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A High Resolution Direction Finding Technique for Underwater Acoustic Signal

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Abstract*: *Target estimation in oceanic platform has gained observable engrossment in military and civilized occasions. In this article, the performance of DOA estimation technique based on subspace and the non-subspace analysis have explored. The Subspace analysis of simple resolution and high resolution algorithms, comparisons and the performance of different parameters have discussed. The analysis is based on uniform linear spaced array elements and the estimation depends on the pseudo random spectra function. Customary MUSIC algorithm decomposes the signal covariance matrix into Eigen decomposition and makes the signal subspace matrix orthogonal to the noise subspace, which minimizes the effect of the noise. But, when the signal intervals are very narrow, the existing algorithm cannot separate the correlated sources as SNR reduced to some extent. An advanced algorithm works on factorization of array signal covariance matrix to get Eigen vector and its values. A simulation outcome displays that, projected method gives greater performance compare to the available algorithm. This paper discussed the underwater properties to analyze the performance in noisy surrounding for the new modified MUSIC algorithm.

Index Terms*: DOA estimation; Subspace analysis; Uniform Linear Array (ULA); signal covariance matrix; MUSIC algorithm*

I. OVERVIEW

In array undertaking techniques, a composite structure of constant antenna elements which receives multiple independent low frequency components are continuously monitored. A Direction of Arrival (DOA) finding carried out using a lone fixed antenna has controlled resolution, as the physical dimension of the operating antenna is inversely proportional to the antenna highest peak beam width. It is not practically probable to increase the size of a single antenna to obtain the accurate sharp beam width. An array of sensors elements provide better executions in parameter estimation and signal reception in terms of accuracy and determination. In signal finding operation, the isolated signals received by the linear sensor array which increases the solidity of useful signals by eliminating the noise signals and intervention. Multiple sensor composite arrays have an immense role in biomedical, sonar, seismic event prediction, direction finding, wireless sensor networks, radar etc [1].

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Different multiple algorithms based on subspace and non-subspace techniques and others can be employed for the direction finding process. It predicted that the signals are available in all the directions of space. So the spatial spaced frequency spectrum of the signal can be upgraded to obtain the signal Direction of Arrival. ESPRIT and MUSIC algorithm are the two extensively used spectral estimation techniques which work on the principle of decomposition of Eigen vectors and values. These subspace based perspectives highly rely on the covariance matrices of arriving signals [2]. ESPRIT works with array composition having simple outline structure. So, the MUSIC algorithm is the most reliable parameter estimation method that can be used for both uniform and non-uniform linear sub-space array structure. The normal MUSIC algorithm works on Uniform Linear Array (ULA) structure, where the array elements are placed in such a way that they match the Nyquist sampling law. The design of non - uniform array is quite complicated and it requires various process & techniques. This technique is capable of performing various tasks depend on intensity, angle of impinging signals related to array normal and array model.

II. EQUIVALENT WORK

An improvement in the antenna sensing array pattern, the target parameter detection process becomes a crucial part of intelligent antenna technology. An antenna array, receives multiple signals, classified at all its array elements with combination of the spatial information and Gaussian noise, but unable to differentiate the signals which is similar and consistent. Therefore, the high resolution DOA estimation algorithm for coherent sources is an integral part of smart array antenna as the signal and noise haven't the orthogonal relation [3]. Multiple Signal Classification is an Eigen dissolution algorithmic rule which excerpts the information for DOA estimation by factorization of the array co-variance matrix to get Eigen vectors with its Eigen values. But due to mutual coupling between the various antenna poles and model errors, MUSIC ignores to give appropriate DOA of a gesture when the correlation level is high. The given algorithm neglects to separate the sources which are nearer.

III. SUGGESTED DESIGN

A. Background of Basic MUSIC Algorithm:

MUSIC is known as Multiple Signal categorization estimation algorithm. It is a simple, familiar high resolution and well ordered flexible technique. It provides accurate angle estimation and number of signal collected at array [3]-[4].

