A NEW ARRAY GEOMETRY FOR DOA ESTIMATION WITH ENHANCED DEGREES OF FREEDOM

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ICASSP 2016 Shanghai, China

Abstract

This work presents a new array geometry, which is capable of providing $O(M^2N^2)$ DOF using only MN physical sensors via utilizing the second-order statistics of the received data. This new array is composed of multiple, identical minimum redundancy subarrays, whose positions follow a minimum redundancy configuration. Thus the new array is a minimum redundancy array (MRA) of MRA subarrays , and is termed nested MRA (NMRA). The sensor positions, aperture length, and the number of DOF of the new array can be predicted if these parameters of MRA subarrays are given .

Keywords: Sensor arrays, minimum redundancy array (MRA), DOA estimation, co-array, nested array .

An example geometry of NMRA

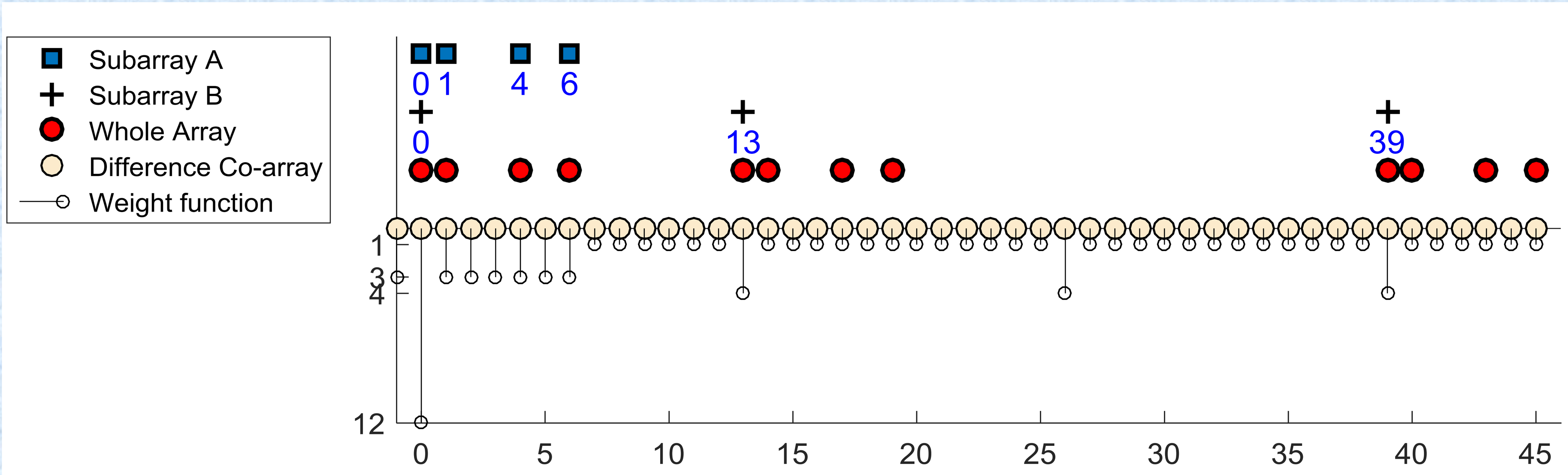


Fig. 1 Geometry of NMRA with 3 identical 4-element minimum redundancy subarrays

Construction of NMRA:

- Subarray A:
  $\mathbf{u}_M = [m_1\ m_2 \cdots m_N]\,d,$
- Subarray B:
  $\mathbf{u}_N = [n_1\ n_2 \cdots n_N]\,D,$
- NMRA :
  $\mathbf{v} = \mathbf{u}_N \oplus \mathbf{u}_M\,.$
  $\oplus$: cross summation

Properties of NMRA:

