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INFLUENCE OF SNR ON DETERMINATION OF LOCATION OF UNDERWATER OBJECT BY MEANS OF ACOUSTICS METHOD

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Localisation of underwater sources is possible by means of measurements of the delay between signals, which are radiated by the source. There are many time delay estimation methods, one of them is the gradient type adaptive algorithm. One of estimation parameters is convergence coefficient, which influences on speed of the estimation process. Selection of the optimal value of this coefficient guarantees achievement of the estimated value of time delay in the shortest time. The value of this coefficient depends on received signals to noise ratio. In this paper has been shown time delay estimation with gradient type adaptive algorithm and factors, which influence on the value of convergence coefficient. There also has been shown influence of SNR on working of the time delay estimation, which can be used in the underwater source localisation system. For research have been used real acoustics signals radiated by a moving ship.

INTRODUCTION

For determination of location of an underwater moving object are used time delay estimation methods, which working is based on the correlation technique. The alternative solution is to use the method with gradient adaptive algorithm, which does not require *a priori* statistics about received signals.

1. TIME DELAY ESTIMATION WITH GRADIENT METHOD

The functional system consists of two components: a sum function and a changeable delay. Input signals are as a sequence of signals samples. Minimizing of the error e(k) in the output of the system is achieved by modification of the changeable delay until the value, which gives us the minimum of the error e(k) [1], [2], [3], [4]. This value of time delay is the estimate of time delay between input signals.

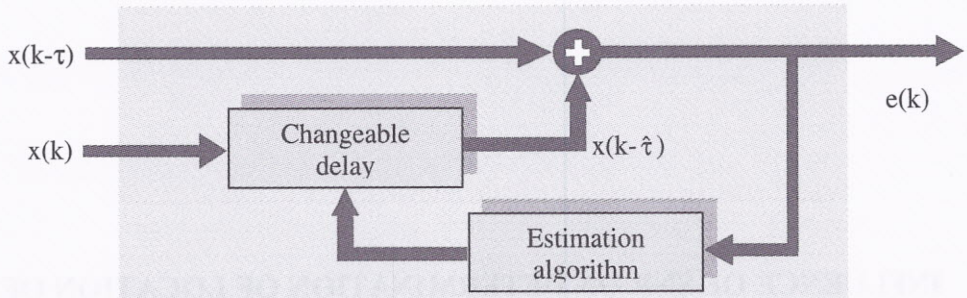

Fig. 1. Time delay estimation with gradient method

Working this method can be described following steps:

1) Calculation of the mean square error signal in k- th iteration step:

$$e(k) = x_1(k) - x_2(k-\hat{\tau}(k)) \quad (1)$$

where $x_1(k)$ - the value of delayed signal in k- th iteration step,
$x_2(k)$ - the value of non- delayed signal in k- th iteration step,
$\hat{\tau}(k)$ - the value of delay in k- th iteration step.

2) Calculation of gradient of the error function in k- th iteration step:

$$\nabla(k) = -e(k) \cdot [x_2(k-\hat{\tau}(k)-1) - x_2(k-\hat{\tau}(k)+1)] \quad (2)$$

3) Calculation of estimate of the delay in next iteration step:

$$\hat{\tau}(k+1) = \hat{\tau}(k) + \mu \cdot (-\nabla(k)) \quad (3)$$

The important issue is correct selection of the convergence coefficient μ. The value of the convergence coefficient μ is chosen from the range:

$$0 < \mu \leq \frac{1}{10\sigma^2} \quad (4)$$

where $\sigma^2 = \sigma_s^2 + \sigma_{sz}^2$
σ_s^2 – variance of the signal,
σ_{sz}^2 – variance of the noise.

Correct choose of this parameter essentially influences on working time delay estimation system. Where the value of the convergence coefficient μ is too high, time delay wont be achieved by the system and it can proceed to infinity. This phenomenon occurs with low value of the signal to noise ratio.

From the another side the minimum value of the convergence coefficient μ is the condition of the convergence speed of the estimate $\hat{\tau}$ to real value. If μ has low value, then the real value is achieved slower by the system. When μ is too low, time delay wont be achieved by the system or can estimate false value. On the basis of research and experiments there was observed, optimal value of the convergence coefficient μ is $\mu_{opt} = \frac{1}{10\sigma^2}$; then time delay between signals is achieved the speediest.

On the basis of (4) the optimal value of convergence coefficient can be described:

$$\mu_{opt} = \frac{1}{10\sigma_s^2\left(1+\frac{1}{SNR}\right)} \qquad (5)$$

Variance σ_s^2 is:

$$\sigma_s^2 = 2\ T_p\ \Delta F \qquad (6)$$

where T - sampling period of the signal,
ΔF – spectrum of the signal.

