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Robust Adaptive Beamforming with DOA Estimation for Smart Antenna

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ABSTRACT: Adaptive antenna is an array of antenna elements with signal processing capability to optimize its radiation pattern in response to the changing signal environment. Adaptive antenna aims at increasing the gain in the direction of desired user and direct nulls in the direction of interfering signals. It involves processing of signals induced on an array of antennas that can estimate the direction of radiating sources and calculate optimum weights for adaptive beamforming. This paper presents a performance evaluation of different direction of arrival (DOA) estimation and adaptive beamforming algorithms. The simulation results show that proposed algorithms provides more accurate and stable results among other DOA estimation techniques while Improved NLMS algorithm shows the fastest convergence rate among other beamforming algorithms. We show that the propose method has achieved good resolution performance better the other direction arrival estimation algorithm. The new proposed algorithms provides fast convergence rate, higher interference suppression capability and low level of minimum Mean Square Error (MSE) at the steady state compared other conventional (i.e. LMS, NLMS, LLMS, VSSNLMS& MIR-LMS) algorithms. The simulation results show the effectiveness of the proposed method.

KEYWORDS: Smart Antenna, LMS, NLMS, LLMS, MI-NLMS, VSSNLMS, Beamforming, MIR-LMS, convergence speed.

I.INTRODUCTION

A smart antenna consists of number of elements (referred to as antenna array), whose signals are processed adaptively in order to exploit the spatial dimension of the mobile radio channel. All elements of the adaptive antenna array have to be combined (weighted) in order to adapt to the current channel and user characteristics. This weight adaptation is the “smart” part of the smart antenna, which should hence be called “adaptive antenna” [1].

To achieve high data rates and high capacity in communication it is needed to reducing the interferences and noise which greatly affects the performance of cellular system, while have to increase the desired signal power. With limited spectrum availability, achieving this goal is difficult due to co channel and adjacent channel interferences. So more advanced technologies are needed to fulfill the need of next generation wireless mobile communication. In recent decades, beamforming antennas for mobile wireless communications have received enormous interest. Beamforming is a promising technology which reduces interferences and noise[2]. Adaptive array signal processing appears as a potential technology to improve the spectrum efficiency. Adaptive array signal processing has focused on methods for high resolution direction of arrival (DoA) estimation and optimum beamforming. DoA estimation is important on array signal processing in wireless interference channel. A many the DoA algorithms have been studied for the desired signal estimation of the incident signals on the receiver [3]. Among of DoA algorithms, Bartlett and Capon algorithms based on Fourier method are traditional DoA signal processing algorithms, but this two methods have poor resolution [4-5]. MUSIC and ESPIRT using subspace method have a high resolution because divide with the signal and noise subspace from eigen-decomposition of the covariance matrix of the received signals. However the subspace method is required much the computational burden. The subspace method usually need to the decorrelation techniques because don`t be directly applied in coherent channel [6].

In smart antenna system, the radiation pattern of the antenna is controlled via certain algorithms using digital signal processors. The inputs to the antenna arrays are assumed as the desired signal, interfering signals, and Gaussian noise. Using some adaptive algorithms, the array weights are controlled and subsequently the output error is minimized. The error is calculated by subtracting the output signal from the reference signal which is minimized using adaptive algorithms by controlling the weights. With the suitable design of adaptive algorithms, the signal-to-interference ratio is maximized or minimized according to the different optimization parameters like variance, MSE, interference nulling, and the steering of main beam toward the user. The two most important aspects of the smart antenna are an estimation of direction of arrival (DOA) and the digital beamforming (DBF). Figure 1 illustrates the functional diagram of the smart antenna system. There are antenna array units with weight adapter, the DOA unit, and an adaptive algorithm unit.

