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Simulation study on DOA estimation using MUSIC algorithm

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***Abstract*- Smart antennas is based on digital signal processing algorithms. The smart antennas system becomes capable to locate and track signals by the both: users and interferers and dynamically adapts the antenna pattern to enhance the reception in Signal-Of-Interest direction and minimizing interference in Signal-Of-Not-Interest direction. Performance of smart antenna system greatly depends on efficiency of digital signal processing algorithms In adaptive array smart antenna, to locate the desired signal, various direction of arrival (DOA) estimation algorithms are used. The DOA algorithms estimate the number of incidents plane waves on the antenna array and their angle of incidence. This paper investigates performance of the DOA algorithm MUSIC on the uniform linear array . The simulation results show that in MUSIC algorithm the resolution of the DOA techniques improves as number of snapshots, number of array elements and signal-to-noise ratio increases.**

***Index terms*: Smart antenna, Adaptive array DOA, MUSIC.**

I. INTRODUCTION

The smart antenna technology is based on antenna arrays where the radiation pattern is altered by adjusting the amplitude and relative phase on the different elements. If several transmitters are operating simultaneously, each source creates many multipath components at the receiver and hence receive array must be able to estimate the angles of arrival in order to decipher which emitters are present and what are their angular locations.[1] This information in turn can be used by the smart antenna to eliminate or combine signals for greater fidelity or suppress interferers to improve the capacity of cellular mobile communication.[3]

Accurate estimation of a signal direction of arrival (DOA) has received considerable attention in communication. In practice, the estimation is made difficult by the fact that is usually an unknown numbers of signals impinging on the array simultaneously, each from unknown directions and with unknown amplitudes. Also, the received signals are always corrupted by noise.[2][3] Nevertheless, there are several methods to estimates the number of signals and their directions. The various DOA estimation algorithms are Bartlett, Capon Min-norm, MUSIC and ESPRIT. But MUSIC and ESPRIT algorithms are high resolution and accurate methods which are widely used in the design of smart antennas. The popularity of MUSIC is more due to its accuracy & robust approach. We present detailed MATLAB simulation results for MUSIC algorithm.[7]

II. DOA ESTIMATION ALGORITHMS

The purpose of DOA estimation is to use the data received by the array to estimate the direction of arrival of the signal.

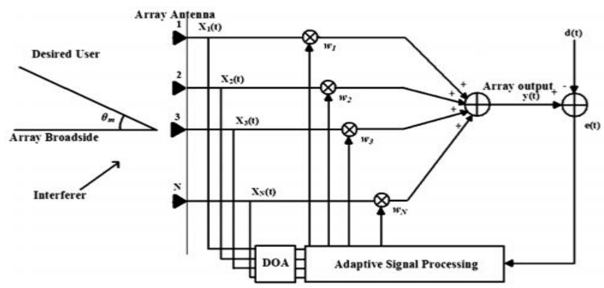

Fig. 1: Block Diagram of a Smart Antenna System

As shown in fig.1 It is an antenna system that can modify its beam pattern by means of internal feedback control while it is operating. The directions of users and interferers are obtained using a direction-of-arrival (DOA) estimation algorithm. DOA estimation are then used by the array to design the adaptive beam former in such way as to maximize the power radiated towards the users and to suppress the interference. In short the successful design of adaptive array smart antenna depends highly on the performance of DOA estimation algorithm. In the design of adaptive array smart antenna for mobile communication the performance of DOA estimation algorithm depends on many parameters such as number of mobile users and their space distribution , the number of array elements and their spacing, the number of signal samples and SNR.[2][4]

Conventional methods also called classical methods which first compute a spatial spectrum and then estimate DOAs by local maxima of the spectrum. Hence high angular resolution subspace methods such as MUSIC and ESPRIT algorithms are most widely used.[6]

III. MUSIC *Algorithm*

MUSIC is an acronym which stands for Multiple Signal classification. It is high resolution technique based on exploiting the eigenstructure of input covariance matrix. This approach was first posed by Schmidt. It is a simple, popular high resolution and efficient Method. It promises to provide unbiased estimates of the number of signals, the angles of arrival and the strengths of the waveforms.[5][11]

