# PERFORMANCE ANALYSIS OF MUSIC AND IMPROVED MUSIC ALGORITHM FOR COHERENT SIGNAL

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***Abstract:** The Smart Antenna System has a great number of applications in the domain of array signal processing. DOA Estimation is an important problem in the field array signal processing. High Resolution Techniques provide excellent results in the detection of unknown signals in the presence of noise. Music and Improved Music Algorithm (IMA) are studied for coherent signal analysis. In music algorithm, spatial smoothing technique is introduced to estimate the direction of arrival (DOA) for coherent and co-related signals. The improved music algorithm uses forward-backward smoothing. Performance of music algorithm depends on the number of estimated sources, number of snapshots taken and the number of array elements. Simulation is done by considering the linear array antenna with λ/2 spacing. It has been observed that the simulated results show better resolution with more number of antenna array elements. By increasing the number of snapshots, increased resolution capacity has also been obtained. The Simulation study of IMA shows better results as compared to Music algorithm.*

***Index Terms:** MUSIC, Improved MUSIC, Smoothing, Coherent, DOA.*

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**Introduction:**

High Resolution Eigen Structure Techniques for direction of arrival estimation is an active research area in the array signal processing. Array Signal processing has various applications in biomedicine, sonar, astronomy, radar, wireless Communication system and Seismic Event Prediction etc. Adaptive or smart antenna adjusts its radiation according to the outer environment. Smart antenna is generally used to detect the direction of arrival estimation. To detect the direction of incoming signals, various types of algorithms exists in the literature. The conventional based and sub-spaced algorithms are generally used. In starting conventional method are used which is based on the beam forming concept. The spectral based methods are also used to detect the incoming signal. The Bartlett method and Minimum Variance Distortion less response (MVDR) or Capon methods are based on the spectral estimation. These methods have low computational complexity because they depend upon the physical size. To overcome the problem of low resolution and accuracy sub space based methods are come in to existence. These methods are based upon the Eigen based structure. Music algorithm is one of the sub space methods. The received signal in array signal processing depends upon the various parameters which affect the performance of the detection algorithms. Spatial Smoothing is generally used in MUSIC algorithm to detect the coherent and correlated signal.

**MUSIC Algorithm**

Multiple Signal Classification (MUSIC) algorithm was proposed by Schmidt in 1979 [3]. This algorithm is used for spatial spectrum estimation of the signals. Prior to this, some algorithms directly processed data received from array covariance matrices. In Music algorithm, corresponding to the signal components the covariance matrix of any array output data is decomposes in to the signal and noise subspace [4]. These two orthogonal subspaces have been used to make a spectrum function. Through this spectral function and spectral peak search we detect DOA signals. There are various parameters on which music algorithm depends namely, the number of antenna array elements, the number of signal snapshots, array element spacing, and SNR [3]. The mathematical model of MUSIC algorithm is described below:

We assumed a uniform linear array which consists of N number of sensors and receives P narrowband signals incident from the different directions $\{\Theta_1, \Theta_2, \Theta_3, \Theta_4$---------, $\Theta_p\}$. The output of the sensor array is given by the equation [6]:

$Y(t) = A(\Theta)\, S(t) + n(t)$ , t= 1,2,3,------L

Where,

$Y(t) = [\, y_1(t), y_2(t), y_3(t),$ -------, $y_N(t)]^T$, the received array data vector is given by the equation

$A(t) = [a(\Theta_1), a(\Theta_2), a(\Theta_3), a(\Theta_4),$-------- $a(\Theta_p)]$

The array matrix is given by the equation is

$s(t) = [\, s_1(t), s_2(t), s_3(t),$ -------, $s_p(t)]^T$

and noise vector is given by the equation

$n(t) = [\, n_1(t), n_2(t), n_3(t),$ -------, $n_N(t)]^T$

The steering vector is given by the equation

$A(\Theta_{i)} = [\, 1, \exp(j2\pi d \sin \Theta_i/\lambda,$ --------------- $\exp(j2\pi\, (N-1)\, d \sin \Theta_i/\lambda]^T$

Where, d= distance between elements of uniform linear array

$\lambda$ = Propagating signal wavelength

$\Theta_{i=}$ signal arrival angle of the $i^{th}$ sources

$_{(.)}{}^T$ = Matrix transposition

The signal array is assumed to be stationary process and the correlation Matrix is defined as by the equation
$R= E[(Y(t)-m_y(t)). (Y(t)-m_y(t))^H]$
Where $(.)^H$ is the conjugate transposition of matrix.
There are following assumptions in the MUSIC algorithm process given below [4]:

i) The additive Gaussian noise and the signals assumed are stationary and Erogodic having zero mean value random process.
ii) The signal sources are uncorrelated
iii) The set of steering vectors are linearly independent to each other.