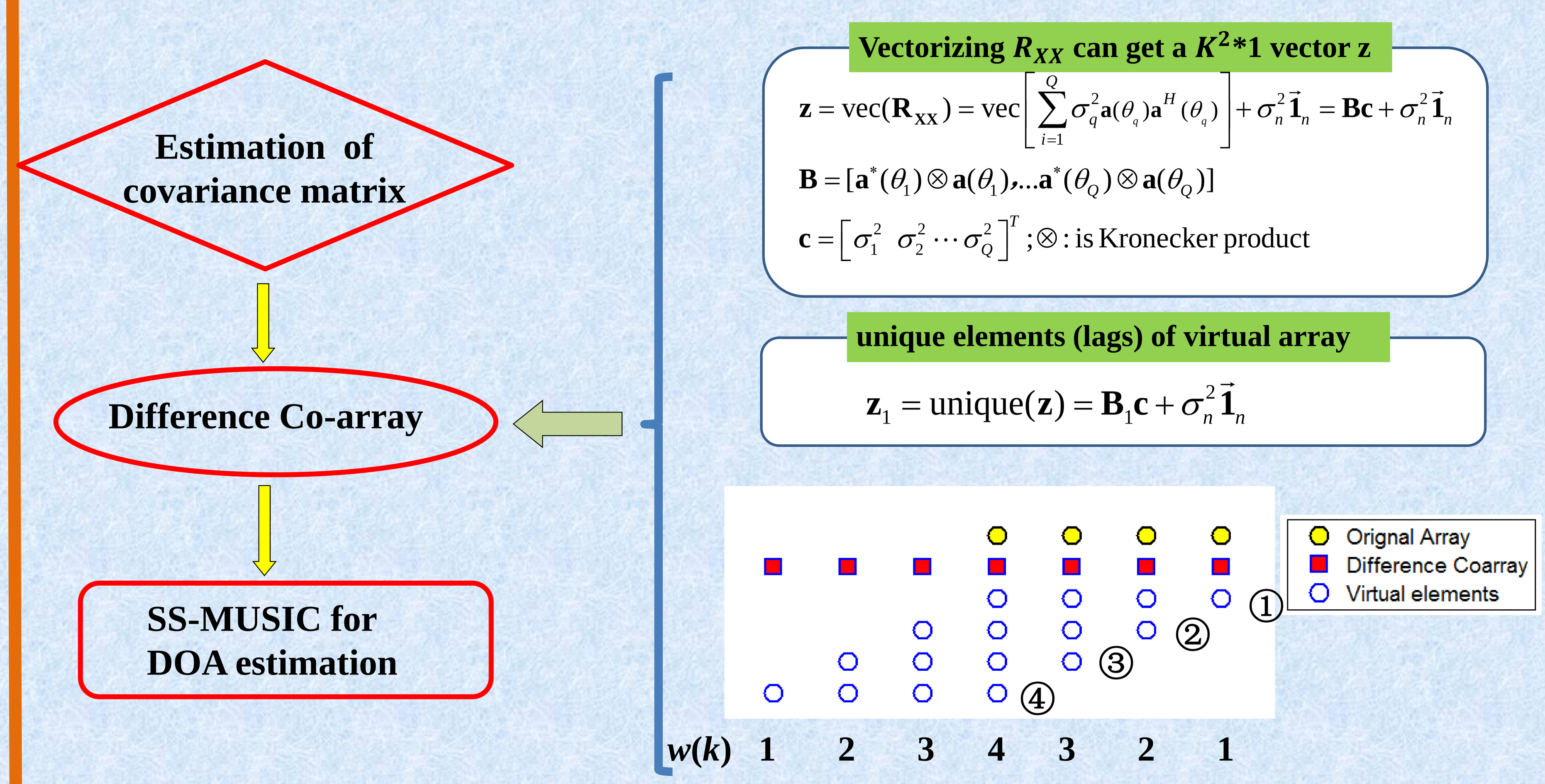
- Location Set: $\mathbb{D}_V = \mathbb{D}_B \oplus \mathbb{D}_A$
- Aperture: $l_V \cdot d = (l_A + l_B \cdot f_A)d$
- DOF: $f_V = f_A \bullet f_B$

Signal Model:

$$\mathbf{x}(t)=\mathbf{A}\mathbf{s}(t)+\mathbf{n}(t)$$

$\mathbf{s}(t)$: source signals vector（Unknown）
Q sources, K-elements array

Procedure of DOA Estimation



The DOF of NMRA

Subarray A and Subarray B are both MRAs and their numbers of DOF can be expressed as f_A and f_B, then

$$f_V = f_A \cdot f_B = (M^2 - M + 1 - M_R)(N^2 - N + 1 - N_R) \propto (M^2N^2)$$

✓ **NMRA can provide $O(M^2N^2)$ DOF using only MN physical sensors.**

Numerical Examples

Simulation 1

Comparison of DOF, Aperture for different array geometries versus total number of sensors

