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A Novel High Resolution DOA Estimation Design Algorithm of Close Sources Signal for Underwater Condition

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ABSTRACT: Underwater target tracking in ocean environment has attracted considerable interest in both military and civilian applications. In this paper the performance of directions finding techniques, subspace and the non-subspace methods are presented. In this paper, the Eigen-analysis category of high resolution and super resolution algorithms, comparison and the performance and resolution analyses of these algorithms are made. The analysis is based on linear array antenna and the calculation of the pseudo spectra function of the estimation algorithms. Traditional MUSIC algorithm decomposes the signal covariance matrix and then make the signals subspace obtained be orthogonal to the noise subspace, which decreases the effect of the noise. But when the signals intervals are very small, traditional improved MUSIC algorithm has been unable to distinguish the signals as the SNR decreases. A new algorithm is proposed using SVD of the covariance matrix. An antenna of Uniform Linear Array configuration is taken for both the algorithms. Simulations results show that proposed method gives better performance than traditional MUSIC algorithm. In this newly Modified MUSIC algorithm, conditions required for under water environment are considered such as water density, permittivity of water, pressure, Signal to Noise Ratio, speed of sound wave in water.

KEYWORDS: Direction of Arrival(DOA); Multiple Signal Classification(MUSIC) algorithm; Uniform Linear Array(ULA); Signal to Noise Ratio(SNR); Snapshots.

I. INTRODUCTION

In signal processing a set of constant parameters upon which the received signals depends are continuously monitored. DOA estimation carried out using a single fixed antenna has limited resolution, as the physical size of the operating antenna is inversely proportional to the antenna main lobe beam width. It is not practically feasible to increase the size of a single antenna to obtain sharper beam width. An array of antenna sensors provides better performances in parameter estimation and signal reception. So have to use an array of antennas to improve accuracy and resolution. Signal processing aims to process the signals that are received by the sensor array and then strengthen the useful signals by eliminating the noise signals and interference. Array signal processing (ASP) has vital applications in biomedicine, sonar, astronomy, seismic event prediction, wireless communication system, radar etc.

Various algorithms like ESPRIT, MUSIC, WSF, MVDR, ML techniques and others can be used for the estimation process. The entire spatial spectrum is composed of target, observation and estimation stages. It assumes that the signals are distributed in space is in all the directions. So the spatial spectrum of the signal can be exploited to obtain the Direction of Arrival. ESPRIT (Estimation of Signal Parameter via Rotational Invariance Technique) and MUSIC (Multiple Signal Classification) are the two widely used spectral estimation techniques which work on the principle of decomposition of Eigen values. These subspace based approaches depend on the covariance matrices of the signals.

ESPRIT can be applied to only array structures with some peculiar geometry. Therefore the MUSIC algorithm is the most classic and accepted parameter estimation technique that can be used for both uniform and non-uniform linear arrays. The conventional MUSIC estimation algorithm works on ULA where the array elements are placed in such a way that they satisfy the Nyquist sampling criteria. The design of non- uniform array is quite tedious and it requires various tools. It can compute the number of signals that are being incident on the sensor array, the strength of these signals and the direction i.e. the angle from which the signal are being incident.

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II. RELATED WORK

With the development of antenna array, the Direction of Arrival (DOA) estimation technique becomes a vital part of smart antenna. The antenna array, which receives number of signals, collecting data at all its array elements with combination of the spatial information, has the ability to process this data optimally and estimate the Directions of Arrival (DOA) of the impinging signals with high-resolution signal arrival estimation algorithms. Therefore, the high resolution DOA estimation algorithm for coherent sources is an essential part of smart array antenna.
MUSIC is an Eigen decomposition algorithm which exploits the underlying information for DOA estimation by decomposing the variance matrix to get eigenvectors and eigenvalues. But due to mutual coupling between the various antenna poles, and due to model error, MUSIC fails to give proper DOA of signals when the noise level is high. MUSIC algorithm fails to differentiate sources which are very closer. The accuracy of the estimation is highly dependent on the type of signal to be detected.

III. PROPOSED ALGORITHM

A. *Design Considerations:*

- Data formulation for MUSIC and Improved MUSIC
- Covariance Matrix
- Eigen decomposition.
- Compute the MUSIC spectrum
- Estimate DOA.

B. *Description of the Proposed Music Algorithm:*
MUSIC is an acronym which stands for Multiple Signal classification. It is a high resolution technique based on exploiting the Eigen-structure of input covariance matrix. It is a simple, popular high resolution and efficient Method. It provides unbiased estimation of the angles of arrival, the strengths of signals and the number of signals.

