DOA estimation and interpolation beamformering with semicircular array

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Abstract

Nowadays adaptive technique allows arrays of any geometry to be used with fast direction-of-arrival (DOA) estimators designed for linear arrays. So the interpolation of data from a given antenna array onto the output of a virtual array is needed before the direction finding technique is applied to the outputs of a uniform linear virtual array (ULVA). In this paper some superresoluntion methods are used to estimate DOA by best-fit transformation matrix T under different non-uniformly spaced array.

Ⅰ. INTRODUCTION

Traditionally, in radar system most proposed direction finding processing algorithms such as MPM, MUSIC, Root-MUSIC are normally restricted to a ULA geometry, as pointed out in [1-4]. But in fact the arrays with non-uniformly spaced elements offer the capability to steer the main beam of the array to any desired azimuth. In this paper, to overcome this problem, we will do some research under the interpolation preprocessing of the real array manifold to the linear virtual array about DOA finding given the simulation results by matlab to ensure the theory.

The paper is organized as follows. In section Ⅱ, we formulate the problem, and in section Ⅲ we present the preprocessing technique for a non-uniformly spaced array. Section Ⅳ shows us the simulation results illustrate the performance of the proposed method. Finally, we take on the conclusion in the section Ⅴ.

Ⅱ. DATA MODEL AND PROBLEM FORMULATION

Consider an array composed of M non-equally spaced elements located in an antenna array. Assume that D narrow-band sources impinge on the array from distinct direction $\Theta_1 ... \Theta_D$. Let Θ denote the azimuth and N is the sample of snapshot. Using the complex envelope representation, a complex base-band model at time t for the received signal can be expressed by

$$U = A(\Theta)S + Noise \tag{1}$$

In the design of the transformation matrix, $A(\Theta)$ is the response vectors, referred to as the array manifold

$$A(\Theta) = \left[a(\theta_1), a(\theta_2), \cdots, a(\theta_D)\right] \tag{2}$$

Ⅲ. THE INTERPOLATED ARRAY TECHNIQUE

In this section we discuss the interpolated array technique to find out the transformation matrix T. The best-fit matrix between the real array manifold $A_r(\Theta)$ and the array manifold corresponding to a ULVA $A_v(\Theta)$ such that $TA_r(\Theta) = A_v(\Theta)$.

The following is a general description of how to obtain the best transformation matrix T to get the array manifold for the ULVA from the non-uniformly spaced array. The first step in designing an interpolated array is to divide the field of view of the array into Q sectors. One sector of Q is defined by the interval $\left[\theta_q, \theta_{q+1}\right]$. Next we define a set of construction directions to cover each sector

$$\Theta_q = \left[\theta_q, \theta_q + \Delta\theta, \theta_q + 2\Delta\theta, \cdots, \theta_{q+1}\right] \tag{3}$$

where $\Delta\theta$ is the step size. Compute the steering vectors associated with the set Θ_q for the given array and arrange them in a matrix as follows

$$A_r(\Theta_q) = \left[a_r(\theta_q), a_r(\theta_q + \Delta\theta), \cdots, a_r(\theta_{q+1})\right] \tag{4}$$

$$A_v(\Theta_q) = \left[a_v(\theta_q), a_v(\theta_q + \Delta\theta), \cdots, a_v(\theta_{q+1})\right] \tag{5}$$

Hence, each row of $A_r(\Theta_q)$ represents the relative signal received at the antenna elements. We denote by $A_v(\Theta_q)$ the section of the array manifold of the virtual array of angles

Θ_q .Finally, we assume that there exists a constant matrix T such that $TA_r(\Theta) = A_v(\Theta)$. The best interpolation matrix is achieved by minimizing the scalar

$$\min_T \left\| A_v - TA_r \right\| \qquad (6)$$

In order to have a unique solution for (8), the least squares solution to (8) is given by

$$T = A_v(\Theta_q) A_r(\Theta_q)^H (A_r(\Theta_q) A_r(\Theta_q)^H)^{-1} \qquad (7)$$

where the superscript H represents the conjugate transpose of a complex matrix.

Ⅳ. NUMERICAL EXAMPLES

4.1. Interpolation technique in semicircular model

First, we consider a semicirular array consisting of 11 half-wave dipole antenna elements loaded at the center as shown in Figure 1. Each element of the array is identically point loaded at the center. The distance between two elements is $\lambda/2$.

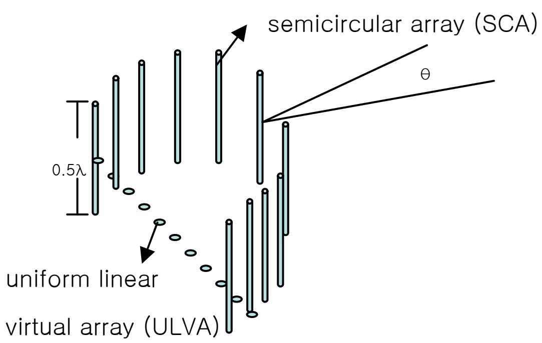

Figure 1. Geometry of a SCA and a ULVA representing the SCA

4.2. DOA in semicircular model

In practice semicircular antenna array is widely used, especially with small step size. We find out DOA with interpolated array using MUSIC, MPM and Root-MUSIC with one sector of 180^0 width and 2^0 $\Delta\theta$. It's assumed that noise is followed by random Gaussion distribution. The average bias simulation using MUSIC, MPM and Root-MUSIC methods [1-4] are shown in Figure 2. All Follow simulation results are obtained by averages of 100 Monte Carlo experiments.

4.3. Interpolation beamforming

After interpolation the semicircular array's beamforming is shown as following Figure 3.

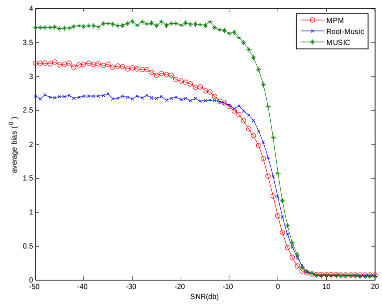

Figure 2. Average bias simulation with noise

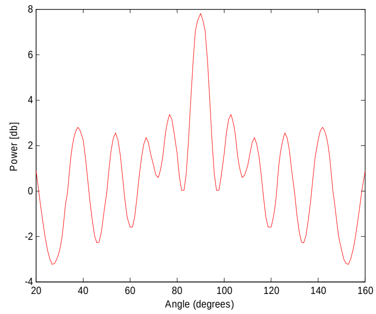

Figure 3. Interpolation beamforming

Ⅴ. CONCLUSION

This paper presents an electronmagnetic preprocessing technique in adaptive radar signal processing. The interpolated technique is applied to find out DOA. And simulations show us that Root-MUSIC method works better than MPM and MUSIC methods under noise situation.In a word, using such a interpolation matrix we can obtain more direct, useful information of these angle and magnitude estimates which are then displayded or further processed by radar data processor.

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