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Basic Study on Long Range Acoustic Positioning for Cruising AUV

巡航型探査機の長距離音響測位に関する基礎的検討

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1. Introduction

Autonomous underwater vehicle (AUV) is being expected to become more efficient and more precisive for the recent human problems such as environment or resources problem. In research and development of the futer AUV, the one of the direction of the improvement is long time and long range cruising in observations. In this type of observations, the AUV is desired to perform without support of the mother ship for efficiency of the observation. In any observations, the AUV needs to navigate itself. Currently, the absolute position of AUV is obtained by the grobal positioning system (GPS) or acoustic positioning system (APS). The AUV must come up to the surface to obtain GPS, but it is not efficient and risky. Then we want to use some APSs, which can be used at long range for handreds or even thouthands km order.

There are two simple approches for the long range APS. The depth of the AUV can be obtained the depth sensor equipped on the AUV. Thus the horizontal position of the AUV is desired to be obtained by the APS. **Fig. 1** shows the general concepts of these two approaches. The one is based on the range estimation between the two reference points and the AUV. And the other is based on the bearing estimation of the same two reference points from the AUV. The former needs the synchronous between the reference points and the AUV. In this paper, some considerations of these approach are provided. Especially about the latter, an experimental result of estimation of bearing at 20km range is shown.

2. Typical method based on the range estimation

The most typical approach for the positioning is based on the ranging from multiple reference points not lower than two points, as shown in Fig. 1, (a). In this approach, the synchronous between the reference points and the AUV is needed. As well known, the sound speed in the sea varies depending on the depth, and its construction is layered horizontally. Then, the acoustic propagation is refracted. The refraction is distinguished at the long horizontal range, as shown in **Fig. 2**. Fig. 2 was simulated by the ray-path calculation up to 200km horizontally. The sound speed profile was Munk's model. The sound fixing and ranging (SOFAR) axis was set at 1,000 meters depth, and the sound source was also set at same depth. The propagation paths are not straight at all. If the horizontal range R_h is calculated by the equation,

$$R_h = \tau c_0 \qquad (1)$$

the error depending on the AUV depth becomes as Fig. 3. τ is propagation time, and c_0 is sound speed at the SOFAR axis. According to Fig. 3, the horizontal range is estimated within 0.5% error. However, the error is systematic and cannot be reduced by averaging.

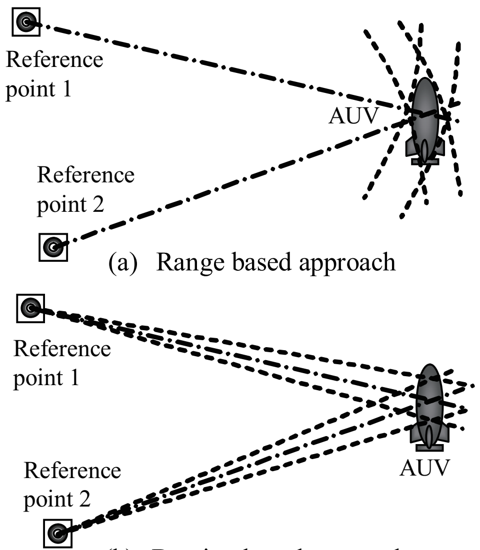

Fig. 1 Two approaches for long range positioning.

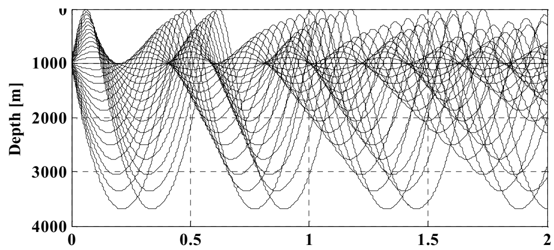

Fig. 2 Propagation paths of acoustics up to 200 km.

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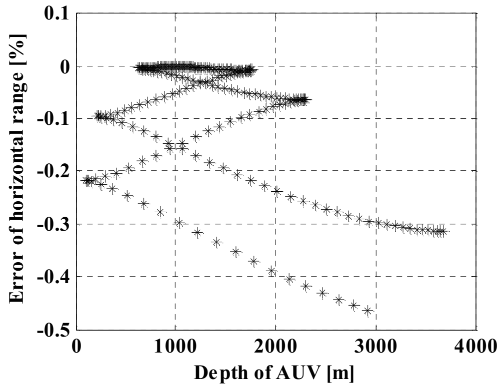


Fig. 3 Error of horizontal range depending on the AUV (receiving acoustic signal) depth.