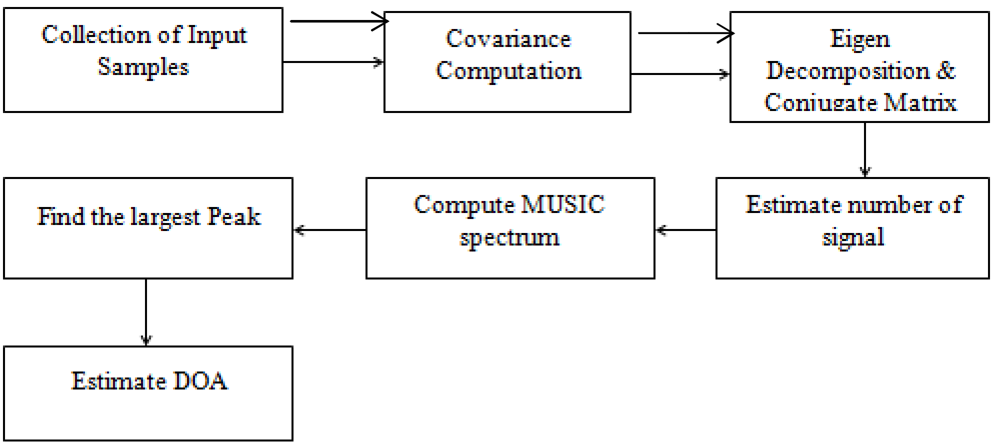

Fig1: Block Diagram of MUSIC

Step 1: Collect input samples Xk , k = 0... N -1 and estimate the input covariance matrix

$$\hat{R}_{XX} = \frac{1}{k}\sum_{K=0}^{K=-1} X_K . X_K^H \qquad eq(1)$$

Where k is Number of Snapshots, X_K is the incoming input signal, X_K^H is the Signal with Noise.

Step 2: Perform Eigen decomposition on $\hat{R}_{xx}$

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$$\hat{R}_{xx}E = E\Lambda \qquad \text{eq(2)}$$

Where Λ= diag $\{\lambda_{0,}\lambda_1,\dots\lambda_{M-1,}\}$ are the Eigen values and E=diag $\{Q_{0,}Q_1,\dots Q_{M-1,}\}$are the corresponding Eigen vectors of $\hat{R}_{xx}$

Step 3: Estimate the number of signals $\hat{L}$ from the multiplicity K, of the smallest eigenvalue λ_{min} as equation $\hat{L}$= *M* - *K*eq(3)

Step 4: Compute the MUSIC spectrum by the following Eq.

$$\hat{P}_{MUSIC}(\theta) = \frac{A^H(\theta)A\ (\theta)}{A^H(\theta)E_nE_n^HA(\theta)} \qquad eq(4)$$

Step 5: Find the $\hat{L}$ largest peaks of $\hat{P}_{MUSIC}(\theta)$ to obtain estimates of the Direction -Of- Arrival.

