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Effect on Passive Localization from the Shape Distortion of Triplet Linear Array Based on Piezoelectric Transducers

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Abstract: The triplet linear array is consisted of three piezoelectric transducers located in line. Passive directing and ranging with triplet linear array is a very useful method for target detecting. In this paper, we presented the principle of passive localization with triplet linear array and the formula for calculating target's location. The theoretical analysis of various error sources that influenced the positioning accuracy when the triplet linear array had shape distortion was described. At last, the effect of shape distortion on passive localization was summarized by simulation experiments. *Copyright © 2012 IFSA.*

Keywords: Piezoelectric transducer, Triplet linear array, Passive localization, Shape distortion.

1. Introduction

The study of passive localization with triplet linear array had been developed from 1960s [1, 2]. The triplet linear array was consisted of three piezoelectric transducers that can accomplish sound-electricity conversion. The general principle of this technology is to estimate the target's position using time delay between sound signals emanated from a remote source and received by three transducers located in line [3].

Now, the triplet linear array used for passive localization is mainly fixed on two place – broadside and line array [4]. The array fixed on broadside can avoid impairing the ship's maneuverability, but the array's size is always restricted by the ship's bulk, as a result of this, the target's detecting range is finite. Otherwise, the size of triplet linear array fixed on line array can break through detecting range's restriction.

But because the line array is flexible, the shape distortion of triplet linear array is inevitable due to the course and speed change induced by ship maneuvering, the unpredictable underwater turbulence, wind and other factors. The shape distortion always brings on positioning error.

In this paper, the principle of passive localization with triplet linear array is presented. The error of passive localization resulted from triplet linear array's shape distortion is discussed, and we also have some simulation experiments for the effect of shape distortion on target's localization.

2. Principle of Passive Localization with Triplet Linear Array

The general principle of passive localization with triplet linear array is to calculating the target's azimuth and distance using time delay between sound signals received by three piezoelectric transducers that compose the triplet linear array.

The geometry model of the triplet linear array is shown in Fig.1.

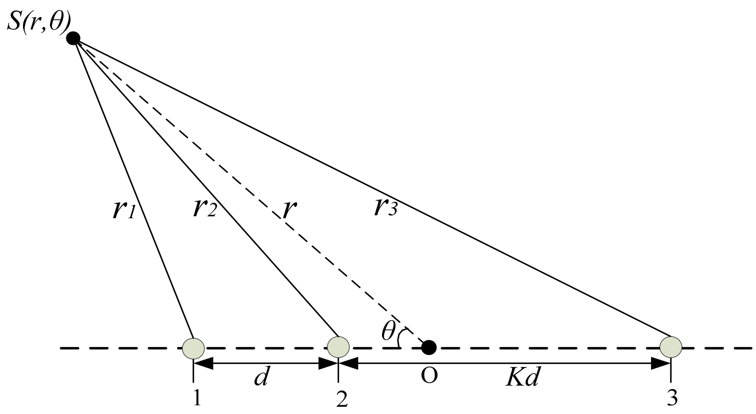


Fig. 1. Geometry model of the triplet linear array.

In Fig. 1, *S* is the sound signal source, and in the polar coordinates, the coordinates of signal source is $S(r,\theta)$. The three transducers are respectively represented as *1*, *2* and *3*, and they are aligned with each other. The ratio of space between *1* and *2* to space between *2* and *3* is *K*. The triplet linear array is named as symmetrical array if *K=1*, and the rest is named as asymmetrical array.

The symmetrical array and the asymmetrical array both have the same principle of passive localization. However, their range detecting accuracy is different, e.g., for two arrays – a symmetrical array and a asymmetrical array with *K=2*, when the time delay errors are equal, the range detecting error of asymmetrical array is as 1.186 times as that of symmetrical array. Otherwise, when the array's size measuring errors are equal, the multiple is 1.125 [5]. We only discuss the symmetrical array in this paper.