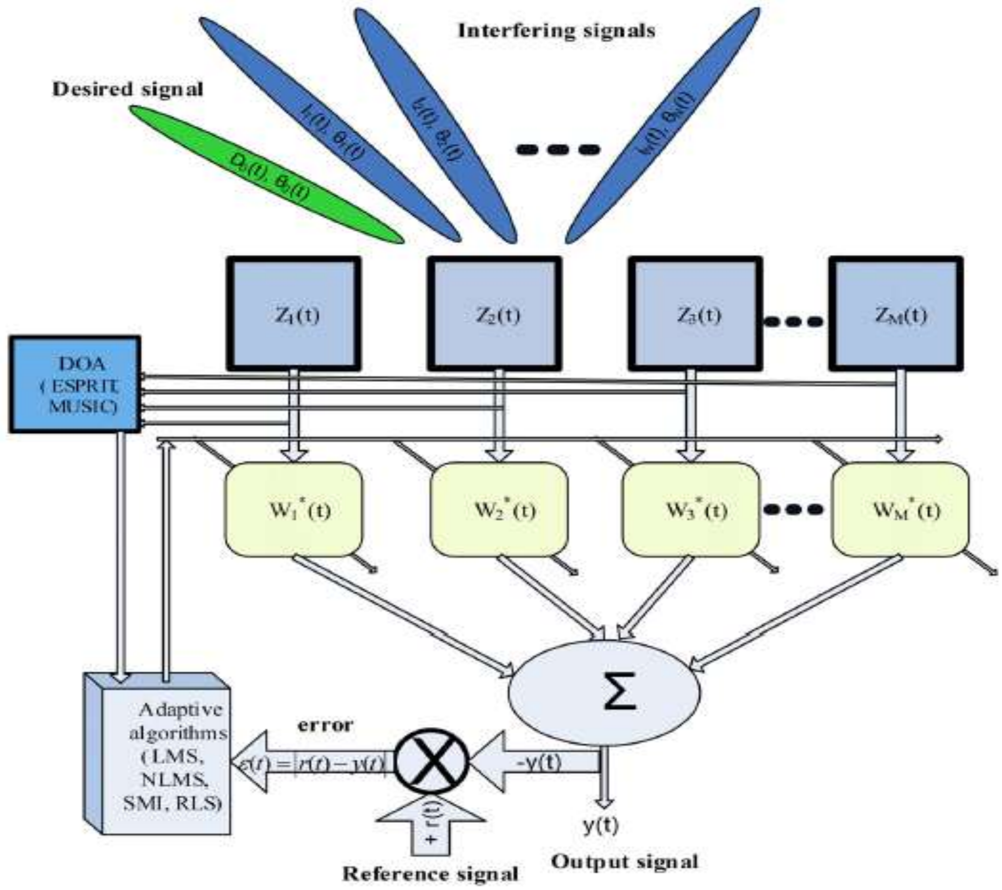


Figure 1: Functional block diagram of a smart antenna for minimizing the mean square error

II. LITERATURE REVIEW

As an application of UACA, author proposes a decoupled interference-plus-noise covariance matrix (INCM) reconstruction method for robust adaptive beamforming (RAB) with UACA [1]. A new adaptive algorithm, called least mean square least mean square (LLMS) algorithm, which employs an array image factor, , sandwiched in between two least mean square (LMS) algorithm sections, is proposed for different applications of array beamforming. Simulation results show that LLMS algorithm is superior in convergence performance over earlier LMS based algorithms [3]. Smart antennas integrate the antenna array with sign processing to optimize mechanically the beam pattern in reaction to the acquired signal. Beam forming may be used for both radio and sound waves; it has determined numerous programs in radar, sonar, seismology, wireless communications, radio astronomy, speech and bio-medicine. This paper discusses the algorithm for blind and non blind adaptive beam forming technique for reliable wireless communication [2]. The hybrid NLMS/RLS algorithm is applied to different types of patch array antenna with resonance frequency 10GHz to demonstrate the performance of the proposed algorithm to each array antenna type.[4]. Author's presents the significance of the beamforming technique employed for the next generation broadband wireless mobile systems. The capacity, data rates, null steering and coverage of the cellular system are improved by using various beamforming techniques such as the Minimum variance distortionless response (MVDR) and Linear constraint minimum variance (LCMV). These two techniques depend on the received weight vector of the desired signal. The simulation result shows that for all the improved system parameters the MVDR technique shows better results than LCMV technique [5].

