International Journal of Science and Technology Volume 2 No. 7, July, 2013

Direction of Arrival Estimation of Radio Frequency Signals and Number of the Receiving Antenna Elements

Nsionu Ifeanyi ; Idigo Victor
Computer Engineering Department, Federal Polytechnic
Umunze Road ,Anambra, Oko, Nigeria

ABSTRACT

The degree of response of a receiving adaptive antenna array to signals arriving at its terminals can be varied by changing the number of elements and processing of the outputs of the individual elements. The combination of the elements and signal processing act as filter in space. In this paper, the authors present the results of simulation as they investigate the impact on signal Direction of Arrival (DOA) estimation of the number of elements. The technique used is the subspace-based and eigen-analysis method of Multiple Signal Classification which is an efficient algorithm for real time optimization of signal/interference relation in mobile wireless communication.

Keywords: *adaptive antenna array, direction of arrival, multiple signal classification*

1. INTRODUCTION

Adaptive antenna systems are meant to monitor continuously their areas of coverage with a view to adapting to the movement of the mobile terminals and providing an antenna pattern that follows the users. A smart antenna system or adaptive antenna combines multiple antenna elements with signal processing capability to optimize its radiation pattern automatically in response to the signal environment.

2. PROBLEM SETUP

Let us consider 4 signals impinging on *M* element arrays with constant element spacing of 0.5λ, where λ is the wavelength that corresponds to the carrier frequency. Let the directions of arrival of the signals be $\theta_1 = 14^o, \theta_2 = 28^o, \theta_3 = 35^o and \theta_4 = 55^o$

The goal of DOA estimation is to use data at array to estimate $\theta_1, \theta_2, \theta_3 and \theta_4$.

We shall vary the number of array elements from 8 to 32 in order to study the effect of this variation on the accuracy of DOA estimation.

3. METHODOLOGY

This paper considers the adoption of the subspace based method MUSIC which stands for Multiple Signal Classification. The space is divided into signal and noise subspace and MUSIC exploits the noise eigenvector subspace. The noise space is spanned by eigenvectors corresponding to the smallest eigenvalues of the array correlation matrix. Given that D signals impinge on M elements; the number of signal eigenvalues and eigenvectors is D, and the number of noise eigenvalues and eigenvectors is M – D. This technique is outlined in [1]. The array correlation matrix, R_{xx} is given by

$$R_{xx} = A * R_{ss} * A^H + \sigma_n^2 I$$

Where R_{ss} = source correlation matrix

$R_{nn} = \sigma_n^2 I$ = noise correlation matrix

$A = [a(\theta_1) \quad a(\theta_2) \quad a(\theta_3) .... \quad a(\theta_D)]$ is an $M \times D$ steering vector.

$R_{ss} = [s_1(k) \quad s_2(k) \quad s_3(k) ... \quad s_D(k)]^T$ *is* a $D \times D$ matrix.

The array correlation matrix has D eigenvectors associated with signals and $M - D$ eigenvectors associated with noise. The subspace $M \times (M - D)$ is spanned by the noise vectors such that

$$E_N = [e_1 \quad e_2 \quad e_3 \quad e_{M-D}]$$

Noise space eigenvectors are orthogonal to the steering vectors at the angles of arrival $\theta_1, \theta_2, \theta_3 ......, \theta_D$. MUSIC formula from the point of view of orthogonality condition, can be shown to be [2]

$$P_{music} = \frac{1}{\left|[a(\theta)^H \cdot E_N \cdot E_N^H \cdot a(\theta)]\right|}$$ which yields sharp peaks at the angles of arrival.

4. SIMULATION

The MUSIC technique is simulated using Matlab. The simulation was run for 4 signals coming from different directions as listed in the problem setup and which impinge on the M- element array. To run the program, it has to be ensured that all files regarding the Music algorithm are in the same directory. The MAIN programme is run in Matlab. The number of elements is entered, spacing between elements, number of desired signals with their corresponding angles of arrival. The program gives the estimated number of signals as output along with the array pattern plots. All that is required is to obtain the values of the highest peaks to get the direction of arrival [3].

5. RESULTS

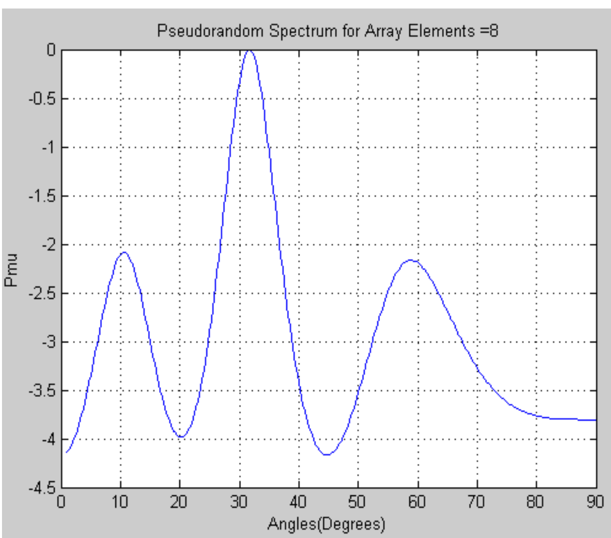

Fig. 1: Plot for estimated directions of arrival $\theta = 14^o, 28^o, 35^o, 55^o$ along the peak of music spectra for 8-element array