3. Method based on the bearing estimation

This approach does not need the synchronous. We can adopt this approach by equipping receiver array on the body of AUV. As shown in Fig. 3, multiple waves are received at one same depth, and these waves income from different directions. However, the horizontal components of these directions, bearing, must be same, because the sound speed profile is layered horizontally. An experiment was performed in Suruga Bay. **Fig. 4** shows the general configuration. Acoustic signal was transmitted from the transmitter and received by the receiver array. The array was consist of 8 elements, and was vertical planer array as shown in **Fig. 5**. The size was H0.7m x W4.9m, horizontally long. The mooring configurations are shown in Table 1. The range was about 20 km. **Fig. 6**, the upper shows a received signal. This signal was 8-th order M-sequence signal, the carrier was 1 kHz and the chip rate was 200 Hz. Fig. 6, the lower shows the cross-correlation of the received signal and M-seq. signal. It can be found that several waves are overwrapped. **Fig. 7** shows the output of a simplest delay-sum beam-former. According to Fig. 7, the vertical direction is not obviously, but we can decide the horizontal direction, namely it is the bearing of the transmitting source.

4. Summary

Some considerations about two approaches, which are based on horizontal range or bearing estimation, for long range APS of AUV were mentioned. In near future, we will progress the research especially about bearing based approach. First of all, there are two topics. The one is about super resolution method for estimation the bearing such as multiple signal classification (MUSIC) method. And the other is about the refraction of acoustics horizontally. This is significant problem for the bearing based approach.

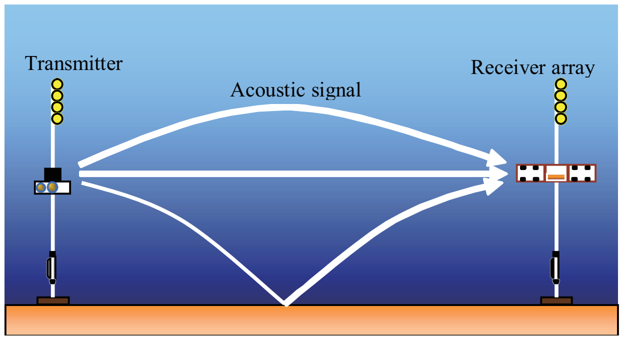


Fig. 4 General configuration of the experiment.

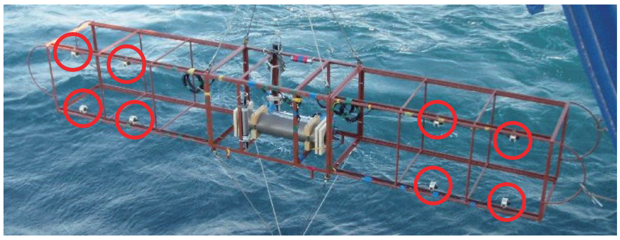


Fig. 5 Picture of the receiver array in the experiment.

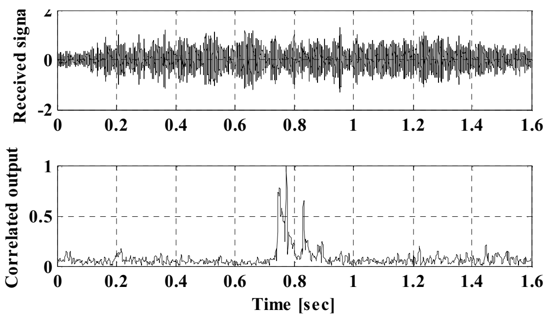
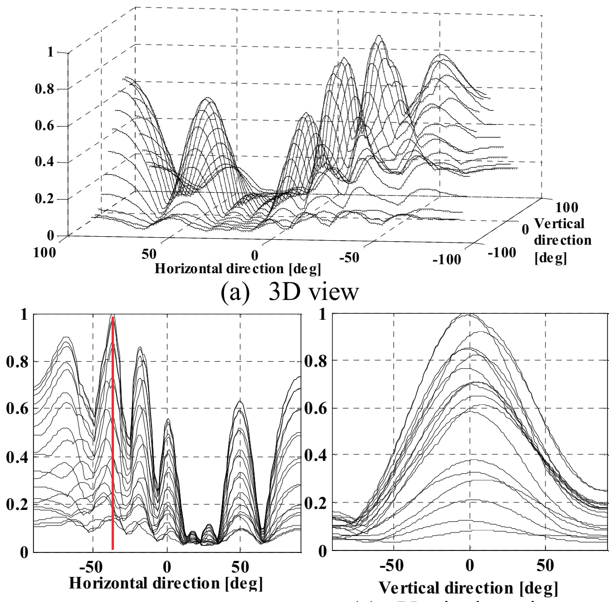


Fig. 6 Received signal and correlated output.



(a) 3D view

(b) Horizontal section (c) Vertical section

Fig. 7 Output of simplest delay-sum beam-former.

Acknowledgment

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