UDT
Undersea Defence Technology
13-15 May 2019
Stockholmsmässan, Sweden

A novel grating lobes suppression method of sparse arrays for acoustic source localization

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#UDT2019

Outline

- Problems to be solved
- Approach
  1) Array Structure
  2) Beamforming Method
  3) Product & Min Processing
  4) Comprehensive Processing
- Results and Discussion
- Conclusions

Problems to be solved

Problem:

Existing algorithms： **ULA**， $d \le \lambda / 2$ ；

Adding sensors to obtain **high resolution**, **high costs**;

Optical fiber sensor: **d=0.1m**, f0 = 7.5kHz;

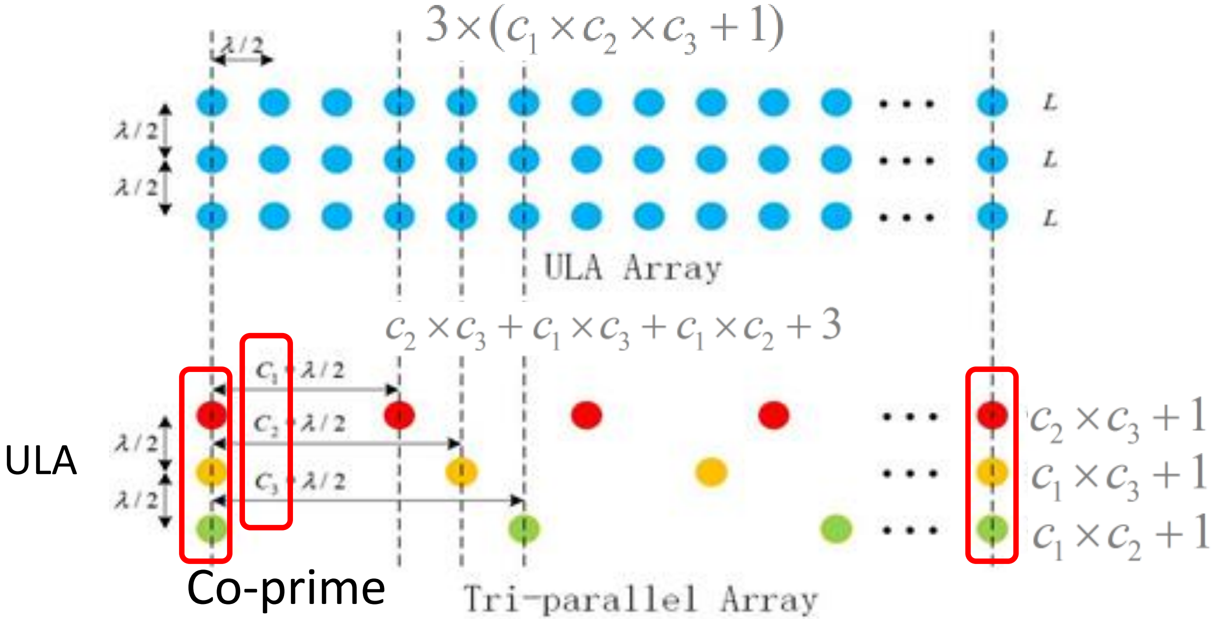
Sparse array is developed, but suffers from azimuth ambiguity caused by the **grating lobes**.

To deal :

A new array structure is designed ;

Comprehensive processing eliminates the azimuth ambiguity caused by grating lobes.

Approach - Array Structure



The array structure of optical fiber sensor array

Approach - Beamforming Method

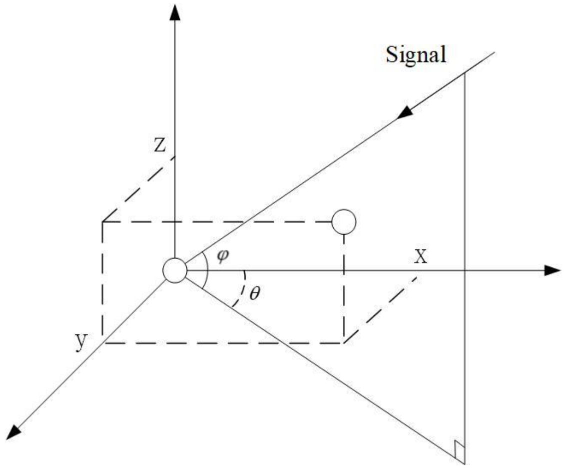
For each sub array, the beamforming is carried out utilizing conventional beamforming (CBF).

The received signal column vector can be expressed as a vector:

$$\mathbf{X}_i(t) = \mathbf{A}_i\mathbf{S}(t) + \mathbf{N}_i(t), i = 1,2,3$$

$$\boldsymbol{A}_i = \begin{bmatrix} \boldsymbol{a}_{i1}(\omega_0) & \boldsymbol{a}_{i2}(\omega_0) & \cdots & \boldsymbol{a}_{iN}(\omega_0) \end{bmatrix}, i = 1,2,3$$

$$\boldsymbol{a}_i(\omega_0) = \begin{bmatrix} \exp(-j\omega_0\tau_{i1k}) \\ \exp(-j\omega_0\tau_{i2k}) \\ \vdots \\ \exp(-j\omega_0\tau_{iM_ik}) \end{bmatrix}, i = 1,2,3, k = 1,2,\ldots,N$$



Approach - Beamforming Method

The basic orientation information obtained from the three sub-arrays respectively.

