ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 2 Issue 8, August 2013

# A COMPARATIVE BEAMFORMING ANALYSIS OF LMS & NLMS ALGORITHMS FOR SMART ANTENNA

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*Abstract*— **Beamforming is a technique of directional signal transmission and recitation. Now a days, because of an increasing demand on wireless communication (like RADAR, satellite communication, mobile communication, broadcasting etc.) the beamforming technique plays a vital role for good transmission and reception purpose. By changing the phase and amplitude of the exciting currents in each of the antenna elements, it is possible to electronically scan the image lobe and/or place nulls in any direction. In beamforming, each users signal is multiplied with complex weights that adjust the magnitude and phase of the signal to and from each antenna. This causes the output from the array of antennas to form a transmit/receive beam in the desired direction and minimizes the output in other direction. In this paper we use different version of LMS adaptive algorithm (basically LMS and NLMS) to steer the antenna beam in particular desired direction. The radiation pattern of for each case plotted in polar plot. Here we steer the beam of of the system in two way (1) Considering the desired direction (position) are in uniformly distributed (2) The desired direction are non uniformly distributed. We campier their simulation results of each case with each other. Adaptive signal processing sensor arrays, known also as smart antennas .The smart antenna adaptive algorithms achieve the best weight vector for beam forming by iterative means.**

*Index Terms*— **LMS algorithm, NLMS algorithm, Smart antenna.**

## I. INTRODUCTION

Throughout the world, there is significant research and development on smart antennas for wireless systems. Smart antenna systems attract a lot attentions now and believably more in the future, as it can increase the capacity of mobile communication systems dramatically [4].This is because smart antennas have tremendous potential to enhance the performance of future generation wireless systems as evidenced by the antennas' recent deployment in many systems. There are two basic types of smart antennas. The first type is the phased array or multi beam antenna, which consists of either a number of fixed beams with one beam

turned on towards the desired signal or a single beam (formed by phase adjustment only) that is steered toward the desired signal. The other type is the adaptive antenna array is an array of multiple antenna elements, with the received signals weighted and combined to maximize the desired signal to interference plus noise power ratio [1].

A smart antenna system at the base station of a cellular mobile system is depicted in Fig.1[3]. It consists of a uniform linear antenna array for which the current amplitudes are adjusted by a set of complex weights using an adaptive beam forming algorithm. The adaptive beam forming algorithm optimizes the array output beam pattern such that maximum radiated power is produced in the directions of desired mobile users and deep nulls are generated in the directions of undesired signals representing co-channel interference from mobile users in adjacent cells.

Prior to adaptive beamforming, the directions of users and interferes must be obtained using a direction-of- arrival (DOA) estimation algorithm.

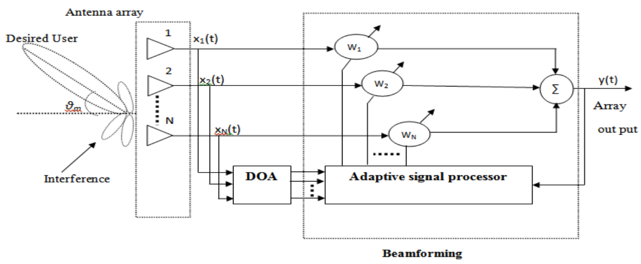


Fig.1 : Block diagram of smart antenna

The goal of direction-of-arrival (DOA) estimation is to use the data received on the downlink at the base-station sensor array to estimate the directions of the signals from the desired mobile users as well as the directions of interference signals [5]. The results of DOA estimation are then used by to adjust the weights of the adaptive beam former so that the radiated power is maximized towards the desired users, and radiation nulls are placed in the directions of interference signals. Hence, a successful design of an adaptive array depends highly on the choice of the DOA estimation algorithm which should be highly

***Manuscript received Jul, 2013.***

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accurate and robust.

Adaptive smart antennas are the array antennas whose radiation pattern is shaped according to some adaptive algorithms [1]. Smart essentially means computer control of the antenna performance. The smart antenna radiation pattern directs the beam towards the users of interest only & nulls toward interference to improve the capacity of cellular system. The adaptive beam forming algorithms takes the fixed beam forming process one step further & allows for the calculation of continuously updated array weights.