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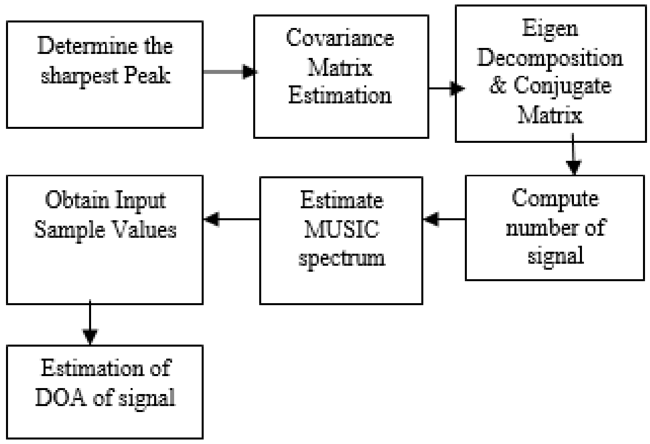

Fig.1: Process of MUSIC Technique

Fig. 1 shows the process of given algorithm and formulation.
Step 1: Consider sample input snapshot X_K, k=0 to N-1 & determine the input array covariance matrix

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

Where k are number of frequency varying sample of arriving signal, X_K is the arriving input signal, X_K^H is the signal with noise factor
Step 2: Accomplish Eigen decomposition on $\hat{R}_{xx}$

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

Where Λ= diagof{ $\lambda_0, \ \lambda_1, \dots \lambda_{M-1}$} represents Eigen values and Where E=diag {$Q_0, Q_1, \dots . Q_{M-1}$} is corresponding Eigen square roots of covariance matrix of array output $\hat{R}_{xx}$
Step3: Calculate the minimum value of noise vector as,

$$\hat{L} = m - k \qquad (3)$$

Step 4: Get the MUSIC spectrum by the given equation.

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

Step 5: Estimate the $\hat{L}$ largest peaks of $\hat{P}_{MUSIC}(\theta)$ to obtain direction of signal arrival from the given equation

B. Illustration of Proposed MUSIC Algorithm:

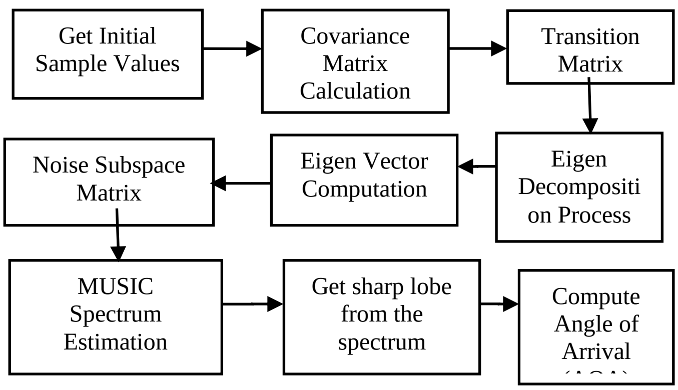

Fig.2: Process of Proposed MUSIC Technique

Fig. 2, allows the complete calculation of the modified MUSIC algorithm, which moved by using the equations shown below. This algorithm has gain over other estimation techniques as it detects the sharp spectrum peaks efficiently to estimate the isolated source signals with high refinement. Generally other estimation processes are controlled with low clarity [6]. The stated algorithm has even proved to have better performance in a multiple classical signal environment. MUSIC invention has better angular resolution, higher precision and reliability with multiple signals. But this algorithm capture a high resolution in direction finding only when the signals being incident on the sensor array are non-coherent and non-correlated. It losses efficiency when the signals are correlated. By considering the coherent signals to be incident on the sensor arrays, analysis has performed to get subsequent result in noisy background.