Arti M.K., Student Member, IEEE et.al suggested: "Beamforming and Combining in Hybrid Satellite-Terrestrial Cooperative Systems". In this paper, authors consider the transmission of signals in a hybrid satellite-terrestrial cooperative system [6]. Matrix Inverse Robust Least Mean Square (MIR-LMS) algorithm is propose where author's uses the sample Matrix Inversion (SMI) algorithm and ratio parameters to control the contribution of normalized product vectors in the weight upgradation process the MIR-LMS algorithm author's find that the signal response is improved, the convergence rate is faster [9].

III. DIRECTION OF ARRIVAL AND BEAMFORMING ALGORITHM

Beamforming algorithms can be classified into two classes, as namely non-blind & blind algorithms. In the case of non-blind adaptive algorithms, a reference signal is used in the process of adjusting the array weights function. On the other hand, no reference signal is used in blind adaptive algorithms. However, when compared with their non-blind counterparts, these algorithms tend to be more computation intensive, and often provide lower accuracy and slower convergence rate [11].

In the non-blind algorithms, the adaptive weights of the array beamformer are usually adapted according to a specified criterion, such as minimization of mean square error (MMSE), or maximization of the signal to interference plus noise signal (MSINR). An error signal, produced by comparing the output signal with a reference signal, is used to iteratively adjust the weights of the beamformer to their optimal values, W_{opt} , so as to obtain the minimum MSE. The trained algorithms could be classified according to their adaptive criterion: least-mean squares method (LMS), sample matrix inversion (SMI) or least-squares method (LS), and recursive least-squares method (RLS) [11].

The adaptive beamforming algorithm improves the output of the array beam pattern in a way which it maximizes the radiated power where it will be produced in the directions of the desired mobile users. Moreover, deep nulls are produced in the directions of undesired signals which symbolize co-channel interference from mobile users in the adjacent cells. Before adaptive beamforming, direction of arrival estimation is used to specify the main directions of users and interferers [4]. The complex weights (w) for the antenna elements are carefully chosen to give the desired peaks and nulls in the radiation pattern of the antenna array. In a simple case, the weights may be chosen to give one central beam in some direction, as in a direction-finding application [6]. The adaptive system takes advantage of its ability to effectively locate and track various types of signals to dynamically minimize interference and maximize intended signal reception [12].

MUSIC algorithm is generally used for DoA estimation, and optimum beamforming is used as the Linearly constrained minimum variance beamforming(LCMV) algorithm. Drawback of these algorithms takes the severe degradation of the estimation accuracy in the coherent signals. An adaptive beamforming algorithm provide a distortionless response to the desired signal while removing noise and interference [7]. However, adaptive beamformer can suffer significant performance degradation in the presence of the mismatch between the actual direction of arrival of the signal and the look direction of the beamformers. In this paper, we propose a novel approach to robust adaptive array antenna using MUSIC algorithm and LCMV beamforing, which improves robustness to uncertainty in the desired signal direction. When signal to noise ratio is high, the proposed algorithm places more emphasis on the observations, estimates direction of arrival of the actual signal reliably and has nearly optimal performance. When signal to noise ratio is low, it relies on the priori knowledge about the source direction of arrival and has wider main beam which is robust the excellent performance of the proposed robust adaptive beamforming. Linear prediction method was studied to improve the DoA estimation of the single direction [8].

