A High DOA Technique for Acoustic Target Detection Underwater Using MUSIC Algorithm

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Abstract **- Underwater obstacle finding 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. The Subspace analysis of high resolution algorithms, comparisons and the performance analysis have done. The analysis is based on linear array elements and the calculation depends on the pseudo spectra function of the valuation algorithms. Traditional MUSIC algorithm decomposes the signal covariance matrix and makes the signal subspace matrix orthogonal to the noise subspace, which decreases the effect of the noise. But when the signal intervals are very small, the traditional MUSIC algorithm has been unable to distinguish the signals as the SNR decreases. A new improved algorithm is introduced using Singular value decomposition of the covariance matrix. A simulation outcome displays that projected method gives greater performance than the MUSIC algorithm. In this paper, an underwater environment is taken into account such as water density, permittivity of water, pressure, Signal to Noise Ratio, speed of sound wave in water for the new modified MUSIC algorithm.**

Keywords**—Subspace Analysis; MUSIC; Uniform Linear Array (ULA); Covariance Matrix; Permittivity**

I. BASIC UNDERSTANDING

In signal processing, a set of constant parameters on which received signal depends are continuously monitored. A Direction of Arrival (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 the sharper beam width. An array of antenna sensors provides better performances in parameter estimation and signal reception in terms of 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. 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 Uniform Linear Array (ULA) where the array elements are placed in such a way that they satisfy the Nyquist sampling criteria.

II. ADJASCENT WORK

With the development of the antenna array, the Direction of Arrival (DOA) estimation technique becomes a vital part of smart antenna. The antenna array, which receives a number of signals, collecting data at all its array elements with combination of the spatial information, has the ability to process this data optimization and estimate the DOA of 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.

Multiple Signal Classification (MUSIC) is an Eigen decomposition algorithm which exploits the underlying information for DOA estimation by decomposing the variance matrix to get eigenvectors and Eigen values. But due to mutual coupling between the various antenna poles, and due to model error, MUSIC neglects to give appropriate DOA of signals when the commotion level is high. MUSIC calculation neglects to separate sources which are nearer. 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 & Improved MUSIC
- Covariance Matrix
- Eigen decomposition.
- Compute the MUSIC spectrum
- Estimate DOA.

B. Description of the Proposed Music Algorithm:

MUSIC which is abbreviated as Multiple Signal classification. It is a high resolution technique based on the Eigen-value decomposition of input covariance matrix. It is a simple, popular high resolution and efficient technique. It provides accurate estimation of the angles of arrival, the strengths of signals and the number of signals.

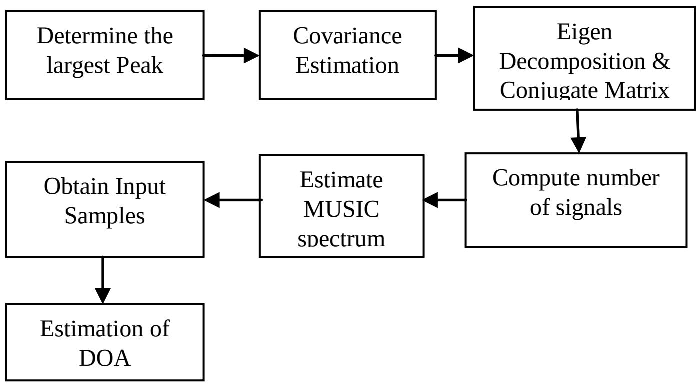

Fig.1: Block Diagram of MUSIC

Fig. 1, shows the overall calculation of MUSIC algorithm, which has to be followed using the below equations.

Step 1: Take input samples X_K, k=0 to N -1 & estimate the input covariance matrix

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

Where k are number of snapshots, X_K is the incoming input signal, X_K^H is the Signal with Noise.

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

$$\hat{R}_{xx}E = E\Lambda$$

Where Λ= diagof{ $\lambda_{0,}\ \lambda_1, \ldots \lambda_{M-1,}$} is Eigen values and

Where E=diag {$Q_{0,}\ Q_1, \ldots . Q_{M-1}$} is corresponding Eigen vectors of $\hat{R}_{xx}$

Step3: Calculate the number of signals $\hat{L}$ from multiplicity K, of the smallest Eigen value λ_{min} in the equation

$$\hat{L} = m - k$$

Step 4: Now we need to compute the MUSIC spectrum by the given equation.

$$\widehat{P}_{MUSIC}(\theta) = \frac{A^H(\theta)A\ \ (\theta)}{A^H(\theta)E_n E_n^H A(\theta)}$$

Step 5: Finally we need to find the $\hat{L}$ largest peaks of $\hat{P}_{MUSIC}(\theta)$ to obtain estimation of the Direction of Arrival (DOA).