In existing algorithm, the peaks of spatial spectrum is not acute and narrow, it fails to determine the arrival angle for coherent signals. Also the sources which are very nearer to each one, the same performance affect the output. For fulfill the requirements of proper DOA estimation, an improved MUSIC algorithm initiated for coherent signals. For improvements in results of MUSIC algorithm, need to initiate an identity matrix for pre-analysis and the new modified received signal array matrix X is given as:
X=AS+N
For an exhibit x, the comparing counts is completed to get its covariance grid Rx
i.e... Rx= E [X X^H]
Here, H is represented as the complex conjugate of the original received array signal matrix
Rx= E [(AS + N) (AS + N) ^H]
= AE [SS^H] A^H+E [NN^H]
=A Rs A^H+R N
Where Rs= E [S S^H],
RN= σ^2 I, is noise mutual relationship pattern
σ2 is surrounding noise signal power.
I represent Identity matrix of M by M.
Generalized, Rx= A Rs A^H + $\sigma^{2}I$,
Ry= E [YY^H] = J Rx*J
As indicated by above equation, the array covariance matrix Rx and Ry added to get composite column vector matrix which also have the same noise vector as separate covariance array matrix represent [7].
R= Rx + Ry
R = AR_S A^H + T [AR_S A^H] * T + 2σ^2 I

As indicated by lattice's conditions, the frameworks Rx, Ry and R have the same clamor subspace. In this manner conduct qualities deterioration of R and acquire its Eigen vector and its root mean square Eigen values, as indicated by evaluated number of sign source with discrete clamor subspaces. Afterwards utilize this new isolated commotion subspace to develop spatial range and to get the DOA estimation by locating the crest. The mathematical analysis shows, the modified algorithm for direction of arrival estimation results in narrow sharpest peaks for coherent signals and close sources. Basic algorithm is unsuccessful to achieve narrow and keen peaks. Proposed algorithm attains sharp peaks to make process much facile and error-free.

IV. RESULTS & DISCUSSION

In this discussion, three DOA factors are examined for output analysis, which shown below.
Three occurrences have discussed here, as:

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Occurrence 1: SNR at 0db and 30db
Occurrence 2: Array sampling at 100 and 1000
Occurrence 3: Spacing between the array sensor elements
By examining above occurrences, the outputs of the Modified MUSIC algorithm have simulated and performances are discussed.

GUI Simulation of Proposed Algorithm:

Occurrence 1 :(a) At SNR=0db

At very high noise environment conditions, this Modified MUSIC algorithm provides high quality estimation of angle of arrival of signals [7]-[8].
Fig. 3 shows the graphical user interfaces and inputs for various parameters.

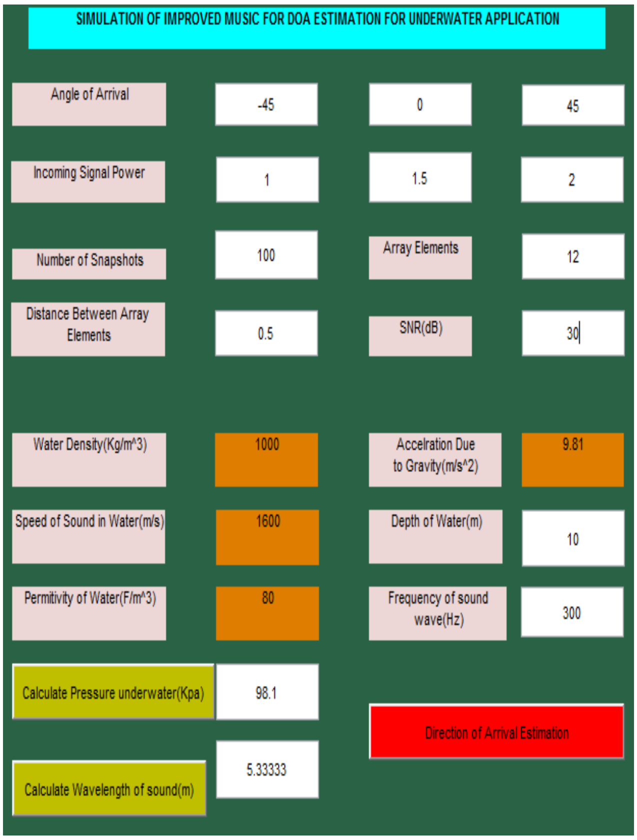

Fig. 3: GUI Structure at SNR=0db

Fig. 3 shows the GUI of an upgraded class of propound algorithm such that, there are three independent narrow band signals which incident at -45°, 0° & 45° respectively.