The cross correlation matrix is given by the following equations after assuming these assumptions:
$R= E [A(\Theta) S(t) S^H(t) A^H (\Theta)]+ E[ N(t) .N^H (t)]$
$= A(\Theta)R_{ss} A^H (\Theta)+ \sigma^2 I_N$
Where, $R_{ss}= E [S(t) S^H(t)]$ is P×P covariance matrix of source signal, $\sigma^2$ is the noise variance and $I_N$ is the N×N Identity Matrix.
From the received data the covariance matrix is estimated. Covariance matrix of the estimated signal is represented by the given equation:
$\hat{R}_{yy} = \frac{1}{k}\sum_{k=1}^{k} Y\,Y^H$
The various steps involved in music algorithm are given below:

a) Find the correlation Matrix from the incoming signals.
b) Decompose the Matrix in to Eigen Values.
c) Calculate the Music Spectrum by finding the Largest Peaks.

**Improved MUSIC Algorithm**

The independent source signal direction is easily detected by the spectrum peaks using Music algorithm. The simulation results of Music algorithm are better in the non coherent signal environment. The signal detection accuracy of music algorithm goes low when the incoming signals are coherent. The covariance Matrix is a non singular matrix and the incoming signals are uncorrelated in music algorithm. To remove the similarity between the signals, Spatial smoothing technique is generally used and the identity transition matrix is used to increase the accuracy in results of music algorithm [7]. To increase the accuracy of Music algorithm an identity transition matrix 'T' is introduced. The new signal received matrix is given below [7]:
$U= TY^*$
Where X* represents the complex conjugate of the original received signal matrix.
$R_U = TR_Y{}^*T$
To obtained a new matrix the two matrix are added up
$R= R_Y + R_U$
$R= AR_sA^H+ T [AR_sA^H]^*T + 2\sigma^2 I$
The matrix is decomposed and the noise subspace is filtered out. The resulted noise subspace is used to obtained spatial spectrum and peaks. The graph of improved music algorithm shows the narrower peaks for coherent signal environment.

**Simulation Results:**

The Simulation Results for Music Algorithm are performed in the MATLAB software. The simulation setup run using linear array antenna which is formed by the number of elements that can be varied and the element spacing is λ/2. The SNR assumed is 20db i.e. SNR=20db. The setup is run using five signals that are coming from the different directions. The performance is analyzed for varying number of snap shots and varying array elements [8].

**Case 1: Results of MUSIC algorithm for Varying Number of Array Elements**

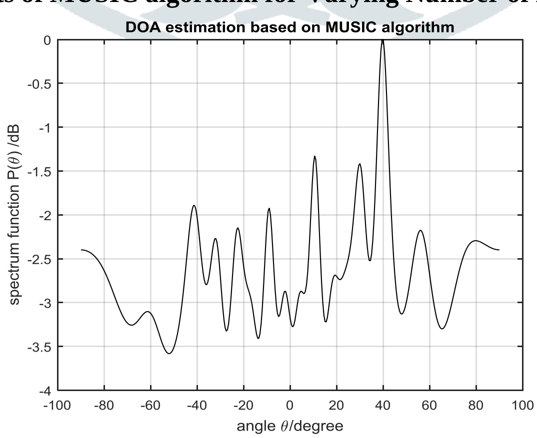


Figure 1: M=20, Snapshots=200, Simulation result of music algorithm coming from the Signals directions =-40 10 20 30 40

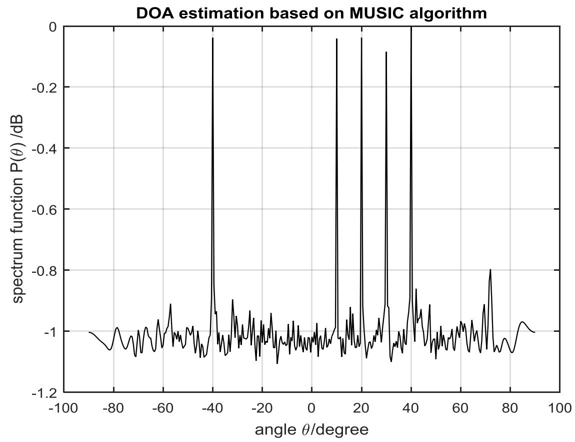


Fig. 2: M=200, Snapshots=200, Simulation result of music algorithm coming from the directions -40 10 20 30 40

