A High Resolution Method for DOA Estimation

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***Abstract*—Smart Antenna is a device with signal processing capability combining multiple antenna elements to optimize its radiation and reception patterns as per designed specifications.**

Smart antennas basically comprise of two functionalities, i.e., Direction of Arrival and Beamforming. This paper explains the estimation of Direction of Arrival using Bartlett method and a novel approach called MUltiple Signal Classification which takes advantage of orthogonal property and performs subspace computation. With a comparative study of both the algorithms, we shall prove the advantages of MUltiple Signal Classification over the Bartlett method with the aid of MATLAB.

***Keywords*—Direction of Arrival (DOA), Bartlett, MUltiple Signal Classification (MUSIC) and Smart Antenna.**

I. INTRODUCTION

Smart Antennas were introduced mainly to combat limited RF spectrum. These are nothing but antenna arrays i.e., they consist of several antenna elements whose signal is processed adaptively [1] so that the spatial domain of mobile radio channel is exploited. Smart antenna techniques are used notably in acoustic signal processing, track and scan radar, radio astronomy and radio telescopes, and mostly in cellular systems [3]. The two main functions of a smart antenna are DOA estimation and Beamforming. A Typical smart antenna system is as shown below. We shall discuss the algorithms that estimate the direction of arrival.

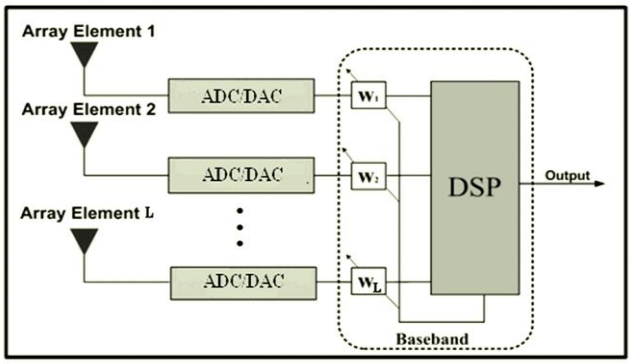

Fig.1. Typical smart antenna system

II. DIRECTION OF ARRIVAL ESTIMATON

In this section we shall see the different algorithms that are used for estimating DOA. They involve finding a spatial spectrum of the waves received by the sensor array, and calculating the DOA from the peaks of this spectrum. The computations are quiet intensive and often complex.

The most important parameter to be considered in DOA is the resolution which is nothing but the ability of an algorithm to detect closely located users. The decrease in resolution leads to increase in bias which is undesirable [2,4].

A. Bartlett Algorithm

It is one of the classical methods of angle of arrival. In this, a rectangular window of uniform weighting is applied to the time series data to be analyzed. For bearing estimation problems using an array, this is equivalent to applying equal weighting on each element. Bartlett method is also called Ordinary Beam-forming Method (OBM). It estimates the power spectrum by using the inverse of array correlation matrix. Since the power spectrum will depend on the inverse of array correlation matrix and from the mathematical science inverse of a large matrix will provide magnitude close to zero and hence infinite power spectrum in some cases which destroys the detection capability, also resolution and bias.

The power spectrum in Bartlett method is given by

$$P_B(\theta) = \frac{S_\theta^H R S_\theta}{L^2} \quad (1)$$

Where, 'S_θ' denotes the steering vector associated with the direction θ.

'R' is the array correlation matrix.

'L' denotes the number of elements in the array.

B. MUltiple SIgnal Classification (MUSIC)

MUSIC is the one of the high resolution subspace method. It promises to provide unbiased estimates of the number of signals, the angles of arrival and the strengths of the waveforms. MUSIC makes the assumption that the noise in each channel is uncorrelated making the noise correlation matrix diagonal.

The MUSIC power spectrum is given by

$$P_{MUSIC} = \frac{1}{a(\theta)^H E_N E_N^H a(\theta)} \quad (2)$$

Where, $a(\theta)$ is steering vector for an angle θ and

E_N is L x L-M matrix comprising of noise Eigen vectors.

