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Analysis of Improved and Traditional LMS Beamforming Algorithm for Smart Antenna

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ABSTRACT

The Least Mean Square (LMS) algorithm, is an adaptive algorithm, which uses a gradient-based method of steepest decent. LMS algorithm uses the estimates of the gradient vector from the available data. LMS incorporates an iterative procedure that makes successive corrections to the weight vector in the direction of the negative of the gradient vector which eventually leads to the minimum mean square error. Compared to other algorithms LMS algorithm is relatively simple; it does not require correlation function calculation nor does it require matrix inversions

The algorithms have been simulated in MATLAB 7.10 version. A simulation tool with a graphical user interface, which implements these algorithms, is developed. Results of numerical simulation are useful for the design of smart antennas systems with optimal performance.

Keywords **–adaptive beamforming, array antenna, DOA , LMS, smart antenna.**

I. INTRODUCTION

The demand for mobile communication resources has increased phenomenally over the past few years. Adaptive, or smart, antenna techniques have emerged as a key way to achieve the ambitious requirements introduced for current and various types of beamforming schemes.

A smart antenna is commonly defined as a multi-element antenna where the signals received at each element are intelligently and adaptively combined to improve the overall performance of the wireless system, with the reverse performance on transmit. Smart antennas have the property of spatial filtering, which makes it possible to receive energy from a particular direction while simultaneously blocking it from another direction. The benefit of smart antennas is that they can increase range and capacity of systems while helping to eliminate both interference and fading.

For optimal processing, the typical objective is maximizing the output signal-to-noise ratio (SNR). For an array with a specified response in the direction of the desired signal, this is achieved by minimizing the mean output power of the processor subject to specified constraints. In the absence of errors, the beam pattern of the optimized array has the desired response in the signal direction and reduced response in the directions of unwanted interference.

II. SMART ANTENNA

Smart antennas can provide higher system capacities, increase signal to noise ratio, reduce multipath and co-channel interference by steering the main beam towards the user and at the same time forming nulls in the directions of the interfering signal. However, severals challenges remain in the development of these adaptive systems and it requires complicated adaptive algorithms to steer the beam and the nulls.

LMS algorithm uses the

A smart antenna combines antenna arrays with digital signal processing units in order to improve reception and transmission of radiation patterns dynamically in response to the signal environment. It can increase channel capacity, extend range coverage, steer multiple beams to track many mobiles and reduce multipath fading and co-channel interference.

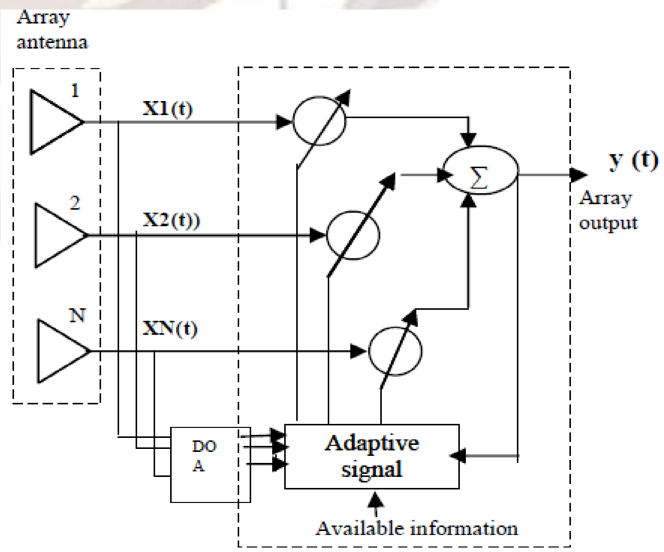

Fig. 1. Functional block diagram of smart antenna

The smart antenna system needs to differentiate the desired signal from the co-channel interferences and normally requires either the knowledge of a reference signal (or training signal), or the direction of the desired signal source. There exists a range of schemes to estimate the direction of sources with conflicting demands of accuracy and processing power. Similarly, there are many methods and algorithms to update the array weights, each with its speed of convergence and required processing time. By changing the complex weights on real time basis maximization of quality in communication channel can be obtained.

The smart antenna system can be divided mainly into three
Parts :

1) The first one performs the direction of arrival (DOA)
estimation and determines the number of incoming signals.