The white spaces in Fig. 4 indicate the high noise in signal. As noise is more in the signal, signal to noise ratio gets weaker to get faded signal DOA estimation to track the signal direction.

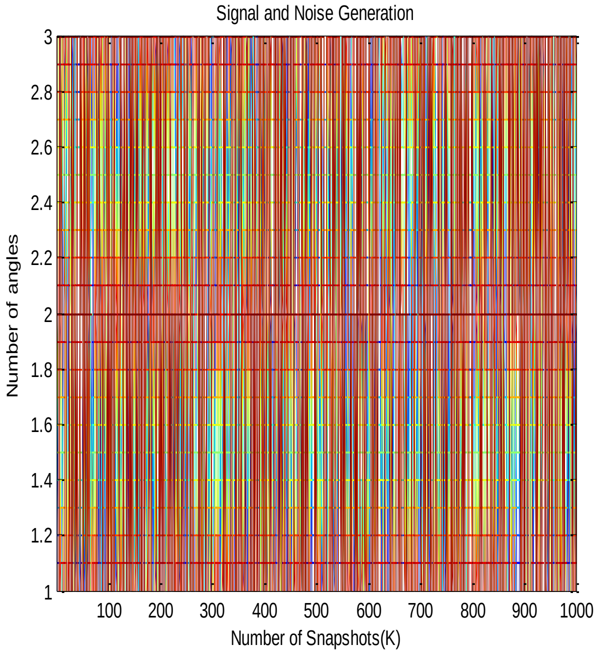

Fig. 4: Signal and Noise generation for case 1(a)

Fig. 5 indicates the generation of the data matrix after the Eigen decomposition of vectors

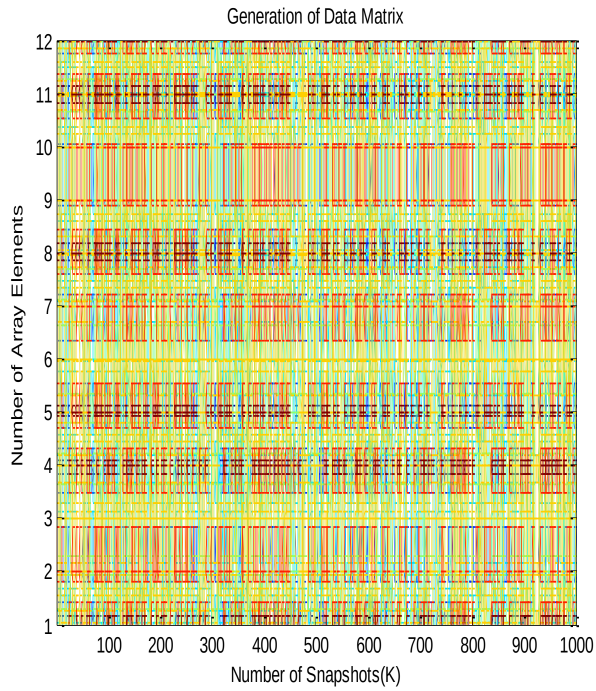

Fig. 5: Generation of Data Matrix for case 1(a)

The below Fig. 6 indicates the spatial covariance array matrix spectrum, where the noise is more, because of magnitude incrimination [8]. The enhanced MUSIC algorithm provides DOA results more precise & will have a consequence on both theoretical and practical applications.

