A Study on Multi-Signal DOA Estimation in Fading Channels

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Abstract—In this study, the proposed algorithm is a correlativity signal in a mobile wireless channel that has estimated the direction of arrival. The proposed algorithm applied the space average method in a MUSIC algorithm. The diagonal matrix of the space average method was changed to inverse the matrix and to obtain a new signal correlation matrix. The existing algorithm was analyzed and compared by applying a proposed signal correlation matrix to estimate the direction of arrival in a MUSIC algorithm.

The experiment resulted in a proposed algorithm with a min-norm method resolution at more than 5°. It improved more than 2° in a MUSIC algorithm.

Index Terms—Array Antenna, MUSIC, Space Average Method, Correlation Matrix, Min-norm Method, Direction of Arrival

I. INTRODUCTION

The signal component cannot be detected in a mobile communication system if the direction of arrival in which the correlation wave is from another direction. An array antenna must be adapted to reduce interference within the signal component.

The adapted array antenna automatically controls the weight of each antenna element in the array in case feeble hope signal wave is received when the arrival direction of the hope signal wave is unknown, or if strong interference wave exists, and forms strong directivity after fast adaptation during a change in the arrival direction of the hope signal wave, and an interference wave direction forms a null point. [1]

The antenna system that is responsible for the SINR of the reception signal must be maximized. Research on the DOA estimation algorithm method regarding estimation signal source arrival and direction of arrival (DOA: Direction of Arrival) from the antenna aligned with space had been used in military, commercial, and social researches. Before this treatise multiplies in weight in line with the reception signal and the costs of the correlation matrix diagonal line to adopt an average, replace this with diagonal line element values and estimation arrival angles after introducing the space average method as the method to stop cross-correlation. This paper is organized as follows. Chapter 2 describes the direction of arrival estimation algorithm. Chapter 3 discusses the results after simulation by the proposed algorithm as well as the conclusion.

II. DOA ESTIMATION ALGORITHM

A. Min-Norm Method

Angle spectrum is obtained by the min-norm method that minimizes linear constraint and output electric power on weight. If the weight average is fixed, it is marked as the following.[2][3]

$$\min_{W} (P_{out} = \frac{1}{2} W^H R_{xx} W) \tag{2.1}$$

subject to $W^H W = 1$

This is changed when the next time evaluation coefficient is minimized by Lagrange's undetermined coefficients method.

$$Q(W) = \frac{1}{2} W^H R_{xx} W + \frac{\lambda}{2}(1 - W^H W) \tag{2.2}$$

Here, λ is an undetermined coefficient. Catch gradient $Q(W)$ about weight value W, and this is approximate to zero in the next time equation.

$$\nabla W Q(W) = R_{xx} W - \lambda W = 0 \tag{2.3}$$

Equation (2.3) presents an eigenvalue problem.

It is an undetermined coefficient λ, R_{xx} relationship, an eigenvalue that increases and can determine that the K number exists. If W^H is adapted from left on both sides of the equation (2.3), it is marked as the following.

$$W^H R_{xx} W = \lambda W^H W = \lambda \tag{2.4}$$

Angle spectrum $P_{MN}(\theta)$ is marked by next time Equation

$$P_{MN}(\theta) = \frac{1}{|W_{MN}^H a(\theta)^2|} \tag{2.5}$$

$W_{MN} : R_{xx}$ minimize eigenvalue eigenvector

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B. MUSIC

The MUSIC (MUltiple SIgnal Classification) method uses eigenvalue and the eigenvector of the correlation matrix of the signal. This time, it can appear as a correlation matrix in the next time equation. [4][5]

$$\begin{aligned} R_{xx} &= E[X(t)X^H(t)] \\ &= ASA^H + \sigma^2 I \end{aligned} \tag{2.6}$$

If eigenvector e_i corresponds to the matrix's eigenvalue $\mu_i (i = 1,2,\cdots,K)$, it is marked as the following.

$$ASA^H e_i = \mu_i e_i \tag{2.7}$$

Corresponding eigenvector is marked as the following.

$$e_i^H e_k = \delta_{ik} \tag{2.8}$$

$(k = 1,2,\cdots K)$ In case thermal noise exists, it is marked as the following.

$$R_{xx} e_i = (ASA^H + \sigma^2 I) e_i \tag{2.9}$$

$$= (\mu_i + \sigma^2) e_i \tag{2.10}$$

Because the eigenvector is orthogonal, it is the orthonormal basis vector of the hermit space of dimension.

$$S = EP\{e_1, e_2, \cdots, e_L\} \tag{2.11}$$

$$N = EP\{e_{L+1}, e_{L+2}, \cdots, e_K\} \tag{2.12}$$

That is, there is space, such as L number direction vector $\{a(\theta_1),\cdots,a(\theta_L)\}$, because it appears as the L number eigenvector, and is expressed by different direction vector linear combinations. Also, its subspace S, N is a signal subspace and noise subspace.

