Undersea Positioning Using Electromagnetic Wave in Consideration of Sea Wave Effects

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***Abstract*—In this study, assuming we specify the positions of the divers rescuing in the accidents and support their works, we investigate undersea positioning technology using the electromagnetic waves with low frequency (10 kHz). In this paper, assuming we employ our positioning system in the factual situation, we investigated the effect of sea waves to our positioning system. Also, we show the result of positioning estimation in case of taking the measure to the sea waves.**

***Keywords*—Antennas, Propagation in the sea, position estimation, electromagnetic wave, RSS, lateral wave**

I. Introduction

In recent years, various ways to utilize the sea environment have been investigated. From this current, developing technologies to support generating new marine industries have also been proceeding. Here, we consider developing technologies with undersea electromagnetic waves. Nowadays, there are many accidents in water all over the world. According to [1], the number of accidents in water in Japan is high and the number of dead and missing people is also high. Accidents in the water are caused by the natural disaster and the sinking incidents of ships. Therefore, the countermeasures to them for all ages are required. And then, rescue operations of divers are expected. However, the views of divers in the sea are sometimes bad, and there are various obstacles floating in the sea. The consideration of safety for divers is required. If divers know their own current positions while rescuing, they will save people much safer. Hence, the establishment of the undersea positioning system via wireless technologies is desirable.

Since divers are moving consequently during their works, the positioning system is required for being a real-time one. Considering the environment with various factors, it is essential that the amount of calculation is little. In this study, we investigate the underwater positioning system employing the electric waves of kHz bands the divers can easily utilize in the sea accidents. The enlargement of the system using electric waves in the sea is expected to follow this study.

Fig. 1 show the overviews of the simulation model of the system positioning an antenna in the sea. We assume that a diver has a transmitting antenna (Tx), and receiving antennas (Rx) are installed on the sea surface or in the air. We collect the data of electric waves from a transmitting antenna, specifying its position in the sea.

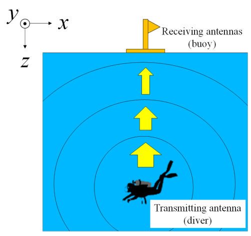


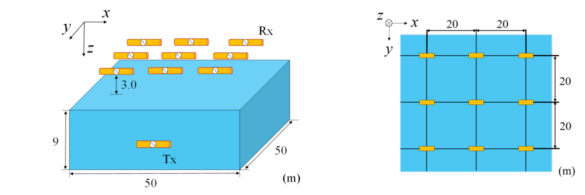
Fig. 1: The image of undersea position estimation.

In the preceding study, we developed the algorithm for undersea positioning system and conducted the simulation of the position estimation with this algorithm [2]. In [2], the effect on our proposed system of the undersea postion estimation from waves on the sea surface was of concern. Therefore, we investigated the effect of sea waves.

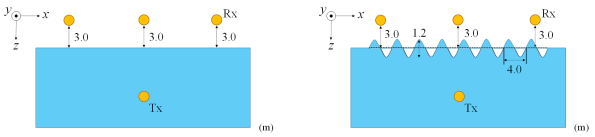
II. Model for Analysis

The simulation model is shown in Fig. 2. For the position estimation in the sea, we assumed the ideal environment which is shallow. The model has a free space with a height of 6 m and a seawater with depth at 9 m (ε_r = 80, σ = 4 S/m). The antennas utilized in this simulation are all dipole ones. The length of Rx is 2 m, and that of a Tx is 0.7 m. Nine Rxs are installed at heights of 3 m from the sea surface. A Tx is deployed in the seawater. Furthermore, assuming that divers can conduct their activities based on the orders from the firefighting headquarter, we set the amplitude and the wavelength of sea waves as 1.2 m and 4 m, respectively.

In addition, we employ 10 kHz waves for the positioning simulation. According to [3], 10kHz waves attenuate 3.5



(a) Overview



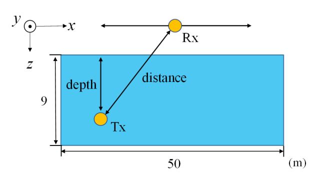
(b) side views without sea waves and with sea waves

Fig. 2: Sea model for the undersea positioning simulation.

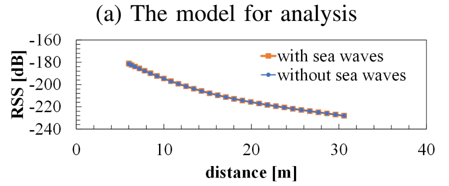
dB/m theoretically, which can be transmitted over 30 m. That is why we utilized the frequency. We employed the Finite-Difference Time-Domain (FDTD) method in this simulation. Furthermore, we conducted the simulation on the assumption that we have already known the depth of the Tx via hydro barometers in advance.

III. The Measure for Waves on the Sea Surface

In Fig. 3, we show the model for analyzing the relation between RSS and the antenna distances numerically, as well as the result of the analysis.



(a) The model for analysis



(b) The result of analysis

Fig. 3: The relation between RSS and the antenna distances.

RSS is a logarithm of the ratio of input and received power.

$$\mathrm{RSS~(dB)} = 10\log_{10}\frac{\mathrm{Received~power~(W)}}{\mathrm{Input~power~(W)}} \tag{1}$$

In Fig. 3(b), there is almost no difference in the tendency of attenuation between sea waves and without sea waves. We guess that this is because of the effect of the large difference in electic conductivities between seawater and the air. Fig. 4 shows the distribution of electric field strength from Tx under the model in Fig. 3(a). From Fig. 4, we assume that the 10 kHz wave permeates only the point on the sea surface just above the Tx, and expands on the sea surface. Therefore, it is effective to install Rxs in the air away from the sea surface for the measure of sea waves.

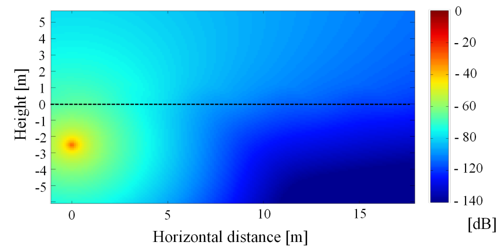


Fig. 4: the distribution of electric field strength.

IV. The Undersea Antenna Positioning Simulation

We conducted the simulation of estimating the position of a Tx which exists at the depth 2 - 8 m in the sea with sea waves. We evaluated the estimation accuracy based on the distance d between the factual position and the estimated one. Assuming the real-time estimation of the diver's position in the sea, we see the maximum 2.0 m as the allowable error, considering the reach of the arms and legs of an adult male. We show the simulation result at the depth of 3 m in Fig. 7.

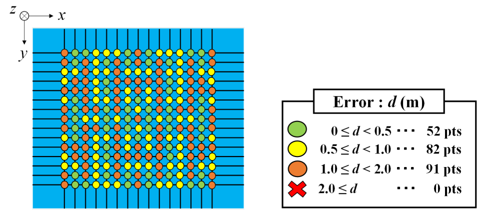


Fig. 5: the result of postition estimation at depth 3 m.

We achieved the target error within 2.0 m at all the 225 points. The rate of 60 % is within the error of 1.0 m.

V. Conclusion

In this paper, we investigate the effect on our positioning system from sea waves. As a result, there is almost no effect from sea waves, and we achieved all the errors within 2.0 m at all 225 points in the case Rx is floating in the air.

As a subject in the future, we need to search the effect of external factors, such as environmental noises, thermal noises. Also, The effect on the radiated power from a wearable transmitter in the presence of the human body on our system is one of the next important issues to investigate.

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