For the symmetrical array with *K=1*, the distances between target and three transducers are respectively as follows

$$
\begin{aligned}
r_1 &= \sqrt{r^2 + d^2 + 2rd\cos\theta} \\
r_2 &= r \\
r_3 &= \sqrt{r^2 + d^2 - 2rd\cos\theta}
\end{aligned}
\tag{1}
$$

The three time delays between sound signals respectively received by three piezoelectric transducers are as follows in the case of the velocity of sound is *C*.

$$
\begin{aligned}
\tau_{12} &= \tau_1 - \tau_2 = \frac{1}{C}(r_1 - r) \\
\tau_{23} &= \tau_2 - \tau_3 = \frac{1}{C}(r - r_3) \\
\tau_{13} &= \tau_{12} + \tau_{23}
\end{aligned}
\tag{2}
$$

where, τ_{12} is the time delay between transducer *1* and transducer *2* and τ_{23} is the time delay between transducer *2* and transducer *3*, and τ_{13} is the sum of τ_{12} and τ_{23}.

According to (1) and (2), the formulas of calculating target's azimuth θ and distance r are

$$\theta = \cos^{-1}\frac{Cd^2\tau_{13} - C^3\tau_{12}\tau_{23}\tau_{13}}{2d^3 - C^2 d(\tau_{12}^2 + \tau_{23}^2)} \tag{3}$$

$$r = \frac{2d^2 - C^2(\tau_{12}^2 + \tau_{23}^2)}{2C(\tau_{12} - \tau_{23})} \tag{4}$$

Especially, if the target is at remote field, the sound waves received by transducers can be approximated to plan waves, so, the target's azimuth and distance can be estimated as follows from Taylor expansion.

$$\theta = \cos^{-1}\frac{C\tau_{13}}{2d} \tag{5}$$

$$r = \frac{d^2\sin^2\theta}{C(\tau_{12} - \tau_{23})} \tag{6}$$

3. Effect on Passive Localization from Triplet Linear Array's Shape Distortion

3.1. Error Sources Caused by Shape Distortion

As we know, when the triplet linear array is fixed on line array, its shape distortion is inevitable because of ship maneuvering, underwater turbulence and other factors, and the shape distortion will bring on offset between actual time delay τ and its theoretical value. Besides, because the three transducers are no longer aligned, the array is not symmetrical yet, and the space between two adjacent transducers is not *d*.

Because the underwater array's distortion is more complicated than we would imagine, it is very difficult to obtain its exact shape, we can sill estimate the target's azimuth and distance by eq. (3) and eq. (4). However, in order to know the conditions for application of these two equations, we do need to discuss the estimating error caused by adopting eq. (3) and eq. (4).

If we estimate the target's azimuth and distance by eq. (3) and eq. (4) without considering the array's shape, the triplet linear array is still regarded as a symmetrical array, and the space between two adjacent transducers is *d*. Actually, we bring in three time delay offsets $\Delta\tau_{12}$, $\Delta\tau_{23}$ and $\Delta\tau_{13}$ in case of adopting eq. (3) and eq. (4).

So we have,

$$\begin{cases} \theta = \cos^{-1} \dfrac{cd^2(\tau_{13}+\Delta\tau_{13}) - c^3(\tau_{12}+\Delta\tau_{12})(\tau_{23}+\Delta\tau_{23})(\tau_{13}+\Delta\tau_{13})}{2d^3 - c^2 d((\tau_{12}+\Delta\tau_{12})^2 + (\tau_{23}+\Delta\tau_{23})^2)} \\ r = \dfrac{2d^2 - c^2((\tau_{12}+\Delta\tau_{12})^2 + (\tau_{23}+\Delta\tau_{23})^2)}{2c((\tau_{12}+\Delta\tau_{12}) - (\tau_{23}+\Delta\tau_{23}))} \end{cases} \quad (7)$$

3.2. Simulation

We adopt the model shown in Fig. 2 to simulate the triplet linear array's shape distortion. The array is symmetrical, and the distance of target is 12 m. The target is set above the array, i.e., the range of target's azimuth θ is from 0^o to 180^o.

