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Edited by

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Message from the CIVS 2010 Conference Chairs

We are pleased to announce that 2010 International Conference on Computational Intelligence and Vehicular System (CIVS2010) will be held in Cheju, Korea (South), November 22-23, 2010. The CIVS2010 will provide opportunities for the delegates to exchange new ideas and application experiences face to face, to establish business or research relations and to find global partners for future collaboration. With a great number of famous scientists around the world attending this Congress, we are sure there will be many useful and significant conclusion and agreements on Computer-aided Manufacturing and Design.

CIVS 2010 is a leading conference on Computational Intelligence and Vehicular System. The goal of this conference is to provide a forum for participants from industry, academic, and non-profit organizations to exchange innovative ideas on intelligent vehicles, their systems, and related manufacturing processes. We welcome papers from all areas of computational intelligence demonstrating applications of theoretical advances to modern and future vehicles and vehicular systems (engine, transmissions, actuators, sensors, networks, communications, interfaces, etc.) and related manufacturing technologies. Although the focus of the symposium is on the application aspects of CI, papers describing simulation-only results are also solicited.

The conference will include invited talks, workshops, tutorials, and other events dedicated to this theme. Welcome to CIVS 2010 Conference. Welcome to Cheju, Korea (South). 2010 International Conference on Computational Intelligence and Vehicular System (CIVS2010) is co-sponsored by Intelligent Information Technology Application Research Association, Hong Kong.

We hope that CIVS 2010 will be successful and enjoyable to all participants. We look forward to seeing all of you next year at the CIVS 2011.

Li Jian, Hubei University of Education, China

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CIVS 2010 Contents

2010 International Conference on Computational Intelligence and Vehicular System (CIVS)

Direction-Of-Arrival Estimation using Special Phase Pattern Antenna Elements in Uniform Circular Array*

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***Abstract* - A theory model in which Uniform Circular Array (UCA) using special antenna elements for Direction of Arrival (DOA) estimation is presented. Simulation results show that although the number of incident sources is larger than the number of antenna elements, DOA spectrum using the proposed antenna model is still better than one using UCA with traditional antenna elements.**

Index Terms* - *Direction of Arrival (DOA), Uniform Linear Array (ULA), Uniform Circular Array (UCA), Multiple Signal Classification (MUSIC).

I. INTRODUCTION

DOA estimation is very important in smart antenna designing and direction finding. In most of the research papers and real systems, the popular antenna array structures in DOA systems are ULA and UCA with simple antenna elements, such as dipoles.

The accuracy of DOA estimation in 360^0 range with ULA and UCA structures is usually dependent on the number of elements in array and elements arrangement. The more element number is large, the more accuracy is high. With UCA structure, unique disadvantage is: the algorithm can not detect sources if the number of antenna elements is not large enough (smaller or little larger than the number of incident sources).

To increases accuracy and overcomes the disadvantage in DOA estimation using UCA with traditional elements, we introduce a theory model using new antenna element structure for UCA. It will be described in next sections in details.

In this paper, we used well-known Multiple Signal Classification (MUSIC) algorithm [1] to estimate DOA for UCA in traditional elements case and proposed elements case. After that, different spatial spectrum results of these structures will be compared and discussed.

The paper is organized as follows. Section II presents an overview description of system, proposed element structure and detailed data model analysis. Simulation results and discussion are given in section III. Section IV is a short conclusion. MUSIC algorithm is given in Appendix in detail.

II. SYSTEM DESCRIPTION, THEORY MODEL OF PROPOSED ANTENNA ARRAY STRUCTURE AND DATA MODEL

A. Overview System Description

Fig. 1 shows the model of DOA estimation system with general antenna array structure.

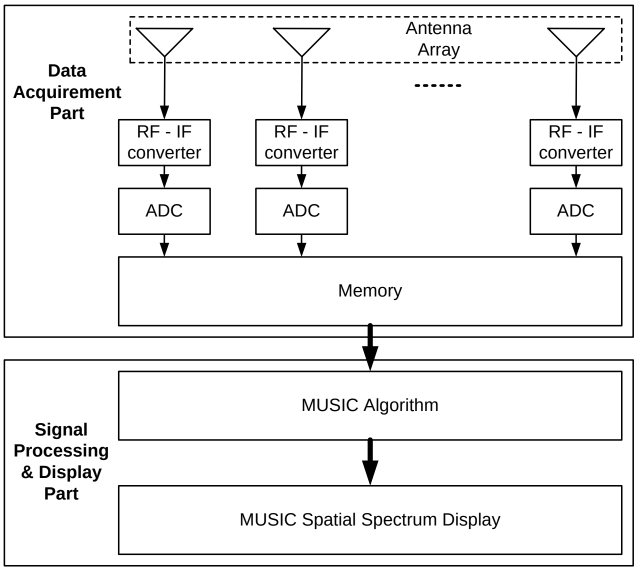

Fig. 1 DOA estimation system with general antenna structure

The system has two parts: Data Acquirement part and Signal Processing & Display part. The former includes antenna array, RF-IF converter and ADC. The later includes MUSIC algorithm and result display.

