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FACTORS AFFECTING DOA ESTIMATION IN UNIFORM LINEAR ANTENNA ARRAY(ULA) PROCESSING

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Abstract

Antenna signal processing includes the subfield Direction of Arrival estimation (DOA). For the past two decades, it is one of the renowned method for determining the DOA in an antenna array have been the Spatial Spectral estimate methods and the Parametric Approach.The primary application of the spatial estimation method is in the analysis of multi-sensor fusion systems, where it is used to pinpoint the origin of a signal and estimate its spatial properties. In this research, we employ the MUltiple SIgnal Classification(MUSIC) algorithm to estimate the direction of arrival in the existence of white noise, and results are compare it to other commonly used estimation methods including MVDR, MIN-norm, and conventional beamforming. The Antenna with Uniform Linear Array (ULA) is constructed in this paper. Parameters including array size, signal-to-noise ratio, and sampling rate are varied in the simulations to see how they affect the DOA estimate resolution.

Keyword: DOA, ULA, Spatial, MUSIC, MVDR, Min-norm, SNR

I.INTRODUCTION

The vast amounts of data rate and bandwidth are used due to the enormous advancement in communication system.The high user density,data rate ,higher traffic and Multipath fading in outdoor progation are the most difficult challenges in mobile communication.Smart antenna systems [1], [2], and [3] are used to circumvent the aforementioned difficulties.Instead of employing fixed single antenna with advanced DOA estimation technique and adaptive beamforming, Antenna array system with sophisticated signal processing boost the DOA estimation and provided improved performance than single antenna element.

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Initial Fourier transform-based linear spectrum estimates use the peridogram but suffer from performance drops owing to the Rayleigh limit. Maximum Likelihood estimate and other forms of statistical analysis are employed later on for their reliability.It offers excellent resolution, but the hunt for higher dimensional space increases the mathematical complexity, making it hard to put into practice[4-6].In spite of their great resolution, the maximum entropy approaches' considerable processing complexity and lack of robustness[5,6] are major concerns.

After the 1980s, eigen value decomposition-based techniques were developed for spectrum estimation.Those estimation is represented by Multiple Signal Classification(MUSIC) and Estimation Signal Parameters via Rotational Invariance Technique (ESPRIT)[7,8].It has been shown[9,10] that MUSIC can be viewed as a 1D version of maximum entropy with the same flavor as Maximum Likelihood estimation.Despite the fact that it has a high calculation complexity, it ultimately shows to be the most effective method.

Although several different super resolution theorems are currently in use, the most common subspace-based strategies for estimating the DOA are MUSIC, Capon, ESPRIT, and Min-norm[11]. Although it is computationally intensive, it improves DOA estimate when analyzing a source with many signals[12].Artificial neural networks are employed for DOA estimation[13] because of the nonlinear and nonstationary character of signals like speech, radar, and biomedical data.

In this study, we analyze the MUSIC algorithm's performance in a Uniform Linear Array (ULA) by changing the array's parameters—including the number of elements, the frequency of snapshots, and the signal-to-noise ratio (SNR)—to find the optimal configuration.

II.DOA ESTIMATION

A. The Design Structure of Spatial Spectrum System

A particular kind of signal estimating called "spatial spectrum estimation" uses space antenna arrays to achieve a signal restriction in space. The incident signal space, the spatial array receiver, and parameter estimation are the three main components of the spatial spectrum system, as illustrated in Figure 1. Three spaces—the target stage, the observation stage, and the estimation stage—can be distinguished inside the space [14].

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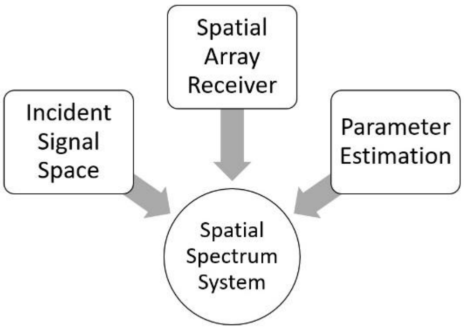

Fig.1 Spatial Spectrum Estimation System

The signal-source parameter and the intricate setting make up the goal stage in the aforementioned design. The receiver of radiation signals from the target stage, where signal and spatial parameters are also received.Spatial spectral estimation techniques are used throughout the estimating phase.