According to signal space information smart antenna can form directional beam in space with the adaptive beam forming algorithm, achieving that the main beam aims at the direction of the expected signal while the side lobe and nulls aims at the interference. Now many adaptive algorithms have been proposed on smart antenna. The NLMS algorithm and LMS algorithm are most commonly used as a adaptive beam forming algorithm .

## II. LEAST MEAN SQUARE (LMS) ALGORITHM

The Least Mean Square (LMS) algorithm, is an adaptive algorithm. 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. Beam forming is directly determined by the two factors. This algorithm can be applied to beam forming with the software Matlab. The result obtain can achieve faster convergence and lower steady state error. The algorithms can be simulated in MATLAB 7.10 version.
Consider a L length LMS based adaptive filter in which 'W' is the weight vector updated in accordance with the statistical nature of the input signal x(n) arriving from the antenna array. An adaptive processor will minimize the error e(n) between a desired signal d(n) and the array output y(n).The knowledge of the received signal eliminates the need for beam forming, but the reference can also be a vector which is somewhat correlated with the received signal. As shown in Fig.2.

The output response of the uniform linear array is given by

$y(n) = \hat{h}^H(n)x(n)$ (1)

We consider the adaptive filter where the input signal x(n) is convolved by an unknown h(n) filter (to produce y(n)) which has an additive interference signal v(n) before being observed as d(n).

The value of error signal estimation is

$e(n) = d(n)-y(n)$ (2)

The estimated convolved signal

$r(n) = y(n) - \hat{y}(n)$ (3)

we arrive at the recursion for the LMS adaptive algorithm for updating the step as

$h(n) = h(n - 1) + 2*\mu e(n)x(n)$ (4)

where μ is constant step and the filter taps can be adaptively updated by using above recursive relation.

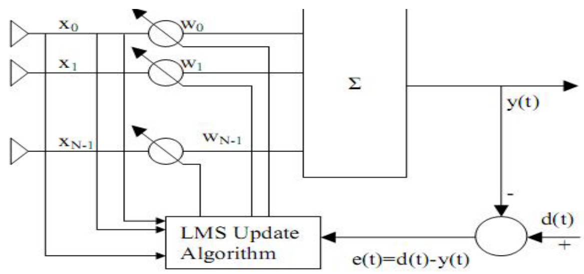


Fig.2 : LMS adaptive Beamforming Network

## III. NORMALIZED LEAST MEAN SQUARE (NLMS) ALGORITHM

The NLMS algorithm has been implemented in Matlab. As the step size parameter is chosen based on the current input values, the NLMS algorithm shows far greater stability with unknown signals [6]. This combined with good convergence speed and relative computational simplicity make the NLMS algorithm ideal for the real time adaptive echo cancellation system. As the NLMS is an extension of the standard LMS algorithm, the NLMS algorithms practical implementation is very similar to that of the LMS algorithm. Each iteration of the NLMS algorithm requires these steps in the following order [7].

1. The output of the adaptive filter is calculated

$$y(n) = \sum_{i=0}^{N-1} w(n)x(n-i) = \mathbf{w}^T(n)\mathbf{x}(n) \quad (5)$$

2.An error signal is calculated as the difference between the desired signal and the filter output

$E(n) = d(n) - y(n)$ (6)

3.The step size value for the input vector is calculated

$$\mu(n) = \frac{1}{\mathbf{x}^{T}(n)\mathbf{x}(n)} \quad (7)$$

4.The filter tap weights are updated in preparation for the next iteration.

$$W(n+1) = W(n) + \mu(n)e(n)x(n) \quad (8)$$

Each iteration of the NLMS algorithm requires 3N+1 multiplications, this is only N more than the standard LMS algorithm. This is an acceptable increase considering the gains in stability and echo attenuation achieve. NLMS converge faster than LMS because the step size is optimize at each iteration. The computational complexity of the more in NLMS than LMS.