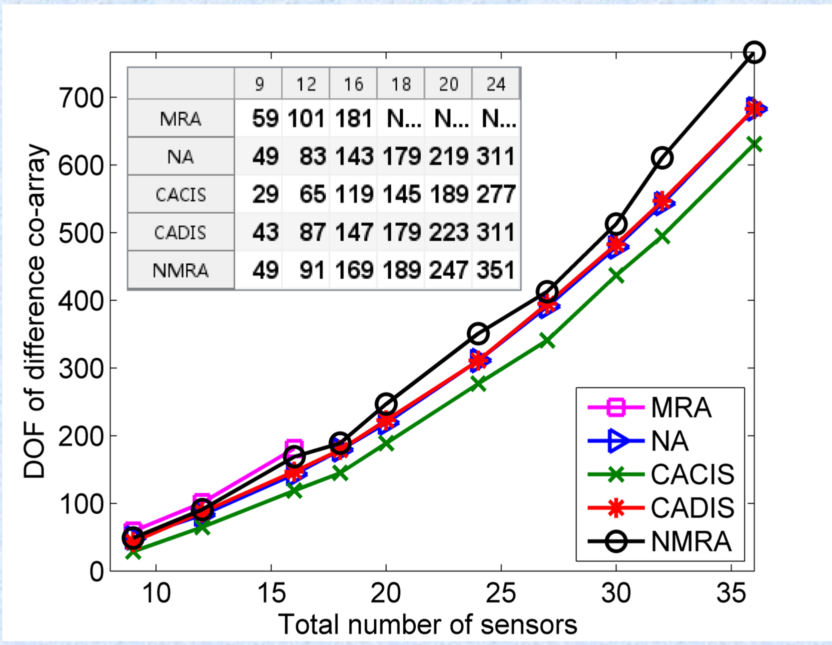


Fig. 2 DOF comparison

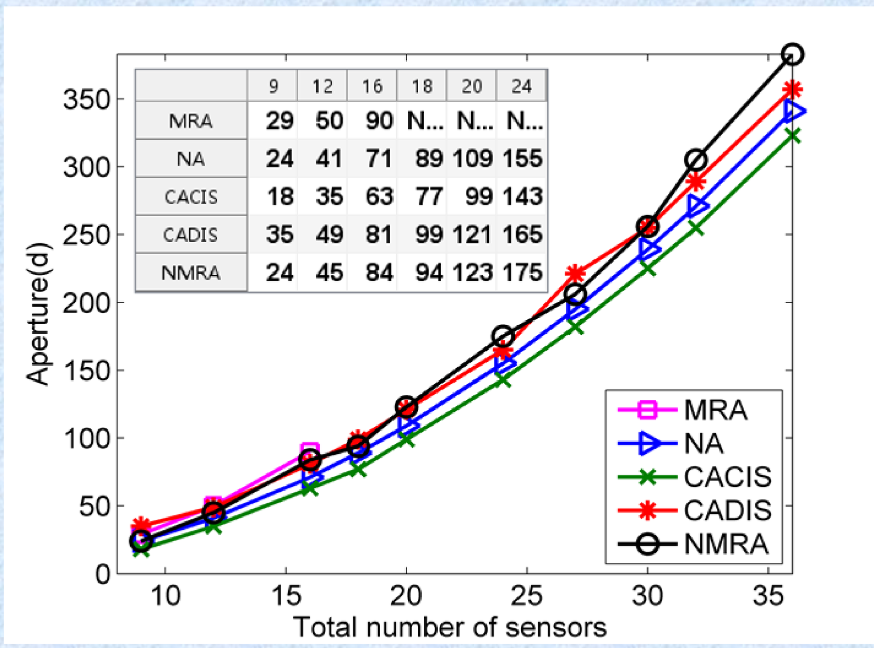


Fig. 3 Aperture comparison

Advantage 1

- ✓ The proposed NMRA can provide more DOF, larger aperture than Nested Array and Coprime Array
- ✓ The superiority becomes more and more obvious with increase of total number of sensors

Simulation 2

DOA estimation comparison of 12 physical sensors, For NMRA, M=3, N=4

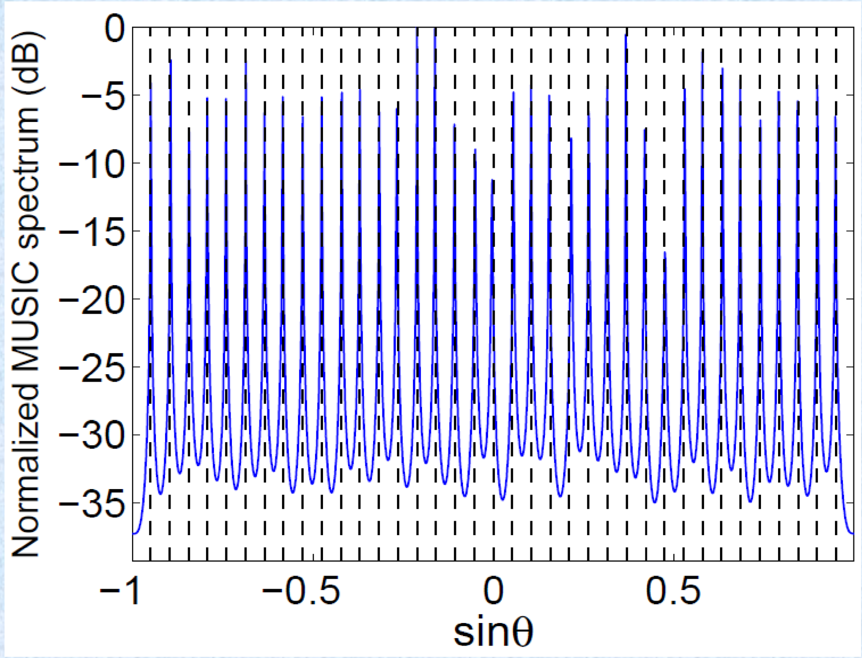


Fig. 4 MUSIC spectrum of NMRA

The NMRA can resolve all the 37 sources correctly, which is much larger than the number of physical sensors (=12).