C. *Description of the Proposed Improved Music Algorithm:*

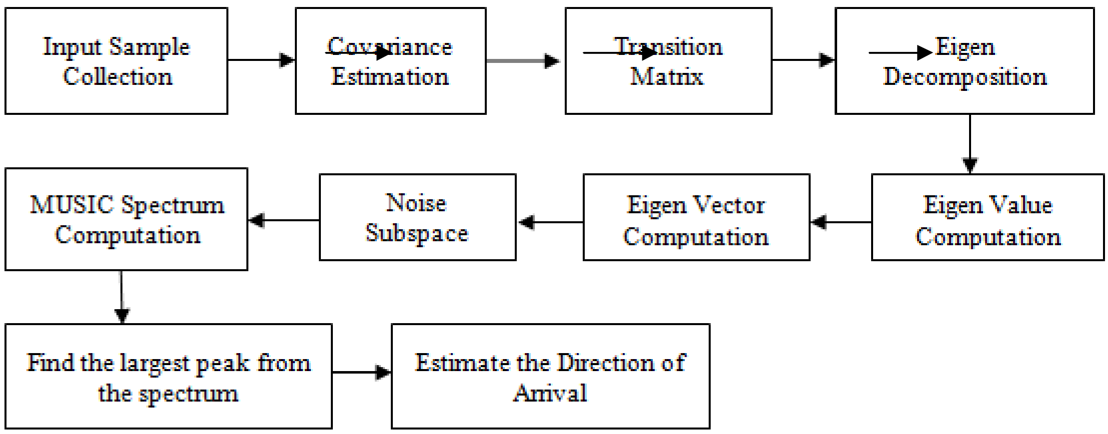

Fig2: Block Diagram of Improved MUSIC

MUSIC algorithm has advantages over other estimation algorithm because of the sharp needle spectrum peaks which can efficiently estimate the independent source signals with high precisions unlike the other estimation processes which are limited with low precisions. It has many practical applications as it provides unbiased estimation results. The MUSIC algorithm to estimate the direction has even proved to have better performance in a multiple signal environment. MUSIC algorithm has better resolution, higher precision and accuracy with multiple signals. But this algorithm achieves high resolution in DOA estimation only when the signals being incident on the sensor array are non-coherent. It losses efficiency when the signals are coherent. Keeping all the parameters same as those used for the conventional MUSIC in all the previous simulations and considering the coherent signals to be incident on the sensor arrays, obtain the following result.

As the peaks obtain are not sharp and narrow, they fail to estimate the arrival angle for coherent signals. So need to move towards an improved MUSIC algorithm to meet the estimation requirements for coherent signals. To improve the results for MUSIC algorithm, simply introduce an identity transition matrix 'T' so that the new received signal matrix X is given as:

X= TJ*

Where J* is the complex conjugate of the original received signal matrix

$$R_X = E[XX^H] = TR_J * T$$

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Now the matrices Rx and RJ can be summed up to obtain a reconstructed matrix 'R'.As the matrix are summed up they will have the same noise subspaces.

$$R = R_J + R_X$$
$$R = AR_SA^H + T[AR_SA^H] * T + 2\sigma^2 I$$

It can be seen that using the improved algorithm for direction of arrival estimation results in narrower peaks for coherent signals. Hence detection of coherent signals can be achieved satisfactorily by the using the improved MUSIC algorithm. MUSIC algorithm fails to obtain narrow and sharp peaks. An Improved version of the MUSIC algorithm as discussed in this paper can be implemented for coherent signals as well. This improved algorithm achieves sharp peaks and makes the estimation process much accurate.

IV. SIMULATION RESULTS

In this paper, three parameters are considered for output analysis, which includes SNR, number of snapshots and distance between the array elements. Here, three cases are considered, they are:

Case 1: By considering SNR 25.
Case 2: By considering Number of snapshots 100.
Case 3: By considering distance between the array elements 5m.

By considering all these three cases, here outputs of the MUSIC algorithm and Improved MUSIC are analyzed and their performances are discussed.

A. *Simulation of MUSIC:*

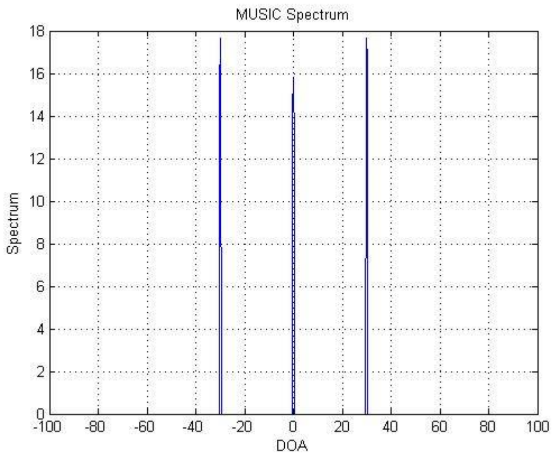

Fig.3. MUSIC Spectrum

The first simulation shows how three signals are recognized by the MUSIC algorithm. There are three independent narrow band signals, the incident angle is -45°, 0° and 45° respectively, those three signals are not correlated, the noise is ideal Gaussian white noise, the SNR is 30dB, the element spacing is half of the input signal wavelength, array element number is 12, the number of snapshots is 100. The simulation results are shown in Figure3.

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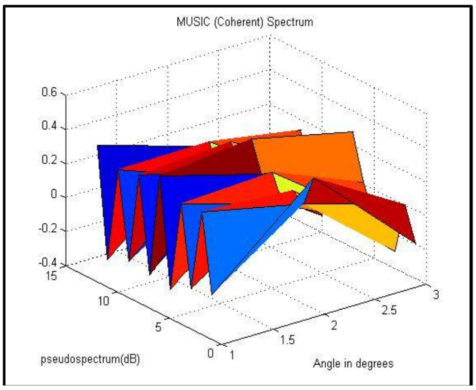

Fig.4. 3D view of coherent spectrum

As can be seen from Figure4, It is a 3D view of coherent spectrum. Under this spectrum model, the DOA estimation can reach any precision; by overcoming the traditional shortcomings of low precision, it can solve the direction problem with high resolution and high precision in a multiple signal environment. Hence, high resolution MUSIC algorithm may measure accuracy, high sensitivity features and have potentially capability with multi-resolution signals; with better performance and higher efficiency, it can provide high resolution and asymptotically unbiased DOA estimation, which has a great significance for practical application.