According to (7), in case of shape distortion, the positioning precision is directly related to the space between two adjacent transducers *d* and the time delay error $\Delta\tau$. So, in this paper, we mainly describe the effect on passive localization from *d* and $\Delta\tau$.

We set the range of time delay error, and choose 10000 random values within the range. Then, the target's azimuth and distance are calculated with these random time delay errors respectively. At last, we take the average value as final result.

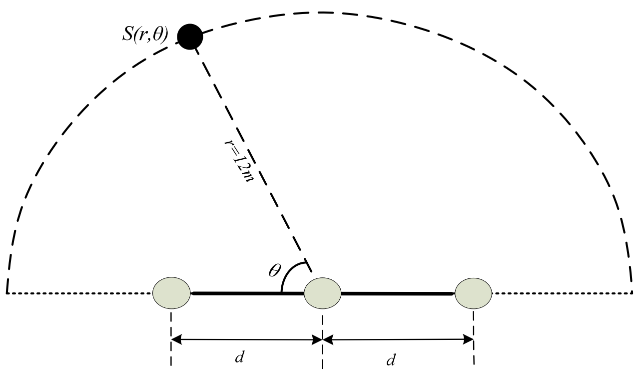


Fig. 2. Simulation model.

Firstly, we have a simulation result as shown in Table 1. The space between two adjacent transducers is 6m, and the range of time delay error is ±1 ms. From the simulation results, we can see that when the range of $\Delta\tau$ is ±1 ms, eq. (3) and eq. (4) only can be adopted to estimate the target's localization when the range of target's azimuth is from 60^o to 120^o. So, in case of shape distortion, the triplet linear array with d = 6 m will not meet the requirement of target detecting.

Table 1. Simulation results (d = 6 m, $\Delta\tau$ = ±1 ms).

	Position		Simulation results			
	$r(m)$	θ(°)	$r(m)$	error (%)	θ(°)	error (°)
1	12	2.8288	-11.3451	194.5429	25.4111+13.3133i	26.2146
2	12	14.1907	-53.3543	544.6192	22.1649+16.1273i	17.9910
3	12	21.9040	3.5105	70.7457	19.0221+15.4846i	15.7505
4	12	35.3741	21.8547	82.1226	27.5968+6.1224i	9.8980
5	12	43.9288	29.4076	145.0634	38.6821+1.0667i	5.3540
6	12	55.1835	24.0299	100.2491	53.0073+0.0069i	2.1762
7	***12***	***68.1297***	***10.2402***	***14.6652***	***67.3000***	***0.8297***
8	***12***	***78.1010***	***12.0283***	***0.2359***	***77.7503***	***0.3507***
9	***12***	***81.1236***	***10.8030***	***9.9749***	***80.9106***	***0.2130***
10	***12***	***90.3819***	***10.1252***	***15.6232***	***90.3563***	***0.0256***
11	***12***	***107.9055***	***13.7827***	***14.8558***	***108.5387***	***0.6333***
12	***12***	***117.3683***	***11.8697***	***1.0859***	***118.7100***	***1.3417***
13	12	122.4211	18.5487	54.5724	124.0827	1.6616
14	12	132.6064	-144.6337	1305.3	136.60-0.3923i	4.0157
15	12	142.1084	-15.1566	226.3050	149.82-4.1878i	8.7770
16	12	157.9624	-19.4586	262.1549	160.36-14.831i	15.0238
17	12	165.6431	-1.1285	109.4045	157.88-16.227i	17.9886
18	12	172.6708	-12.1496	201.2468	154.82-13.607i	22.4488

