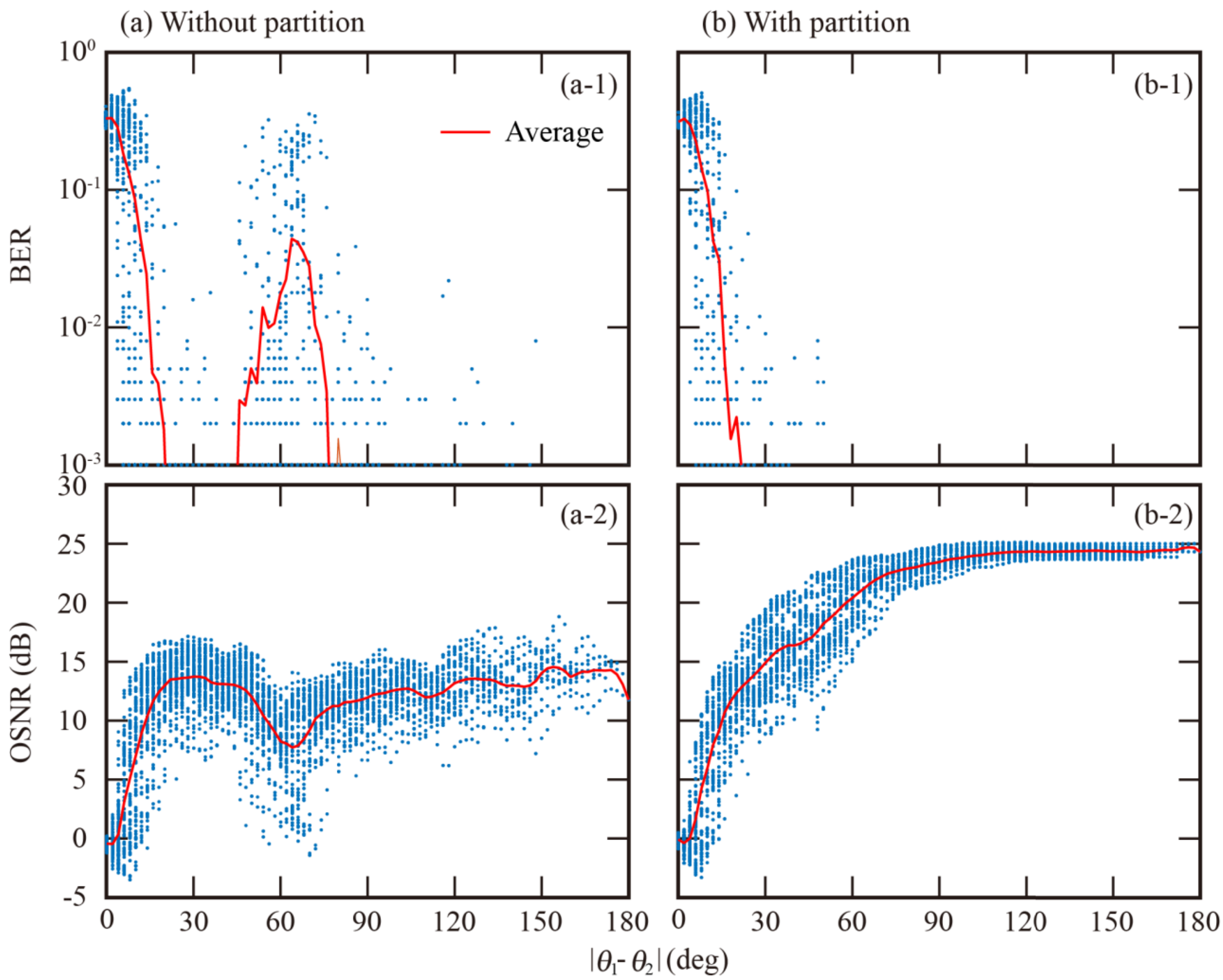

Fig. 2 Results of calculation; (a-1) Relationship between BER and $|\theta_1 - \theta_2|$ without partitions, (a-2) relationship between OSNR and $|\theta_1 - \theta_2|$ without partitions, (b-1) relationship between BER and $|\theta_1 - \theta_2|$ with partitions, and (b-2) relationship between OSNR and $|\theta_1 - \theta_2|$ with partitions.

sequence of 100 bit and message sequence of 1,000bit modulated by BPSK, and up-converting to the frequency of 100 kHz (signal bandwidth: 100 kHz). The received signals are equalized by RLS-DFE (FF: 51 taps, FB: 50 taps, and forgetting factor: 0.999). Finally, the communication performance is evaluated by the output signal-to-noise ratio (OSNR) and bit error rate (BER) of each θ.

In the simulation, we consider two received signals arrive from the angle of θ_1 and θ_2 in multi-user communication. The caluculated BERs and OSNRs with and without the partitions are compared in various θ_1 and θ_2.

3.2 Simulation Results

Figure 2 shows results of calculation. We found that BER and OSNR deteriorated at $|\theta_1 - \theta_2|$ = 60° as shown in Figs. 2(a-1) and 2(a-2), which is caused by sound passing the bordering lenses. We consider that this problem is improved by the partitions as shown in Figs. 2(b-1) and 2(b-2). We also found that OSNR with partitions is improved at $|\theta_1 - \theta_2| > 30°$ with compairing Figs. 2(a-2) and 2(b-2).

The obtained results suggest that the partitions can addres the crosstalk problem that occurs under specific condition, and can improve communication performance.

4. Conclusions

In this paper, we designed the compound eye lens system having the partitions and evaluated its communication performance with simulation. We found the partitions were effective to address the problem and improve the performance.

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References

1. Sozer *et al.*: IEEE J. Ocean. Eng., **25** (2000) 72.
2. Y. Sato *et al.*: Proc. USE2019 (2019) 1P6-2.
3. Y. Sato *et al.*: Jpn. J. Appl. Phys. **46** (2007) 4982.