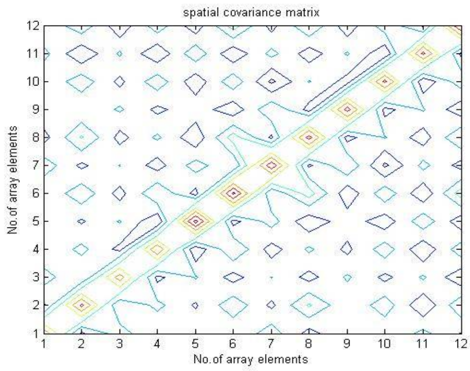

Fig.5.Spatial Covariance Spectrum

The third simulation shows spatial covariance spectrum,as the number of array element increases, there is increase in the spatial covariance, as the spatial covariance increases, there is increase in the noise as well.

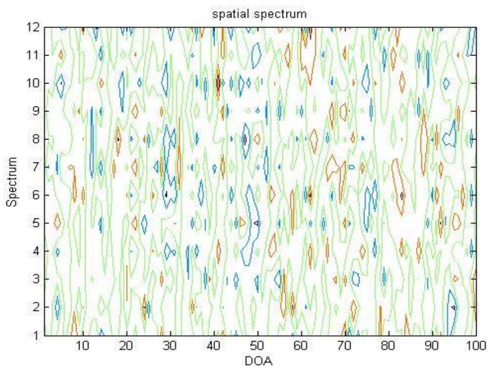

Fig.6.Spatial Spectrum

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The above Figure shows a spatial spectrum which is basically an environment noise present while receiving the incoming signal.

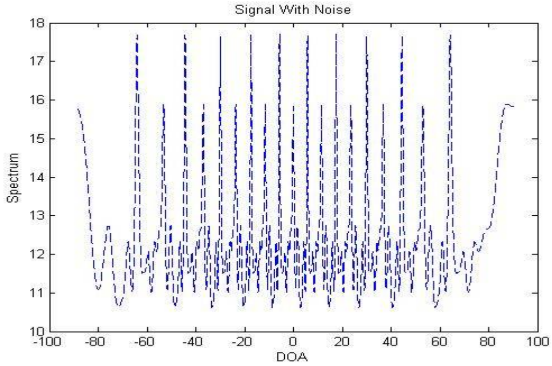

Fig.7. Signal with noise

The fifth simulation figure shows signal with noise, as the name itself tells it's the received signal with the noise present. The incident angle is -45°, 0° and 45° respectively. The signals which are shown beyond these angles are so called noise.

B. *Simulation of Improved MUSIC:*

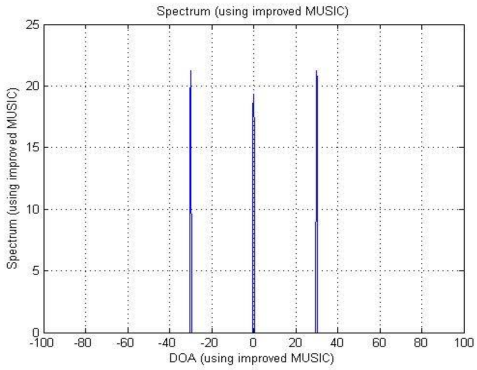

Fig.8. Improved MUSIC Spectrum

As can be seen from Figure3, this simulation is an improved version of that,There are three independent narrow band signals, the incident angle is -45°, 0° and 45° respectively., the SNR is 30dB, the element spacing is half of the input signal wavelength, array element number is 12, the number of snapshots is 100. Here in the improved MUSIC the amplitude of each signal is increased rapidly. Thus giving high resolution.The simulation results are shown in Figure8.

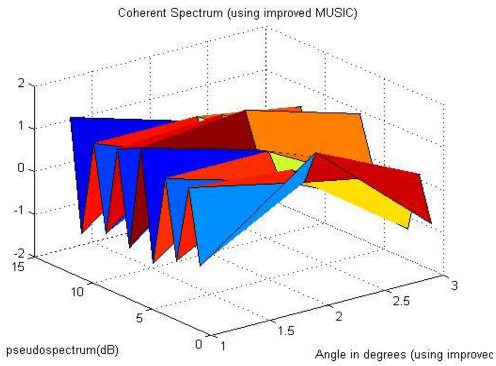

Fig.9. 3D view of coherent spectrum

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As can be seen from Figure4, It is an improved 3D view of coherent spectrum. Where the pseudo spectrum value increases as increase in the amplitude. While improved MUSIC algorithm can be better applied to remove the signal correlation feature, which can distinguish the coherent signals, and estimate the angle of arrival more accurately.

