A Novel High Resolution Adaptive Beam Forming Algorithm for High Convergence

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Abstract

This paper introduces a new robust four way LMS and variable step size NLMS beam forming algorithm to reduce interference in a smart antenna system. This algorithm is able to resolve signals arriving from narrowband sources propagating plane waves close to the array end fire. The results of previously used adaptive algorithm have the fixed step size NLMS will result in a trade-off issue between convergence rate and steady-state MSE of NLMS algorithm. This issue is solved by using four way LMS and VSSNLMS which will improve the efficiency of the convergence point. The proposed algorithm implemented reduces the mean square error (MSE) and shows faster convergence rate when compared to the conventional NLMS.
Keywords: Adaptive Antenna, Beamforming, Means Square Error (MSE), Convergence

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I. INTRODUCTION

A. Introduction

In today's world numbers of mobile users are increasing day by day, hence it is necessary to serve such a huge market of mobile users with high QOS even though the spectrum is limited. This becomes a major challenging problem for the service providers to solve. A major limitation in capacity and performance is co-channel interference caused by the increasing number of users and the multipath fading and delay spread. Research efforts investigating effective technologies to mitigate such effects have been going on and among these methods Adaptive antenna employment is the most promising technology. This project works on Adaptive Antenna which ensures high capacity providing with the same Quality of Service(QOS).In a normal scenario currently the mobile towers employ parabolic dish or a horn antenna but this suffers if the SNR is low the signals have to be repeatedly retransmitted from mobile station to base station. The use of Adaptive Antenna considers an array of antennas in which the antenna will receive the delayed versions of the electromagnetic wave and adds them to achieve high SNR.

B. Problem Statement

In the earlier antenna radiation was directed based on frequency or time, Therefore spectrum was not utilized efficiently because as the number of users increases the quality of service decreases. Hence, in this work a solution to use the Adaptive antenna frameworks have been proposed and used as an efficient means to meet the quickly expanding the traffic volume. This issue of Technology has discusses the importance of various advanced antenna schemes for improving the same amount of spectrum and provides service to the large amount of mobile users is deduced. This is done by separating the users with respect to direction.

II. ADAPTIVE ANTENNA

Adaptive antenna is the one which adapts itself to pick the user signal in any direction without user intervention , basically it undergoes through a two phase process:

- Direction detection Estimation (DDE) using a suitable algorithm and sensor data.
- Beam forming which forms a beam in the desired direction and nulls in the interference direction.

Direction Detection Estimation (DDE) methods are used to detect the incoming wave and the other signals which arrive from different parts of the space can be processed to extract different type of data including direction desired incoming signal falling on the antenna array.

Beam forming is a process of forming the Main beam in the desired direction and nulls in the direction of jammers direction. The block diagram is shown in Figure1 shows an adaptive antenna structure with N antenna elements, DDE blocks, Adaptive signal processor algorithms to make adaptive antenna system smart, where incoming signal is processed by beam forming algorithms the figure also shows main beam formed in the direction of desired signal and nulls in the jammers direction.