As described, the eigenvector of a $K - L$ number is a min-norm method weight vector.

Therefore, it can compose an angle spectrum by the min-norm method of $K - L$ number [6].

If normalization occurs by multiplying $a^H(\theta)a(\theta)$, it can display an angle spectrum as the following.

$$P_{MU} = \frac{a^H(\theta)a(\theta)}{a^H(\theta)E_N E_N^H a(\theta)} \tag{2.13}$$

III. PROPOSED ALGORITHM

Sub-array draws $N(= K - M + 1)$ from K element linear array to M element. [7][8] Input vector of sub array 1 is marked as the following.

$$X_1(t) = AF(t) + N_1(t) \tag{3.1}$$

$$A = [a(\theta_1), a(\theta_2), \cdots, a(\theta_L)] \tag{3.2}$$

Only, $N_1(t)$ is subarray 1's internal noise vector. This time, input vector of all subarray is marked by next time equation.

$$X_n(t) = AB^{n-1}F(t) + N_n(t) \tag{3.3}$$

($n = 1,2,\cdots N$) Here, matrix B is marked by next time equation.

$$B = diag[v_1, v_2, \cdots v_L] \tag{3.4}$$

$$v_1 = \exp(-j\frac{2\pi}{\lambda} d \sin\theta_l) \tag{3.5}$$

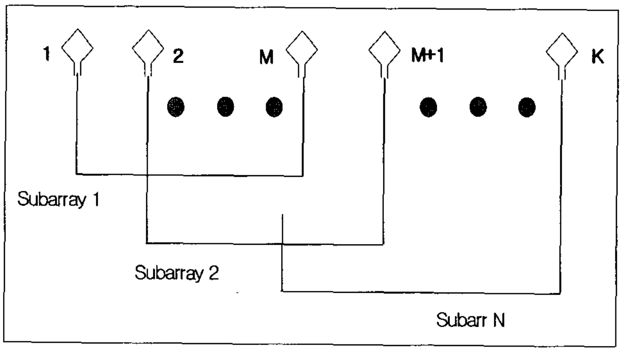

Fig. 1 M Element sub array of K element array

Correlation matrix R_{xx}^n is marked by the next time equation.

$$R_{xx}^n = E[X_n(t)X_n^H(t)] \tag{3.6}$$

Correlation matrix uses the space average method in the next time equation.

$$\overline{R}_{xx} = A\overline{S}A^H + \sigma^2 I \tag{3.7}$$

IV. SIMULATION

These chapters use the min-norm method, MUSIC algorithm, and the proposed algorithm for the purposes of comparison. Arrival direction is 3 by [-20° -15° 30°].

Figure 2 show a graph to estimate arrival direction by the min-norm method. Figure 2 estimates two arrival directions, and resolution decreased. Figure 3 shows a graph that estimates arrival direction by MUSIC algorithm. Three arrival directions were estimated but were not exact, [-20° -15° 30°]

Figure 4 shows a graph estimated by the proposed algorithm in this paper. Three arrival directions were estimated correctly in [-20° -15° 30°].