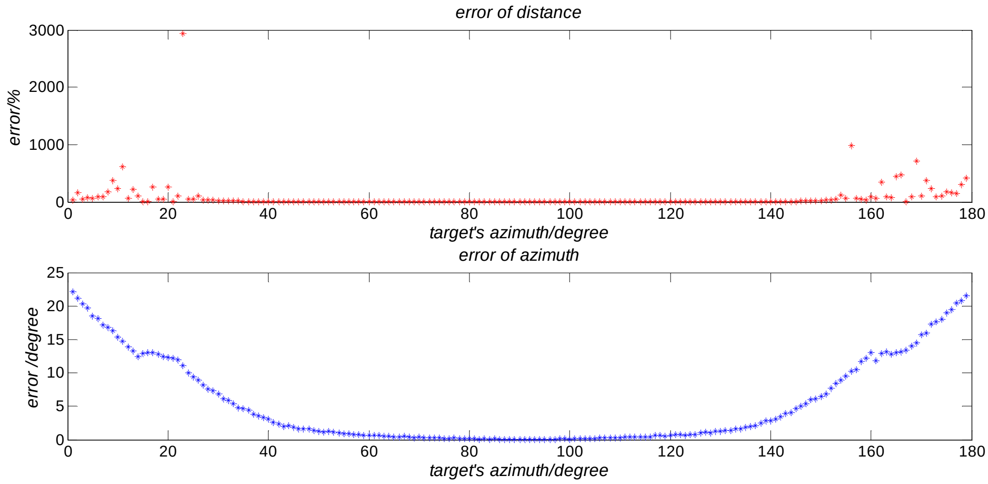
Fig. 3 illustrates the simulation results of an array with d = 10 m. For the array, when the range of time delay error $\Delta\tau$ is ±1 ms, eq. (3) and eq. (4) basically can be adopted for position estimating when the range of target's azimuth is from 35^o to 145^o.

The above simulation shows that the space between two adjacent transducers d has very close relationship with localization error caused by shape distortion. The larger the value of d is, the less impact shape distortion has on localization precision. In practice, in order to improve localization precision, we should make the size of array as larger as circumstances will permit.

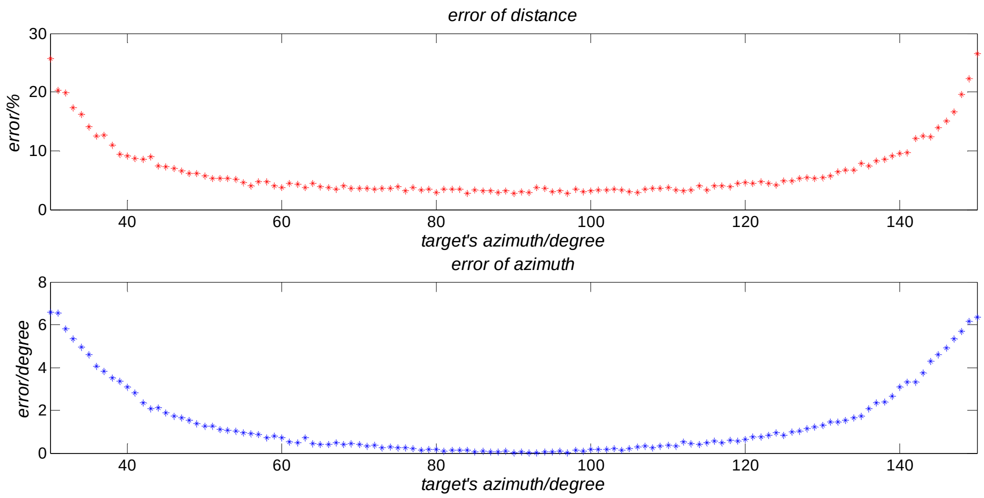
Fig. 5 and Fig. 6 show the effect on localization precision from time delay error in case of shape distortion. The larger the time delay error is, the lower the localization precision will be.

Obviously, the more severe shape distortion will result in larger time delay error. The relation between shape distortion and time delay error is shown in Fig. 7 and Fig. 8.

For a array with d = 10 m, when the angle offset of three transducers are all less than 15^o, the time delay error $\Delta\tau$ will generally be kept within ±2 ms. Besides, the closer the three transducers' angle offset approximates to each other, the smaller the time delay error $\Delta\tau$ is, and the higher the localization precision estimating by eq. (3) and eq. (4) is.



(a) Target's azimuth is 0~180^o.