B.MUSIC Algorithm

The MUSIC algorithm was initially proposed by Schmidt in 1979[15].The MUSIC approach employs an attribute inversion on the covariance matrix, which is a representation of the antenna array output data, in order to distinguish signal from noise. This step is necessary for the procedure. After that, we make use of the newly created pair of orthogonal subspaces in order to produce a spectrum function, extract it by performing a peak search in the spectrum, and, last, recognize DOA signals. DOA estimators that yield high-resolution outputs produce these results by combining signal subspace methods with classical procedures such as the MUSIC algorithm. To construct a signal and noise subspace, the MUSIC spectral estimation method makes advantage of the auto covariance or auto correlation of the eigen structure of a signal added noise model. calculating the DOA of an antenna array in the same way that the spatial covariance matrix is calculated.

Since the signal subspace is orthogonal to the noise subspace, it is always present when a signal is received. The steering vectors are derived from the received signal. To find the vector that is orthogonal to the noise subspace, a search is performed over all possible sets of steering vectors.For the incoming signal the the corresponding steering vector **a**(θ) is given by:

$$P_{MUSIC}(\theta) = \frac{1}{a^H(\theta)\, Q_n Q_n^H a(\theta)} \quad (1)$$

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Signals with values of after all steering vectors have been handled are deemed DOA. Estimation of the "spectrum" of many signals using equation (1). With the MUSIC approach developed by Schmidt et al. [15], we can estimate the direction of arrival (DOA) of a signal by first evaluating a basis for noise subspace (Qn), and then using the angles between these peaks to identify the r peaks in Equation (1).

The MUSIC algorithm's high performance has led to its widespread adoption across a variety of array processing systems. However, the algorithm does not provide a particularly reliable estimate of the DOAs of correlated signals, and the search for peaks in the data increases the computational complexity.

III.Factors affecting DOA estimation simulation results

Many factors, including the incoming signal's origin and the environment in which the DOA estimation is performed, might affect the accuracy of the outcome [16]. In this study, we examine the effects of these common parameters on the processing of signals in uniform linear arrays by doing some simple simulation experiments and analyzing the results.

A. Array elements

The super resolution approach's estimation efficiency may shift depending on the dimensions of the base arrays. If the parameters of an array remain constant, then a higher number of array items will result in better estimate performance using a super resolution technique.

B.Snapshots

The number of samples is proportional to the number of time-domain snapshots. The number of snapshots is defined in the frequency domain as the number of DFT time sub segments.

C.SNR

SNR can be defined as below with the power of signal source is $\sigma^2{}_p$, noise power is $\sigma^2{}_n$,

$$SNR=20 \log (\sigma_P / \sigma_n) \qquad (2)$$

The efficiency of a super-resolution detection-of-action (DOA) estimation algorithm based on signal-to-noise ratio is of immediate relevance. Super-resolution algorithms perform poorly

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under low signal-to-noise levels. Improving the algorithm's performance when the signal-to-noise ratio (SNR) is low is, thus, the primary focus of research into the super resolution DOA technique.

IV. Results and Discussion

A. Simulation for MUSIC Algorithm

This simple simulation shows how the MUSIC algorithm can be used to forecast the occurrence of two signals.Two narrow-band signals are created for the simulation and incident on a uniform linear array at 25° and 65°, respectively.These signals do not interact with one another.White gaussian noise is used, with 300 samples, 20 array elements, and a signal-to-noise ratio (SNR) of 15 dB.Fig.2 displays the simulation results.