B. Theory model of Proposed Antenna Element for UCA

Model and phase pattern of a traditional element (dipole) is showed in Fig 2.

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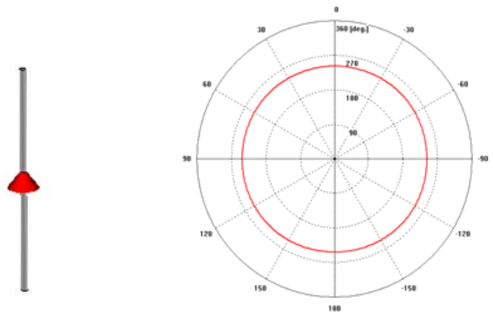

(a) (b)

Fig. 2 Model (a) and phase pattern (b) of traditional element

According to [2], special phase patterns can be created by dipoles combine. One of them is showed in Fig. 3

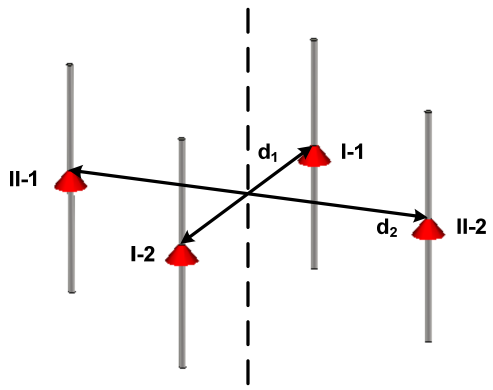

Fig. 3 One of structures which has special phase pattern

where: d_1 is the distance between I-1 and I-2 dipoles and d_2 is the distance between II-1 and II-2 dipoles.

TABLE 1
PARAMETERS OF ANTENNA ELEMENTS IN FIG.3

I-1 Dipole amp/phase excitation	I-2 Dipole amp/phase excitation	II-1 Dipole amp/phase excitation	II-2 Dipole amp/phase excitation	d1	d2
$1/90^0$	$1/270^0$	$1/0^0$	$1/180^0$	0.5λ	λ

where λ is the operation wavelength.

With parameters in Table 1, the special phase pattern is presented in Fig.4

Compare with traditional element, proposed element has phase pattern is very specially different from traditional element. It has nonlinear form and can be expressed by [2]:

$$\Phi(\theta) = arctg\left[\frac{\sin\left(\frac{k\lambda}{2}\sin\theta\right)}{\sin\left(\frac{k0.5\lambda}{2}\cos\theta\right)}\right] \quad (1)$$

where θ is the direction of propagation, k is the wave number.

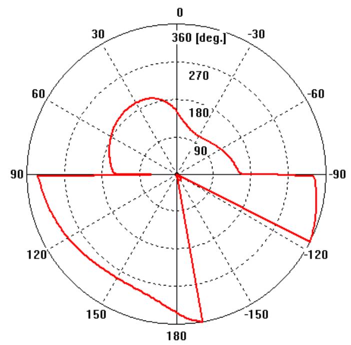

Fig. 4 Phase Pattern of the Proposed Element

C. UCA with Proposed Elements

Proposed antenna element which includes 4 dipoles in Fig.3 can be considered as one element with phase pattern likes in Fig.4.

Then, UCA with proposed elements is shown in Fig.5.

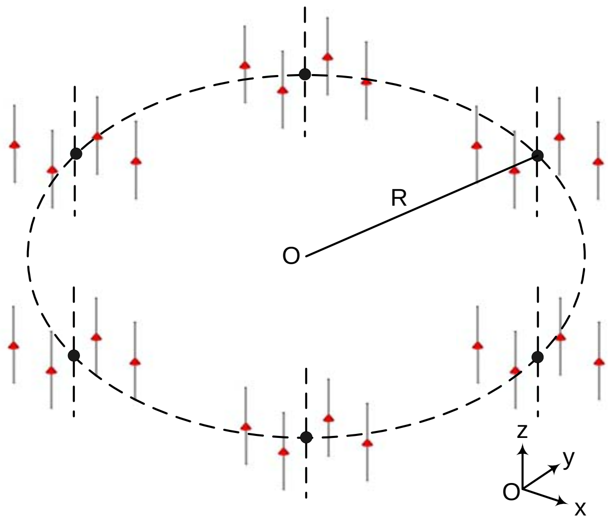

Fig. 5 UCA with 6 Proposed Antenna Elements

where R is the radius of circular.

