Modified Sources Number Estimation Methods of the Acoustic Vector Hydrophone Array Based on Gerschgorin Disk Criterion

Xuhu Wang*, Yongwei Liu, Qunfei Zhang

School of Communication and Electronic Engineering, Qingdao University of Technology. Email: hgcwxh@163.com

Introduction

The sources number estimation methods of the acoustic vector hydrophone array based on Gerschgorin disk criterion (VGDE) are analyzed in this paper. Since the success detection signal to noise ratio of the original VGDE method is relatively high, the compressed radius VGDE approach (CR-VGDE) and the modified CR-VGDE approach (MCR-VGDE) are proposed to reduce the detectable signal to noise ratio and improve detection performance of the acoustic vector hydrophone array. The radius of Gerschgorin disks are weighted and the Gerschgorin disks in the CR-VGDE approach, therefore, the signal Gerschgorin disks and noise Gerschgorin disks are further separated in the weighted compression process, which improves the detection performance of the acoustic vector hydrophone array. As the adjustment factor need to be set manually in the CR-VGDE method, a design approach of the dynamic adjustment factor is presented in the MCR-VGDE method. Simulation results indicate the detectable signal to noise ratio of the two modified processing approaches are lower than that of the original VGDE approach.

Methods

In original VGDE method, the covariance matrix of the AVH array receiving signals is done a unitary transformation illustrated in (1). Then we use the detection criterion illustrated in (2) to estimate the sources number. Where $L$ is snapshot number, $D(L)$ is a adjustment factor associated with snapshot number. When $k$ increases from 1, the VGDE ($k$) will become negative at $k=k_0$ firstly, and then the incident signals number is $k_0$.

$$R_r = T^*RT = \Phi \Phi^H$$ (1)

$$VGDE(k) = D(L) \sum_{k=1}^{M} L > 0, k = 1,2,\ldots,4M - 5$$ (2)

In CR-VGDE method, we do similar transformation of the matrix $R_r$ in (1) and calculate the radii of the Gerschgorin disks using it. The transformation is illustrated in (3). Then we can get the modified detection formula illustrated in (4), the adjustment factor $\Delta(L)$ is a fixed value which needs to be manually set according to the snapshot number.

$$R_r = DR_r D^H = \begin{bmatrix}
X_{kk} & 0 & \cdots & 0 \\
0 & X_{kk} & \cdots & 0 \\
\vdots & \ddots & \ddots & \vdots \\
0 & \cdots & 0 & X_{kk}
\end{bmatrix}$$ (3)

$$CR \cdot VGDE(k) = \Delta(L) = \sum_{k=1}^{M} \frac{D(L)}{4(M - 1)} \sum_{k=1}^{M} \sqrt{L} > 0, k = 1,2,\ldots,4M - 5$$ (4)

To improve this condition, we design a dynamic adjustment factor illustrated in formula (5) and call the process MCR-VGDE method.

$$D^{(M)}(L) = \frac{D}{4(M - 1) - k} \sqrt{\sum_{k=1}^{M} L}$$ (5)

where $D$ is a constant associated with the noise output power of the acoustic vector hydrophone.

Numerical Simulation

We compare the detection performance of the VGDE, CR-VGDE and MCR-VGDE methods through several numerical examples. In these examples, we consider a linear array with eight acoustic vector hydrophones and assume 2 (or 3) narrow sources impinging on the linear array. All the results come from 100 Monte Carlo experiments. Figure.1 shows success probability of sources number detection change following the SNR when acoustic source signals come from 5 and 30. Figure.2 shows success probability of sources number detection change following the SNR when acoustic source signals come from 5, 30 and 50.

Summary

The multi-sources detection methods using Gerschgorin disk criterion of the acoustic vector hydrophone array are analyzed. We derive a weighted compression method to improve detection performance of the AVH array. To improve the condition in which the adjustment factor need to be set manually, we design a dynamic adjustment factor which is calculated according to the values of the Gerschgorin disk centers. Simulation results show that the detectable SNR of the two modified processing methods is lower than that of the original VGDE method. The compression of the Gerschgorin disks radii and dynamic adjustment factor can improve detection performance effectively.

References