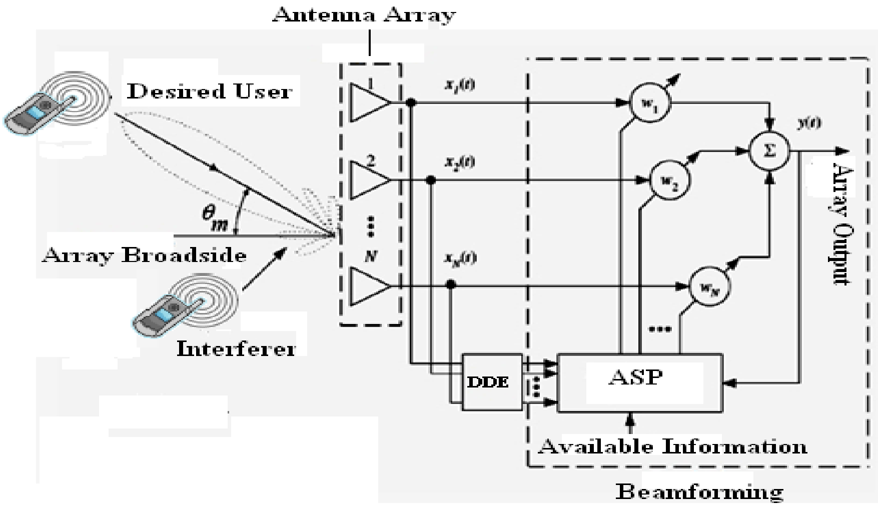

Fig. 1: Adaptive Antenna

Wireless communications system,as compared to their wireline counterparts,there is a unique challenges.in recent years due to increase in number of users and the increase in demand for high bit rate data service there is substantial increase a traffic for mobile and personel communication systems.these challenges can be handeled by adaptive antenna system which can provide. High network capacity by reduction of signal to interference ratio, Improved quality and the coverage service. Increased gain by combining the signals from multiple antennas, high efficiency in rejection of interference,reduction of co-channel interference and multipath fading,it can also provide higher signal to interference noise ratio and lower power levels.

III. ADAPTIVE BEAMFORMING

The fixed beamforming approaches are usually applied to fixed arrival angle emitters. If the arrival angles don't change with time, the optimum array weights won't need to be adjusted. However, if the desired arrival angles change with time, it is necessary to devise an optimization scheme that operates on-the-fly so as to keep recalculating the optimum array weights. In this scenario of ever-changing electromagnetic environment, a receiver signal processing algorithm is needed for the continuous update of the weight vectors, so that the spatial filtering beam will adaptively steer to the targets's time-varying DOA, thus resulting in optimal transmission/reception of the desired signal. The adaptive algorithm takes the fixed beamforming process one step further and allows for the calculation of continuously updated weight.this process is known as adaptive beamforming. Figure2 shows that the main beam is formed in the desired user direction and nulls in the interference user direction.

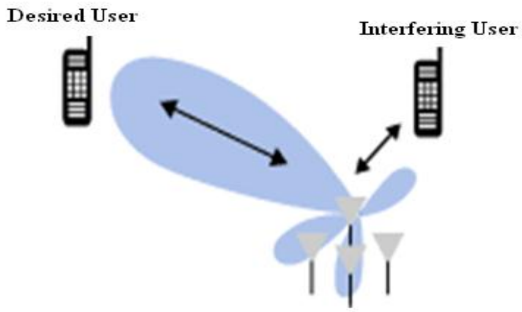

Fig. 2: Adaptive beamforming

Our main aim in this project is to form main beam towards the desired direction that is called as loop direction and nulls to the reduced radiations towards the interference direction this can be done through various beamforming algorithms. in the previous approach NormalisedLMS algorithm is used which form the main beam in such a way that the Mean Square Error is the lowest means lesser convergence.

In the current approach Fourway LMS and Variable Step Size Normalized Least Mean Square (VSSNLMS) algorithm is used which overcomes the disadvantage of normalized Least Mean Square (LMS) algorithm that is the slow convergence.

A. Normalized LMS Algorithm

The functionality of Normalized Least Mean Square (NLMS) adaptive beam forming algorithm[6] is presented in Figure 3,Where $x(k)$ is the input signal which may contains the desired signal and the interference signal, whereas $y(k)$ is the output signal which is computed based on the incoming signal and the signal from the beam forming algorithm ,and this output signal y(k) is subtracted from the desired signal $d(k)$ to calculate the error signal $e(k)$. $x(k)$ and $e(k)$ are both combined in the NLMS algorithm that controls the adaptive beamformer behavior to reduce the mean square error (MSE).

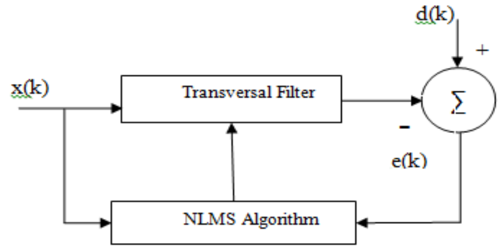

Fig. 3: NLMS algorithm

The weight update equation for the NLMS algorithm is given by

$$w(k+1) = w(k) + \frac{\mu e(k) x(k)}{\sigma + \|x(k)\|^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$\mu = step\ size$

$e(k) = error\ signal$

$x(k) = recieved\ signal$

$\sigma = is\ a\ small\ const\ factor$

$w(k) = weight$

The step size is given by

$$\mu = \frac{2}{3tr(R_{xx})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where R_{xx} is the autocorrelation matrix.