C. Description of the Proposed Improved MUSIC Algorithm:

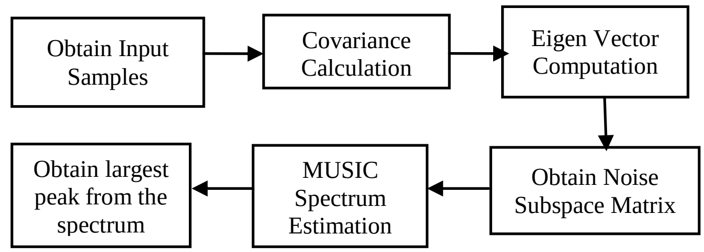

Fig.2: Block Diagram of Improved MUSIC

Fig. 2, shows the overall calculation of the Improved MUSIC algorithm, which followed by using the equations below. 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 same parameters 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 estimated requirements for coherent signals. To improve results of MUSIC algorithm, we introduce an identity transition matrix 'T' and the new received signal matrix X is given as:

X=AS+N

For an exhibit yield x, the comparing counts is done to get its covariance grid Rx

i.e.. Rx= E [XXH]

Where H is given as the complex conjugate of the original received signal matrix

Rx= E [(AS+N). (AS+N)H]

AE [SSH] AH+E [NNH]

ARsAH+RN

Where Rs= E [SSH],

RN= $\sigma 2I$, is noise correlation matrix.

σ2 is signal of noise power.

I is unit matrix of M*M.

Now, consider Rx= ARSAH+$\sigma 2I$,

Ry= E [YYH] = JRX*J

As indicated by lattice's conditions, the frameworks Rx, Ry and R have the same clamor subspace. It can be seen that using the improved algorithm for direction of arrival estimation results in narrower peaks for coherent signals. Hence the 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.

Case 2: By considering Number of snapshots.

Case 3: By considering distance b/w the array elements.

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

A. Simulation of MUSIC:

The simulation result for fig. 3 shows how the MUSIC algorithm identifies the three signals. There are three signals which are independent narrow band signals and the incident angle of these signals are -45°, 0° and 45° respectively. These three signals are not correlated, the noise is IGWN (ideal Gaussian white noise) and Signal to noise ratio is assigned as 30dB, the number of array elements are 12, and the no. of Snapshots is given as 100. Their shaft width is fundamentally the same as. Along these lines, the no. of exhibit component can be reasonably chosen by conditions and ensures the precision of estimation of range. With progress in the speed of operation, work efficiency can be improved.

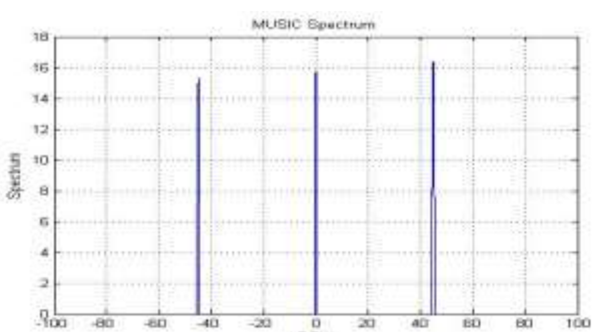

Fig.3: MUSIC Spectrum

As can be seen from Fig. 4, it is a spatial covariance matrix spectrum of coherent structure. Under the below spectrum model shown, the DOA calculation can achieve any accuracy by conquering the customary insufficiencies of low exactness; it can deal with bearing issues with high determination &high accuracy in various sign environment. In this way, high determination MUSIC count may evaluate precision, higher affectability components and potential capacity with multi determination signals, better execution and higher proficiency, it can give higher determination and asymptotically adjusted DOA figuring, which has huge ramifications for viable applications.