(b) Target's azimuth is 30^o~150^o

Fig. 3. Simulation results for d = 10 m, $\Delta\tau$ = ± 1 ms.

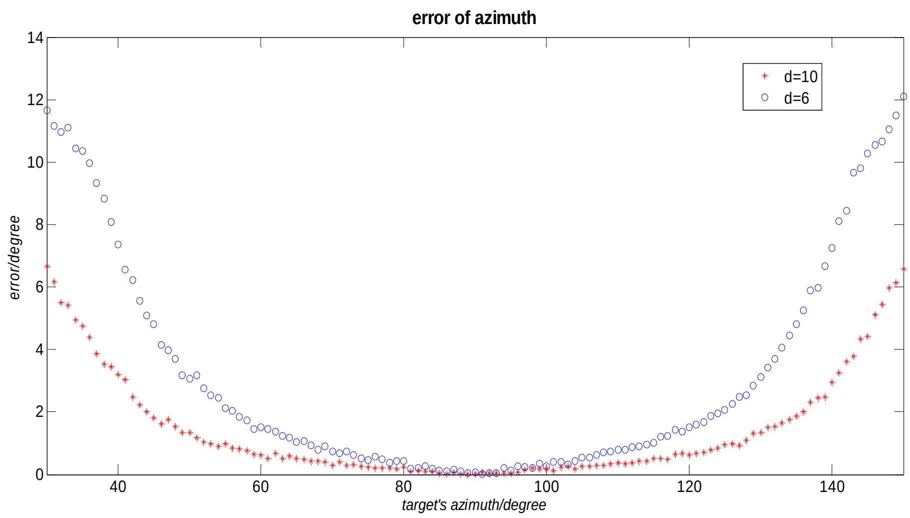


Fig. 4. Error of target's azimuth caused by *d*.

