International Conference on Innovative Trends in Electronics Communication and Applications 2015 [ICIECA 2015]

ISBN	978-81-929742-6-2
Website	icieca.in
Received	02 - April - 2015
Article ID	ICIECA009

VOL	01
eMail	icieca@asdf.res.in
Accepted	15 - November - 2015
eAID	ICIECA.2015.009

Analysis of MIMO performance with Beam Forming Algorithms

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Abstract: *The growth of digital wireless communication is marvelous in last few decades. The demand for higher data rate is more and it can be achieved by increasing the bandwidth and channel capacity. Increasing the bandwidth is more challenging, since we are having very limited spectrum. And here capacity is increased to achieve higher data demand through space selectivity. Smart antenna with beam forming algorithm provide higher capacity and higher quality than other system. In this paper the performance of the smart antenna is analyzed with LMS and NLMS algorithm with stimulation results. It is found that the performance of smart antenna is high in NLMS algorithm.*

Keywords*:* MIMO, Beam forming, LMS

INTRODUCTION

The demand in communication capacity is achieved by the employment of the space division multiple access technique. The signal transmitted on the same frequencies can be separated by the smart antenna array and they are separated in spatial domain. Which increase the performance and improved network efficiency of the mobile system.

The features of a wireless channels are thin. Hence for some region the characteristics are zero. Since in spatial domain it varies with DOA. For reducing the bandwidth requirement sparsely spaced element is needed for increasing the convergence rate by reducing the reference training sequence.

The performance of the smart antenna is tested with LMS and NLMS algorithm. Good robustness against execution errors and low computational complexity adds remark to the NLMS. The NLMS having good convergence rate then LMS. Its convergence and computing time are less. For implementation in cost effective way our work is to find the less computing time algorithm.

SYSTEM MODEL

Types of Beamforing Algorithm:

The algorithm of the adaptive antenna is classified based on whether training signal is used and not used [1]. It is classified as blind and non-blind algorithm[2].

Non-Blind Algorithm:

In this algorithm, the training signal is known to both transmitter and receiver the receiver received it from transmitter during training

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period[3] with the training signal the beam former in the receiver can calculate the optimal weight vector.

The data is transmitted after the training period weigh vector which is calculated previously with training signal[4]. For the working of beam former the non-blind algorithm is used in NLMS, LMS and also in steepest-decent.

LMS ALGORITHM

For The property of robust and easy implement, the LMS is having application for equalization, echo cancellation modeling control and beam forming. The antenna is customized to have maximum gain in the direction of desired signal and the gain is low or null in the undesired direction. The beam forming system is show in fig 1.

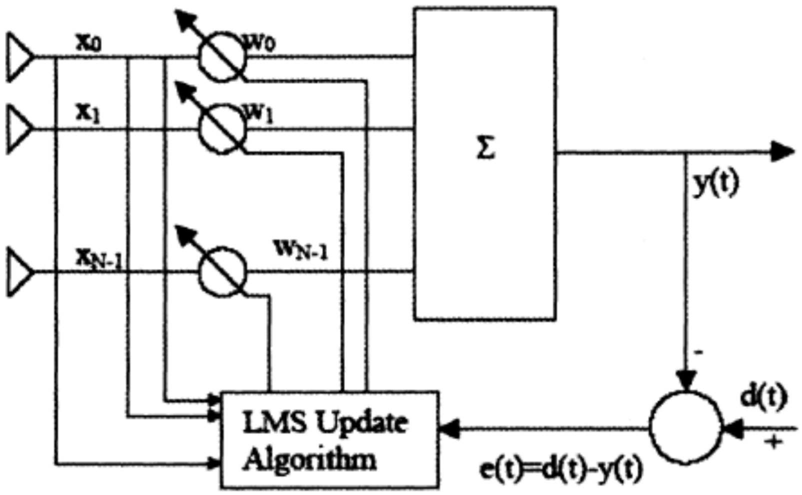

Fig1: LMS beam forming algorithm

The antenna is customizing by combining the output of individual sensors and they are scaled based on the corresponding weight. And with the help of minimum squared error the LMS can compute the weight . Spatial filtering involves the signal estimation in receiver by reducing the error with the help of reference signal d(t)[5]. And it has some correlation with desired signal and beam former output y(t). The solution is obtained by iteration using LMS algorithm.