IV. VARIABLE STEP SIZE NORMALIZED LEAST MEAN SQUARE (VSSNLMS)

The main aim of the developed Variable Step Size (VSS) NLMS algorithm is to replace the fixed step size μ that is used in NLMS by a variable one. This is to avoid a trade-off issue between convergence rate and steady-state MSE. In this algorithm a large step size is used in the initial stages to speed the rate of convergence and a smaller step size is used near to the steady state of the Mean Square Error (MSE) to obtain an optimum value. The weight update equation for array weight is given by

$$w(k+1) = w(k) + \frac{\mu(k) e(k) x(k)}{\sigma + \|x(k)\|^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

And the step size varied for the various iterations and is given by the equation

$$\mu(k) = \{ \begin{array}{ll} ((\frac{6}{N})^2 (p - (\frac{N}{6}))^2) + 0.001 & 1 \le p \le \frac{N}{6} \\ 0.0001 & \frac{N}{6} \le p \le N \end{array} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where N= number of samples,e(k) is error signal which is given by
e(k)=s(k)-y(k)

s(k) is the sampled incoming signal,y(k) is the output signal ,x(k) is the received signal by the array of antenna w(k+1) is the new updated array weight.

V. FOUR WAY LMS

In this section new approach of beam forming to increase convergence speed of LMS is presented.

LMS algorithm has low computation complexity however; its convergence rate is slow. In this section, a novel implementation scheme for LMS algorithm is simulated to form a modified LMS algorithm. The scheme as shown in figure 4 consists of one feedback module called as converse-speediness module, two LMS algorithm modules, and one speediness module which connects two LMS algorithm modules. Meanwhile, two LMS algorithm modules can be implemented parallel, as well as the speediness module and converse-speediness module. Simulation results are also presented which shows convergence rate of the FOUR WAY LMS algorithm i.e. 4 times faster than that of LMS algorithm.

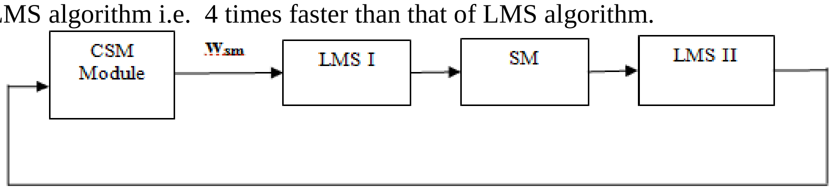

Fig. 4: four way LMS Block diagram

The convergence speedy module uses the equation in order to calculate the array weights is given by

$$w_{csm}(n+1) = w_{csm}(n) + ([I - 2\mu_{csm} R_x]^{-1}[v_k - 2\mu P_k]) \quad \ldots\ldots (5)$$

$W_{CSM}(n+1)$ are the LX1 updated array weights ,I is the LXL identity matrix, μ is the step size, R_x is the LxL autocorrelation matrix of induced signal x(n), v_k are Lx1 array weights obtained from LMSII module initially this value is zero and P_k is the cross-correlation is shown in equation8.

$$\mu_{csm} = \frac{1}{3tr(R_x)} \quad \ldots\ldots (6)$$

$$R_x = E[x x^H] \quad \ldots\ldots (7)$$

$$P_k = E[s x] \quad \ldots\ldots (8)$$

For the LMS algorithms, LMSI and LMSII The weight update equation is given by

$$w(n+1) = w(n) + 2\mu x(n)e(n) \quad \ldots\ldots (9)$$

And for speediness module the weight equation[8] is

$$w_{sm} = \psi(\psi(w_k)) - \frac{power\{\psi(\psi(w_k)) - \psi(w_k)\}}{\psi(\psi(w_k)) - 2\psi(w_k) + w_k} \quad \ldots\ldots (10)$$

and $\psi(w_k) = M_K w_K + N_K$ ……… (11)

Where MK=I-2μRK and NK=2μPK ……… (12)

R_K is correlation matrix, and P_K is cross correlation matrix.

susbstitute equations 11,12 into equation 10 and simplified we get

$$w_{SM} = v_{value} - \frac{N_{value}}{D_{value}} \quad \ldots\ldots (13)$$

VI. SIMULATION RESULTS

The performance of the adaptive beamforming algorithms can be done by Matlab simulations. The Normalised Least Means Square(NLMS),Variable Step size LMS(VSSLMS) and the Fourway LMS Algorithms can be simulated by using matlab and the results obtained and are compared with the Means Square Error(MSE) is shown in following section for the case of with by assumption of the desired and jammers directions.

