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Performance Analysis of Existing Direction of Arrival Algorithms for Various Mobile Sources and Antenna Elements

Yashoda B.S[1], Dr. K.R. Nataraj[2]

Ph.D Research Scholar[1]
Jain University, Bangalore, India.
Email ID: Yashoda_bs@yahoo.com
Professor and Head[2]
Department ECE, SJBIT, Bangalore, India.
Email ID: nataraj.sjbit@gmail.com

Abstract: - In today's world the number of mobile users is increasing day by day with the limited capacity there is a need for intelligent techniques that can provide same QOS (Quality of Service) across mobile users. In this paper existing methods namely Bartlett Method, Maximum Likelihood and MUSIC (Multiple Signal Classification) Method are described and simulated for various combinations of antenna elements and mobile separation configurations.

Keywords: MUSIC, QOS, DOA

I. Introduction

Smart Antenna is a combination of multiple antennas. The smart antenna has 2 major blocks namely Direction of Arrival (DOA) and Beam forming. DOA is responsible for locating the mobile sources by computing the power spectrum while beam forming transmits the radiation in the look direction based on input from DOA. There are many DOA algorithms in the literature each of the approaches have their own way of determining the power spectrum in the network.

II. Background

There is a huge amount of work that is performed on the direction of arrival algorithms and this is the latest technology used in mobile communication. MUSIC [1] is an acronym which stands for Multiple Signal Classification. MUSIC provides the estimates of the source directions and then finds out the values in such a way that the bias is less. The Normalized Power method is an inheritance of Fourier-based spectral analysis [2] to sensor array data. It maximizes the beam for a specific direction. In the paper [3] estimation of quasi-stationary signals is performed and Khatri-Rao (KR) subspace is used to find the DOA in such a way that the noise correlation is reduced but the computation time is very high due to the fact that if other existing DOA methods takes N iterations this methods takes 2N-2 iterations. In the paper [4] the antenna array is divided into 2 doublets and then independent Eigen vectors will be found on the first L-1 antenna elements covariance matrix and last L-1 covariance matrix. The direction of arrival estimation is performed by using the tangent formula rather than computing the power spectrum.

III. Algorithms

A. MUSIC Method (Multiple Signal Classification)

MUSIC method makes use of Noise Subspace in order to find the actual source directions. The Noise Subspace is obtained as the combination of noise Eigen a vector which corresponds to low magnitude. The MUSIC method power spectrum is given by the equation

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

Where, $a(\theta)$ is steering vector for an angle θ and E_N is L x L-M matrix comprising of noise Eigen vectors.

The flowchart for MUSIC Method can be described as follows **Normalized Power Method**

In normalized power method first the amplitude matrix is computed and then the steering vectors are computed for all the directions and once they are computed the combination is performed to obtain manifold vector. Once it is obtained then the source correlation matrix and noise correlation matrix are found out and finally the power spectrum is obtained for the variability between -90 degree to +90 degree. The power spectrum for the normalized power method is given by the following equation.

$$P_{NormalizedPower}(\theta) = \frac{S_\theta^H R S_\theta}{L^2}$$

Where, 'S_θ' is steering vector associated with the direction θ, 'R' array correlation matrix and 'L' antenna elements. The flowchart for the normalized power method can be described as follows.

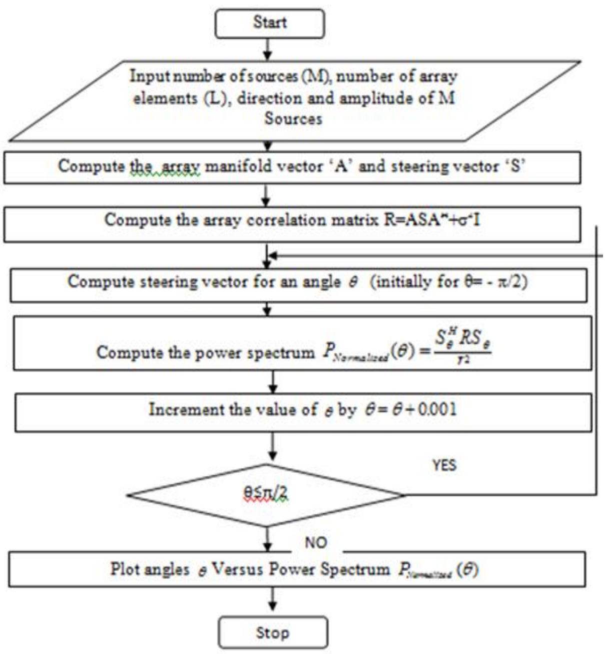

Fig1: Normalized Power Method

Fig1 shows the complete flow of Normalized Power Method for the estimation of mobile users.