The phase and amplitude of the incoming signal is adjusted by multiplying the received signal x(t) with the coefficient of the weight vector w. y(t) is the result of the weighted signal. The error e(t)between the desired signal and output y(t) is minimized by employing adaptive algorithm[6]. The output y(n) of the beam forming can be expressed as

$$y(n) = w^H x(n) \tag{1}$$

Where $$w = [w_1, w_2 \ldots., w_k]^H \tag{2}$$

And $$x(n) = [x_{1(n)}, x_2(n) \ldots. x_k(n)] \tag{3}$$

Where H represents the hermitian transpose. The complex vector of weight $w_1, w_2 \ldots., w_k$ adjust the amplitude and phase. The desired beam can be produced by adding together the MMSE weight adaptation with the steepest decent algorithm produces LMS algorithm[7]. For each new samples the weight vectors are updated, this process is called sample by sample techniques. Because of the successive correction the gradient vector leads to the MMSE.

$$\boldsymbol{w}(n+1) = w(n) + \frac{1}{2}U(-\nabla \mathrm{J}(\mathrm{n})) \tag{4}$$

W(n) represents the weight vector at n, W(n+1) represent weight vector at n+1. U represents the step size which control the convergence speed. The value for the gradient vector is calculated through covariance matrix R and cross-correlation r.

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$$\nabla J(n) = -2r(n) + 2R(n)W(n) \tag{5}$$

Where

$$\boldsymbol{R}(n) = x(n) * x^h(n) \tag{6}$$

and

$$r(n) = x(n) * d^*(n) \tag{7}$$

As we know the error vector $e(n) = d(n) - y(n)$

Substitute the value of gradient vector in the equation number (4) , we get

$$\boldsymbol{w}(n+1) = w(n) + x(n) * d^*(n) - x(n) * x^h(n)w(n) \tag{8}$$

$$\boldsymbol{w}(n+1) = w(n) + x(n)(d^*(n) - x^h(n)w(n)) \tag{9}$$

Sub e(n)

$$\boldsymbol{w}(n+1) = w(n) + Ux(n)e^*(n) \tag{10}$$

The gradient value changes randomly as per the input vector. When the rate of convergence U is slow, then it will gives good estimation of large amount of data.

By sending known pilot sequence to the transmitter the knowledge of the transmitter signal is measured, which required by the algorithm[8]. The step size parameter controls the convergence speed. Hence the algorithm depends on the step size. The step size is a positive constant value which control the size of increment applied in one iteration to the next. Three factors determines the response of the LMD algorithm they are

A. Number of weight
B. Step size parameter
C. Eigen value of the correlation matrix

ADVANTAGE: The Main advantage of the LMD is the low computational complexity which is O(L), L is the number of tap weight.

DISADVANTAGE: The main disadvantage is low convergence rate and fluctuation which creates problem in tracking and acquisition.

NLMS ALGORITHM

The NLMS (normalized least mean square algorithm) is used in number of signal processing and control applications. It works by adapting the finite impulse response filters co-efficient. The weight vector can be calculated easily by using NLMS the values are stable and faster in convergence [9]. NLMS is the modification of the LMD algorithm.

The LMS algorithm suffers from the gradient noise amplification problems. The product vector in (10) ($x(n)e^*(n)$) is applied to the weight vector and it is proportional to the input vector x(n). For that $x(n)e^*(n)$ have to be normalized. Hence the final weigh vector of the NLMD algorithm represented by

$$\boldsymbol{w}(n+1) = w(n) + \frac{U}{|x(n)|^2} x(n)e^*(n) \tag{11}$$

The step size of the NLMS algorithm is reduced, which make huge change in weight vector updation. Since the step size varies with respect to input make the convergence faster and more stable[10]. It is shown in equation (11) that step size is divided by the square of the input signal to remove the gradient noise amplification.