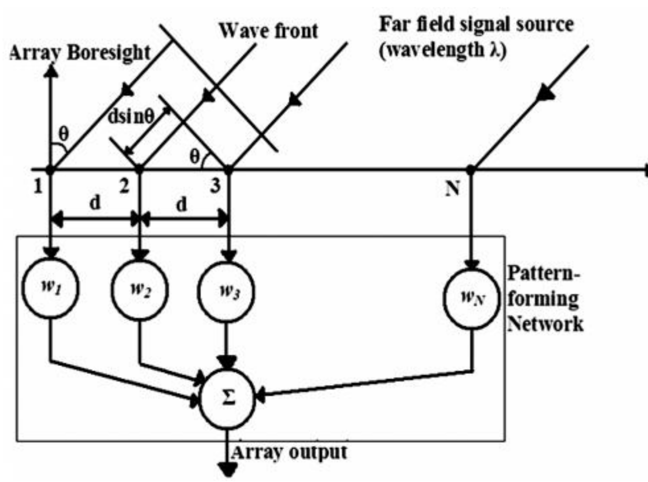

Fig. 2: Geometry of a Uniform Linear Array

If the number of signals impinging on N element uniform liner array as shown in fig.2 is D, the number of signal eigenvalues and eigenvectors is D and number of noise eigenvalues and eigenvectors is N - D. The array correlation matrix with uncorrelated noise and equal variances is then given by

$R_{xx}= A*R_{ss}*A^H + 6^{2*}I$ (1)

Where A= [a(θ1) a(θ2) a(θ3) --- a(θD)] is M x D array steering matrix.

H denotes harmition transpose or conjugate transpose

R_{SS} = $[s_1(k)\ s_2(k)\ s_3(k)\ ----\ s_D(k)]^T$ is D x D source correlation matrix.

□$_n^2$ is the variance of noise & I is the identity matrix

R_{XX} has D eigenvectors associated with signals and N–D

eigenvectors associated with the noise. We can then construct the N x (N-D) subspace spanned by the noise eigenvectors such that

$E_N = [E_1\ E_2\ E_2 ------- E_{N-D}]$ (2)

The noise subspace eigenvectors are orthogonal to array steering vectors at the angles of arrivals θ_1, θ_2, θ_3, θ_D and the MUSIC Pseudospectrum is given as

$$P_{MUSIC(\theta)} = 1/abs((a(\theta)\theta_H\ E_N\ E_N^H\ a(\theta))$$

However when signal sources are coherent or noise variances vary the resolution of MUSIC decreases to overcome this we must collect several time samples of received signal plus noise. The natural estimate the correlation matrices via time averaging is then given by[8][9][10]

$$R_{XX} = \sum_{K=1}^{K} X(K) * X(K)^H$$

The MUSIC Pseudospectrum using with time averages now provides high angular resolution for coherent signals.

III. SIMULATION RESULTS

The effect of changing different parameters on the performance of the MUSIC algorithms has been investigated. A *uniform linear array* structure has been considered in our simulation experiments and all inputs were made fixed when the effect of changing a parameter value was investigated.

In these simulations, it is considered a linear array antenna that are evenly spaced with the distance of λ / 2 . The noise is considered to be additive gaussian white noise. It is considered that two signals are emitted from two sources placed on the directions Θ_1= - 14^o and Θ_2 = +35^o,& having amplitudes 0.5 & 1 respectively .

Case 1: The first parameter that was analyzed is the number of snapshots , fig.1(a) shows MUSIC peaks with K=50 with keeping SNR and N at 20 and 4 respectively.

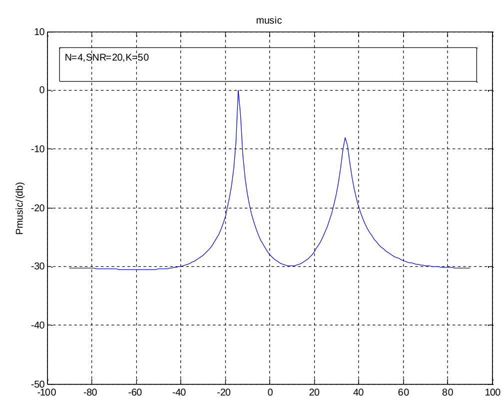

Fig .1(a) DOA's with reduced number of signal snapshots

With keeping the SNR & N constant samples fig 1(b) shows the effect of increasing the l samples of incident signal, we will get sharper peaks with K=400.