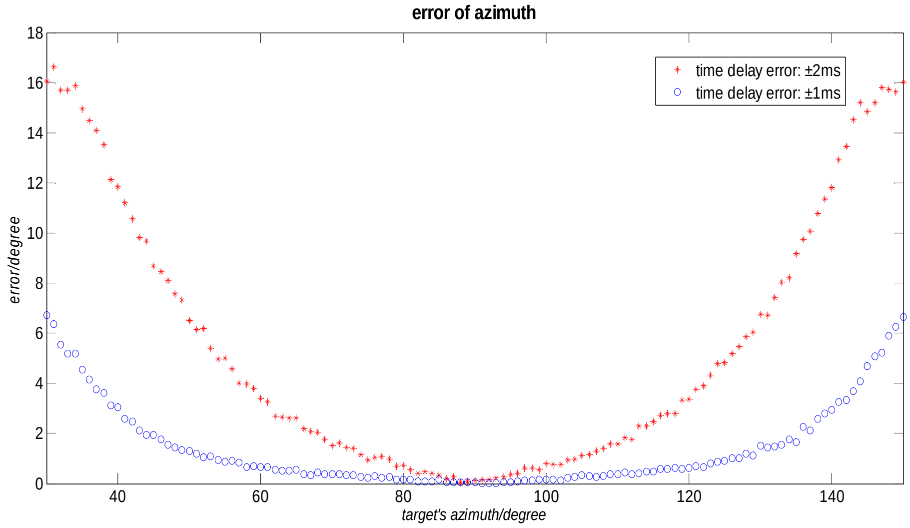


Fig. 5. Error of target's azimuth caused by $\Delta\tau$

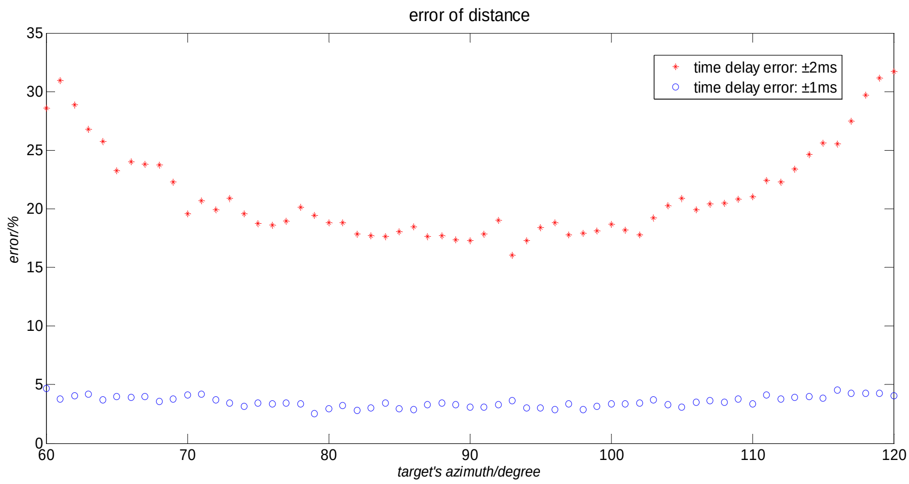


Fig. 6. Error of target's distance caused by $\Delta\tau$

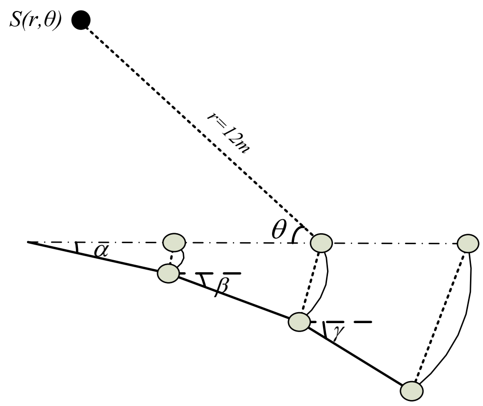
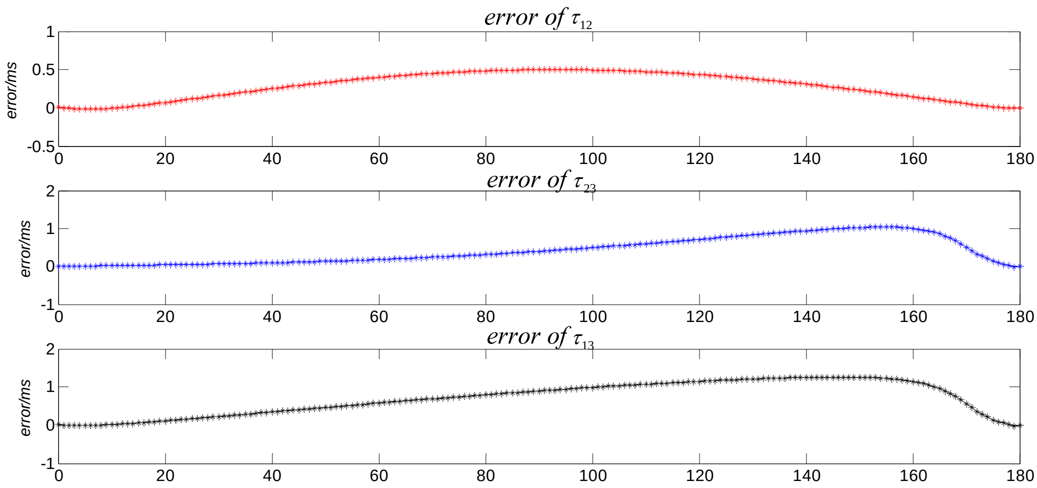
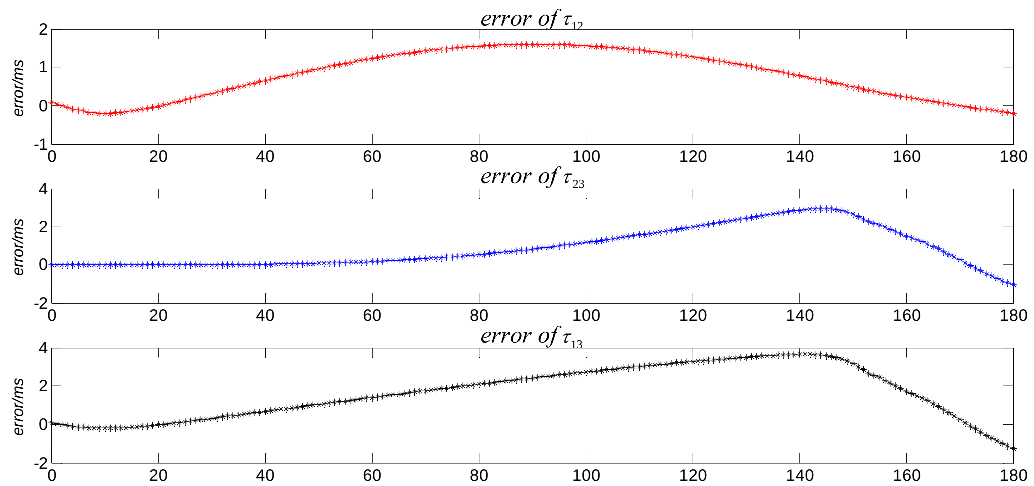