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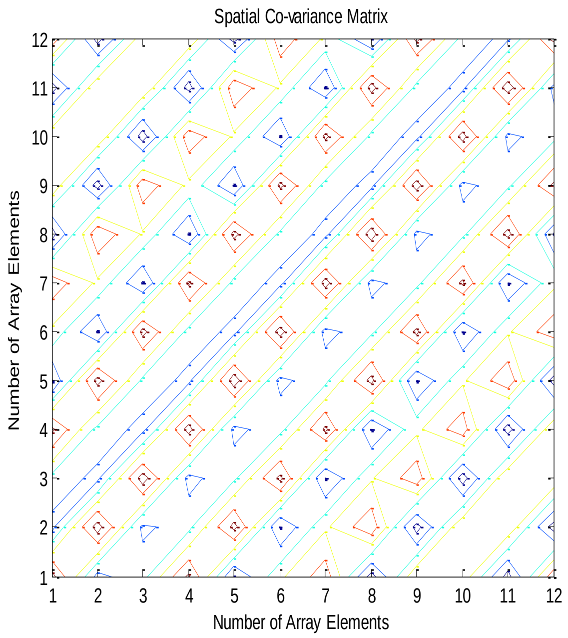

Fig. 6: Spatial Co-variance Matrix for case1 (a)

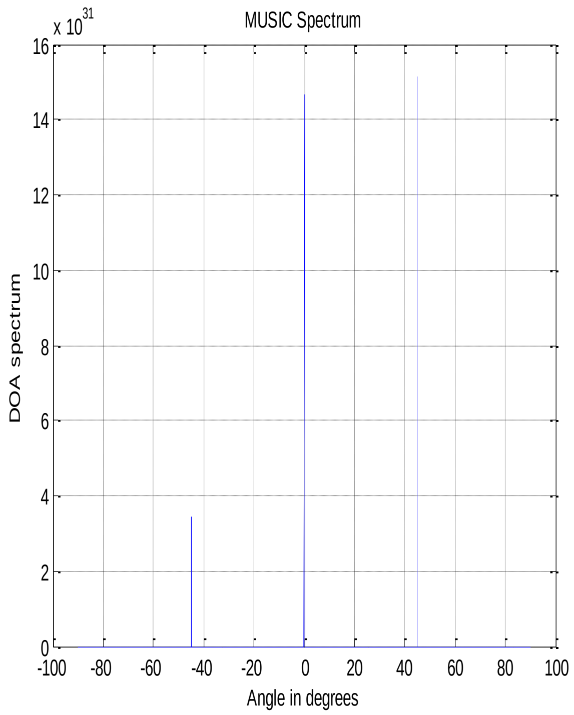

Fig. 6 Modified MUSIC Spectrum for case 1(a)

In given proposed algorithm, the strength of each incoming signal is increases compare to existing technique. Thus provides high performance than simple MUSIC in noisy environment as spatial covariance between the signal and noise is not related.

Occurrence 1 :(b) At SNR=30db

Fig. 7 shows the graphical user interfaces with inputs at various parameters. Fig. 7 indicates the performance of an improved version of simple approach of estimation having three autonomous limited frequency signals with the different angle like discussed in occurrence 1 process at 30dB SNR.

Fig. 7: GUI Structure at SNR=30db

From the given Fig. 8 observations, it is clearly shown in the results below that noise is less compared to signal at SNR 30dB. At SNR=30db, fig. 8 shows small instances of white spaces in the data which indicates noise content in the data or signal of interest(SOI).

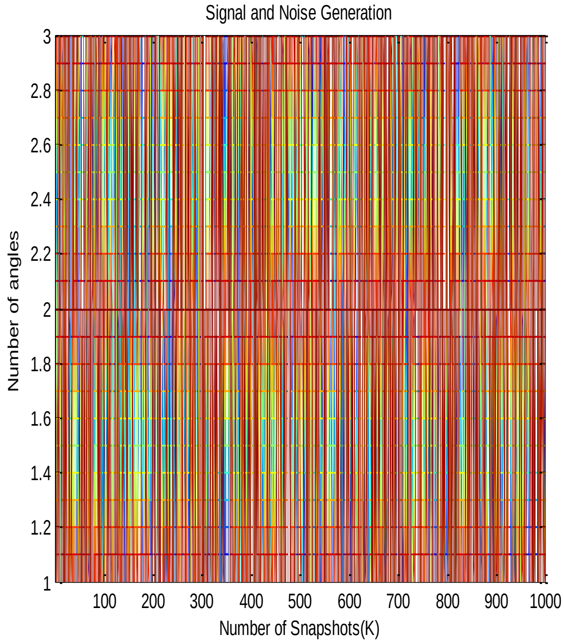

Fig. 8: Signal and Noise generation for case 1(b)

Fig. 9 indicates the generation of the data matrix after the Eigen decomposition of covariance matrix vectors.