## IV. SIMULATION RESULTS

### 1. LMS ALGORITHM

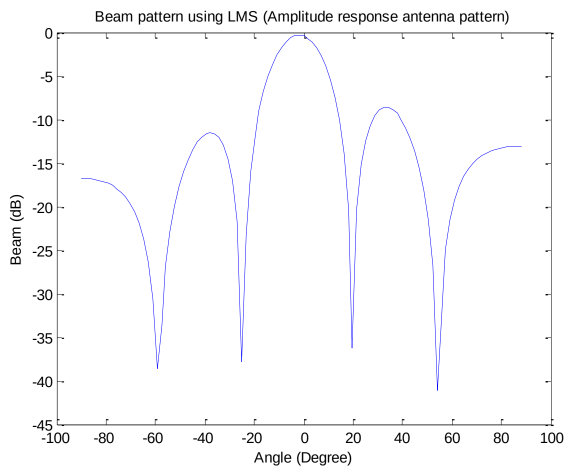


Fig.3 : LMS Antenna Coverage Pattern

Here, Least Mean Square (LMS) algorithm uses a gradient based method of steepest decent. 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. LMS algorithm is relatively simple; it does not require correlation function calculation nor does it require matrix inversions.

Fig.3 shows the radiation pattern for desired users with signals arriving at angles -40,0,60 degrees with the different signal strength. Number of snapshots are 2000, number of array elements N=16 with spacing between elements,d =0.5λ.

### 2. NLMS ALGORITHM

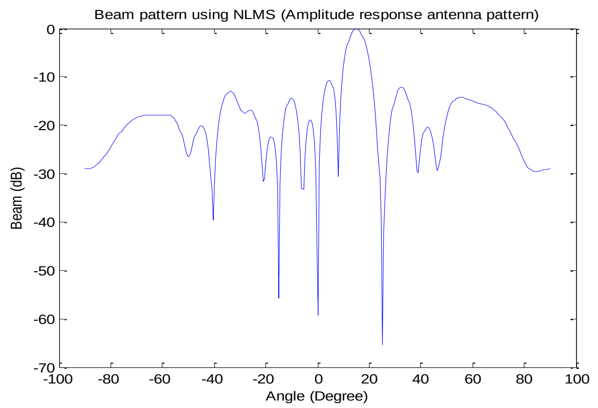


Fig.4 : NLMS Antenna Coverage Pattern

Fig.4 shows the beam pattern for desired users with signals. The plots correspond to the 200 iterations. The figure shows that the response is successfully steered towards the desired signal source and away from the strongest interfering sources. Number of snapshots are 100, number of array elements N=16 wit h spacing between elements, d =0.05λ,SNR=0, JNR= 30. Working frequency 3 GHz, Sample frequency 18 GHz.

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 beam-former performance such that very small or very large spacing between array elements can degrade beam-former performance.

From different numerical calculation it has been observed that element spacing of 0.05λ is a good value, the value of sharper beams (positive interference or desired user) is high in case of normalized least mean square algorithm as compare to traditional least mean square method.

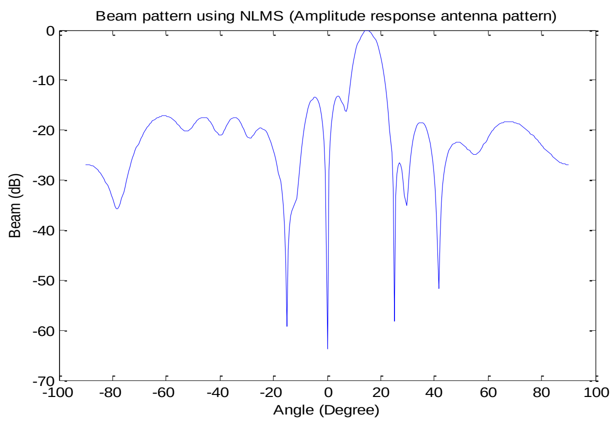


Fig.5 : NLMS Antenna Coverage Pattern

Fig.5 shows the beam pattern for desired users with signals arriving at angles 15,25,-15,0 degrees with the different signal strength .Number of snapshots are 100, number of array elements N=20 with spacing between elements ,d

=1.0λ,SNR=0, JNR= 40,working frequency 4Ghz,Sample frequency 18Ghz.

It has been noticed from results that the radiation pattern for NLMS case show faster convergence rate and can form deeper nulls in the direction of interference for desired users.

## V. CONCLUSION

In these algorithms, the LMS algorithm is the most popular adaptive algorithm, because of their low computational complexity. However, the LMS algorithm suffers from slow and data dependent convergence behavior. The NLMS algorithm, an equally simple, but more robust variant of the

LMS algorithm, exhibits a better balance between simplicity and performance than the LMS algorithm. Due to its good characteristics the NLMS has been largely used in real-time applications.

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