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A novel Architecture for DOA estimation of signals to track target source positions

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***Abstract*—MUSIC is traditionally considered better than other algorithms for DOAs. With the increasing demand of near perfect target localisation, and less interference at higher noise regions, coupled with ability to differentiate closely spaced sources, MUSIC algorithm provides us with the scope of improvements. MUSIC fails to give proper DOA of signals when the noise level is high. It also fails to differentiate sources which are very close by. A new algorithm is proposed using SVD of the covariance matrix obtained. A ULA antenna array configuration is taken for both the algorithms. Simulations results show that proposed method gives better performance than traditional MUSIC algorithm**

***Keywords*— DOA, SVD, ULA, MUSIC**

I. Introduction

In today's world of advance scientific intelligence and warfare, estimation of DOA of a signal offers vast area of research and improvement. The applications of DOA can be found in mobile communications, to defence systems, from underwater target acquisition to teleconferencing. The techniques for DOA estimation can be divided broadly into There are various algorithms available for estimating DOA, mentioned as MUSIC, ROOT-MUSIC, Maximum likelihood, ESPRIT and so on. All the available algorithms have some limitations. In this paper, MUSIC is being considered and analysed since it outperforms all other algorithms. MUSIC. MUSIC algorithm when studied provides with certain limitations. MUSIC algorithm is an effective technique for estimating direction of arrival (DOA), but it can only do with uncorrelated signals. When the signals to be detected are very closely spaced, MUSIC tends to give only one signal by overlapping the other nearby signal, thus failing to identify the other signal. Being a subspace technique, it needs to know the type of signal to be detected so that the required modifications and conditions can be processed to the algorithm. More so, MUSIC algorithm requires that the number of sensors used in the antenna array be more than the number of the signals to be detected, failing which the technique fails. There are coherent signal and related signal in the actual communication environment. If the condition does not meet, there will be bias occurred and even failure in the use of MUSIC algorithm for signal DOA estimation. In order to solve the problem of the DOA estimation of coherent signals, an improved algorithm is presented in this section by processing the covariance matrix of the array output signal, which can effectively estimate the signal DOA and detect the coherent signal source. In this paper, we have developed a traditional MUSIC algorithm and analysed its outputs using ULA antenna configuration. The proposed algorithm is also analysed and its simulation results are compared with that of MUSIC.

II. Proposed Architecture

A uniform linear array (ULA) composed of M sensors and d narrowband signals of the different DOAs [a(θ_1) a(θ_2) a(θ_3)…..a(θ_d)] was considered. Then, the array output is given by

$$x(t) = a(\theta)\, s(t) \qquad (1)$$

Here s(t) is the signal coming from the source and the steering vector and $s(t) = \exp(j\omega t)$ and x(t) is the array output. $a(\theta) = [1, \exp(j\phi), \ldots, \exp(j(L-1)\phi)]^T$ and the phase delay between the sensors, $\phi = -\omega d \cos\theta / c$. A single signal at the DOA θ , thus results in a scalar multiple of the steering vector. The output equation can be put in a more

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compact form by defining a steering matrix and a vector of signal waveforms

A(θ) = [a(θ1) a(θ2) a(θ3)…..a(θd)] (2)

S(t) = $[s_1(t), s_2(t), s_3(t), \ldots\ldots s_d(t)]^T$ (3)

In the presence of an additive noise v(t), an observed snapshot from the M array elements was modelled as

$x_K(t)$ = A(θ) S(t) + v(t) (4)

The array covariance matrix R of the received signal vector in the forward direction can be written as

$$R_{xx}=E[X(t)X(t)^H]=\frac{1}{L}\sum_L^K[X(t)X(t)^H] \quad (5)$$

Then the DOAs of the multiple incident signals can be estimated by locating the peaks of the MUSIC spectrum given by

$$P_{MUSIC}(\theta) = \frac{1}{a(\theta)^H E_N E_N^H a(\theta)} \quad (6)$$

Where $E_N = [e_{d+1} \;\; e_{d+2} \ldots\ldots\ldots e_{M-1}]$ is subspace noise.

Now, after having obtained a MUSIC algorithm, we modify the steps so as to improve its performance.