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ADVANTAGE: The main advantage of the NLMS algorithm over the LMS algorithm is the faster convergence for correlated[11] and whitened input and the stableness of the output with the varying range of values independent input data[12]. And to implement a shift input of data the NLMS require additional addition, Multiplication and division over the LMS algorithm.

SIMULATION RESULTS

In wireless communication convergence and radiation pattern analysis determine the performance of the algorithm. Matlab14 is used to simulate the training based algorithm. The system of four antennas with ½ wavelength spacing is considered. The BPSK modulation in AWGN radio channel are considered.

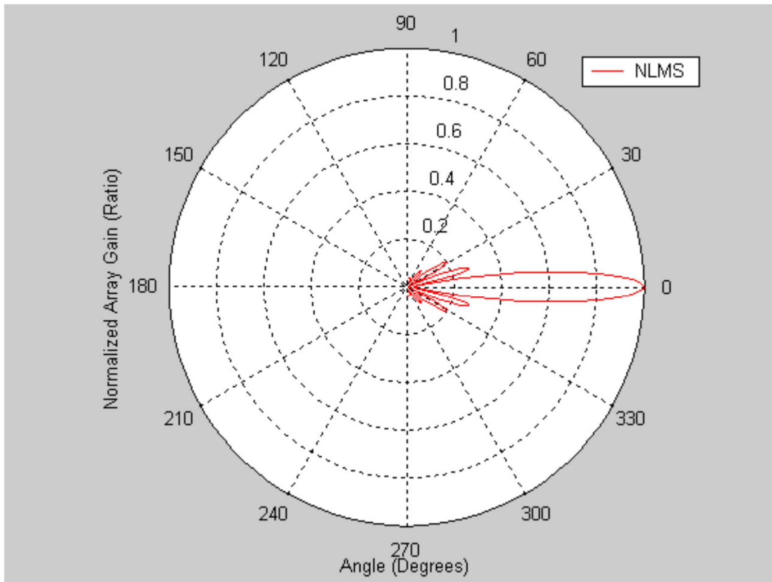

Fig2A: Radiation pattern of NLMS

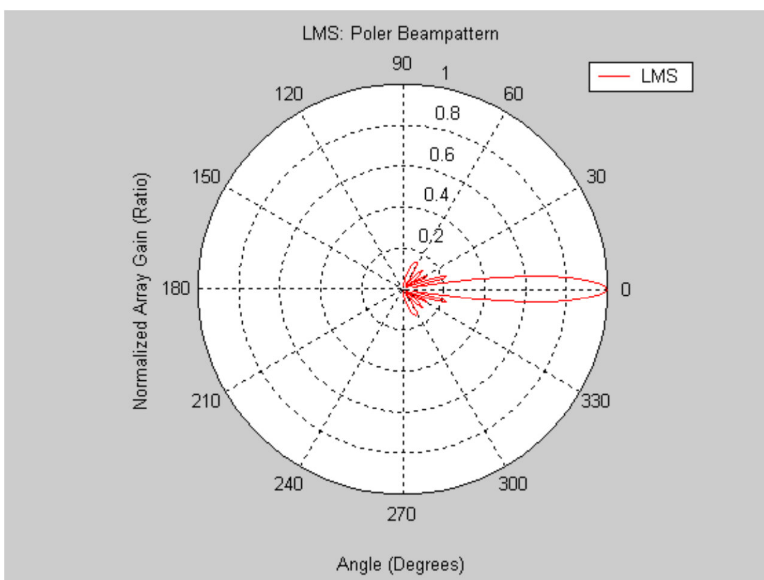

Fig2B: Radiation pattern of LMS and NLMS

Figure 2 shows the comparison of LMS and NLMS. Both the beams are in desired direction where NLMS have length gain and narrow beam width. Also LMS has many lobes while NLS has only two side lobes.

