DOA Determination by Using An Antenna System Without Phase Center and MUSIC Algorithm.

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Abstract-Defining the direction of arrival (DOA) is an important problem in radar surveillance, mobile communications.,etc. There are many algorithms to address this. Among them some famous papers can be regards as MUSIC, ESPRIT, MLE. The signal model in that algorithms bases on assuming that array elements are similarly in both amplitude and phase pattern. This paper presents a new approach to find the DOA by using an antenna system without phase center and MUSIC algorithm. The antenna system consists of two antenna elements. In this suggested approach the phase pattern of array elements are taken in to account. The power spectrum improvement are verified by the simulation and the number of detected source is not limited by the number of antenna elements.

Keyword: DOA, MUSIC, array of elements without phase center.

I.INTRODUCTION

Directional finding problem leading to high resolution signal parameter estimation such as MUSIC, ESPRIT, MLE. Using eigen structure to analysis the covariance matrix of data sample of array elements is proposed in MUSIC[1]. The conventional estimation method using maximum likelihood estimation technique for DOA is investigated in MLE[2].The geometry properties of the array element are used in ESPRIT model[3].Structure of linear array now changed to doublets or the array decomposed to 2 sub-linear arrays. Because the MLE performs searching all over array manifold it costs longer of computation. Although the MUSIC is consider as an efficient method in term of computation but the number of detected source is limited by the number of array elements. In the ESPRIT, directly estimation of DOA is carried out but structure of antenna array is still complex.

II. PROBLEM FORMULATION

In general, the antenna array consists of N elements. They can be arranged as a linear, circular or planar array. The signals impinge on the antenna from various angle of arrival since diffraction, reflection ,..etc. The signal received by the array can be expressed as

$$x(t) = A(\theta)S(t) + n(t) \qquad (1)$$

Where the input signal vector is given by

$$s(t) = \{s_0(t), s_1(t), \dots\dots\dots\dots s_{N-1}(t)\ \} \qquad (2)$$

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Si(t) is the input signal at ith elements. We assume that the noise signal are statistical independent, followed Gaussian distribution with zero mean and identical variance.(δ)

$$n(t) = \{n_0(t), n_1(t), \ldots\ldots\ldots n_{N-1}(t)\} \qquad (3)$$

The array manifold,A(θ), is composed by D steering vector corresponding to D incident signals.The steering vector with incoming signal from angle of θ is given by

$$a(\theta) = \{1, \exp(-\beta d \cos\theta), \ldots \exp(-(n-1)\beta d \cos\theta)\} \quad (4)$$

Where β is propagation constant, d is distance between two consecutive elements. In nature , the directional finding problem is estimation of θ in multipath propagation which is real environment in mobile communication, sonar communication and radar surveillance.

III. MUSIC ALGORITHM

MUSIC is short of Multiple Signal Classification proposed in[1]. In this paper, the correlation matrix of output signal is given by

$$R_{xx} = E\{x\, x^H\} \qquad (5)$$

Therefore, the relation between incoming signal and output signal can be expressed as

$$R_{xx} = A R_{ss} A + \delta^2 I \qquad (6)$$

Consider the case when λ is eigen-vector of Rxx then we define

$$\lambda = \{\lambda_0, \lambda_1, \ldots\ldots \lambda_{N-1}\} \qquad (7)$$

That eigen vector will be satisfied the determinant as follows

$$|R_{xx} - \lambda_i I| = 0 \qquad (8)$$

Substitute (6) into (8), it can be easy to see that the eigenvalue of $ARssA^H$ is

$$v = \{v_i | v_i = \lambda_i - \delta^2\} \ldots\ldots\ldots i = 0,1,\ldots N-1 \quad (9)$$

Because D is less than N then $ARssA^H$ will be positive semidefine with rank D. Thus N-D eigenvalue will be equal to zero or N-D eigenvalue of Rss will be equal σ^2. So, minimum eigenvalue will be determined. Eigenvector associated with that eigenvalue names, q_i , will be solution of

$$(R_{xx} - \lambda_i I) q_i = 0 \ldots\ldots\ldots i = 0, \ldots N-1 \qquad (10)$$

