

An underwater acoustic beacons positioning method using single hydrophone

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Abstract. When an aircraft crashed the sound emitted by the beacon would help to detection and location the black box. While in the deep sea research, it is hardly to use the USBL, SBL and LBL as usual. In this paper a new method was introduced. In this method, the beacon could be located with only one hydrophone. The time difference of the hydrophone at different place was used to located the beacon. To verify the performance of this method, the simulation was processed. The results show that this method is effectively.

1. Introduction

When an aircraft crashed the sound emitted by the beacon (pinger) would help to detection and location the black box for prompt recovery and analysis. Because the Operating Life of the Beacons is limited, it is very important to search and location the beacon as quickly as we can [1, 2].

It is well known that the traditional technique for localization acoustic beacons is Long Baseline, Short Baseline and Ultra Short Baseline. USBL uses phase differencing measurements between closely spaced (< 1 m) hydrophones to estimate the direction and elevation angle of an incoming signal. These are combined with travel time measurements to estimate range for pinger positioning. SBL is based on a similar concept, except that the hydrophones are more widely spaced (5 - 20 m) and instead of phase differencing, time difference of arrival is used. Both USBL and SBL systems are commonly mounted on vessel hulls, but can also be moored on the bottom or mounted in buoys at the surface. LBL systems measure travel-times between an array of transponders and a moving pinger. With multiple travel time, or range measurements, a least squares algorithm can be used to estimate the position of the pinger using either a hyperbolic or spherical solution. However sometimes only have one hydrophone especially in a deep ocean search. The attitude of the hydrophone array can't be obtained easily in a deep ocean search. Therefore, the common methods were hard to be used at this time [3-6].

In this paper, we will propose a method to locate the acoustic beacon with only single hydrophone. This paper is organized as follows: In the section 2, we introduce the location method. In section 3, we present solution of the method.

2. Basic Principle

The acoustic beacon is at $M(x, y)$. The receive is a single hydrophone, which goes along $A_1 A_2 A_3$. Each position and time of $A_1 A_2 A_3$ are known.



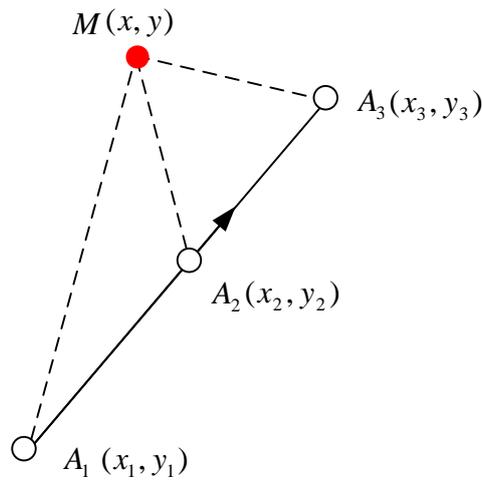


Figure 1. The location model of the method

The pulse length of the beacon is 10ms. The pulse repetition period is 1s.

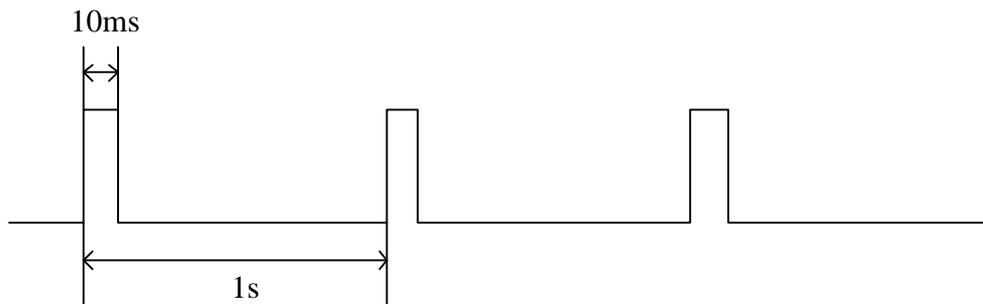


Figure 2. The signal of the acoustic beacon

The receive hydrophone spends t_s to go from A_1 to A_2 . In this time the receiver has received n pluses, which is timed t_n . And, there is a time difference $\Delta t = t_s - t_n$. So, the difference of distance between MA_1 and MA_2 is

$$\Delta t_{12}(c) = \sqrt{(x_1 - x)^2 + (y_1 - y)^2} - \sqrt{(x_2 - x)^2 + (y_2 - y)^2} \quad (1)$$

And The difference of distance between MA_1 and MA_3 is

$$\Delta t_{13}c = \sqrt{(x_1 - x)^2 + (y_1 - y)^2} - \sqrt{(x_3 - x)^2 + (y_3 - y)^2} \quad (2)$$

Solved the equation, then the position of M can be obtained.