D. Data model Analysis

Assume that amplitude pattern of each proposed element is constant; the number of elements in UCA is N. Data model can be described as follows:

The antenna array receives signals from L narrowband sources, which are randomly distributed in the xy-plane in the far field of antenna array. Phase patterns of proposed elements are rotated step by step by electrically control system. Each step is considered as N elements in general antenna array. The array steering vector of θ_i direction is expressed as:

$$\mathbf{a}(\theta_i) = [\mathbf{a}_1(\theta_i) \;\; \mathbf{a}_2(\theta_i) \;\; \ldots \;\; \mathbf{a}_M(\theta_i)]^T \quad (2)$$

where

$$\mathbf{a_1}(\theta_i)=\begin{bmatrix} e^{j\Phi(\theta_i)} & e^{j\left[\Phi(\theta_i)+\frac{2\pi}{\lambda}R\cos\left(\theta_i-2\pi\frac{1}{N}\right)\right]} & \dots & e^{j\left[\Phi(\theta_i)+\frac{2\pi}{\lambda}R\cos\left(\theta_i-2\pi\frac{N-1}{N}\right)\right]}\end{bmatrix}$$

$$\mathbf{a_2}(\theta_i)=\begin{bmatrix} e^{j\Phi(\theta_i+\Delta\theta)} & e^{j\left[\Phi(\theta_i+\Delta\theta)+\frac{2\pi}{\lambda}R\cos\left(\theta_i-2\pi\frac{1}{N}\right)\right]} & \dots & e^{j\left[\Phi(\theta_i+\Delta\theta)+\frac{2\pi}{\lambda}R\cos\left(\theta_i-2\pi\frac{N-1}{N}\right)\right]}\end{bmatrix}$$

$$\mathbf{a_M}(\theta_i)=\begin{bmatrix} e^{j\Phi(\theta_i+(M-1)\Delta\theta)} & e^{j\left[\Phi(\theta_i+(M-1)\Delta\theta)+\frac{2\pi}{\lambda}R\cos\left(\theta_i-2\pi\frac{1}{N}\right)\right]} & \dots & e^{j\left[\Phi(\theta_i+(M-1)\Delta\theta)+\frac{2\pi}{\lambda}R\cos\left(\theta_i-2\pi\frac{N-1}{N}\right)\right]}\end{bmatrix}$$

M-1 is the number of rotated steps, $\Delta\theta$ is rotated angle.

The acquired data after (M-1)th step is given by:

$$\mathbf{x}(t)=\sum_{i=1}^{L}\mathbf{a}(\theta_i)s_i(t)+\mathbf{n}(t) \quad (3)$$

where $s_i(t)$ is source at θ_i direction which is assumed that uncorrelated with the others, $\mathbf{n}(t)$ is noise vector which is modeled as temporally Additive White Gaussian Noise (AWGN).

After that, MUSIC algorithm is used to estimate DOAs as follows:

The covariance matrix of $\mathbf{x}$ (temporal averaging over K snapshots) [4] is given by:

$$\hat{\mathbf{R}}_{\mathbf{xx}}=\frac{1}{K}\sum_{k=0}^{K-1}\mathbf{x}_k\mathbf{x}_k^H \quad (4)$$

where $(.)^H$ denotes complex conjugate transpose.

The idea of MUSIC algorithm bases on eigenvectors and eigenvalues of $\hat{\mathbf{R}}_{\mathbf{xx}}$: the eigenvectors corresponding to the smallest eigenvalues form the noise subspace and also orthogonal to the steering vectors [3]. Therefore, MUSIC spatial spectrum is expressed as:

$$\mathbf{P}_{\mathbf{MUSIC}}(\theta)=\frac{\mathbf{a}^H(\theta)\mathbf{a}(\theta)}{\mathbf{a}^H(\theta)\mathbf{U_n}\mathbf{U_n}^H\mathbf{a}(\theta)} \quad (5)$$

where $\mathbf{U}_n$ is the matrix which includes eigenvectors of noise subspace. Orthogonality between steering vectors and $\mathbf{U}_n$ will minimize the denominator of (5) and hence it will make up peaks in MUSIC spectrum. These peaks will correspond to the DOAs of the sources [3].