We set

$$A = \{a(\theta_0), a(\theta_1), \ldots a(\theta_{D-1})\} \qquad (11)$$

$$V_n = \{q_i, i = D \ldots N-1\} \qquad (12)$$

Then

$$A^H q_i = 0 \ldots\ldots\ldots i = D, \ldots\ldots\ldots N-1 \qquad (13)$$

The DOA, θ, is the extremes of power spectrum function

$$P(\theta) = \frac{1}{a^H(\theta) V_n V_n^H a(\theta)} \qquad (14)$$

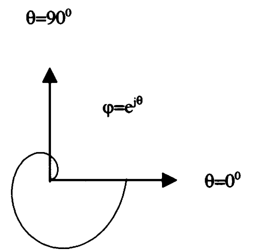

Figure 3: Phase pattern of the second element in polar coordinate

IV. PROPOSED STRUCTURE

The information containing in the array manifold is straightforward. The more array element are used the more information we get. The signal model in part II bases on assuming that array elements are with phase center. In the structure suggested by us, the array elements, in general, are without phase center in azimuth plane [4],[5]. For this example, the structure consists of two elements. One of which is an antenna with phase center (a monopole), its phase pattern is presented in Figure 3 and the other one is without phase center which is combination of two couples of dipoles, its phase pattern is presented in Figure 4. The structure of proposed antenna is depicted in Figure 5. In this case, the phase patterns of the first antenna and the second antenna will be expressed as the functions of azimuth angle (DOA).

$$\varphi_A(\theta) = C \qquad (15) \qquad\qquad \varphi_B(\theta) = \theta \qquad (16)$$

Now the modified streering vector is given by

$$a_M(\theta) = \{1, \exp[-j\varphi_B(\theta)]\} \qquad (17)$$

Then modified power spectrum function will become

$$P_M(\theta) = \frac{1}{a_M^H(\theta) V_n V_n^H a_M(\theta)} \qquad (18)$$

V. SIMULATION RESULTS

The antenna array of simulation consists of two elements with phase patterns expressed by (15) and (16)(Figure 5). For comparision, the simulation has also been done with the conventional linear array of two elements. In our simulation, the original source is sinusoid with frequency of 900MHz and amplitude of 5mV. The simulation is carried out in AWGN channel with SNR be equal 20 dB. In conventional MUSIC algorithm, the power spectrum get the high value at desired DOA whereas low value at the other. The angle of scanning performed from zero degree up to 360 degree. The results of simulation shown that the power spectrum of DOA in proposed structured is higher than conventional linear array (Figure 2). This result is significant when the antenna system working on poor condition in low SNR environment. Especially, with our structure the number of source that can be detected simultaneously is not limited by the number of antenna element.(Figure 1)

VI.CONCLUTIONS

In this paper, a new approach to find the DOA by using an antenna system without phase center and MUSIC algorithm is presented. This antenna system consists of only two antenna elements. Therefore, antenna structure is quite simple and it is idle for manufacturing. When using MUSIC algorithm, the power spectrum for DOA estimation of our structure is higher than linear antenna array. In conventional system the number of source that can be detected simultaneously is limited by the number of antenna element. With our structure, it can overcome that shortcoming.

VII. REFERENCES

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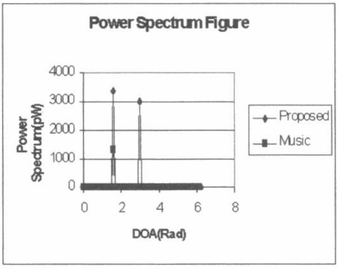

Figure 1: Power spectrum at DOA of 1.6 rad and 3 rad using linear array and the array without phase center.

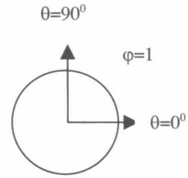

Figure 4: Phase pattern of the first element in polar coordinate

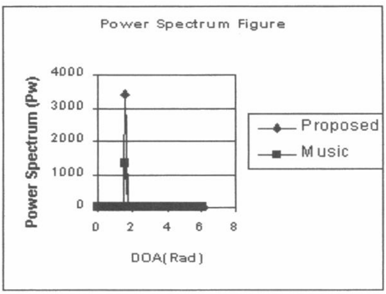

Figure 2: Power spectrum at DOA of 1.6 rad using linear array and the array without phase center.

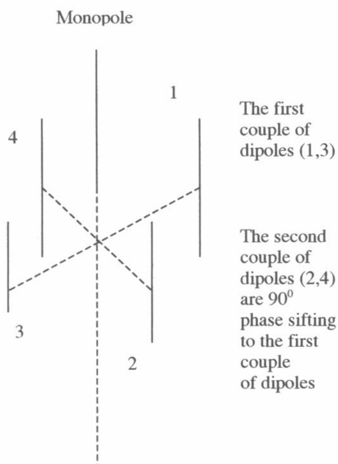

Figure 5: Physical structure of proposed antenna