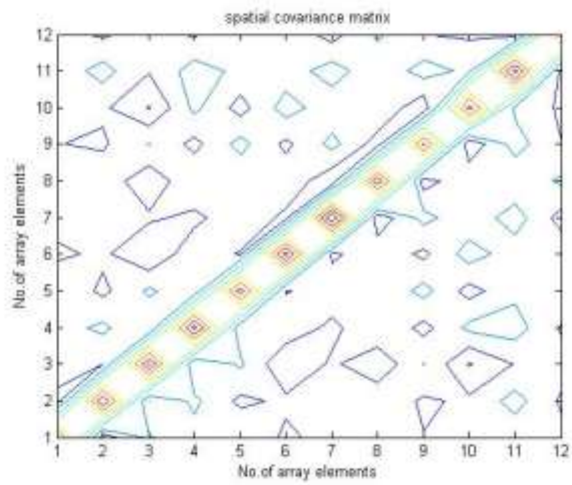

Fig.4: Spatial Covariance Spectrum

The fig. 5 simulation shows signal with noise, as the name itself suggests 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.

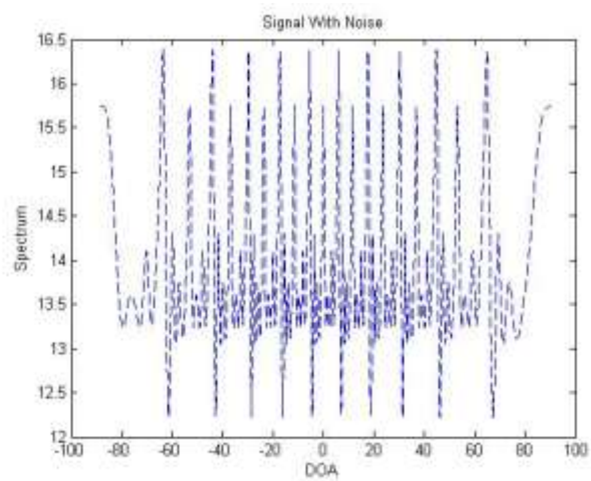

Fig.5: Signal with Noise

B. Simulation of improved MUSIC:

As, It can be seen from Fig. 6, this simulation is an improved version of modified MUSIC such that, There are three autonomous narrow band signals, for which the incident angle is -45°, 0° & 45° respectively. The SNR is 30dB, the number of array of elements is 12 & the no. of snapshots is 100. Here an improved MUSIC algorithm, the amplitude of each signal is increased rapidly, thus provides high resolution with better performance than simple MUSIC. Also it provides the greater sensitivity in terms of no. of snapshots, angle of arrival etc.

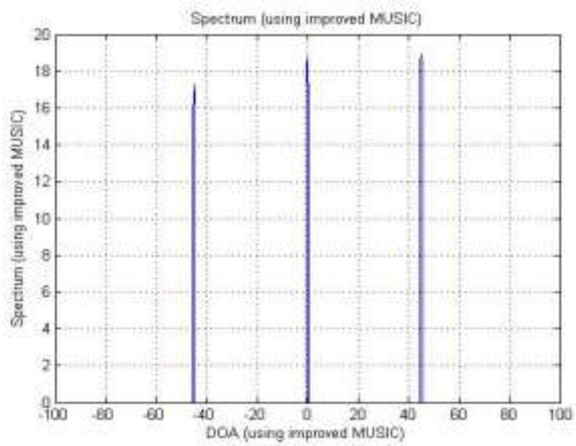

Fig.6: Improved MUSIC spectrum

The above simulation fig. 7 shows spatial covariance spectrum, where the noises are reduced due to increase in the amplitude. The new Improved MUSIC algorithm can provide DOA calculation more accurately & will have an effect both on theoretical and practical applications.

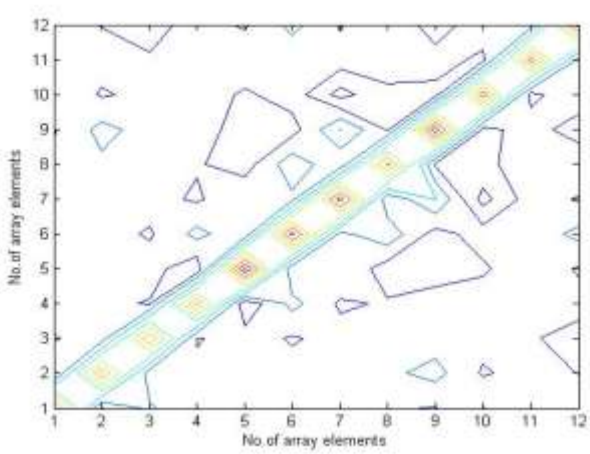

Fig.7: Spatial Covariance Spectrum

As can be seen from Figure 8, the below figure shows a spatial spectrum of Improved MUSIC which is basically an environment noise present while receiving the incoming signal.

