Proceedings of Symposium on Ultrasonic Electronics, Vol. 32 (2011) pp. 165-166
8-10 November, 2011

The Multipath Effect on Target Location Estimation

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1. Introduction

A HLA(Horizontal Line Array) sonar is basically passive, in which acoustic sensors are linearly arranged in order to estimate the bearing of the target. Plane wave beamforming is a technique of converting the difference in phase between the sensors into a bearing of a target on the assumption that a transmission path of a sound wave is a straight line on horizontal plane. [1] The range to the target is estimated through a TMA(Target Motion Analysis) technique by accumulating deteced bearings. [2] Thus, a plane wave condition is included in the range estimation results of the target. The plane wave condition is that a signal of the target reacheds along a linear path on the horizontal plane having the same angle to every sensor of the HLA sonar. However, a sound wave is propagated along a reflection and refraction path, rather than along a horizontally linear path, due to the influence of the underwater sound velocity structure. [3] As shown in **Fig.1** acoustic signal radiated from the target reaches sonar through various paths.

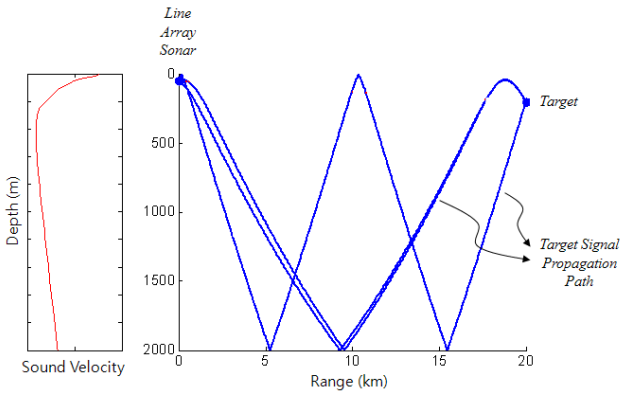

Fig. 1 Transmission paths of the target signal.

Several transmission paths of the target signal exist and each has a different angle of arrival. The path according to refrection and refraction causes an error in the target bearing estimation results using plane wave beamforming. The target bearing estimation results are inevitably different from the actural bearing.

2. Simulation

As shown in **Fig. 2**, when the acoustic sensors of the HLA are on the y axis and the target is in a ϕ bearing at the center of the array, the bearing of the target detected from beamforming output is a θ bearing by the angle of arrival μ of the target signal.

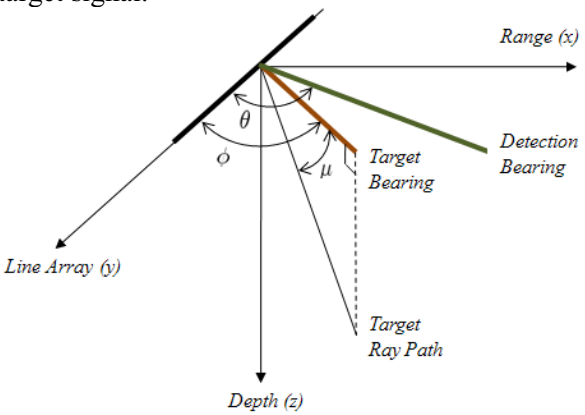

Fig. 2 Relationship between the actual target bearing and detected bearing.

A relationship between the actual target bearing(ϕ) and detected detection bearing (θ) is represented by a cosine function as expressed by eq. 1 shown below

$$\theta = cos^{-1}[cos(\phi)cos(\mu)] \qquad (1)$$

In the underwater, the angle of arrival(μ) is generally greater or smaller than 0, so as shown in eq.1, the detection bearing(θ) of the target detected by the HLA is mostly greater than the actual target bearing(ϕ).

3. Analysis

To analyze the multipath propagation effects on the target location estimation, the conversion mechanism of the multipath into the bearing is simulated. The target bearing error is estimated using the model based simulation on the ray theory with typical sound speed profiles in summer and winter seasons. The numerical raytracing followed by eigenray searches and estimations of ray amplitudes, phases and travel times, the arrival structure as a function of time and elevation angle was constructed. A transmission path having the strongest sound pressure was extracted. And calculate a bearing error according to the angle of arrival searched in the searching step. The erroneous bearing is observed from the

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beamforming outputs simulated with the modeled multipath. **Fig. 3** and **Fig. 4** show passive bearing error simulation in winter and summer seasons.

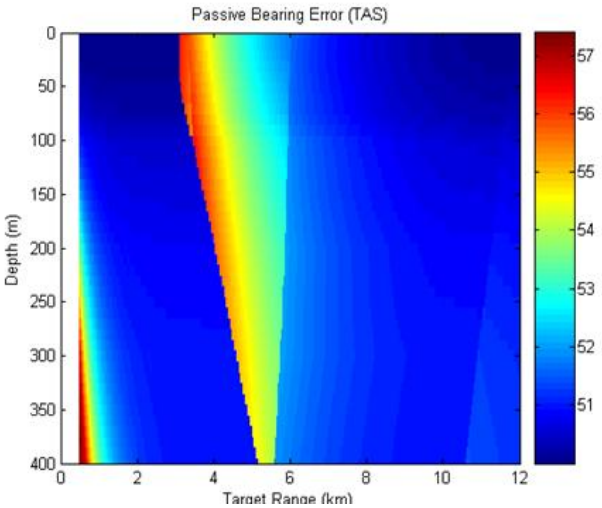

Fig. 3 Passive bearing error simulation (simulated using typical sound velocity profile in winter)

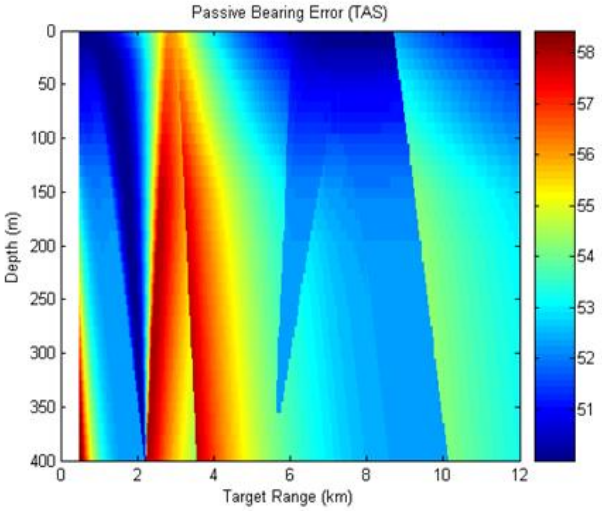

Fig. 4 Passive bearing error simulation (simulated using typical sound velocity profile in summer)

In case of the summer season, the multipath propagation with a high receiving angle occurs due to strong inverse slope of the sound speed profiles, the estimated target location can be different from the real target bearing and range.

4. Conclusion

A multipath effect on target location estimation is examined. The multipath transmission phenomenon according to refraction and refraction of a sound wave causes target bearing of the HLA and it changes with sound velocity profile.

References

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3. H. Medwin and C. S. Clay: *Fundamentals of Acoustical Oceanography* (Academic Press, 1998) p. 92.