III. SIMULATION RESULTS AND DISCUSSION

The simulation is carried out for UCA with traditional elements and UCA with proposed elements over 1000 snapshots. After that, performance of MUSIC algorithm using these antenna array structures will be compared each other. Some discussion will be presented at the end of this section.

A. Simulation Results

Simulation Parameters are described in table 2.

Fig. 6 illustrates the spatial spectrum for UCA with traditional elements and UCA with proposed elements. As shown, the former estimated 16 peaks with 1 desired peak, 15 undesired peaks and all peaks are not sharp. Meanwhile, the latter estimated 24 desired peaks with 5^0 resolution and all peaks are sharp.

TABLE 2
SIMULATION PARAMETERS

Parameters	UCA with traditional elements	UCA with proposed elements
Element Number	24 elements = 24 dipoles	6 elements = 24 dipoles (Rotated Step number: 100; Rotated Angle: 2^0)
Element Distance	$\lambda/2$ (no mutual coupling between arbitrary two dipoles)	App. 2λ (no mutual coupling between arbitrary two dipoles)
UCA Radius	$24\frac{\lambda}{2}\frac{1}{2\pi}$	$24\frac{\lambda}{2}\frac{1}{2\pi}$
Source Number	24	24
Source SNR (dB)	20	20
DOA (degree)	[5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120]	[5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120]

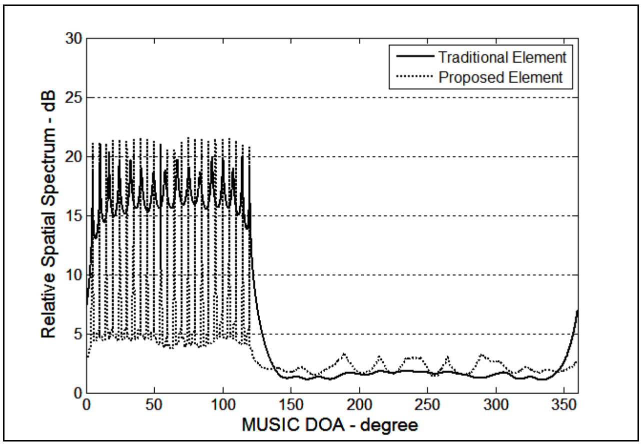

Fig. 6 MUSIC spatial spectrum

B. Discussion

According to introduction section, MUSIC algorithm using UCA with proposed elements can estimate DOAs in spatial spectrum exactly although the number of incident sources is approximate or larger than the number of antenna elements. The simulation result in Fig. 6 illustrated this idea.

The reason of the results can be explained as follows: Theory DOA estimation of proposed structure is similar to UCA with traditional elements. To increase accuracy and can detect sources in case the number of antenna elements is not large enough, the proposed method made increase the number of elements by rotation phase pattern of proposed elements. Each phase pattern rotated step of proposed elements is corresponding to making up N traditional elements in UCA. Therefore, after M-1 rotated steps, proposed structure makes up MxN elements.

A limitation of this DOA method is amplitude pattern of proposed element has not been considered in detail yet. (In II.D part, we assumed that it is constant).

However, UCA using nonlinear phase pattern antenna elements still has meaning in looking for a DOA estimation method which has the number and accuracy of DOA peaks in spatial spectrum do not depend on the number of real antenna elements.

IV. CONCLUSION

DOA estimation algorithm (MUSIC) using UCA with new antenna element structure was investigated and compared with traditional UCA structure. Investigation results assert once again that: proposed antenna structure can be used to estimate DOAs exactly in case the number of antenna elements is not large enough. In the future work, we will consider impact of amplitude pattern on accuracy of DOA spectrum and look for a real antenna element model which has the most optimal amplitude and phase pattern.

APPENDIX

A. MUSIC algorithm with general antenna model [5]

Assume that: in 2D spatial coordinates, there is a narrowband signal impinges on the l^{th} antenna element like in Fig. 7.