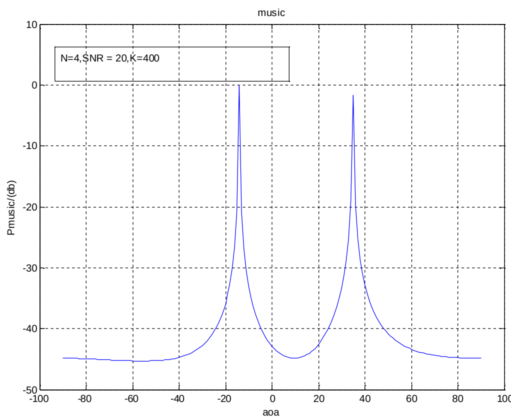

Fig.1(b) Effect of increasing number of signal snapshots

Case 2 : Next simulation results shows effect of varying SNR. Fig.2(a) shows MUSIC psudospectrum with N=4,K=100 & signal to noise ratio is 5.The MUSIC peaks gets spreaded with increased SNR. we can observe that peaks become more sharper, that angular resolution is improved The signal power is taken as 0.05 & 0.015 respectively.

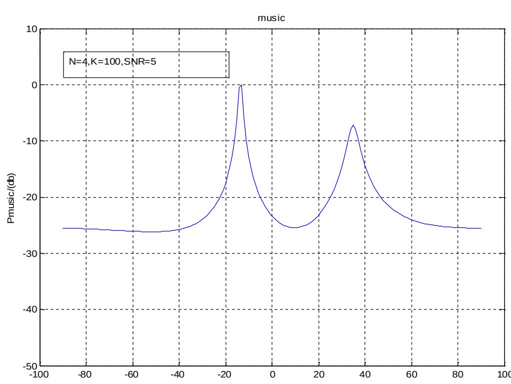

Fig.2(a) SNR=5, N= 4, K = 100

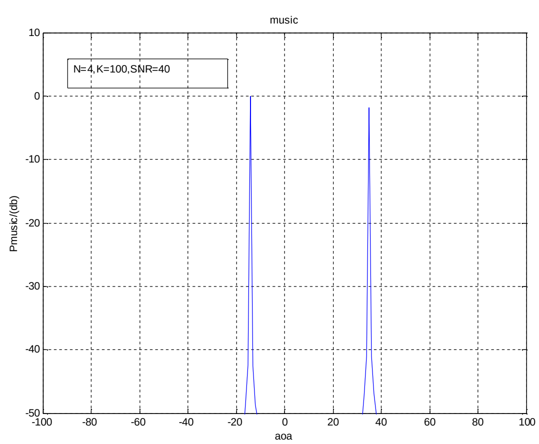

Fig.2(b) High angular resolution with increased SNR(= 40)

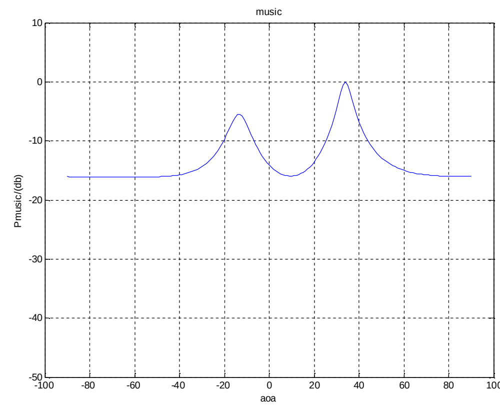

Fig 3(a) MUSIC spectrum with N = 4

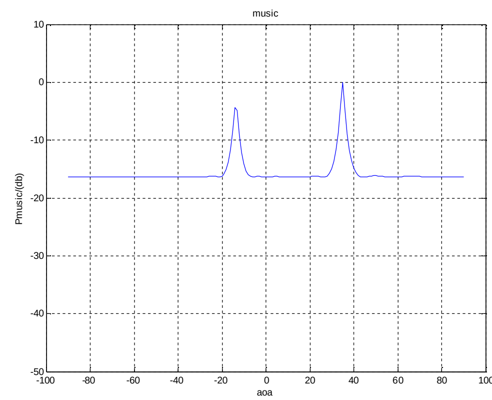

Fig 3(b) MUSIC spectrum with N = 16

Case 3 : For fig 3(a) & (b) signal power taken as 0.05& 0.09 respectively. From simulation results it is clear that with more number of antenna elements we can estimate the exact angles more accurately.

IV. CONCLUSION

1. Number of elements: Increasing the number of elements increases the resolution for multiple sources. If the number of signals is large then a higher element array predicts the directions of arrival better.
2. Noise: With lower noise, the peaks become sharper. The presence of added noise causes a spreading effect on the peaks.
3. Number of samples: Increasing the number of samples does not bring about a greater improvement in the plots. However , number of samples must be greater than number of incident signals for workable results

This analysis is useful in implementation of direction of arrival based smart antenna system.

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