Number of antenna elements 10;

Desired angle 30^0

Number of interference users 2; and their directions of the angle are 10^0 and 50^0;

The directional range for the beam pattern is 0 to $\pm 90^0$

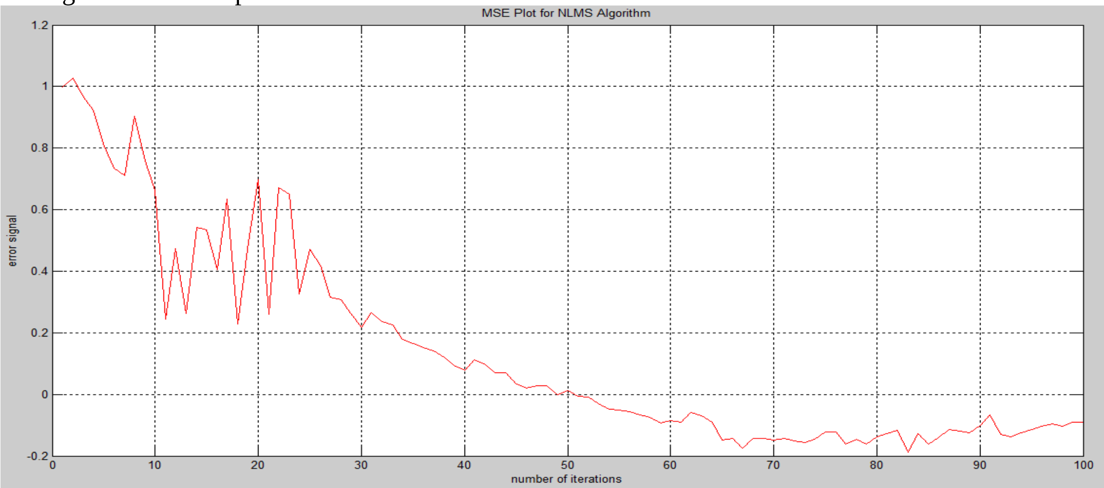

Fig. 5: MSE of NLMS Algorithm

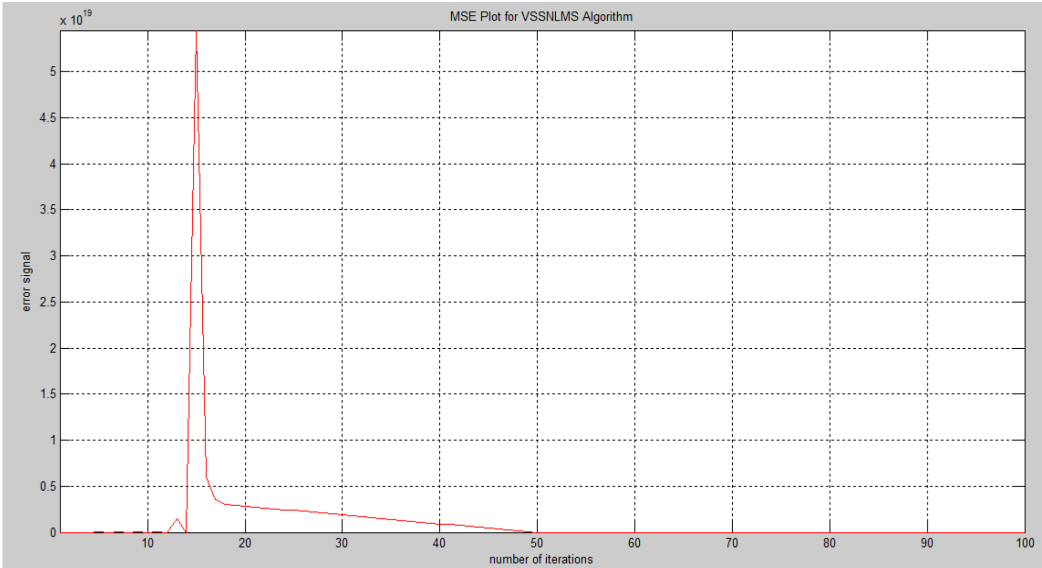

Fig. 6: MSE of VSSNLMS Algorithm

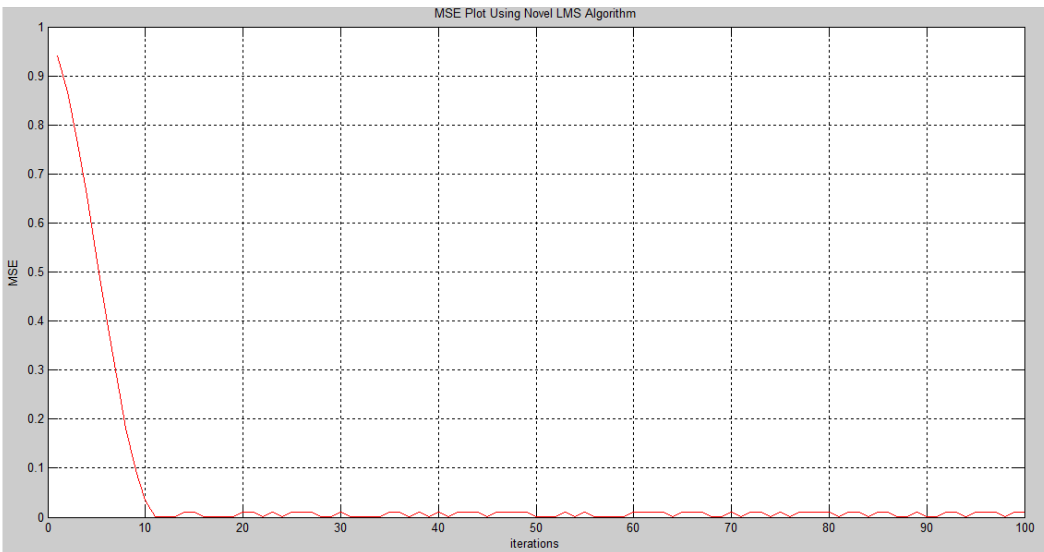

Fig. 7: MSE of Fourway LMS Algorithm

VII. CONCLUSION

From the simulation results we conclude that Fourway LMS algorithm in the design of adaptive antenna system will enhances the performance of the adaptive antenna system by reducing the Means Square Error(MSE) which results in faster convergence at a faster rate compared other beamforming algorithms such as VSSNLMS and Normalized LMS algorithm.the proposed fowrway LMS algorithm is best suited for beamforming as it can track the desired signal in less number of iterations,than the other conventional beamforming algorithms.

VIII. FUTURE SCOPE

Beamforming is a technology that promises to reshape the future of Telecom industry by focusing on problems of transmission fidelity and spectral efficiency. There have been intensive developments in this field. There is still scope for future improvements. Some of the drawbacks can be overcome by extension of this project work which is listed

1) Uniform linear array of sensors can be replaced with Uniform Circular Array [UCA] of sensors, which increases resolution of beam and removes symmetrical structure about array axis and beam can be steered over both azimuth and elevation angles.
2) The Beamforming algorithms simulated in this project took only the present samples in estimating the weight vector but new algorithms have emerged which utilizes both present as well as past data namely Quasi Newton method of Beamforming which increases accuracy.

3) The Beamsteering algorithms assumed that Amplitude of sources are well known but the actual implementation will also require estimation of target direction using Kalman Filtering.
4) In Four Way LMS four blocks were executed in parallel. This can be extended to a large number parallel blocks and hence increasing convergence speed of beamforming again by a large amount.
5) Many applications also require steering of nulls in jammer directions hence Null Steering Beamformer can be implemented to steer nulls and ESPRIT AOA can also be implemented to obtain better resolution.

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