2) The second part performs the DOA classification. It
finds out which signals originate from the user and which ones from the interferers.

3) The third part consists in the Beamforming algorithm.
It forms an antenna pattern with a main beam steered in the
direction of the user, while minimizing the influence of the
interfering signals and the noise.

An antenna array has spatially separated sensors whose outputs are fed into a weighting network . In general any combination of elements in different geometric structures can form an array.

In this paper we make the following assumptions
About antenna array:
1) There is no mutual coupling between elements.
2) All incidents fields can be decomposed into a discrete number of plane waves. That is there are finite numbers of
signals.
3) The bandwidth of the signal incident on the arrays is small compared with the carrier frequency

III. ADAPTIVE BEAMFORMING

Adaptive beamforming is a commonly employed technique
that enables system operation in an interference environment
by adaptively modifying the system's antenna pattern so that
nulls are generated in the angular locations of the interference sources. This approach is applicable to scenarios where multiple antenna elements are individually weighted to produce a desired directivity pattern. A typical method of
forming the adaptive weights is via the MVDR algorithm,
which implements a single linear constraint that maintains unit gain in the boresight direction.

IV. LMS ALGORITHM

The Least Mean Square (LMS) algorithm is an adaptive algorithm, which uses a gradient-based *method of steepest decent* LMS algorithm uses the estimates of the gradient vector from the available data. LMS incorporates an iterative procedure that makes successive corrections to the weight vector in the direction of the negative of the gradient vector which eventually leads to the minimum mean square error. Compared to other algorithms LMS algorithm is relatively simple; it does not require correlation function calculation nor does it require matrix inversions.

The LMS bam former configuration is shown in Figure 2.

From the *method of steepest descent*, the weight vector equation is given by,

$$w(n+1) = w(n) + 1/2\,\mu[-\nabla(E\{e^2(n)\})] \quad (1)$$

Where μ is the step-size parameter and controls the convergence chachteristics of the LMS algorithm; $e^2(n)$ is mean square error between the beamformer output

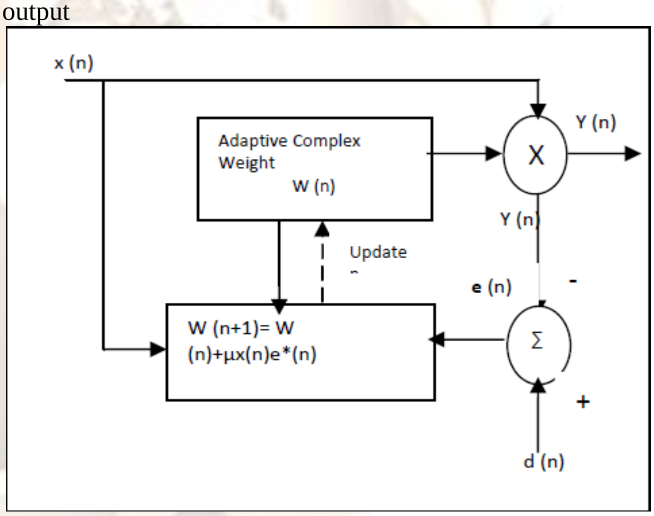

Fig. 2 Block diagram of LMS algorithm.

y(n) and the reference signal which is given by,

$$e^2(n) = [d^*(n) - w^h x(n)]^2 \quad (2)$$

The gradient vector in the above weight update equation can be computed as,

$$\nabla_w (E\{e^2(n)\}) = -2r + 2Rw(n) \quad (3)$$

Output, $y(n)= w^{h}x(n)$ (6.8)
(7)

Error, $e(n) = d^{*}(n) – y(n)$ **(6.9)**
(8)

Weight, $w(n+1) = w(n) + \mu x(n)e^{*}(n)$
(9)

In the *method of steepest descent* the biggest problem is the computation involved in finding the values *r* and *R* matrices in real time. The LMS algorithm on the other hand simplifies this by using the instantane ous values of covariance matrices *r* and *R* instead of their actual values i.e.

