Verification of Underwater Position Estimation Using Received Power Profile Through Pseudo-Scale Model

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***Abstract* - In this paper, we propose a method based on the received power profile for diver position estimation in shallow sea using electromagnetic waves, and verify it by pseudo-scale model experiments. In our verification, we extract three regions in the sea where divers may exist based on the information of the diver's depth and the 1 dB margin of the received power, and examine the position estimation method to select the overlapping region.**

***Keywords* — Underwater position estimation, received power profile, pseudo-scale model.**

I. INTRODUCTION

Conventionally, sound waves and light waves have been used as transmission media in the sea, but in the shallow sea where rescue is performed in a marine accident, it is disadvantageous for position estimation due to the effect of ambient reflection and turbidity of seawater. For the use of electromagnetic waves in the loss medium, there is an advantage that there are no problems of ambient reflection or turbidity in spite of its large attenuation. In addition, with the progress of communication/measurement technology and electronic devices, the use of electromagnetic waves in the sea has been attracting attention again in recent years.

In this paper, the authors propose an underwater position estimation in shallow sea based on the received power profile using electromagnetic waves [1]-[3]. To verify our proposal, we introduce a pseudo-scale model and conduct experiments in the laboratory [2]. The position estimation method uses the value of the diver's depth gauge mounted on the transmitting antenna and the three strongest powers received by the receiving antennas mounted on the nine buoys installed on the sea surface. The area where the diver exists is specified from the overlapping area of the three areas where the diver may exist, which is calculated back from the received power profile provided in advance.

II. UNDERWATER POSITION ESTIMATION MODEL AND PSEUDO-SCALE MODEL

A. Underwater Position Estimation Model [3]

Fig. 1 shows an underwater position estimation model. The receiving dipole antennas R_n $(n = 1, 2, \cdots, 9)$ are installed on nine buoys floating on the sea surface ($z = 0$ m), and the transmitting dipole antenna and depth gauge are attached to the diver in the sea. It is assumed in advance that the received power profiles $p_n(x, y, z)$ of receiving antennas on the sea surface with respect to the transmitting antenna are discretely given as a function of the diver's position (x, y, z). The electromagnetic wave radiated from the transmitting antenna can be measured as received power T_n by the receiving antennas R_n, and the diver's depth z_d measured by the depth meter can be received.

B. Pseudo-Scale Model [2]

Fig. 2 shows our experimental system of a pseudo-scale model with a scale factor of $n = 200$ for a 10 kHz underwater position estimation model. In the pseudo-scale model, the frequency is 400 MHz, the water tank is filled with salt water, and two sheathed dipole antennas with a length of 10 mm are used as the transmitting and receiving antennas. They are arranged parallel to the x-axis and faced each other in the salt water. The measured conductivity of the salt water was $\sigma = 3.91$ S/m. The scanning range of the transmitting antenna is set to $|x| \leq 100$ mm, $0 \text{ mm} \leq y \leq 200$ mm, $5 \text{ mm} \leq z \leq 50$ mm. In addition, the receiving antenna is moved to 9 positions at 100 mm intervals in the x and y directions. By changing the positions of the transmitting and receiving antennas as described above, the receiving power profile $p_n(x, y, z)$ that relates the position of the transmitting antenna and the received power at specified 9 positions can be obtained.

III. UNDERWATER POSITION ESTIMATION METHOD AND ITS EVALUATION

A. Procedure of Underwater Position Estimation

Fig. 3 shows an outline of the position estimation method. It is assumed that the diver's depth z_d is known. The three receiving antennas are described as $R_m^{(s)}$ $(m = 1, 2, 3)$ in descending order of the received power T_n at the receiving antenna R_n. Then, the received power measured by the receiving antenna $R_m^{(s)}$ is expressed as $T_m^{(s)}$.

In our position estimation algorithm, z_d, $R_m^{(s)}$, and $T_m^{(s)}$ are used to find the area where the diver exists. Since the received power profile $p_n(x, y, z_d)$ provided in advance represents the relationship between the position of the diver and the received powers, the position of the diver can be estimated by calculating back from the received powers. If we set the received power margin to $\Delta T = 1$ dB, and the area

L_m included in the received power range $B(T_m^{(s)}, \Delta T) = [T_m^{(s)} - \Delta T, T_m^{(s)} + \Delta T]$ of the received antenna $R_m^{(s)}$ can be extracted from the received power profile p_n. Since the diver at the position (x_d, y_d, z_d) is included in the three regions L_m, it can be estimated that the diver exists in the overlapping area $L = L_1 \cap L_2 \cap L_3$.