The covariance matrix is decomposed using Singular Value Decomposition given as

SVD (R_{xx}) = USV^H (7)

A matrix RA can be calculated as

$$RA = E_s B E_s^H \quad (8)$$

Where $E_s = [e_1 \;\; e_{d+2} \ldots\ldots\ldots e_{d-1}]$ is signal subspace where

B= diagonal (1/SS – sigma*I) (9)

SS = diagonal (S_s) and SN = diagonal (S_N)

sigma = trce (S_N)/(M – D) (10)

The new modified MUSIC algorithm is given by

$$f_{MUSIC}(\theta) = \frac{a(\theta)^H * RA * a(\theta)}{a(\theta)^H E_N E_N^H a(\theta)} \quad (11)$$

As noticed from the denominator, the orthogonality between a(θ) and UO will make it minimum, and hence will increase fMUSIC (θ). Hence the D largest peaks of the MUSIC spectrum correspond to the DOAs of the signals impinging on the array.

III. SIMULATION RESULTS

1. Simulation result for MUSIC

Source positions (40°, 0°, 30°) and SNR =10dB

In this simulation we assume same uncorrelated signals impinging on antenna array at -40°, 0°, 30° but with a higher noise level at SNR = 10dB. It is observed in fig 1. that the peaks of the spectrum can be found at -40°, 0° only. For incident angle 30°, no peaks can be found at the same position on the spectrum plot. The reason can be attributed to the increase in noise levels accompanying the signals. And as such, the MUSIC algorithm neglected the signal as a noise while plotting the spectrum. Thus, MUSIC spectrum fails to give proper outputs at higher noise level.

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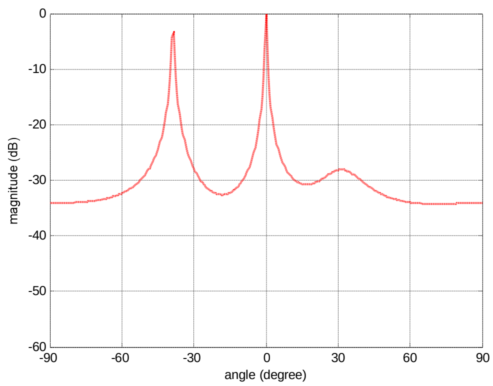

Fig 1. MUSIC at low SNR

Source positions ($0^\circ, 30^\circ, 34^\circ$) and SNR= 30dB

In this simulation we take the source positions to be $0^\circ, 30^\circ, 34^\circ$ with respect to the antenna array. The noise level is considered low at SNR = 30dB. In plotting the output spectrum of MUSIC in fig 2. We can find only two peaks at 0° and 34° as shown in the fig. Thought the noise level is low, the algorithm still could not give peaks at 30°. It is due to the fact that since the two signals at 30° and 34° are very close, the algorithm mistook it as only one signal after overlapping the two signals. Thus it can be concluded that MUSIC again fails to give proper DOAs for closely spaced sources.

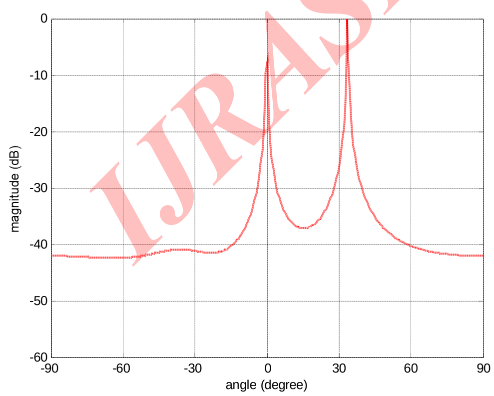

Fig 2. MUSIC for nearby sources

2. Simulation result for Modified MUSIC

Source positions ($-40^\circ, 0^\circ, 30^\circ$) and SNR = 10dB

In this simulation condition, we take three different signals with incident angles $-40^\circ, 0^\circ, 30^\circ$ on the axis of the antenna array. The number of sensors taken is 5. The noise accompanying the signal is increased as given by the SNR = 10dB. The output spectrum is plotted and is given by the fig. 3. the peaks of the spectrum gives the signal detected and the angles corresponding it gives the DOAs. It can be seen that the all the three signals are detected properly correctly with proper DOAs. With regard to the previous MUSIC algorithm, this new algorithm doesn't consider one of the signals to be noise and hence not neglected.