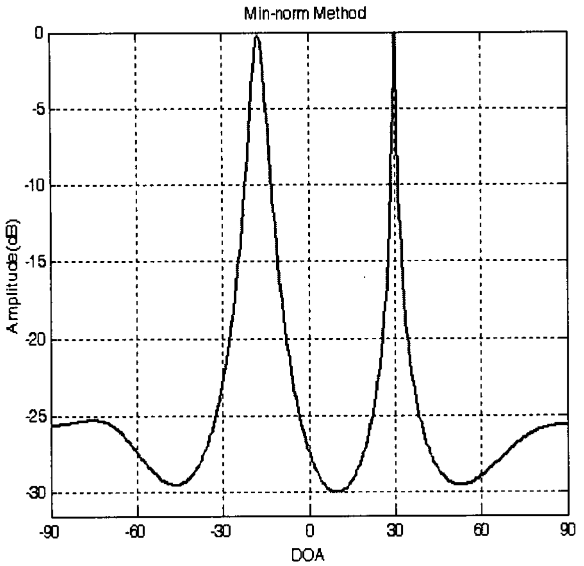

Fig. 2 Min-norm method

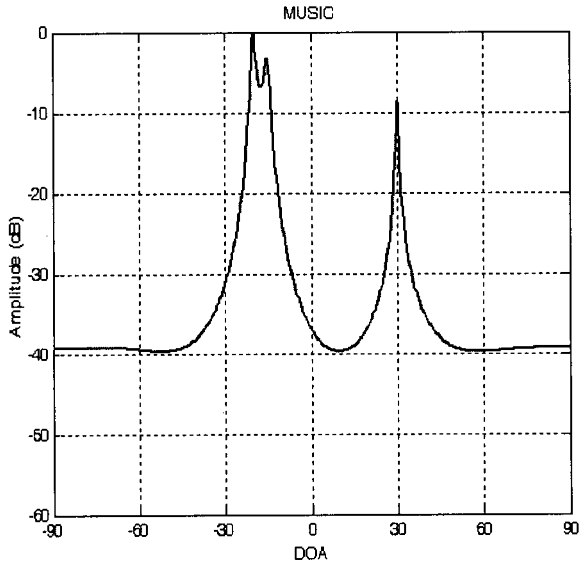

Fig. 3 MUSIC Algorithm

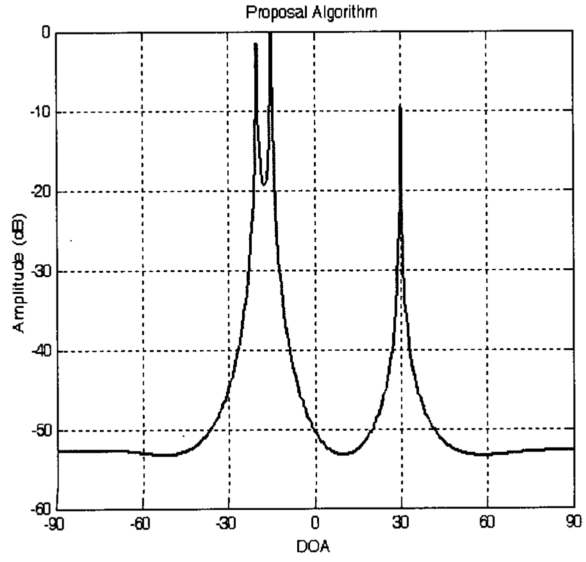

Fig 4. Proposed Algorithm

V. CONCLUSIONS

This research presented an estimated algorithm and an estimated arrival direction in case there was signal correlation.

The min-norm method resulted in a 6° difference and estimated two arrival directions.

The MUSIC algorithm estimated three arrival directions, but did not express correct values, and if the signal source increased, resolution decreased. The proposed algorithm in this paper proved that existing DOA algorithm correctly estimated three arrival directions whose resolutions were superior. This paper estimated signal source arrival direction by 5°, even if the signal source number increased. Hereafter, algorithms that estimate arrival direction by 4° lower should be studied.

REFERENCES

[1] D.C.Cox, “Delay Doppler characteristics of Multipath Propagation at 910MHZ in a Surban Mobile Radio Enviroment”, IEEE Trans AP, vol. AP-20, No.5, 1972, pp.625-635.

[2] H.Krim and M.Viberg, “Two Decades of Array Signal Processing Research-The Parametric Approach-,” IEEE SPM, vol.13, no.4, 1996, pp.67-94.

[3] V.F.Pisarenko, “The Retrieval of Harmonics from Covariance Functions,” Geophys, J.Roy. Astron. soc. vol.33, 1973, pp.347-366.

[4] R.O.Schmidt, “Multiple Emitter Location and Signal Parameter Estimation,” IEEE Tran AP, Vol.34, No.3, 1986, pp.276-280.

[5] Takashi Miwa, Ikuo arai, “Super-Resolutin Imaging for point Reflectors Near Transmitting and Receivering Array,” IEEE Tran, AP, vol.52, no.1, 2004, pp.220-230.

[6] Y.Ogawa, N,Hanmaguchi, K.Ohshima, and K.Itoh, “High-Resolution Analysis of Indoor Multipath Propagation Structure,” IEICE Trans. com. vol.E78-B, no.11, 1995, pp.1450-1457.

[7] R.T.Williams, “An Improed Spatial Smothing Technique for Bearing Estimation in a Multipath Enviroment,” IEEE Tran AP, Vol.36, No.4, 1988, pp.425-432.

[8] T.J.Shan, “On Spatial Smoothing for Direction- of-Arrival Estimation of Coherent Signal,” IEEE Tran ASSP, Vol.33 ,No.3, 1985,pp.806-811.

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