Fig. 7. Shape distortion of array.



(a) $\alpha = 2^o, \beta = 4^o, \gamma = 6^o, d = 10$



(b) $\alpha = 10^o, \beta = 12^o, \gamma = 15^o, d = 10$

Fig. 8. Relationship of array's shape distortion and time delay error.

According to all the above simulation results, we have the effect on passive localization from the triplet linear array's shape distortion as follows.

1. The larger the space between two adjacent transducers is, the smaller the localization error caused by triplet linear array's shape distortion is. So, in practical applications, we should make the size of array as larger as circumstances will permit.

2. The more serious the triplet linear array's shape distortion is, the larger the time delay error is, and the lower the localization precision is.

3. In case of shape distortion, the estimating error of target's distance is larger than that of target's azimuth obtaining by eq. (3) and eq. (4).

4. In case of shape distortion, the closer the angle between target and array approximates to *90*^{o}, the smaller the estimating error obtaining by eq. (3) and eq. (4) is.

5. When we can't obtain the triplet linear array's exact underwater shape, we can use eq. (3) and eq. (4) to estimate the target's distance and azimuth approximatively. However, the localization error is directly related to the space between two adjacent transducers and the time delay error. In practice, we should make a concrete analysis to determine whether to adopt the two estimating formulas or not.

4. Conclusions

The underwater line array based on triplet linear array is apt to have shape distortion. Although we can set several course sensors among the array to compensate the array's shape distortion, the fitting error still has a negative effect on localization precision. So, in case of shape distortion, how to get the target's position is a difficult question.

In this paper, we discussed the error of positioning caused by triplet linear array's shape distortion, and the effect of shape distortion on target's localization was simulated. From the simulation results, we found that in case of shape distortion, there were some apply conditions to use eq. (3) and eq. (4) to estimate the target's distance and azimuth approximatively. This paper will provide reference for improving passive localization precision with triplet linear array.

References

[1]. Hassab. J. Contact localization and motion analysis in the ocean environment: A perspective, *IEEE Ocean. Eng.*, Vol. 8, No. 3, 1983, pp. 136-147.

[2]. Song Xinjian, Hui Junying, Yin Dongmei, Li Yanmei, Research on underwater noise target passive ranging technology, *Applied Acoustics*, Vol. 24, No. 3, 2005, pp. 133-139.

[3]. G. Clifford Carter, Time delay estimation for passive sonar signal processing, *IEEE Trans. on Acoustics, Speech, and Signal Processing*, ASSP-29, 3, 1981, pp. 463-469.

[4]. Song Xinjian, Study on Digital Noise Targets Passive Ranging Sonar, *A Dissertation for the Degree of D. Eng, Harbin Engineering University*, 2004.

[5]. Yu Quanlei, The Realization of Passive Positioning on TigerSHARC, *A Dissertation for the Degree of M. Eng, Harbin Engineering University*, 2009.

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