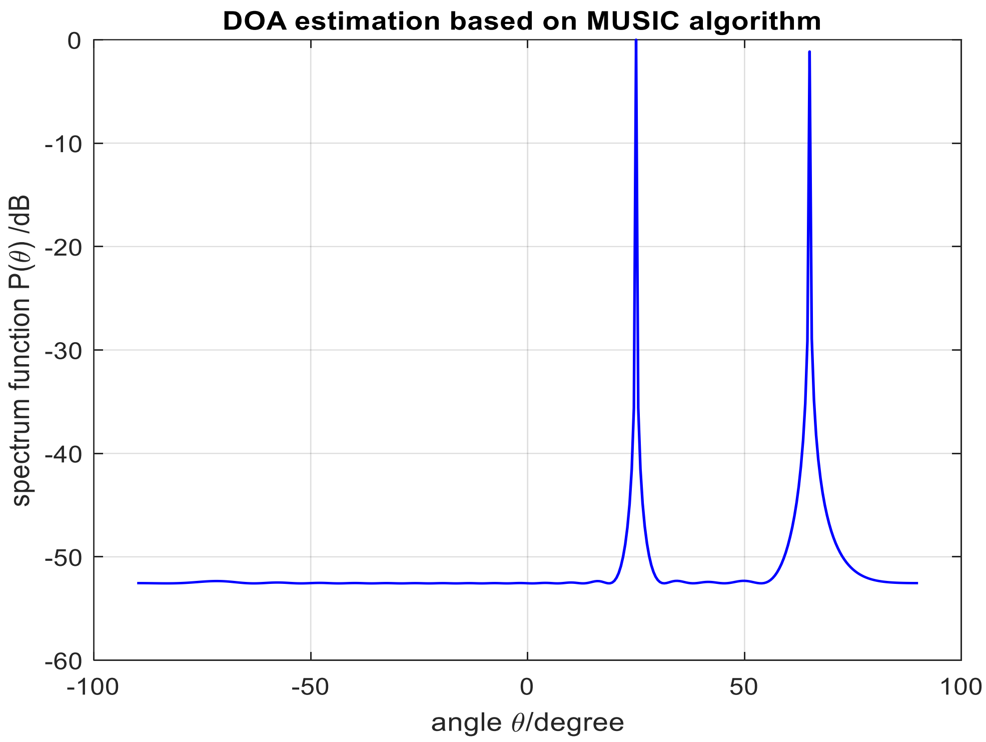

Fig.2 Simulation of MUSIC algorithm

In order to correctly estimate the DOA of an independent signal source, the MUSIC method must first accurately estimate the number and direction of the incident signal. To handle the direction problem in a multiple-signal setting with high resolution and high accuracy, the precise model allows the DOA estimation to achieve any precision by outperforming the restrictions of the old-fashioned technique. Since the MUSIC algorithm has the potential to

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measure precision, extreme sensitivity features, and work with multi-resolution signals with improved performance and advanced competence, it is able to provide high resolution and asymptotically unbiased DOA estimation, which is of great practical significance.

B. Performance Analysis by Varying SNR

This simple simulation shows how the MUSIC algorithm can be used to forecast the occurrence of two signals.Two narrow-band signals are created for the simulation and incident on a uniform linear array at 25° and 65°, respectively.These signals do not interact with one another.Ideal white gaussian noise is used, and the number of samples is 300, the number of array elements is 20, and the signal-to-noise ratio (SNR) varies from SNR1=-10db to SNR2=-15db to SNR3=-40db.Figure 3 displays the simulation results.