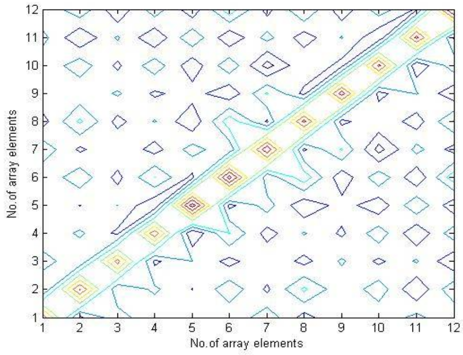

Fig.10. Spatial Covariance Spectrum

The above simulation shows spatial covariance spectrum, where the noises are reduced due to increase in the amplitude.Improved MUSIC algorithm can make DOA estimation more complete, and have a marked effect both on theoretical and practical study.

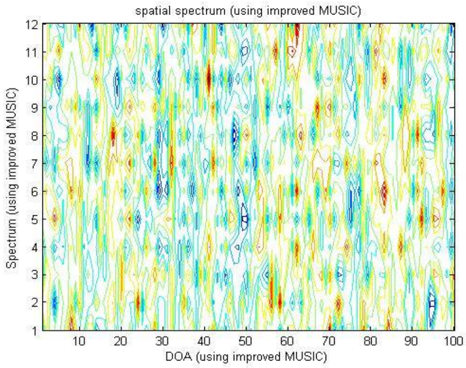

Fig.11. Spatial Spectrum

As can be seen from Figure6, the above Figure shows a spatial spectrum of Improved MUSIC which is basically an environment noise present while receiving the incoming signal.

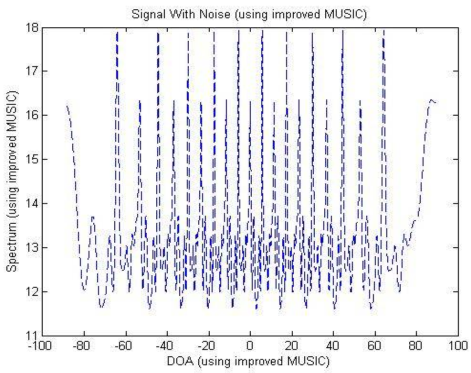

Fig.12. Signal with noise

As can be seen from Figure7, Fig.12 is improved music signal with noise.The dashed line shows the noise. With the other conditions remaining unchanged, with the increase in the number of noise, the beam width of DOA estimation spectrum becomes narrow, the direction of the signal becomes clearer, and the accuracy of MUSIC algorithm is also increased.

V. CONCLUSION AND FUTURE WORK

DOA estimation plays an important role in array signal processing, and has a wide range of applications. In many areas, such as communication, radar, sonar, weather forecasting, ocean and geological exploration, seismic survey and biomedicine, DOA estimation problems may occur.

The key to DOA estimation is to use an antenna signal array which is located in different spatial regions to receive signals from signal sources in different directions. Then the use of modern signal processing methods may quickly and accurately estimate the direction of the signal sources. In recent years, a variety of DOA estimation algorithms has achieved fruitful results, which provides a solid theoretical foundation for practical application. In this paper, I have done some research for multiple signal classification theoretical study and simulation. The main contents and conclusions made in this paper are summarized as follows:

In this paper, by describing DOA estimation, spatial spectrum estimation, and giving a mathematical model of DOA estimation, an understanding of DOA estimation was provided. And then the MUSIC algorithm (Multiply Signal Classification) was implemented in MATLAB, and simulations were performed. From the simulations, it could be seen that the MUSIC algorithm has a higher resolution the more the number of array elements, the more the number of snapshots, and the larger the difference between the incident angles. When the array element spacing is less than half the wavelength, the MUSIC algorithm resolution increases in accord with the increase of array element spacing, however, when the array element spacing is greater than the half of wavelength, except the direction of signal source, other directions appeared as false peaks in the spatial spectrum. When the signal is coherent, classical MUSIC algorithm has lost effectiveness, and improved MUSIC algorithm is able to effectively distinguish their DOA.

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BIOGRAPHY

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