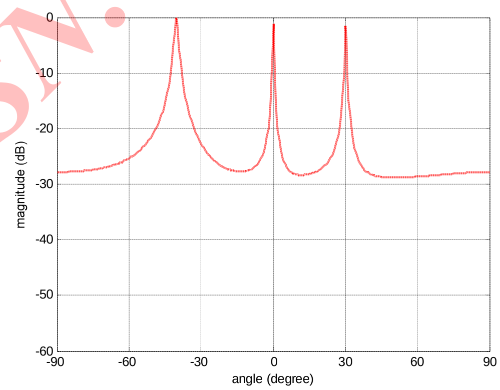

Fig 3. Modified MUSIC at low SNR

Source positions ($0^\circ, 30^\circ, 34^\circ$) and SNR= 30dB

In the simulation case considered here, we take the source positions to be $0^\circ, 30^\circ, 34^\circ$ with respect to the antenna array so that two sources are very nearby, differentiated only by a mere 4°. The noise surrounding the signal sources are assumed to be low as given by the SNR = 30dB. The algorithm spectrum is plotted as shown in fig 4. It can be seen that the spectrum contains three peaks denoting the detection of three signals at $0^\circ, 30^\circ, 34^\circ$ which agrees with our assumption.

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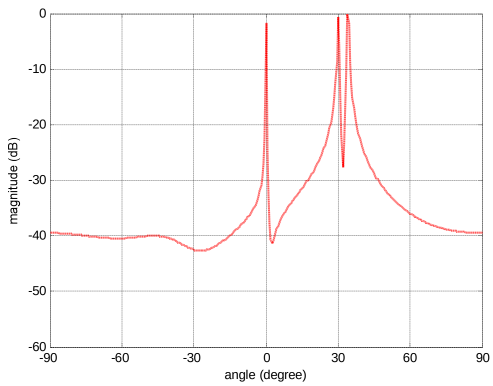

Fig 4. Modified MUSIC for nearby sources

Source positions ($0^{\circ}, 30^{\circ}, 34^{\circ}$) and SNR= 10dB

In this case, we assumed three signals incident at angles $0^{\circ}, 30^{\circ}, 34^{\circ}$ with respect to the antenna axis. The noise level around the signals is increased as SNR = 10 dB. The output spectrum is plotted as shown in the fig 5. It is observed that we find three peaks but not at desired positions. Though we found peaks at 30° and 34° , we could not find peaks at 0°, from which it can be concluded that the algorithm fails to detect a third signal

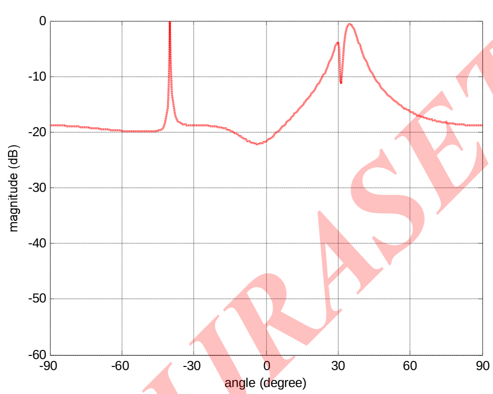

Fig 5. Modified MUSIC at lower SNR

IV. CONCLUSIONS

The proposed algorithm for estimating DOA was developed after carrying out certain modifications in MUSIC algorithm, by processing the covariance matrix of the array output signal. MUSIC algorithm works fine for low level noise regions, but when the noise level is increased its performance starts to degrade. MUSIC also fails to detect signals which are very close by. As such, it cannot differentiate two signals separated by AOA s of 4°, under normal conditions. The proposed algorithm was able to detect signals under a certain degree of high noise levels and also for close by sources The modified algorithm fails when the noise level is increased to a certain level. At such levels, it starts to detect noise signals as the desired signals. So we tend to get more peak in signal spectrum graph, making it difficult to find out the real signals. In both the algorithms that we have analysed, both can only give azimuth angles, not the elevation angle also, since we have used ULA and not UCA.