IV. PROPOSED ALGORITHM:

A smart antenna system is an integration between array antenna and digital signal processing techniques. The signal processing methods are divided into two processes; a direction of arrival (DOA) process and an adaptive beamforming process. The DOA algorithm computes the directions of arrival of the incoming signals. Then, the adaptive beamforming algorithm is used to choose the convenient weights of each array element to extract the desired source signal from the acquired data of antenna array while canceling interference and noise as shown in figure 2**.**

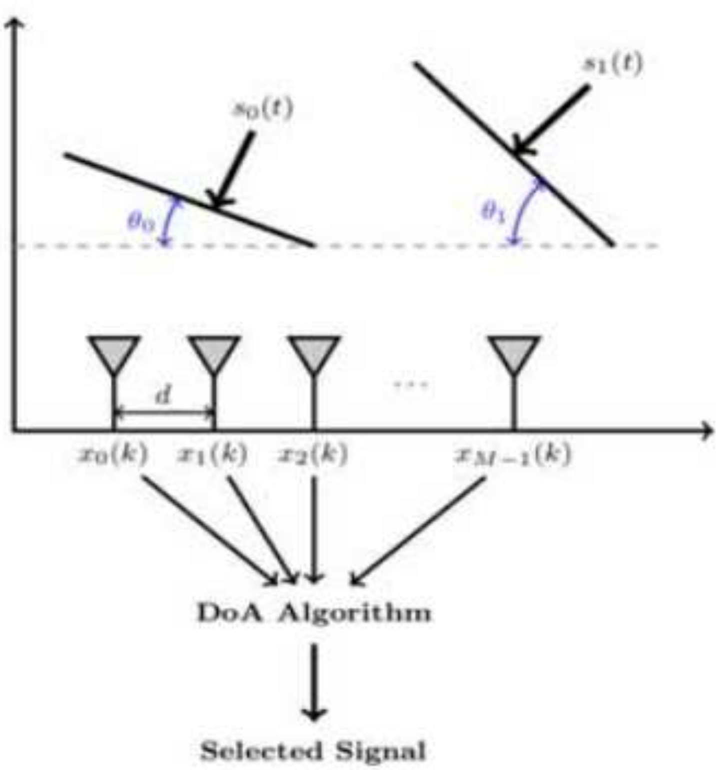


Figure 2: Uniform linear array (ULA); d is the distance between the sensors; θi the elevation angle and M is the number of sensor array antennas

The input signals picked up by the antenna elements with initializing the weighting function are first processed by a proposed algorithm. To enhance the convergence rate overall algorithm, the previous error sample, $e_{M\text{-}NLMS}$, from the M-NLMS algorithm stage is fed back to combine with the current error sample, $e_{NM\text{-}NLMS}$, of the NM-NLMS algorithm stage to form the overall error signal, $e_{NM\text{-}NLMS}$, for updating the tap weights of the proposed algorithm stage. This may improve the stability of the proposed algorithm against sudden changes in the input signals. As shown in Figure 1, a common external reference signal is used for proposed algorithm stages. This mode of operation will from now on be referred to as the external referencing mode.