$R(n) = x(n)x^{h}(n)$
(4)

$r(n) = d^{*}(n)x(n)$
(5)

Therefore the weight update can be given by the following equation,

$$w(n+1) = w(n) + \mu x(n)[d^{*}(n) – x^{h}(n)w(n)]$$

$$= w(n) + \mu x(n)e^{*}(n) \quad (6)$$

The LMS algorithm is initiated with an arbitrary value *w*(0) for the weight vector at *n*=0. *The* successive corrections of the weight vector eventually leads to the minimum value of the mean squared error,

Therefore the LMS algorithm can be summarized in following equations;

V. CONVERGENCE AND STABILITY OF THE LMS ALGORITHM

The LMS algorithm initiated with some arbitrary value for the weight vector is seen to converge and stay stable for,

$$0 < \mu < 1/\lambda_{max} \quad (10)$$

Where λ_{max} is the largest eigenvalue of the correlation matrix *R*. The convergence of the algorithm is inversely proportional to the eigenvalue spread of the correlation matrix *R*. When the eigenvalues of R are widespread, convergence may be slow. The eigenvalue spread of the correlation matrix is estimated by computing the ratio of the largest eigenvalue to the smallest eigenvalue of the matrix. If μ is chosen to be very small then the algorithm converges very slowly. A large value of *μ* may lead to a faster convergence but may be less stable around the minimum value.

VI . SIMULATION RESULTS

Simulation results are shown for traditional LMS and Imroved LMS algorithm . In Traditional LMS step size is fixed where as in improved LMS step size is variable .

A GUI has been built to ease the simulation. A layoutof the GUI is depicted in Figure 3. The user can input thesignal parameters including angle(s) of arrival , their signal power, number of data snapshots , element of linear array and distance berween elements.

Case 1: Figure 3, It is considered that there are three desired users with signals arriving at angles -45,0,60 degrees with the different signal strength .Number of snapshots are 2000, number of array elements N=16 with spacing between elements ,d =0.5λ

Case 2: Figure 4 shows the performance degration as number of array elements are decrease to 8 and spacing between array elements, d =0.2λ. Other parameters are assumed to be same .

It has been noticed from results that sharper beams are directed towards desired signals as more elements are used in antenna array .Also, spacing between array elements has an effect on beamformer performance such that very small or very large spacing between array elements can degrade beamformer performance (6.7) From different numerical calculation it has been observed that element spacing of 0.5λ is a good value .

The Graphs are same for the traditional LMS and Improved LMS Algorithms for Direction of Arrival of Signals .

Case3: Figure 5 and Figure 6 shows the error curves for traditional LMS and Improved LMS algorithms .