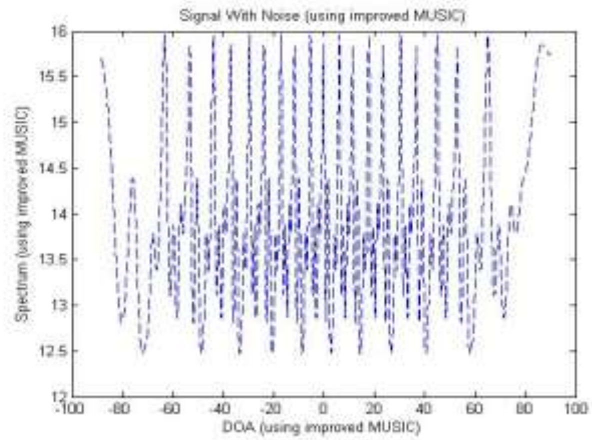

Fig.8: Signal with Noise

As can be seen from fig.8, is an improved MUSIC signal with noise. The dashed line shows the noises and the other remaining conditions unchanged. While in the expansion in the no. of commotions, the shaft width of DOA count gets to be smaller and accordingly the course of signs gets to be clearer and more honed, the exactness of Music calculation is likewise expanded. The estimation of SNR can influence the execution of high determination DOA count. The simulation results are shown in fig. 8.

V. CONCLUSION

Direction of arrival estimation algorithm, found out its limitations and also the effect of array geometries. Based on research a conclusion stated as, a widely used MUSIC algorithm was developed and its performance was analyzed in terms of accuracy and resolution. The ULA antenna geometry pattern used commonly for estimating the DOAs has been studied and its merits and disadvantages were considered comparable to UCA. ULA gives an edge over UCA in terms of its simplicity, but it only gives an azimuth angle, while UCA can give both azimuth and elevation angle. The proposed calculation for evaluating DOA was produced subsequent to making certain adjustments in MUSIC calculation, by preparing the covariance grid of the exhibit yield signal.

In terms of computational complexity, MUSIC tends to be easier as compared to our proposed algorithm. Thus, to get better DOA resolution the scanning rate by the search vectors should be small, which certainly results in a high computational complexity

The application of both the proposed algorithm and the MUSIC is limited to the signal sources which are less than the no. of array elements. These techniques use subspace calculation and Eigen decomposition methods to which it leads to higher complexity. Therefore it limits the use of applications where fast DOA calculation is not necessary.

REFERENCES

[1] DebasisKundu. Modified MUSIC Algorithm for estimating DOA of signals.Department of Mathematics Indian Institute of Technology, kanour, India. November 1993.

[2] Fei Wen, Qun Wan, Rong Fan, Hewen Wei. Improved MUSIC Algorithm for Multiple Noncoherent Subarrays.IEEE Signal Processing Letters. Vol. 21, no. 5, May, 2014. [23] Chen, Xiaoming. "Using Akaike information criterion for selecting the field distribution in a reverberation chamber." Electromagnetic Compatibility, IEEE Transactions on 55.4 (2013): 664-670.

[3] Xianda Zhang, Zheng Bao, Communication Signal Processing, National Defence Industry Press, 2000.

[4] Haykin S. Array Signal Processing. Prentice Hall. 1985.

[5] S.Unnikersnna Pillai. Array Signal Processing, Springer verlag, 1989.

[6] HongY Wang, Modern Spectrum Estimation, Dongnan University Press, 1990.

[7] Xianci Xiao, Modern Spatial Spectrum Estimation, Haierbin Industry University Press, 1992.

[8] PerteStoica, Maximum Likelihood Method for Direction of Arrival Estimation. IEEE Trans on ASSP. 1990. Vol. 38(7). P1132~1143.

[9] Michael L. Miller. Maximum Likelihood Narrow-band Direction Finding and EM Algorithms. IEEE Trans on ASSP. 1990. Vol. 36(10). P1560~1577.