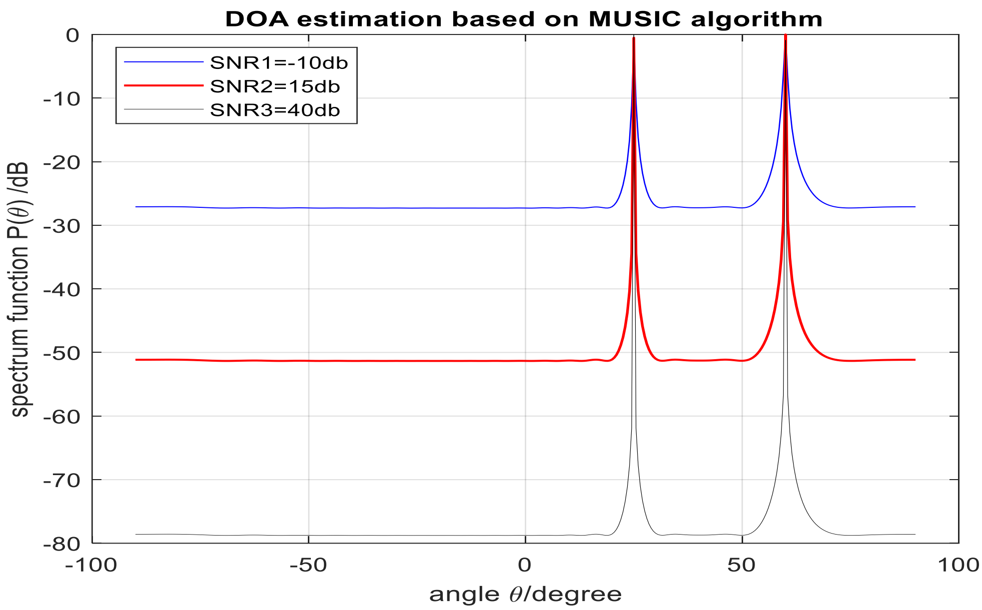

Fig.3 SNR Effect in DOA Estimation

As depicted in Figure 3, an increase in the signal-to-noise ratio (SNR) results in a narrower beam width in the spectrum of direction of arrival (DOA) estimation. This leads to a sharper signal track and an enhancement in the accuracy of the Multiple Signal Classification (MUSIC) method. The performance of a high resolution direction of arrival (DOA) estimate algorithm can be directly influenced by the value of the signal-to-noise ratio (SNR). The performance of the MUSIC algorithm experiences a significant reduction when operating at low signal-to-noise ratio (SNR). Consequently, enhancing the accuracy of estimation under low SNR conditions

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has been a prominent area of investigation in the field of high resolution direction of arrival (DOA) estimation.

C. Performance Analysis by Varying Snapshot

This basic simulation shows how the MUSIC algorithm can be used to forecast the presence of two signals.Two narrow-band signals are constructed for the simulation and incident on a uniform linear array at 25° and 65°, respectively.There is no mutual influence between these signals.There are 20 array elements, 20 items in each snapshot, and the SNR is 20 dB. The noise is white gaussian.The outcomes of the simulation are shown in Figure 4.

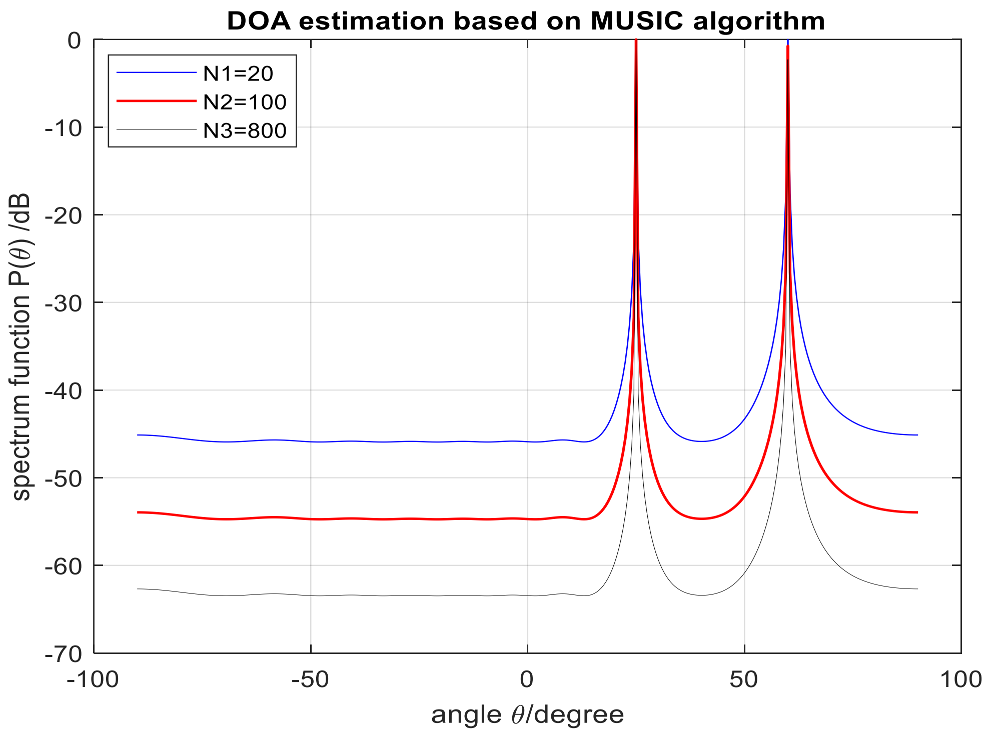

Fig.4 SnapShot Effect in DOA Estimation

Figure 4 shows that when the number of snapshots increases, the beam width of the predicted spectrum decreases, the orientation of the array element enhances, and the accuracy of the MUSIC method grows. Consequently, the accuracy of the DOA estimate can be improved by increasing the number of sample snapshots; however, this will increase the amount of data that must be processed. The MUSIC algorithm will also become slower due to the increased quantity of calculations it must perform. Acceptable sample snapshots are the greatest solution in applications since they ensure an accurate DOA estimation, reduce the amount of calculation, and increase productivity without wasting resources.