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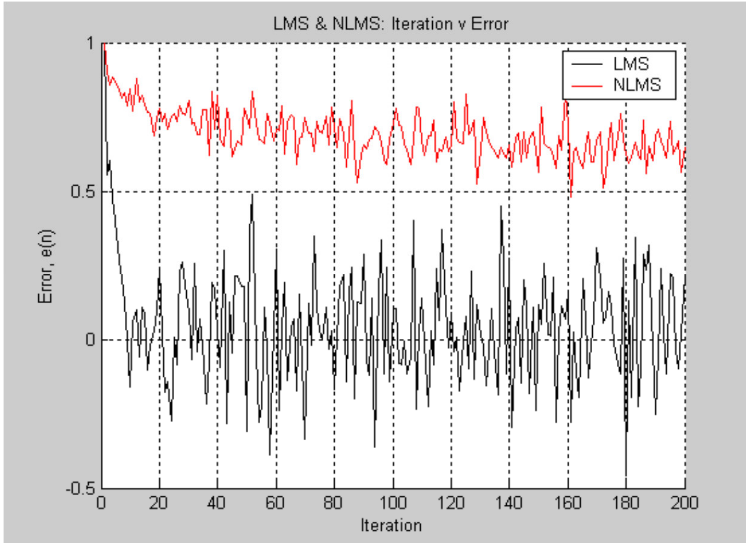

Fig3: Error Convergence of LMS and NLMS algorithms

Figure3 shows the error convergence of both LMS and NLMS. It is found that NLMS is much more stable and less fluctuation for each iteration with optimal step size. NLMS will give good radiation pattern. While the result for LMS shows unstable and low convergence.

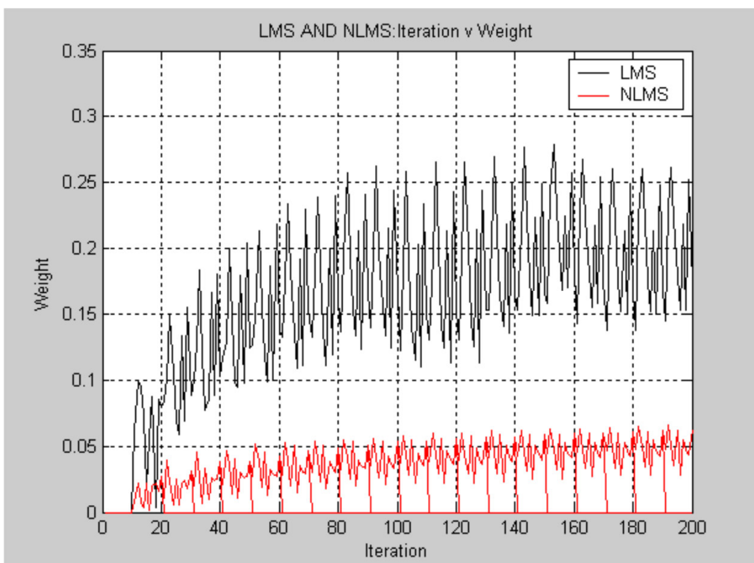

Fig4: Wight vector convergence performed of LMS and NLMS algorithms

The variation for the weight value is high in LMS Algorithm, Hence it is less stable when compared with NLMS. In NLMS also produces some spikes but not that much as compared to the LMS. And also less number of iteration are needed for the converges. Which make the system to converge quickly. With the help of the two results we can conclude NLMS is best in because of being stable and its convergence rate then LMS algorithm.

CONCLUSION

In this paper two non-blind beam forming algorithm- LMS and NLMS are compared on a smart antenna system. It is found that when the number of antenna elements are more the performance of LMS and NLMS would be more. It is analyzed that the error performance of LMS algorithm produce more fluctuations and convergence time is more when compared with the NLMS.

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The radiation pattern and more directional of NLMS out performances LMS. However NLMS is little higher computational cost than LMS. The reason is the extra step size and it is divided by norm of input vector. The result is small and unnoticeable NLM is good algorithm it can be used in applications for slow-noise magnitude variation.

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