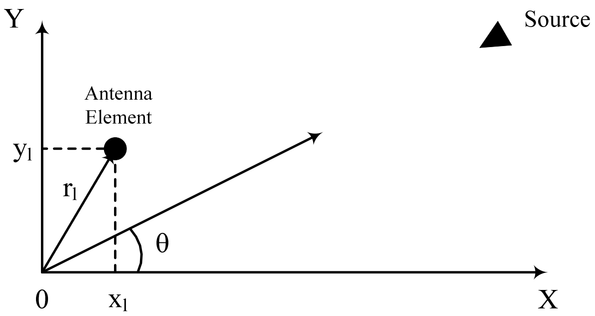

Fig. 7 General antenna model

The output is modeled by:

$$\begin{aligned} x_l(t) &= g_l(\theta)e^{-jk(x_l\cos\theta + y_l\sin\theta)}s(t) + n(t) \\ &= a(\theta)s(t) + n(t) \end{aligned} \quad (6)$$

with $g_l(\theta)$ is radiation pattern of l^{th} antenna element.

If M signals impinge on L sensors in the presence of an additive noise $\mathbf{n}(t)$ and assume that $g_l(\theta)$ is constant then the outputs of antenna elements are:

$$\mathbf{x}(t) = \mathbf{A}(\theta)\mathbf{s}(t) + \mathbf{n}(t) \quad (7)$$

where:

$\mathbf{x}(t) = [x_1(t), x_2(t), ..., x_L(t)]^T$ is signal vector at antenna elements.

$\mathbf{A}(\theta) = [\mathbf{a}(\theta_1), \mathbf{a}(\theta_2), ..., \mathbf{a}(\theta_M)]$ is steering matrix

$\mathbf{a}(\theta) = [a_1(\theta), a_2(\theta), ..., a_L(\theta)]^T$ is steering vector

$\mathbf{s}(\theta) = [s_1(t), s_2(t), ..., s_M(t)]^T$ is source vector

$\mathbf{n}(t) = [n_1(t), n_2(t), ..., n_L(t)]^T$ is noise vector

MUSIC algorithm is expressed as follows:

Step1: Calculate Spatial Covariance Matrix

$$\begin{aligned} \mathbf{R} &= \mathrm{E}\{\mathbf{x}(t)\mathbf{x}^H(t)\} = \mathbf{A}\,\mathrm{E}\{\mathbf{s}(t)\mathbf{s}^H(t)\}\mathbf{A}^H + \mathrm{E}\{\mathbf{n}(t)\mathbf{n}^H(t)\} \\ &= \mathbf{APA}^H + \sigma^2\mathbf{I} \end{aligned} \quad (8)$$

with

$$\mathrm{E}\{\mathbf{s}(t)\mathbf{s}^H(t)\} = \mathbf{P} \quad (9)$$

$$\mathrm{E}\{\mathbf{n}(t)\mathbf{n}^H(t)\} = \sigma^2\mathbf{I} \quad (10)$$

Step2: Decomposition Spatial Covariance Matrix

$$\mathbf{R} = \mathbf{APA}^H + \sigma^2\mathbf{I} = \mathbf{U}\Lambda\mathbf{U}^H \quad (11)$$

with $\mathbf{U}$ is unitary and $\Lambda = diag\{\lambda_1, \lambda_2, ..., \lambda_L\}$ which $\lambda_1 \geq \lambda_2 \geq ... \geq \lambda_L > 0$.

Depend on eigenvalues with $\lambda_1 \geq \lambda_2 \geq ... \geq \lambda_M > \sigma^2$, $\lambda_{M+1} \approx \lambda_{M+2} \approx ... \approx \lambda_L \approx \sigma^2$, we can partition the eigenvalue/eigenvector pairs into signal and noise subspaces.

So, we can write (11) into:

$$\mathbf{R} = \mathbf{U_s}\Lambda_\mathbf{s}\mathbf{U_s}^H + \mathbf{U_n}\Lambda_\mathbf{n}\mathbf{U_n}^H \quad (12)$$

From (11) and (12) we have:

$$\mathbf{R} = \mathbf{APA}^H + \sigma^2\mathbf{I} = \mathbf{U_s}\Lambda_\mathbf{s}\mathbf{U_s}^H + \mathbf{U_n}\sigma^2\mathbf{U_n}^H \quad (13)$$

From (13), if $\mathbf{APA}^H$ is full rank then eigenvectors $\mathbf{U_n}$ in noise subspace are orthogonal to $\mathbf{A}$. So we can write:

$$\mathbf{U_n}^H\mathbf{a}(\theta) = 0 \quad (14)$$

with $\theta \in \{\theta_1, \theta_2, ..., \theta_M\}$

Step3: Calculate MUSIC spatial spectrum

$$\mathbf{P_{MUSIC}}(\theta) = \frac{\mathbf{a}^H(\theta)\mathbf{a}(\theta)}{\mathbf{a}^H(\theta)\mathbf{U_n}\mathbf{U_n}^H\mathbf{a}(\theta)} \quad (15)$$

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