3. The Solution

Set the A_1 to be the original point. Where, $x_1 = 0, y_1 = 0$, then (1) can be write as

$$x_2^2 + y_2^2 - 2x_2x - 2y_2y = \Delta t_1^2 c^2 + 2\Delta t_1 c \sqrt{x^2 + y^2} \quad (3)$$

Where, $r_2 = \Delta t_{12}c$, so we can get

$$\frac{x_2^2 + y_2^2 - r_2^2}{2r_2} - \frac{x_2x}{r_2} - \frac{y_2y}{r_2} = \sqrt{x^2 + y^2} \quad (4)$$

Where, $F_{2r} = \frac{x_2^2 + y_2^2 - r_2^2}{2r_2}$, so we can get

$$F_{2r} - \frac{x_2x}{r_2} - \frac{y_2y}{r_2} = \sqrt{x^2 + y^2} \quad (5)$$

As the same one, we can get

$$F_{3r} - \frac{x_3x}{r_3} - \frac{y_3y}{r_3} = \sqrt{x^2 + y^2} \quad (6)$$

$$F_{4r} - \frac{x_4x}{r_4} - \frac{y_4y}{r_4} = \sqrt{x^2 + y^2} \quad (7)$$

Then the equation can be re-write as

$$A_1x + B_1y + D_1 = 0 \quad (8)$$

$$A_2x + B_2y + D_2 = 0 \quad (9)$$

Where,

$$A_1 = \left(\frac{x_2}{r_2} - \frac{x_3}{r_3}\right) \quad A_2 = \left(\frac{x_2}{r_2} - \frac{x_4}{r_4}\right)$$

$$B_1 = \left(\frac{y_2}{r_2} - \frac{y_3}{r_3}\right) \quad B_2 = \left(\frac{y_2}{r_2} - \frac{y_4}{r_4}\right)$$

$$D_1 = F_{3r} - F_{2r} \quad D_2 = F_{4r} - F_{2r}$$

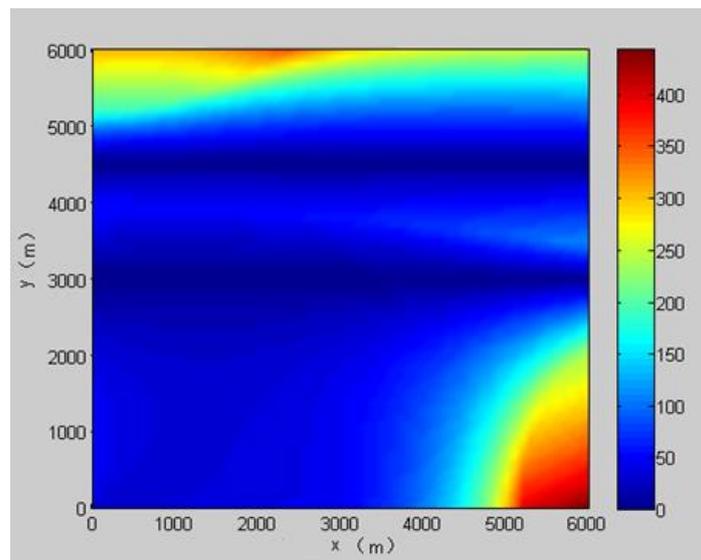
The equation of (1) and (2) can be solved, as

$$x = \frac{B_1D_2 - B_2D_1}{A_1B_2 - A_2B_1} \quad (10)$$

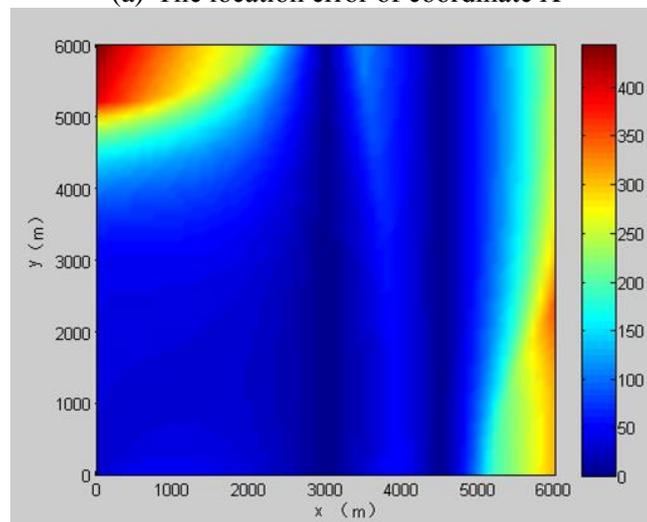
$$y = \frac{B_1D_2 - B_2D_1}{A_1B_2 - A_2B_1} \quad (11)$$

4. Simulation Results

To verify the performance of this method, the simulation has been processed. In the simulation, the time error is less than 0.1s, and the location error of the hydrophone is less than 0.1m. The simulation results (the location errors of the beacon) are shown in Fig.3. The error of locating is less than 500m in 6km.



(a) The location error of coordinate X



(b) The location error of coordinate Y

Figure 3. The location error of this method

5. Summary

In this paper, we tackle the problem of localization the underwater acoustic locating beacons of the “black box”. In the deep-sea research, it is hardly to use the USBL, SBL and LBL. So a new method is introduced. In this method, the beacon was located with only one hydrophone, by the time difference of the hydrophone at different place. To verify the performance of this method, the simulation has been processed. The error of locating is less than 500m in 6km in the simulation. The results show this method is effectively.

6. Acknowledgment

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7. References

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