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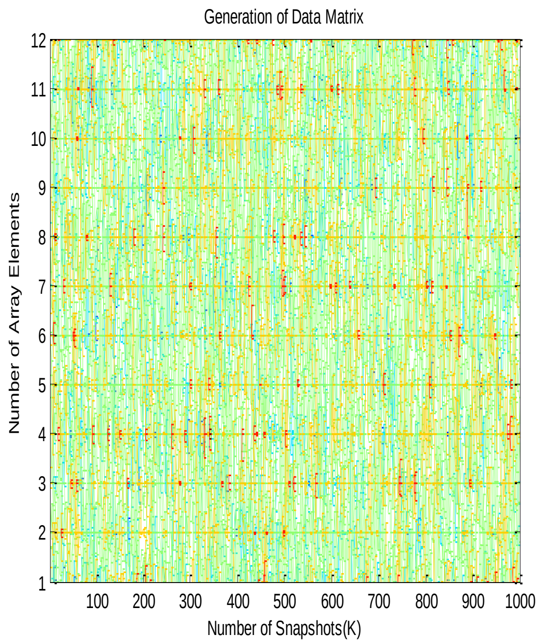

Fig. 9: Generation of Data Matrix for case 1(b)

The above Fig. 10 shows that, the spatial covariance matrix of array spectrum, where the quantity of noise is reduced with increase in the strength of the signal in noise-free surrounding [8]-[9]. The refined MUSIC algorithm delivers a better DOA matrix calculation.

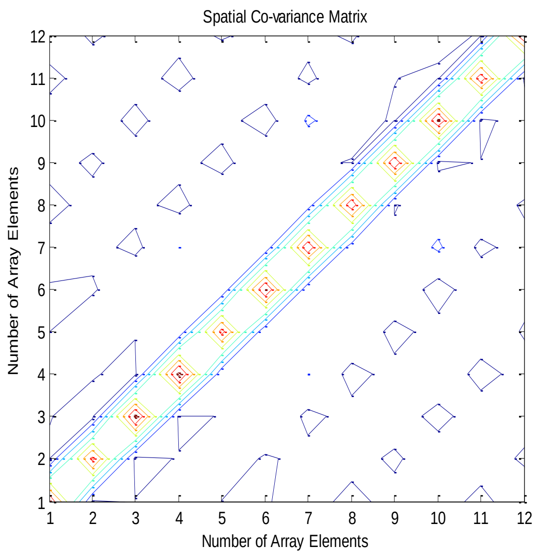

Fig. 10: Spatial Co-variance Matrix for case1 (b)

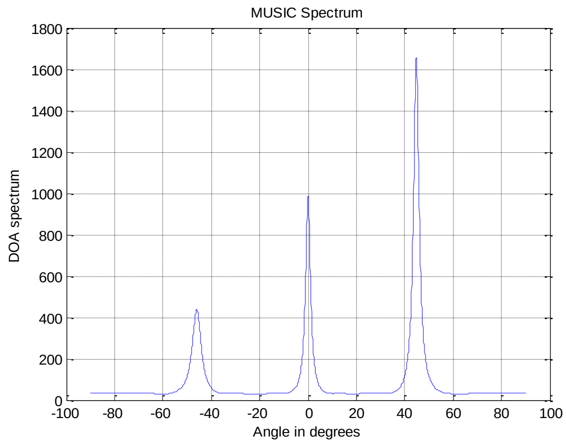

Fig. 11: Modified MUSIC Spectrum for case 1(b)

Occurrence 2: (a) Number of Snapshots=100

Occurrence 2 (a), suggested the output performances related to number of snapshots, which shows that the quantity of number of spaced frequency sample affect the performance of direction estimation. As the number of sample decreases, gradually resolution of arrival of signal direction also degrades. It is observed from above Fig. 12, that for better accuracy, it is important to take moderate number of snapshots.