Spatial Spectrum: $P_i(\theta,\varphi)=\boldsymbol{a}_i^H(\theta,\varphi)\boldsymbol{R}_{ix}\boldsymbol{a}_i(\theta,\varphi), i=1,2,3$

$$\boldsymbol{R}_{\mathrm{ix}}=\frac{1}{p}\sum_{n=1}^{p}\left[\boldsymbol{X}_i(n)\boldsymbol{X}_i^H(n)\right]$$

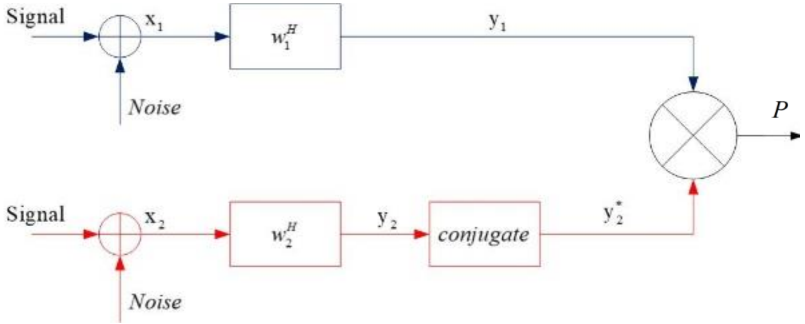
Output: $y_i(\theta,\varphi)=\boldsymbol{w}_i^H(\theta,\varphi)\boldsymbol{X}_i$

Due to the spatial under-sampling, the spatial spectrum obtained by the conventional beamforming scanning of each sub-array is affected by grating lobes, which seriously affect the quality of signal azimuth estimation.

Approach – Product & Min Processing

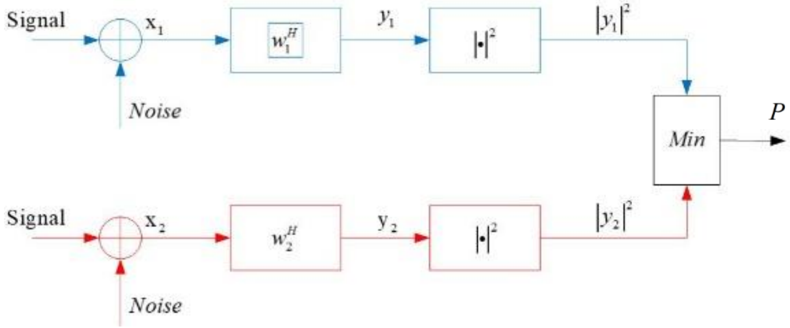
Product Processor:

$$P_{i,j}(\theta,\varphi) = y_i(\theta,\varphi) * conj(y_j^T(\theta,\varphi)),$$
$$i \neq j \in [1,2]$$



Min Processor:

$$P_{\min 1,2} = \min(P_1(\theta,\varphi), P_2(\theta,\varphi))$$



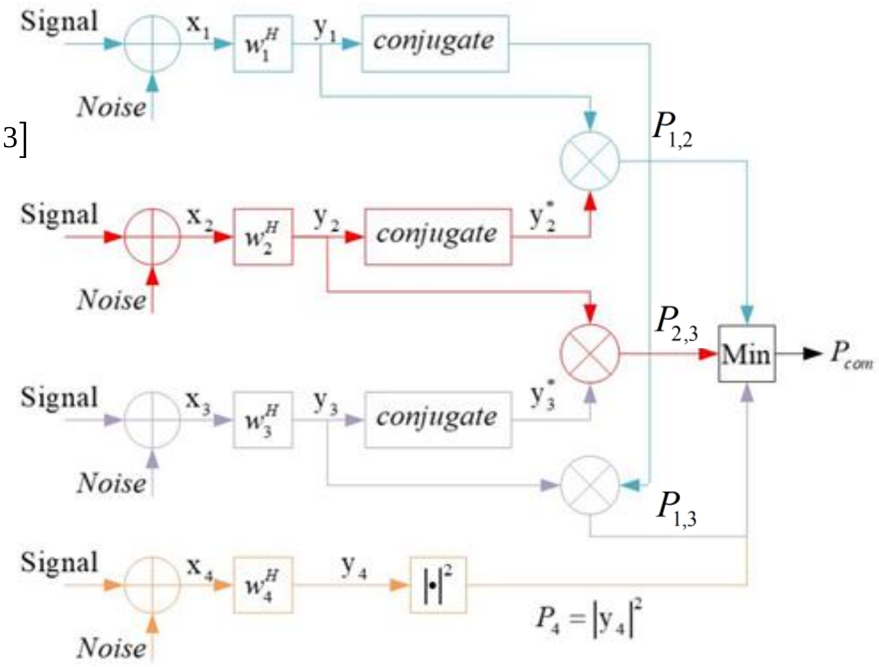
[1] Gaussian Source Detection and Spatial Spectral Estimation Using a Coprime Sensor Array With the Min Processor