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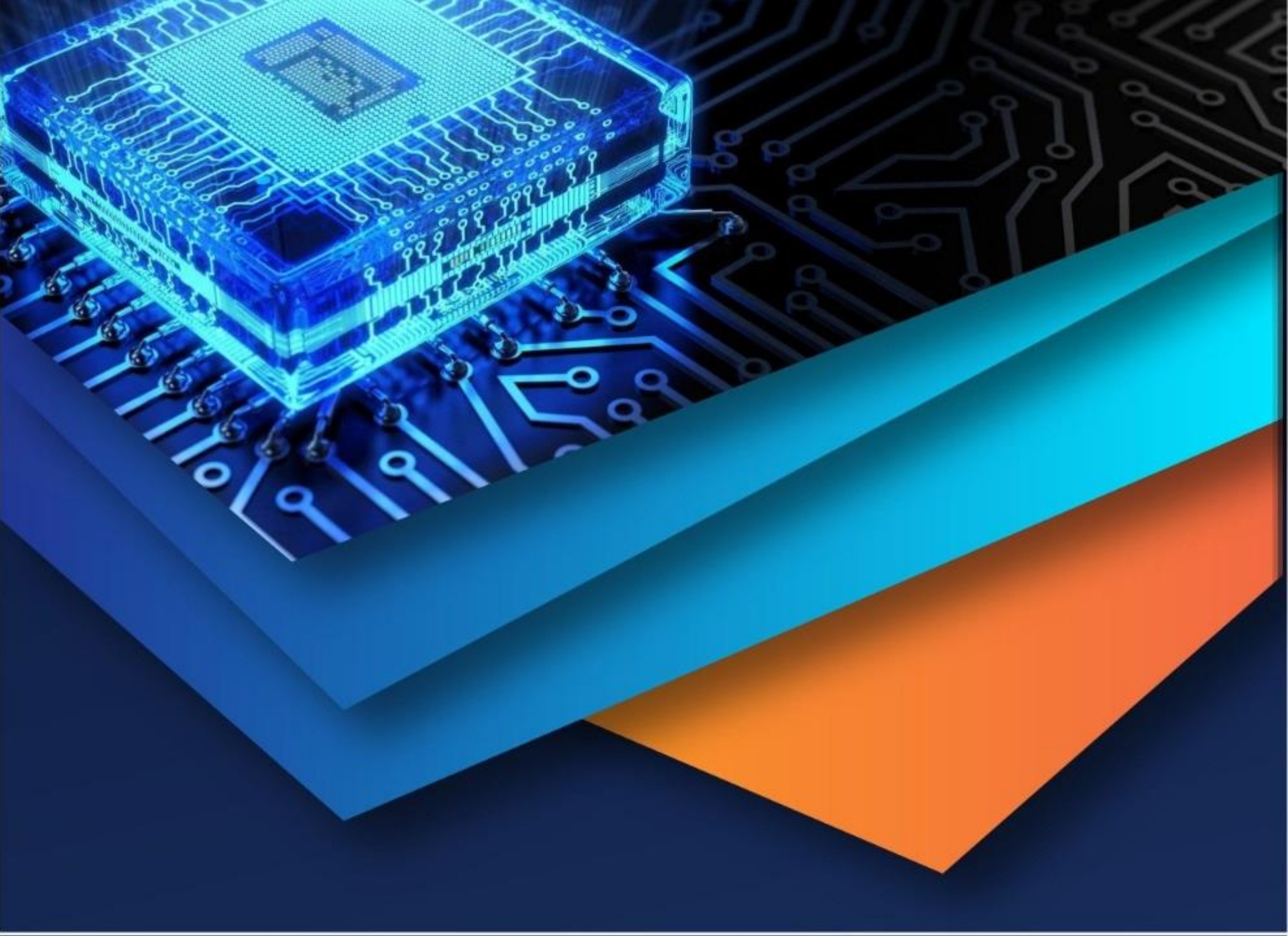

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