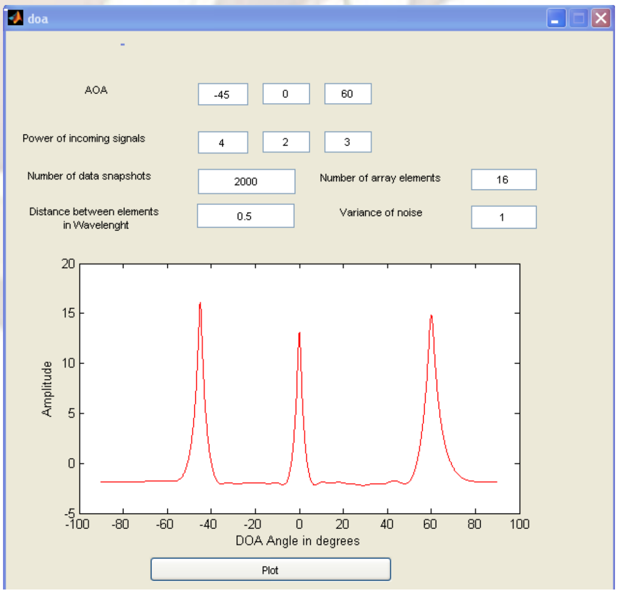

FIG. 3. DOA GRAPH FOR N= 16, D =0.5Λ

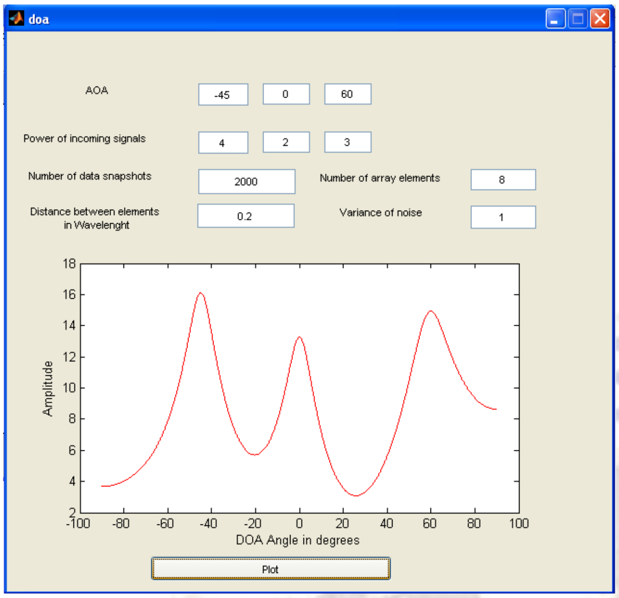

Fig 4. DOA graph for N=8 and d =0.2λ.

The error curve plot shows that system error is less for Improved LMS as compared to Traditional LMS algorithm .

VII . CONCLUSIONS

This paper discussed adaptive beamforming algorithms like traditional and improved LMS algorithm used in smart antenna. The convergence speed of LMS algorithm depends on eigenvalues of array correlation matrix. Traditional algorithm has slow convergence speed as step size μ is fixed. In Improved LMS as μ is variable , the convergence rate is higher with low steady state error .

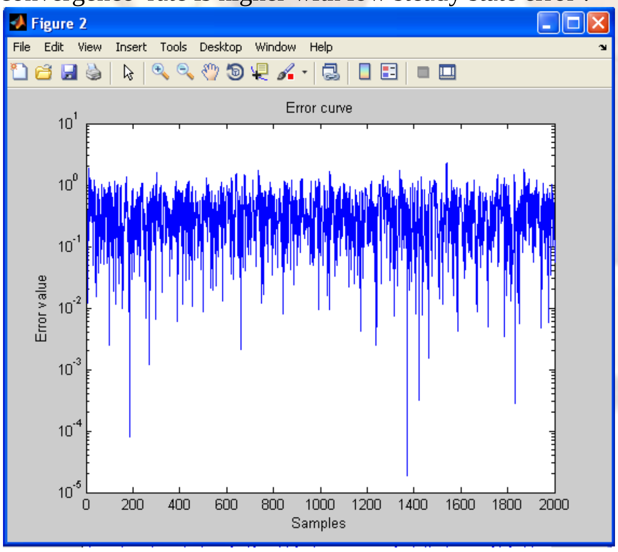

FIG.5 ERROR CURVE FOR TRADITIONAL LMS ALGORITHM

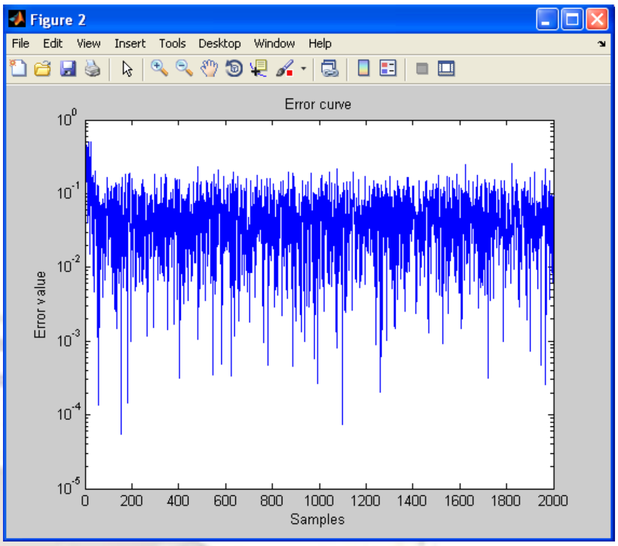

FIG. 6. ERROR CURVE FOR IMPROVED LMS ALGORITHM

This paper studied the effect of linear antenna array parameters in terms of its size and element spacing . It was found that the performance of LMS beamformer improves as more elements are used in the antenna array This improvement can be seen in the form of sharper beams directed towards the desired users . By studing the effect of spacing between antenna elements , it was seen that using small or large spacing values could degrade the performance of LMS beamformer. An element spacing value of 0.5λ ensures successful performance of LMS beamformer .

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