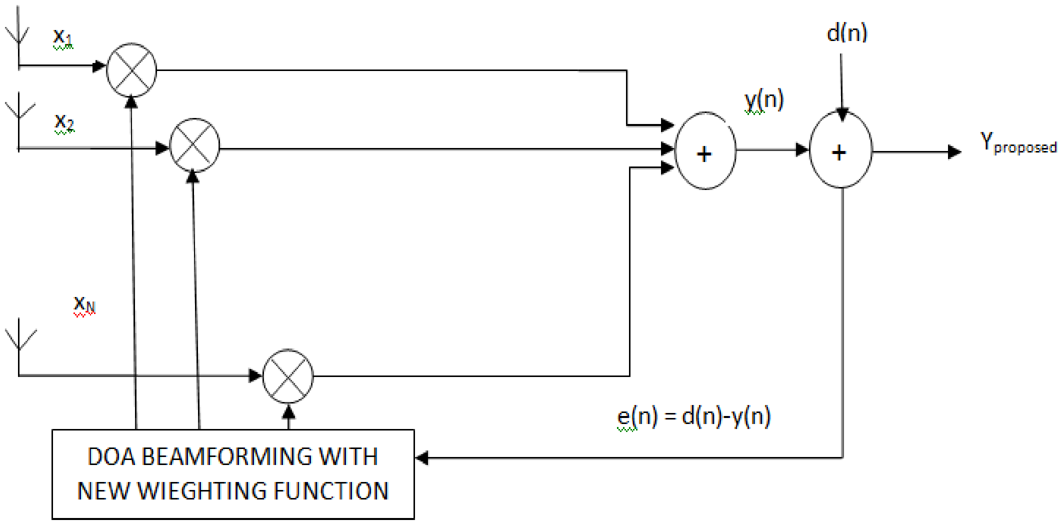
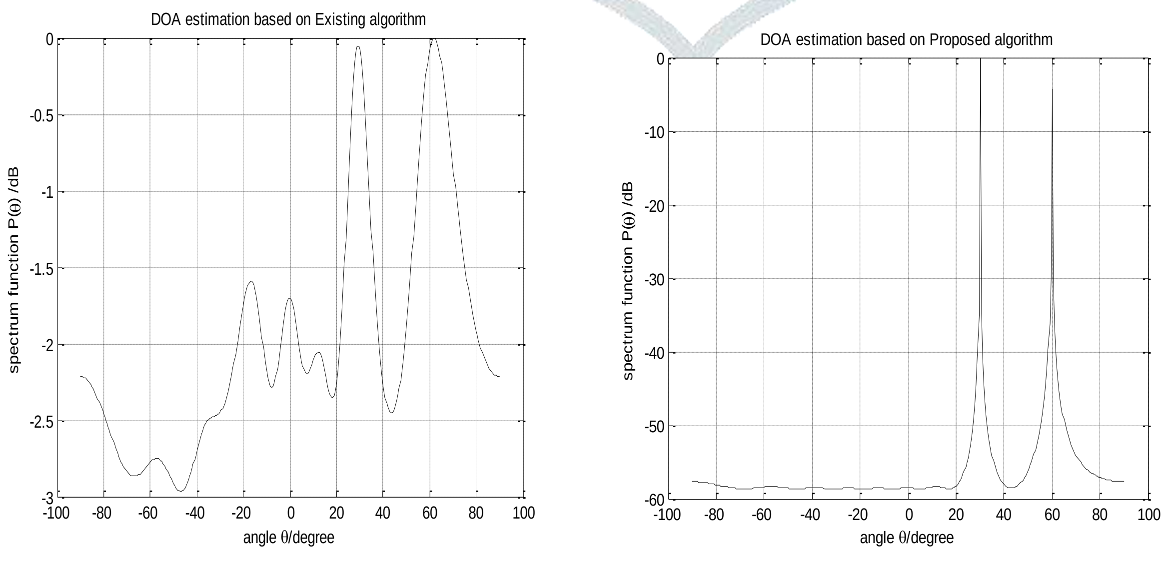


Figure 3: Proposed Algorithm with an External Reference Signal

V. SIMULATION AND RESULT

The first simulation shows how two signals are recognized by the Proposed DOA algorithm. There are two independent narrow band signals, the incident angle is 30 and 60 degree respectively, those two signals are not correlated, the noise is ideal Gaussian white noise, the SNR is 20 dB, the element spacing is half of the input signal wavelength, array element number is 10, the number of snapshots is 200. The simulation results are shown in Figure 4



(a) (b)

Figure 4: Simulation result of DOA algorithm a) Existing algorithm b) Proposed algorithm

The desired signal is taken as a cosine signal at an angle of 0°. Two interfering signals are considered at angles of 20° and -40°. For this analysis, N=16 and d=0.5λ are chosen. Figure 5 shows that the adaptations of weights of the proposed algorithm with other conventional algorithm. The proposed algorithm converges to their optimum values in just 5 iterations. This convergence is much faster than NLMS (50 iterations), LLMS (40 iteration), VSSNLMS (30 iteration) & MIR-LMS (25 iteration).