Comment: Fig. 1 shows clearly the plot for 4 signals with their respective angles of arrival $\theta = 14^o, 28^o, 35^o$ *and* 55^o using 8 elements array. It can be observed that the final output of the system does not reflect the exact angles of arrival. Only 3 of the signals were identified as shown in the table below

Desired θ	**14**	**28**	**35**	**55**
Output θ	9	-	32	57

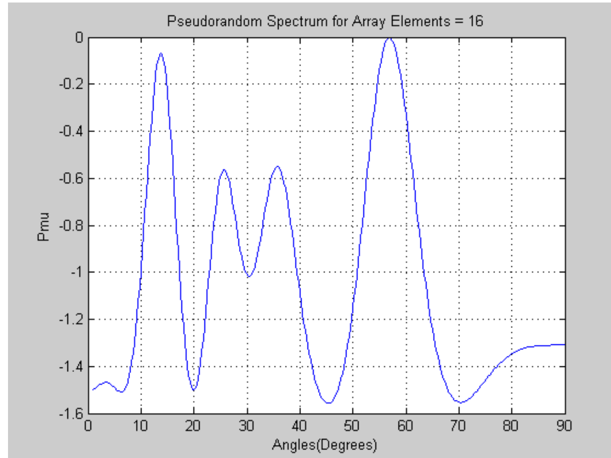

Fig.2: Plot for estimated directions of arrival $\theta = 14^o, 28^o, 35^o, 55^o$ along the peak of music spectra for 16-element array

Comment: Fig. 2 shows the plot of the same 4 signals from their same directions using 16 array elements. Here, there is improved resolution of the direction of arrival. Only 2 of the angles are in disagreement slightly as shown.

Desired θ	14	28	35	55
Output θ	14	28	36	57

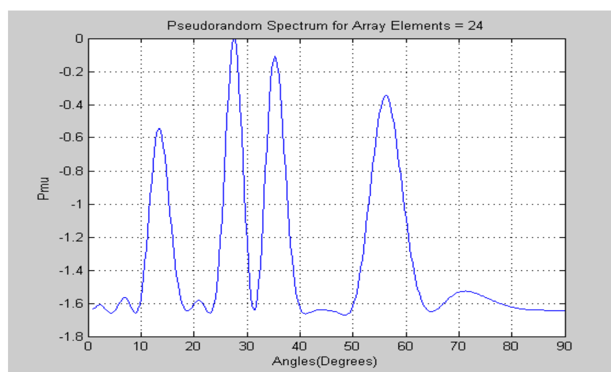

Fig.4: Plot for estimated directions of arrival $\theta = 14^o, 28^o, 35^o, 55^o$ along the peak of *music* spectra for 24-element array

Comment: Fig.4 shows the output with 24 array elements. The smart antenna system here very closely reflects the desired directions of the 4 signals represented very distinctly on the plot.

Desired θ	14	28	35	55

Output θ	14	28	35	56

Fig.5 shows an improved output of the system as it seeks to identify the 4 signals. The number of elements is 32. All the angles of arrival, as may be seen in the table below, are resolved.

Desired θ	14	28	35	55
Output θ	14	28	35	55

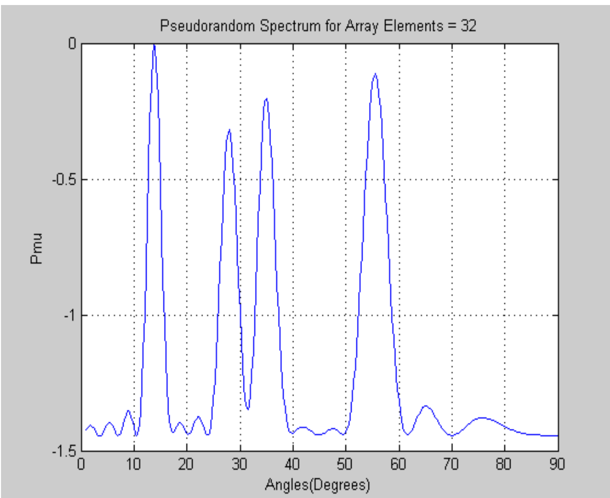

Fig.5: Plot for estimated directions of arrival $\theta = 14^o, 28^o, 35^o, 55^o$ along the peak of music spectra for 32-element array

6. Summary

The observed effect on DOA estimation of variation of the number of array elements is such that increasing the number of elements leads to an improvement in angle resolution for multiple sources. If the number of signals is large, then a higher element array will predict better the directions of arrival of the desired signals. However, there is a limit to the number of array elements for a particular operation. It should be noted that the more the elements the more power the system will demand.

REFERENCES

[1] Frank Gross, "Smart Antennas for Wireless Communications" with Matlab by McGraw-Hill Companies Inc. 2005

[2] Nikhil Shetty, "Direction of Arrival Estimation Algorithms" April 7 2004

[3] Nsionu I I ," Improving GSM Network Capacity Using Smart Antenna System" 2012