Snapshots number =1000
Source number =37

500 Monte Carlo trials
Source number =16

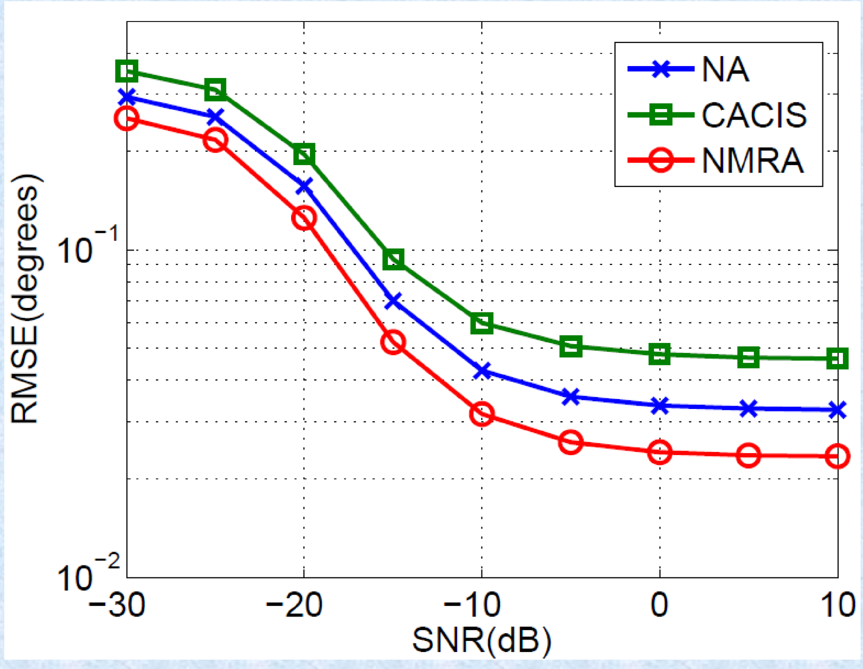


Fig. 5 RMSE versus SNR

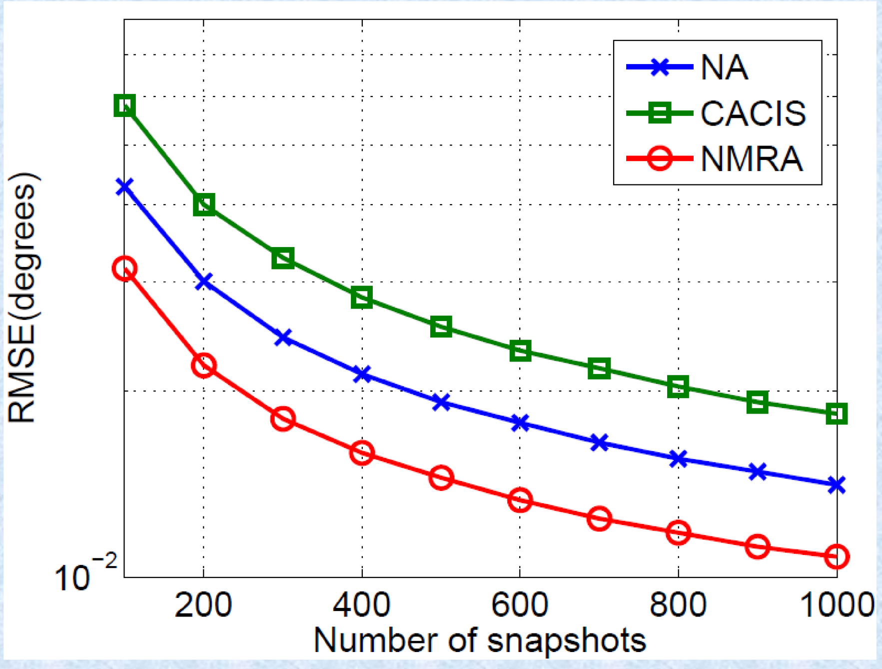


Fig.6 RMSE versus Snapshot

Advantage 2

- ✓ The NMRA has better DOA estimation performance than the NA and CACIS.

Conclusions

- Proposed a new array geometry, NMRA, which can be easily constructed.
- NMRA has a larger aperture as well as a higher number of DOF than the nested array and the CACIS.
- It can resolve more sources than sensors.
- It has a better DOA estimation performance than the NA and CACIS.