Approach - Comprehensive Processing

$$P_{i,j}(\theta,\varphi) = y_i(\theta,\varphi) * conj(y_j^T(\theta,\varphi)), i \neq j \in [1,2,3]$$

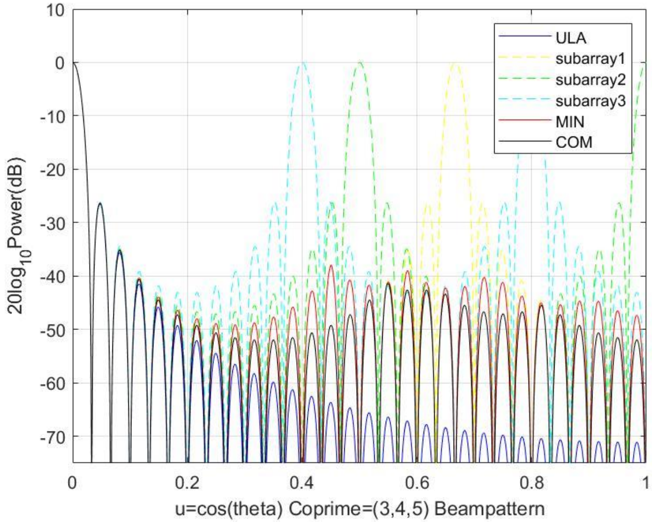
$$P_{\min 1,2,3} = \min(P_{1,2}(\theta,\varphi), P_{2,3}(\theta,\varphi), P_{3,1}(\theta,\varphi))$$

$$P_{Com} = \min(P_{\min 1,2,3}, P_{ula})$$



Results and Discussion

Assume that c1=3, c2=4, c3=5 , so sub-array 1,2,3 has 21,16,13 sensors separately . The compared ULA has 3 lines, each line has 60 sensors.



Beam Patterns

Results and Discussion

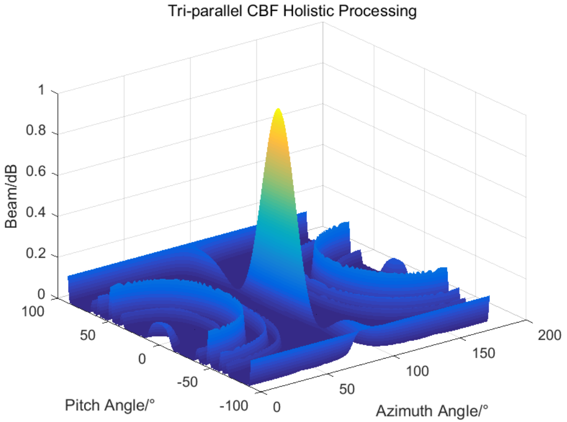


Fig.1

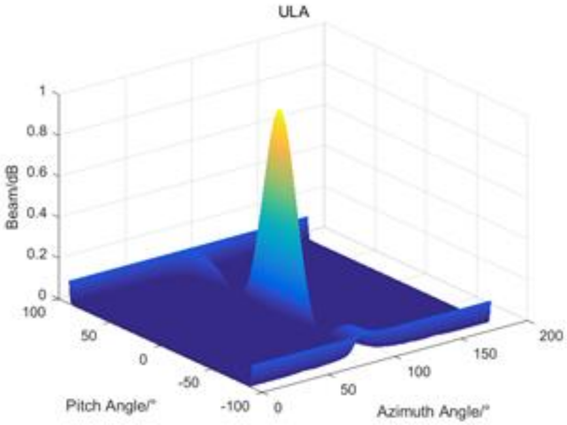


Fig.2

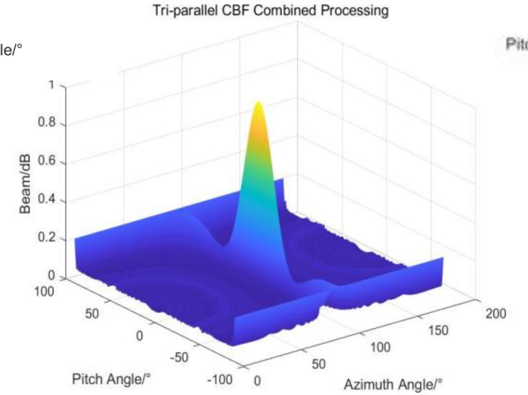


Fig.3

Conclusions

- Improve the resolution;
- Reduce the complexity of calculation and cost;
- Achieve large aperture using a novel coprime sparse sensor arrays;
- Suppress grating lobes;
- Lower side lobes than Min Processor.

The end

THANK YOU !