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D. Performance Analysis by Varying Array Element

The MUSIC algorithm's ability to predict the connection between two signals is demonstrated in the introductory simulation.Two narrow band signals are created and slam into a uniform linear array at different angles (25 degrees and 65 degrees, respectively) to carry out the simulation.There is no relationship between these signals.The noise is a white gaussian, the SNR is 20 dB, there are 300 samples, and the array element varies as follows (from lowest to highest): M1 = 5, M2 = 25, and N3 = 100.The results of the simulation may be seen in Figure 5.

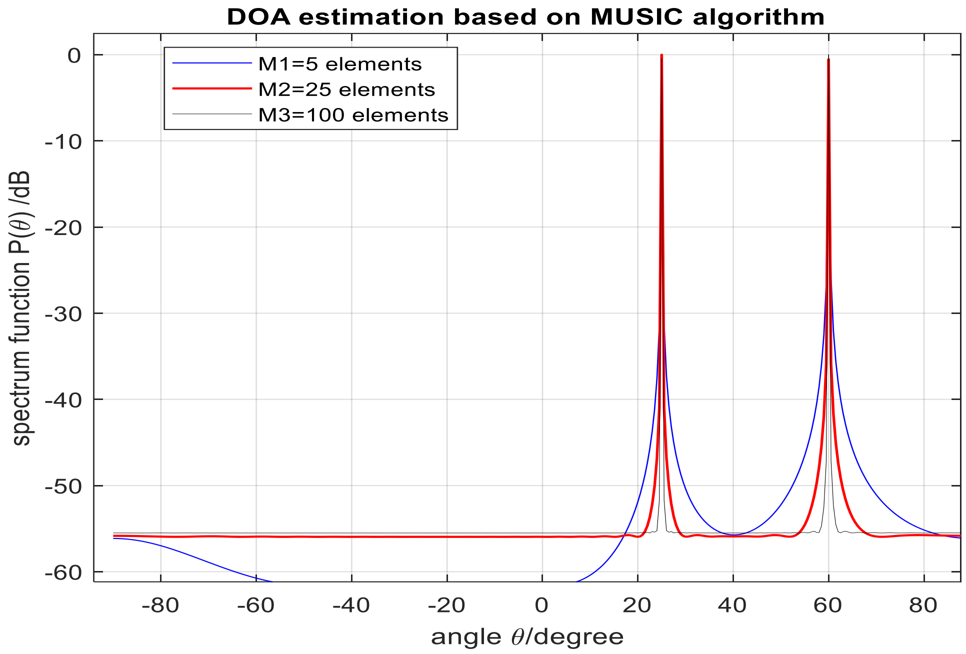

Fig.5 Array Element Effect in DOA estimation

As shown in Fig.5, when all other parameters are held constant and when the number of array elements is increased, DOA estimation spectral beam width reduces, and the directivity of the array improves. This improves the array's capability to separate various spatial signals. Increasing the number of array components is one way to improve the precision of DOA estimates; but, doing so also increases the amount of data that must be processed, which in turn reduces processing performance.

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V. Conclusion

For the purpose of determining the Direction of Arrival of signals, a Uniformed Linear Antenna array has been developed and the MUSIC algorithm has been employed.The investigation and study are carried out by shifting the values of fundamental factors like snapshots, SNR, and antenna array elements.Based on the findings, it has been established that the MUSIC algorithm possesses a higher resolution the greater the number of array components it uses and the greater the number of snapshots it takes. The performance of the MUSIC algorithm will suffer when the moving signal has a low signal-to-noise ratio (SNR) and a modest difference in incident angle. In the future, research is going to be carried out on a number of different antenna array structures, and an analysis will be carried out on the MUSIC algorithm in relation to those array forms.

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