A NOVEL METHOD FOR ESTIMATION OF MORE DOA WITH LESS ANTENNAS

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***Abstract*—In this paper, we propose a new method to estimate more directions of arrival (DOA) while having fewer antennas in the array. Indeed, we decompose the original array into two subarrays. Next, we make a Hadamard product between both steering vectors of subarrays to get the Hadamard steering vector. The lasts elements of the Hadamard steering vector are vertically concatenate with original steering vector. After that we apply MUltiple SIgnal Classification (MUSIC) algorithm for estimation of DOA of source signals. We used MatLab software to make the simulations and we get very good results.**

Keywords—DOA estimation; steering vector; MUSIC; Hadamard product.

I. INTRODUCTION

Smart signal processing for Direction of arrival (DOA) estimation is the subject of much research works over the last several decades because it's a very important aspect of mobile wireless communication systems [1]. This technic is also use in radar [2] and sonar [3] applications. High resolution algorithms provide the best DOA estimation results, and the most popular of them is MUSIC. The Optimisation of MUSIC algorithm has been proposed in [4] and we can note that the number of DOA that can be estimated is always less than number of antennas in the array. So, we need a lot of antennas in the array to estimate greater number of DOA of source signals.

Instead having a lot of antennas in the array, we propose a method to virtually increase the number of antennas already existing in the array. This allow to estimate a greater number of DOA while having few antennas in the array.

This paper is organised as follow: First, we describe respectively the signal model and MUSIC algorithm for DOA estimation in sections II and III. We explain the proposed method in section IV, and we present the simulation results in section V. finally, we conclude this paper in section VI.

II. SIGNAL MODEL

We consider K uncorrelated far-field narrowband signals with same wavelength λ, incidents on L-Shaped array in the directions (θ_k, ϕ_k) where θ_k and ϕ_k denote respectively the elevation and azimuth directions of kth incident signal. We used same L-Shaped array as in [1] as shown in Fig.1 with M antennas on each Uniform Linear Array (ULA) that form the L-Shaped array. The antennas spacing is $d = \lambda/2$. We suppose that the sources are punctual, and the antennas are omnidirectional with unitary gain.

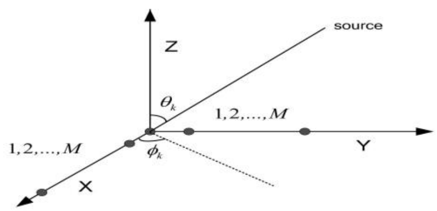

Fig. 1. The geometrical configuration of the L-shaped array

The incident signal on x-axis and y-axis is:

$$X(t) = A_x.S(t) + N_x(t) \quad (1)$$

$$Y(t) = A_y.S(t) + N_y(t) \quad (2)$$

Where: $A_x = [a_{x,1}, \dots, a_{x,K}]$ and $A_y = [a_{y,1}, \dots, a_{y,K}]$

$$a_{x,k} = \left[1, e^{j\varphi_{x,k}}, \dots, e^{j\varphi^M{}_{x,k}}\right]^T \quad (3)$$

$$a_{y,k} = \left[1, e^{j\varphi_{y,k}}, \dots, e^{j\varphi^M{}_{y,k}}\right]^T \quad (4)$$

$$\varphi^m{}_{x,k} = 2\pi.\frac{d}{\lambda}.(m-1).\sin\theta_k.\cos\phi_k \quad (5)$$

$$\varphi^m{}_{y,k} = 2\pi.\frac{d}{\lambda}.(m-1).\sin\theta_k.\sin\phi_k \quad (6)$$

The covariances matrices are estimated by:

$$\hat{R}_{xx} = \frac{1}{V}.X.X^H \text{ and } \hat{R}_{yy} = \frac{1}{V}.Y.Y^H \quad (7)$$

Where V denotes the number of Samples and $[\ ]^H$ denotes the Hermitian operation.

III. CLASSICAL MUSIC

The principle of MUSIC is to project the steering vectors on the noise subspace. After that, we get the following function:

$$F(\phi, \theta) = a(\phi, \theta)^H.E_n.E_n{}^H.a(\phi, \theta) \quad (8)$$

Where $[\ ]^H$ denote the Hermitian.