B. Maximum Likelihood Method

Maximum likelihood method follows the same phenomenon of Normalized Power Method but it computes the inverse of total correlation matrix so that the likelihood is maximized. The power spectrum is computed using the
following equation.

$$P_{MLM} = \frac{1}{a^H(\theta) R_{inv} a(\theta)}$$

Where, $a^H(\theta)$ is the hermitian transpose of $a(\theta)$ and R_{inv} is the inverse of autocorrelation matrix.
The flowchart can be described as follows

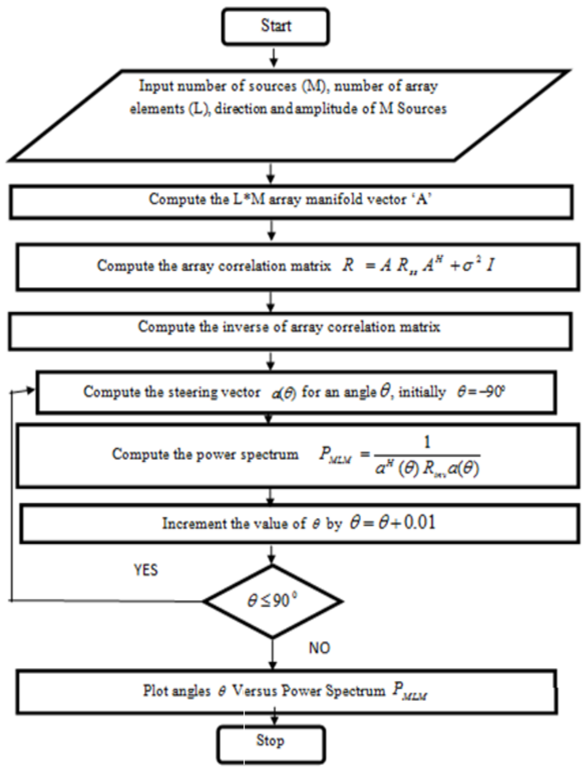

Fig2: MLM Method

Fig2 shows the complete flow of Maximum Likelihood Method (MLM) for the estimation of mobile users.

C. Maximum Entropy Method (MEM)

MEM DOA method assumes that the entropy is maximized at a time in one specific direction of source. It is built on top of normalized power method and after computation of total correlation matrix it finds the column vector of the correlation matrix which corresponds to maximum entropy and utilizes it in the power spectrum. The power spectrum is given by the equation.

$$P_{ME} = \frac{1}{[S_\theta^H C C^H S_\theta]}$$

Where, C is column of R^{-1} and S_θ is the steering vector. $P_{ME}(\theta)$ is based on selecting one of L^{th} array elements as a reference