B. Discrete Mesh Settings

The target for diver's position estimation is within an error of 2 m and the pseudo-scale model with $n = 200$ corresponds to an error within 10 mm. In our position estimation, the plane in the sea determined by the depth of the transmitting antenna is divided into square meshes of 10 mm each, and the mesh where the diver exists can be specified by our proposed algorithm.

C. Evaluation of Proposed Underwater Position Estimation

The position estimation can be evaluated based on the received power profile. Using this profile, we can calculate the values of the received power T_n for the nine receiving antennas against the position $I(x, y, z)$ of the transmitting antenna, and determine the estimated area L for the diver's position I according to the procedure as described before. Then, the estimated area can be visualized as a set of meshes, and the number of meshes constituting the estimated area L is defined as $C(L)$. We should notice that $C(L)$ is preferably 1 but can be 2 or more. In this paper, our position estimation is evaluated by the value of $C(L)$.

The proposed position estimation method was evaluated by the above evaluation method. $C(L)$ is limited to 1 in 94.8 % of all diver's positions Is tested. The number of diver's positions Is where $C(L) = 2, 3, 4$ is 5.2 % of the total positions Is tested.

For $C(L) = 2, 3, 4$, there are 87 diver's positions where non-adjacent meshes are estimated. This is because the distribution of the received power is not always isotropic or is disturbed. Of these, there are 46 diver's positions Is that estimate non-adjacent meshes belonging to the range of $-20\text{ mm} \le x \le 20\text{ mm}$ and $100\text{ mm} \le y \le 140\text{ mm}$. That is, if there is the diver in this range, multiple meshes will be estimated.

IV. CONCLUSION

In this paper, we investigated a method for estimating the position of divers in the sea using discrete received power profiles obtained in advance by an experimental system for pseudo-scale models. The area where the diver exists was limited by superimposing the areas for the maximum three received powers, assuming that the received power had a margin of 1 dB. It was clarified that the estimated position can be limited to one mesh at a rate of 95 % or more of all diver positions. In the future, we will add the fourth received power for more accurate position estimate and consider how to select the received power margin.

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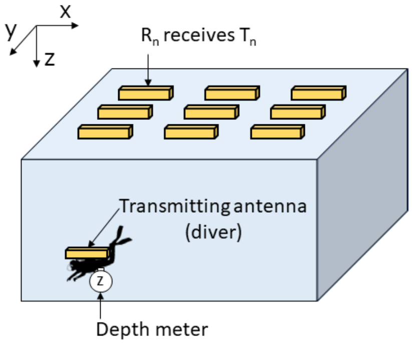

Fig. 1. Underwater Position Estimation Model.

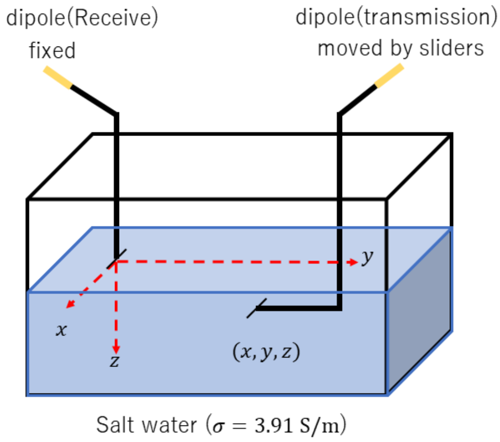

Fig. 2. An experimental setup for the pseudo scale model.

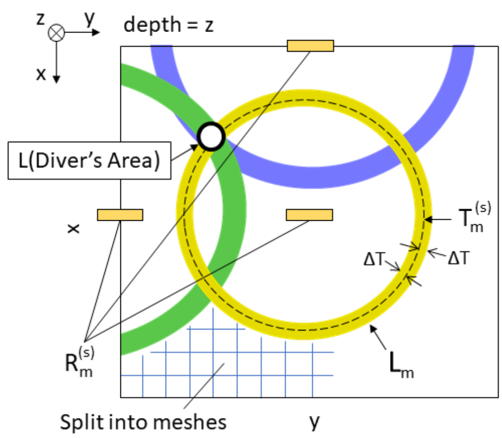

Fig. 3. Overview of the position estimation method.