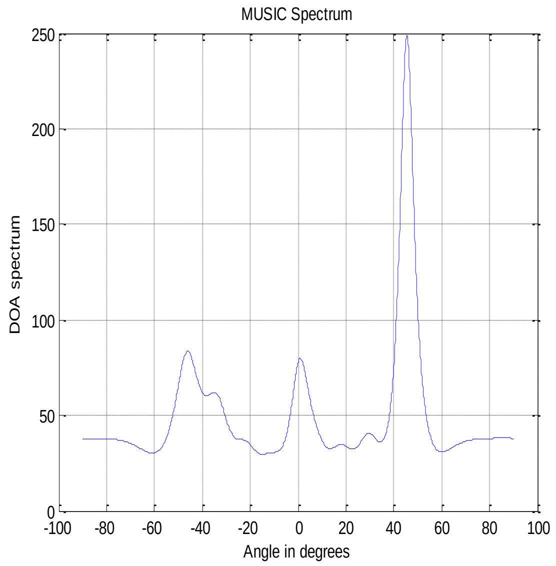

Fig. 12: Modified MUSIC Spectrum for case 2(a)

As snapshots increases, computation efficiency decreases due to large storage, hence complexity increases.

Occurrence 2: (b) Number of Snapshots=1000

Here in case 2 (b), to analyze the output performances, number of snapshots are considered, which shows that as the number of snapshots increases accuracy of direction of arrival estimation increases, which improves the DOA performance. It is observed from above

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Fig. 13, that for better accuracy, it is important to take moderate number of snapshots. For maximum number of snapshots, there will be less noise present at the output but it creates more delay.

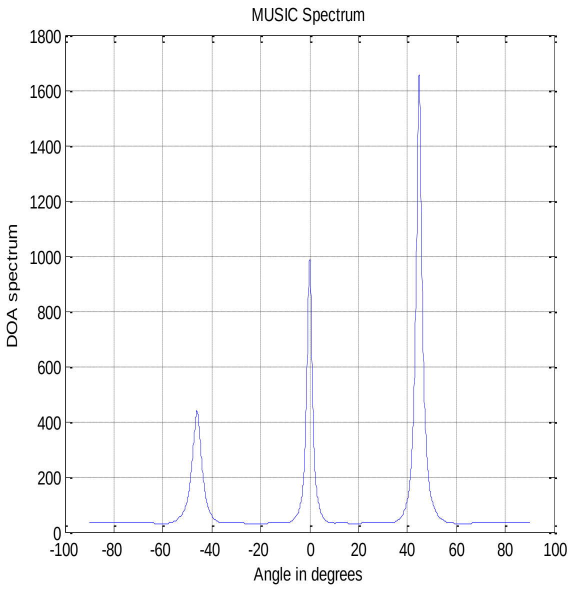

Fig. 13: Modified MUSIC Spectrum for case 2(b)

Consequently new enhanced Music can be better associated with expel the sign relationship quality, which can perceive the reasonable flags and figure the edge of landing all the more absolutely by Using improved MUSIC algorithm [10]-[11].

Case 3: (a) Distance between position elements d=0.5m

The distance across the space array elements plays an important role in obtaining the higher resolution.