The flowchart of MEM method can be described as below

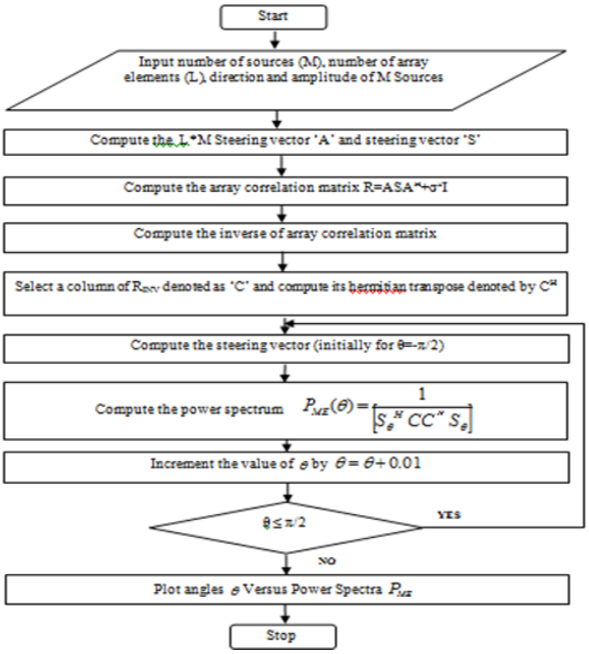

Fig3: MEM Algorithm

Fig3 shows the complete flow of Maximum Likelihood Method (MLM) for the estimation of mobile users.

D. MUSIC Method (Multiple Signal Classification)

MUSIC method makes use of Noise Subspace in order to find the actual source directions. The Noise Subspace is obtained as the combination of noise Eigen a vector which corresponds to low magnitude. The MUSIC method power spectrum is given by the equation

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

Where, $a(\theta)$ is steering vector for an angle θ and E_N is L x L-M matrix comprising of noise Eigen vectors.

The flowchart for MUSIC Method can be described as follows

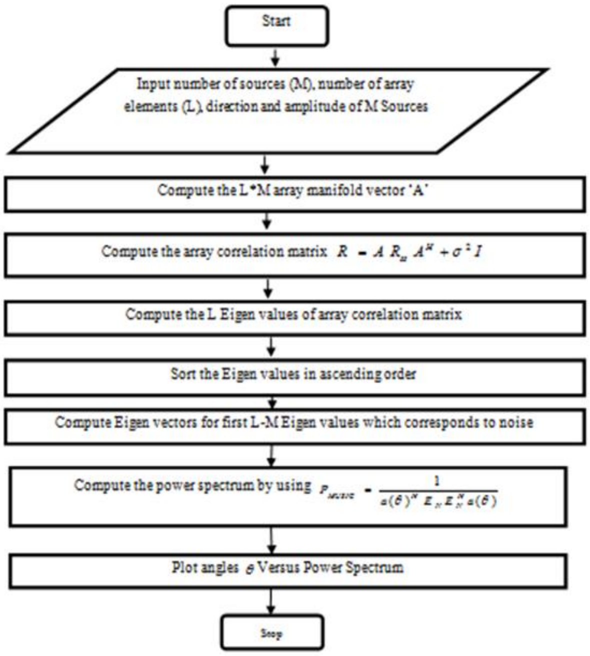

Fig4: MUSIC Algorithm

Fig4 shows the complete flow of Multiple Signal Classification (MUSIC) for the estimation of mobile users.

IV. Results

Simulation Set Up

Parameter Name	**Parameter Value**
Type of Antenna Array	Uniform Linear Array
Type of Antenna Element	Dipole
Variability	$-90 \le \theta \le 90$

The most important parameters for comparing the DOA Algorithms are

1) **Bias:**

   The difference between actual direction and estimated direction.

2) **Resolution:**

   The capability of an algorithm to distinguish between users which have equal amplitude and nearly equal angles.

Case1: Low RF Elements and Far Away Users

Parameter Name	**Parameter Value**
Number of Antenna Elements	8
Number of Users	3
Amplitude of Sources in volts	[1v 2v 3v]
Direction of Sources	[30 45 60]

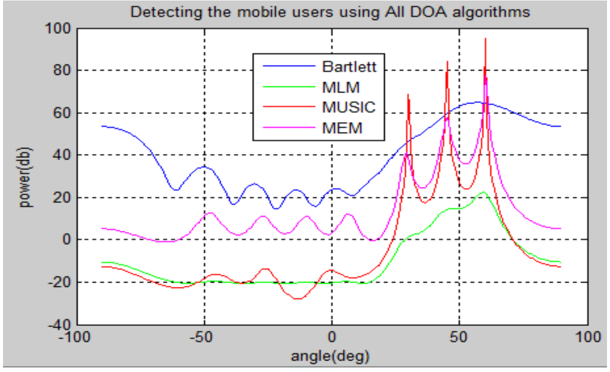

Fig5: Performance Analysis case 1

Fig5 shows the Performance Analysis1 as shown in the fig MUSIC and MEM perform better as compared MLM and Bartlett.