The zeros of this function maximize the following spectral function and are the directions of arrival of the incident signals.

$$P_{MUSIC} = \frac{1}{a(\phi,\theta)^H.E_n.E_n{}^H.a(\phi,\theta)} \quad (9)$$

IV. PROPOSED METHOD

The proposed method consists in virtually increase the number of antennas in the array for estimation of more DOA of source signals. To do this we proceed as follow:

First, we subdivide original steering vector $a_{\eta,k}$ into two vectors by one element shifting. This is illustrated below:

$$a_{1\eta,k} = \left[1, e^{j\varphi_{\eta,k}}, \ldots, e^{j\varphi_{\eta,k}{}^{M-1}}\right]^T \quad (10)$$

$$a_{2\eta,k} = \left[e^{j\varphi_{\eta,k}}, \ldots, e^{j\varphi_{\eta,k}{}^{M}}\right]^T \quad (11)$$

Where $\eta = x \; or \; y$

After that we obtain the Hadamard steering vectors $a_{3\eta,k}$ by using Hadamard product as below:

$$a_{3\eta,k} = a_{1\eta,k} \odot a_{2\eta,k} \quad (12)$$

Where $\odot$ denotes the Hadamard product

$$a_{3_{\eta,k}} = \left[e^{j\varphi_{\eta,k}}, \ldots, e_{\eta,k}{}^{j\varphi_{\eta,k}{}^{M}}, \ldots, e_{\eta,k}{}^{j\varphi_{\eta,k}{}^{2M-1}}\right] \quad (13)$$

The last elements of $a_{3_{\eta,k}}$ are in principle, the probable sequences of eventual antennas situated at the positions:

$$\ldots \ldots \ldots ; (2M-4); (2M-2)$$

Really, there are no antennas in these positions. But, these $\boldsymbol{M^+}$ additional positions are virtual, with:

$M^+ = \frac{M-2}{2}$ if M is an even number and $M^+ = \frac{M-1}{2}$ if M is an odd number. We can notice that $\boldsymbol{M^+} \approx 45\%.\boldsymbol{M}$

Next, last elements of $a_{3_{\eta,k}}$ from the P*th* element, are vertically concatenate with original steering vector.

with: $P = \frac{M+2}{2}$, if M is an even number and $P = \frac{M+1}{2}$, if M is an odd number. Finally, we applied MUSIC algorithm.

V. Simulation Results

we used MatLab software to implement the proposed method. we use same signal model as in section II. We assume that *M = 15* and Signal to Noise Ration *SNR=10dB*. By varying the number of incidents source signals from 10 to 20, we get the dynamic shown in Fig. 2. We assume that the noise between antennas of array is gaussian white noise with zero mean and variance σ^2.

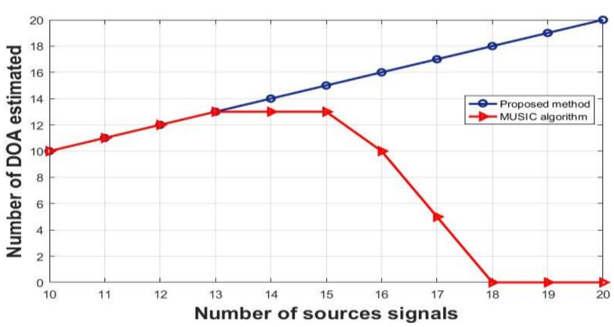

Fig. 2. Dynamic.
Number of DOA estimated VS Number of sources signals

We note that it is not possible to estimate more than 13 DOA when having 15 antennas on each ULA using MUSIC algorithm because, for more efficiency of MUSIC algorithm, the number of antennas in the array must be greater than number of source signals [4].

While using proposed method, we estimated all the 20 DOA when having only 15 antennas on each ULA because, we get $\boldsymbol{M^+ = 7}$ additional virtual antennas.

So, we have *15+7=22* antennas on each ULA.

Fig. 3. Shows the angular resolution of the proposed method compared to [5] where the Autor used a sparse L-shaped array to estimate the ambiguous DOA and after that he removes the ambiguation by disambiguation procedure.

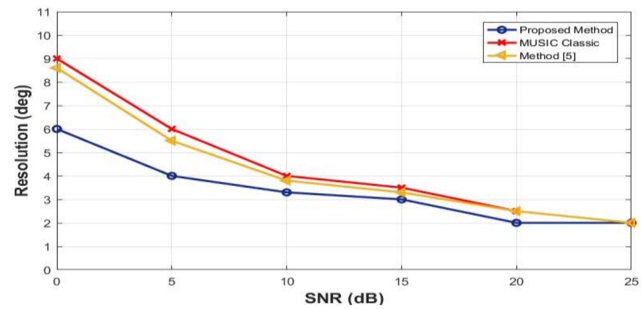

Fig.3. Angular resolution VS SNR

We note that, using the proposed method we get a good angular resolution than MUSIC and method [5]. By using proposed method when SNR=0dB the angular resolution is 6° while 8.9° for MUSIC and 8.5° for method [5].

VI. Conclusion

In this paper, we proposed a new method to increase the number of antennas in the array for more estimation of DOA of uncorrelated signals. The simulation results show us that our proposed method ESV-MUSIC allow to estimate greater number of DOA of uncorrelated signals with few antennas in the array, and the angular resolution is better than that of [5] and better than that of MUSIC algorithm.

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