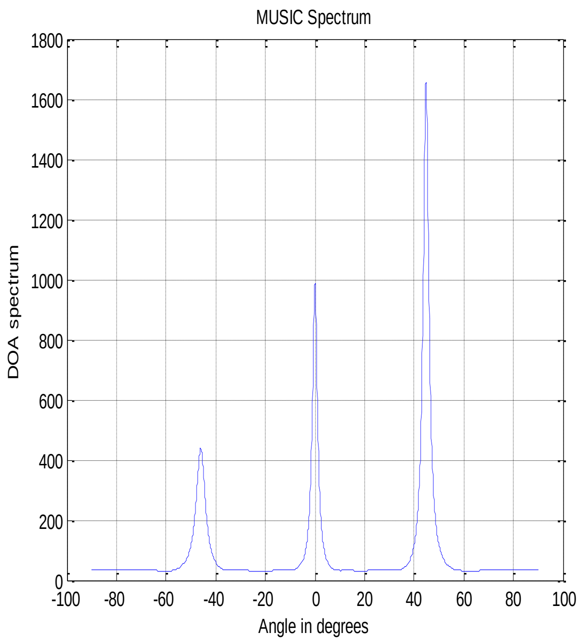

Fig. 14: Modified MUSIC Spectrum for case 3(a)

As the distance between the sensor array element is less, there will be high resolution output and vice versa. The results are shown in the above Fig. 14.

Case 3: (b) Distance between array elements d=5m

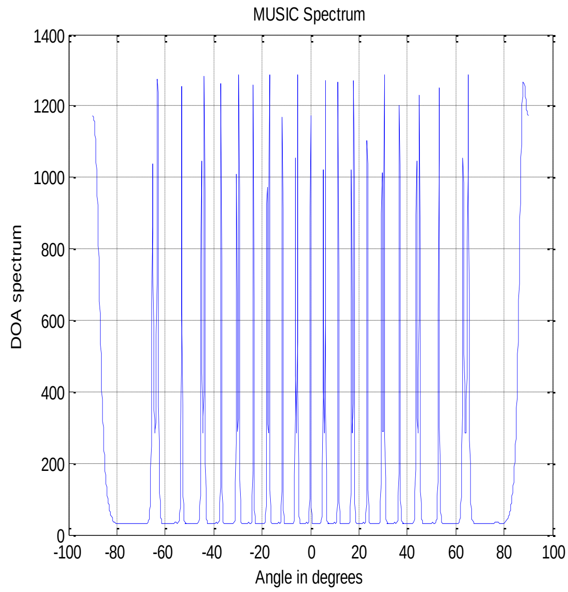

Fig. 15: Modified MUSIC Spectrum for case 3(b)

The results are shown in the above Fig. 15, as the distance between the sensor array elements increases, less resolution output due to radius of signal will be less compare to array element spacing and vice versa.

REFERENCES

1. Debasis Kundu et.al, "Modified MUSIC Algorithm for estimating DOA of signals", Department of Mathematics, Indian Institute of Technology (IIT) kanpur, India. November on 1993.
2. Fei Wen, Qun Wan "Improved MUSIC Algorithm for Multiple Noncoherent Subarrays", IEEE Signal Processing Letters. Vol. 21, no. 5, on May, 2014.
3. Khairy A. El-Barbary, Tawil S. Mohamed, "High Resolution Direction of Arrival Estimation (Coherent Signal Source DOA Estimation)" ‖International Journal of Engineering Research and Applications (IJERA),Vol. 3, Issue 1, ISSN:2248-9622, pp.132-139, January-February 2013
4. Chen Xiaoming et.al, "Using Akaike information criterion for selecting the field distribution in a reverberation chamber", Electromagnetic Compatibilities, IEEE Transactions on 55.4 (2013): 664-670.
5. Xianda Zhang "Communication Signal Processing", National Defence Industry Press Ltd., 2000.
6. Haykin S., "Array Signal Processing", Prentice Hall. 1985.
7. S.Unnikersnna Pillai, "Array Signal Processingn Proceeding", Springer verlag, 1989.
8. HongY Wang, "Modern Spectrum Estimations", Dongnan University Press, 1990.
9. Xianci Xiao, "Modern Spatial spaced Spectrum Estimation", Haierbin Industry University Press, 1992.
10. PerteStoica, "Maximum Likelihood Method for Direction of Arrival (DOA) Estimation", IEEE Transaction on ASSP. 1990. Vol. 38(7). P1132~1143.
11. Michael L. Miller,"Maximum Likelihood Narrow-band Direction Finding Technique and EM Algorithms", IEEE Transaction on ASSP. 1990. Vol. 36(10). P1560~1577.

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