**Case 2: Result of MUSIC algorithm for Various Number of Snapshots**

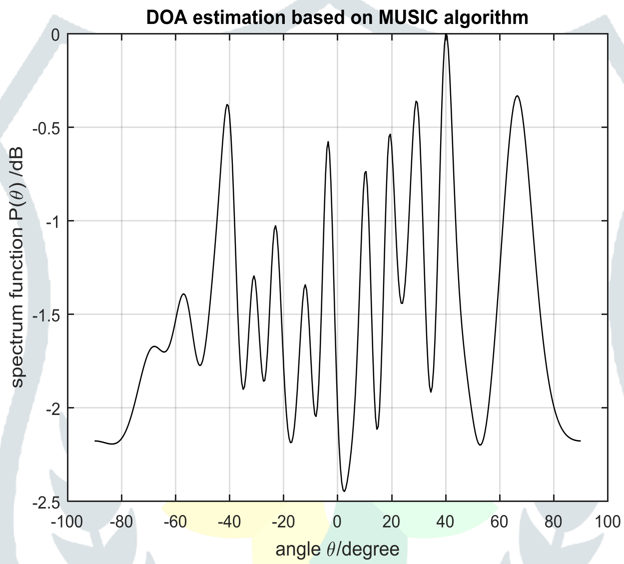


Fig. 3 M=20, Snapshots=40, Simulation result of music algorithm coming from the directions -40 10 20 30 40

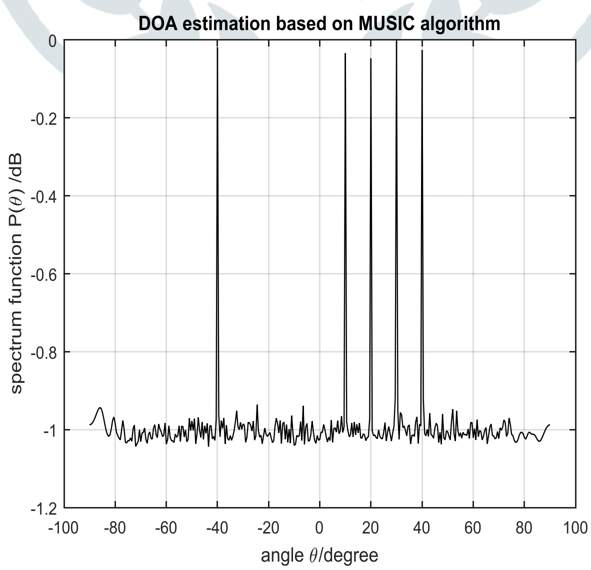


Fig. 4 M=20, Snapshots=400, Simulation result of music algorithm coming from the directions -40 10 20 30 40

**Simulation Results of Improved Music Algorithm:**

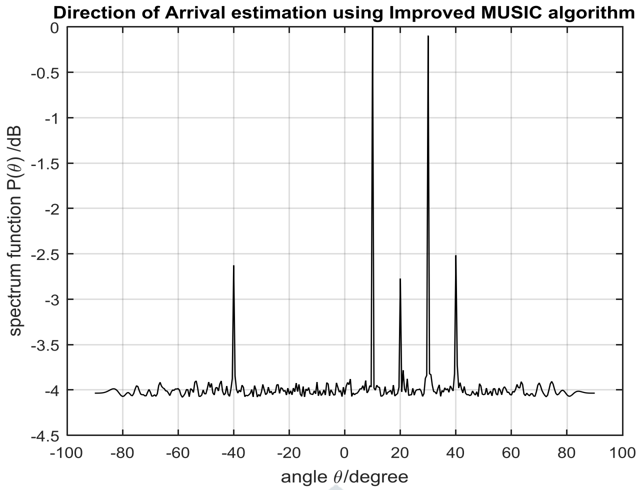


Fig. 5 M=10, Snapshots=200, Simulation result of Improved music algorithm coming from the directions -40 10 20 30 40

**Conclusions:**

The subspace based Music and Improved Music algorithms are studied in this paper. The results show that improved music algorithm is more accurate under coherent signal detection. The improved music algorithm gives better results as compared to the music algorithm. The simulation results show the better accuracy of IMA.

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