Case2: Low RF Elements and Nearby Users

Parameter Name	Parameter Value
Number of Antenna Elements	8
Number of Users	3
Amplitude of Sources in volts	[1v 2v 3v]
Direction of Sources	[30 34 38]

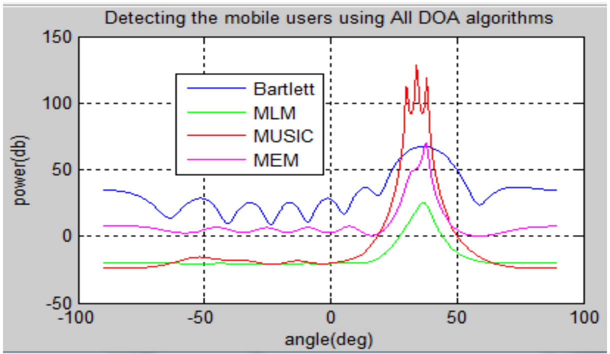

Fig6 shows the Performance Analysis2

As shown in the fig MUSIC performs the best whereas Bartlett, MEM perform better as compared MLM and Bartlett.

Case3: Large RF Elements and Far Away Users

Parameter Name	Parameter Value
Number of Antenna Elements	100
Number of Users	3
Amplitude of Sources in volts	[1v 2v 3v]
Direction of Sources	[30 45 60]

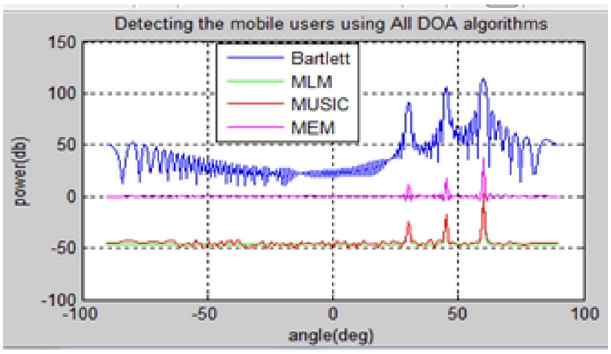

Fig7: Performance Analysis 3

Fig7 shows the Performance Analysis3 as shown in the fig all algorithms perform better.

Case4: Large RF Elements and Nearby Users

Parameter Name	Parameter Value
Number of Antenna Elements	100
Number of Users	3
Amplitude of Sources in volts	[1v,2v, 3v]
Direction of Sources	[10 13 16]

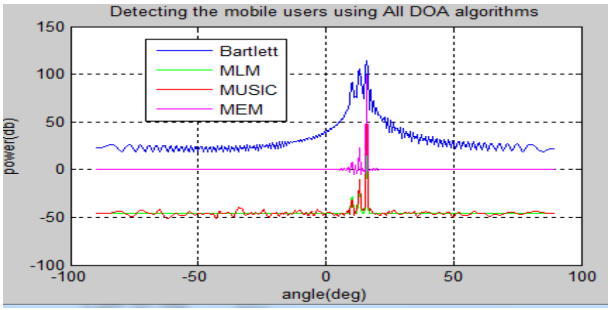

Fig8: Performance Analysis 4

Fig8 shows the Performance Analysis4 as shown in the fig all algorithms perform better.

V. Conclusion

The various algorithm namely Bartlett, MLM, MEM and MUSIC algorithm is simulated on various mobile configurations. The following conclusions can be drawn from the results

1. For the case of Mobile Users which are Far Away and have less RF Sources then MUSIC and MEM performed better and are able to detect the users but Bartlett and MLM method failed to detect
2. For the case of Mobile Users which are Nearby and have less RF Sources then MUSIC performs better and are able to detect the users but Bartlett, MEM and MLM method failed to detect
3. For the case of Mobile Users which are Far

Away and have More RF Sources then all the algorithms perform better

4. For the case of Mobile Users which are nearby and have More RF Sources then all the algorithms behave well.

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