III. SIMULATION RESULTS OF BARTLETT METHOD

The Bartlett algorithm works well for users who are located at wide angles, but resulting in high bias. Unique peaks are created as shown in figure below. However, when the users are at narrow angles, then the algorithm fails to detect individual users.

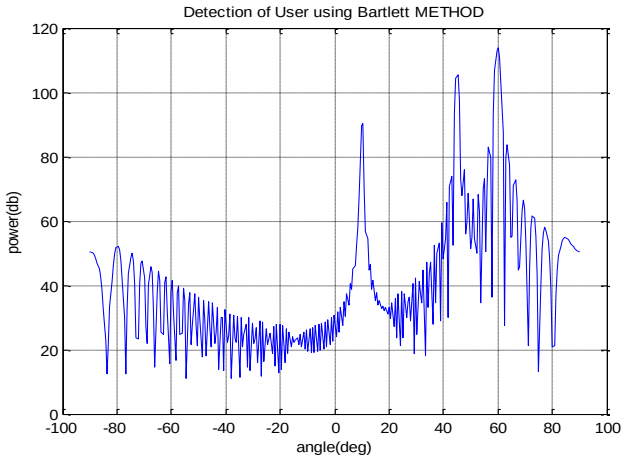

Fig.2. Detection of widely spaced users

Figure.3 shows a broad single peak at approx. 18^0 while in reality the algorithm had to detect 3 individual users placed at 10^0, 14^0 and 17^0 respectively.

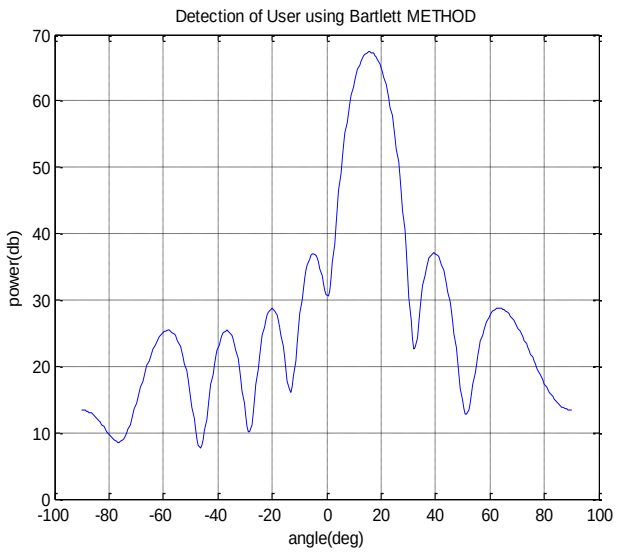

Fig.3. Algorithm fails to detect closely spaced users.

IV. SIMULATION RESULTS OF MUSIC ALGORITHM

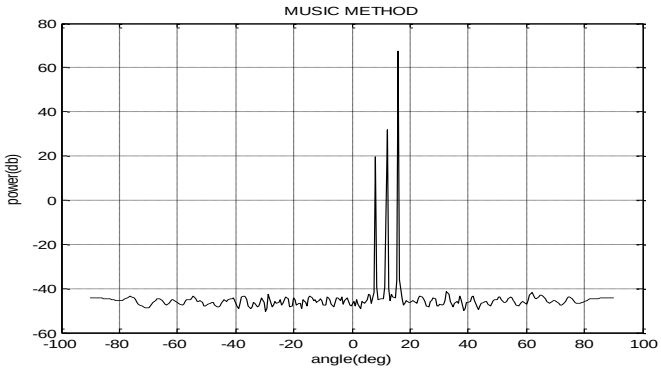

Fig.4. Detection of users using MUSIC

In case of MUSIC algorithm, we can clearly detect individual users irrespective of their angle of separations. As it can be seen above, unique peaks are formed indicating 3 individual users located close at 10^0, 14^0 and 17^0 respectively.

V. CONCLUSION

Thus we conclude that the Bartlett performs quite well for users far apart, compromising on bias. But fails in case the users are close to each other.

The MUSIC algorithm performs well providing high resolution capability even for closely located users. Thus the bias in MUSIC is very less which makes it the ultimate choice for estimating the DOA but the tradeoff would be RF cost.

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