Show the convergence behaviors of conventional method (i.e. NLMS, LLMS, VSSNLMS, and MIR-LMS) & proposed schemes.

From figure 6 (a) desired signal is shown by green cross sign, output of NLMS algorithm is shown by black line, output of LLMS algorithm is shown by green line, output of VSSNLMS is shown by blue line, output of MIR-LMS is shown by red line & output of proposed algorithm is shown by blue circle sign from the comparison it is easy to conclude that antenna output is more accurate in proposed Algorithm as compared to the other conventional algorithm.

In figure 4 (c) shows the ensemble average of the mean square error (e^2) in which black line shows the error plot for NLMS algorithm, green line shows the error plot for NLMS algorithm, blue line shows the error plot for VSSNLMS algorithm, red line shows the error plot for VSS-LMS algorithm & blue cross sign shows the proposed algorithm. The proposed algorithm schemes are able to converge within a few iterations to a low error floor.

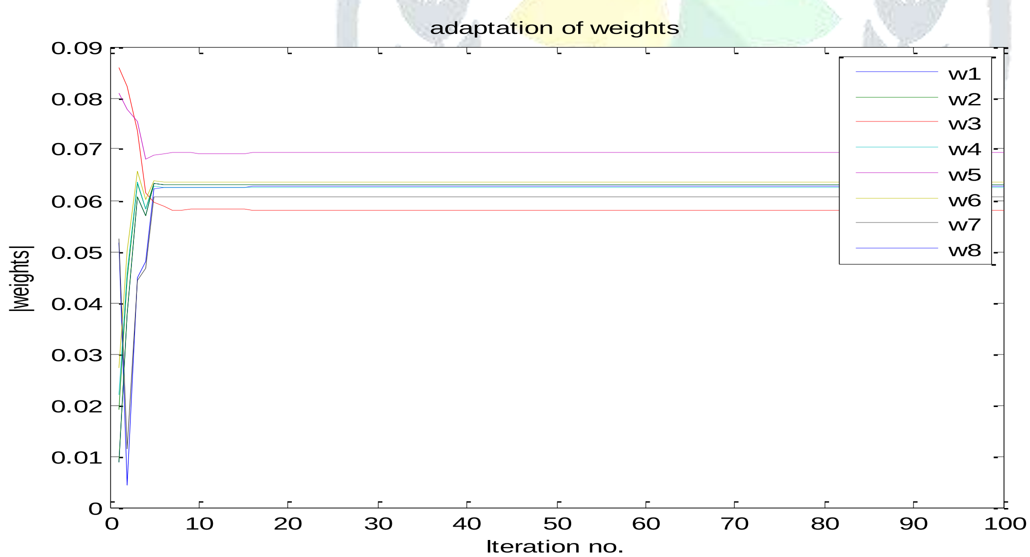