2. RESULTS

For time delay estimation have been used signals radiated by a moving ship on different distances. Hypothetical received signals have been shown in Fig. 2. Recorded signals have different signals to noise ratios ($SNR_1>SNR_2>SNR_3$), so they have different optimal convergence coefficients ($\mu_1>\mu_2>\mu_3$). Results of time delay estimation these signals have been shown in Fig. 3.

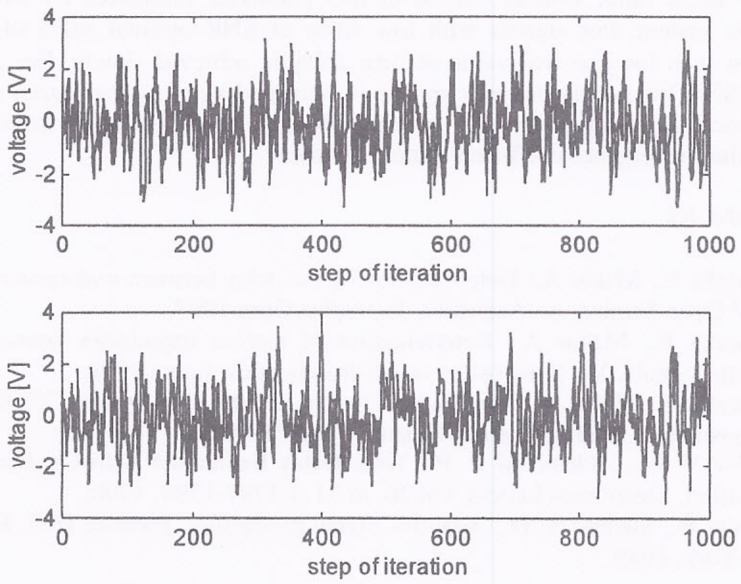

Fig. 2. Received signals

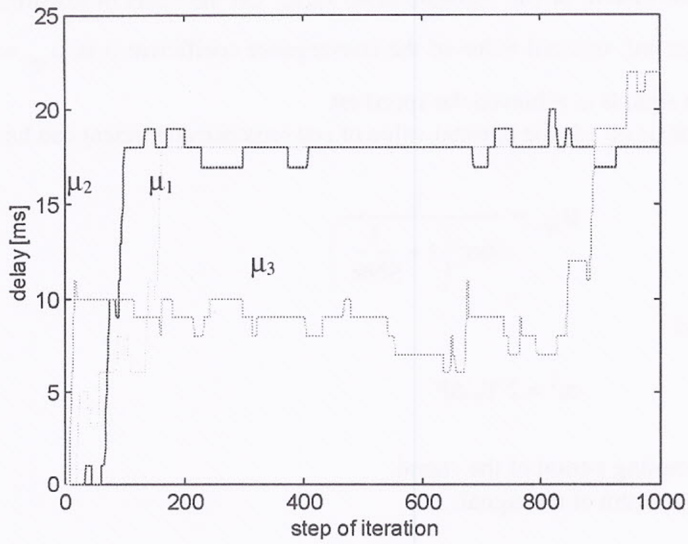

Fig. 3. Time delay between received signals obtained for different SNR

3. CONCLUSIONS

The convergence coefficient of the estimation algorithm is closely connected with the signal to noise ratio. Correct choose of this parameter influences on working time delay estimation system. For signals with low value of SNR optimal value of the convergence coefficient μ is low, so real value of time delay is achieved slowly. For signals with high value of SNR time delay between signals is estimated within a few dozen steps of iteration. During localisation of underwater moving objects, which are away from receivers, initial value of the convergence coefficient should be low.

REFERENCES

1. Kozaczka E., Makar A.; Determination of the delay between underwater acoustic signals, XLIV Open Seminar on Acoustics, Jastrzębia Góra 1997.
2. Kozaczka E., Makar A.; Determination of motion trajectories sources of underwater acoustic signals, XV Symposium on Hydroacoustics, Jurata 1998.
3. Kozaczka E., Makar A.; Underwater Source Localisation System. 2[nd] EAA International Symposium on Hydroacoustics, Gdańsk- Jurata 1999
4. Vasilev V. N., Aidemirski P. P., Time Delay Estimation with Gradient Type Adaptive Algotithm, Electronics Letters, vol.26, nr 21, s.1797-1798, 1990.
5. Widrow B., Stearns S. D., Adaptive signal processing, Prentice-Hall, Englewood Cliffs, New York, 1989.