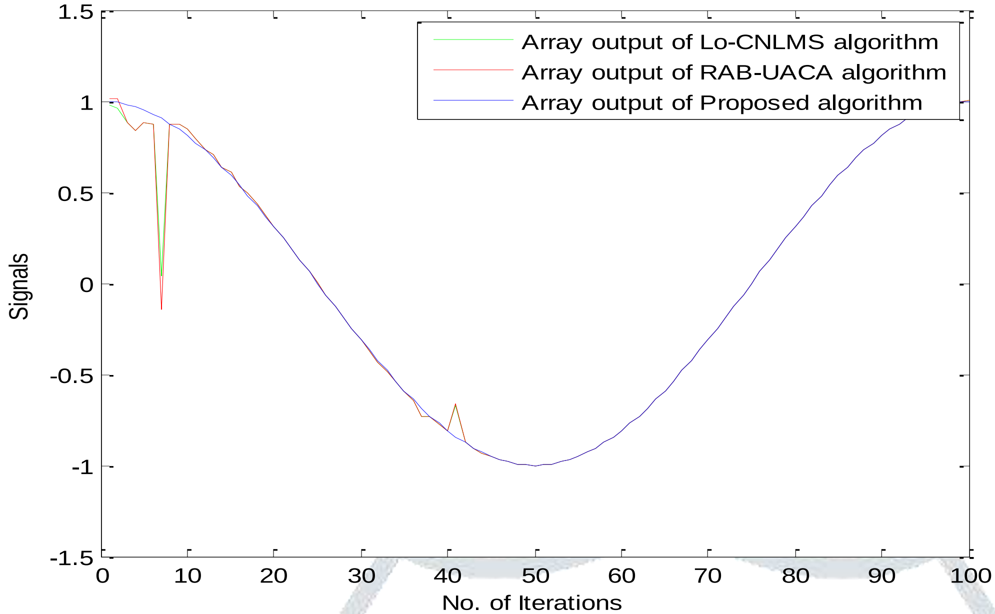
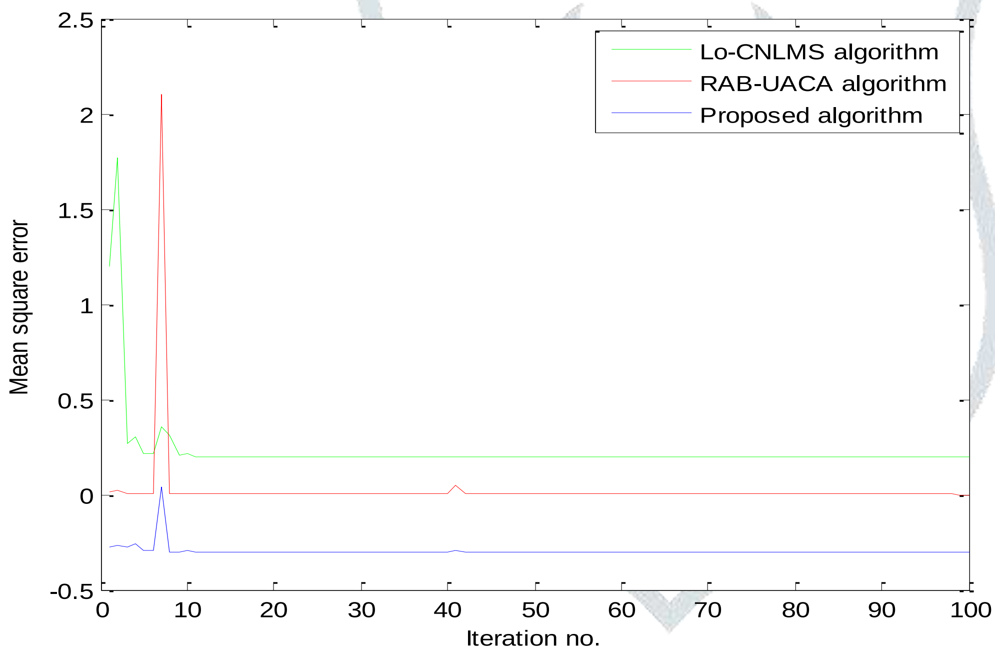


Figure 5: Convergence Rate of the weight vectors for: a) NLMS algorithm, b) LLMS Algorithm, c) VSSNLMS Algorithm, d) MIR-LMS Algorithm & e) Proposed Algorithm.



(a)



(b)

Figure 6: Shows the convergence of proposed algorithms with Lo-CNLMS and RAB-UACA for N=16 Elements and SNR = 20 dB a) Shows the Acquisition and Tracking of Desired Signal and b) Shows the Mean Square Error v/s No. of iterations.

VI. CONCULSION:

In this paper weight vectors obtained by the proposed DOA-based beamforming algorithms are closer than the final desired weight vectors compared to the conventional ones. It can be seen obviously in the comparative studies which are presented in terms of SNR and MSE measures. In addition to the higher performances obtained by the proposed algorithms, faster convergence and also lower deviation in tracking study than the respected conventional ones are the main features of the proposed DOA-based beamforming algorithm.

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