A LMS and NLMS Algorithm Analysis for Smart Antenna

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ABSTRACT: *The Demand of New Communication techniques arising day by day, due to the Increasing the numbers of users. Many techniques are used like cell sectoring, cell splitting, directional Antenna etc., these all technique has motive only to increase the efficiency the communication system. The Smart Antenna is useful part for, mainly where Interference is Capital problem in the communication system. The smart Antenna plays an important Role to reduce interference in communication Environment. The adoption of smart/adaptive antenna techniques in future wireless systems has impact on the efficient use of the spectrum of network, to reduce the cost of establish new wireless networks. SAs can place nulls in the direction of interference via adaptive updating of weights linked to each antenna element. SAs cancel out the co-channel interference resulting in better quality of reception and reduce the no. of dropped calls. In this paper, we analyze the performance of smart antenna system on LMS and NLMS algorithms. In this paper, the conclusion and analysis section with graphs of comparison is simulated using MATLAB.*

Keywords: Smart Antenna, NLMS, LMS, Beamforming, Convergence Time

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1. Introduction

Smart antennas refer to Array of antenna technologies that increase the system capacity by reducing the co-channel interference and increase the quality by reducing the fading effects in communication system.

By the use of different algorithms, we adapt the weight of smart antenna and we receive the desired signal. Every Algorithm has its own merits and demerits, According to our need we use algorithm, with different convergence time, complexity and Efficiency of that algorithm.

In this paper, we implement the LMS and NLMS algorithm for adaptive beamforming techniques. Beamforming creates the radiation pattern of the antenna in the particular desired direction and by placing nulls in the unwanted direction.

The performance of the algorithm can be implemented with different parameters such as effect of number of antenna elements, the spacing between antenna array elements, the different angles of interference increases. We divide the whole paper, Section-I deals with introduction, Section-II deals with LMS and NLMS algorithm in Detail, Section-III deals with simulation of both algorithms with different parameters in MATLAB and section-IV shows the conclusion of whole paper.

2. Mathematical Background of LMS and NLMS Algorithm

2.1 LMS (LEAST MEAN SQUARE) Algorithm

Least Mean Square (LMS) algorithm, introduced by Widrow and Hoff in 1959,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. Least mean square algorithm (LMS) is useful than other algorithms because of its simplicity and ease of computation. The LMS algorithm can be described by the following three equations,

$$y(n) = w^H(n) \, . \, x(\mathrm{n}) \ldots\ldots\ldots\ldots.. \quad (1)$$

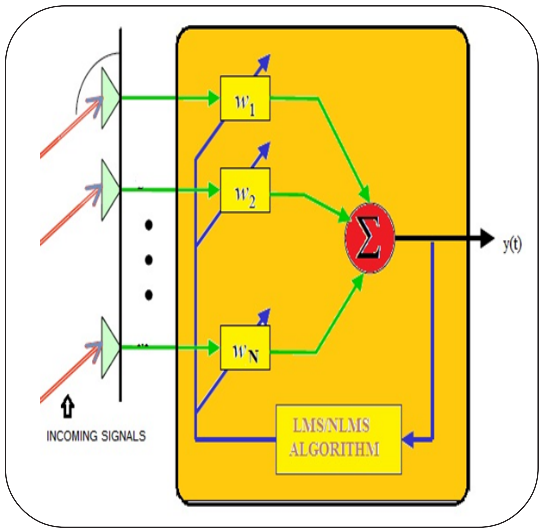

Figure 1. Basic Diagram of Smart Antenna

$$e(n) = d(n) - y(n) \ldots\ldots\ldots\ldots......(2)$$

$$w(n+1) = w(n) + \mu \, . \, x(n) \, . \, e^*(n) \ldots\ldots\ldots\ldots(3)$$

μ is a gain constant and control the rate of Adaptation. *e* (*n*), *y* (*n*), *x* (*n*) and *d* (*n*) are error between desired and o/p signal, x(n) is *i*/*p* signal, *d* (*n*) desired signal respectively.

LMS algorithm uses continuous adaptation and weight vector sequence converges to the optimum solution when the weight adjusts. The array factor for *N* element equally spaced linear array is given by:-

$$AF(\theta) = \sum_{n=1}^{N} w_n e^{(j(n-1)\{2\prod d/\lambda . (cos\,\theta) + \alpha\}} \ldots\ldots.. \quad (4)$$

The spacing between the elements of antenna α is given as:-

$$\alpha = \frac{-2\prod d}{\lambda} cos\,\theta$$

and the weight vector is seen to converge and stay stable for:

$$0 < \mu < 1/\lambda_{max}$$

where λ_{max} is largest eigen value of correlation matrix. The step size is given by $\mu = 1/4$ trace (*R*). *R* is the correlation matrix.

2.2 Normalized Least Mean Square (NLMS) Algorithms

Normalized Least Mean Square Algorithm is an adaptation of the LMS algorithm, which overcomes the LMS algorithm's stability problems due to its weight vector's actualization, *w* (*k*+1), being directly proportional to the input vector *x* (*k*).

In other words, the Normalized least mean squares filter (NLMS) is a variant of the LMS algorithm that solves this problem by normalizing with the power of the input.

$$w(k+1) = w(k) + \mu(k) \,.\, x(k).e^{*}(n) \ldots\ldots\ldots(5)$$

In the equation(5), the step size is given by

$$\mu(k) = \frac{\mu}{\|x(k)\|^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Where μ is a constant . the value of μ lies in between 0 and 2. [8]

$\mu(k)$ is the normalized version of LMS (NLMS) because step size is divided by the norm of the input signal to avoid gradient noise amplification due to $x(n)$.

3. Analysis of LMS and NLMS Algorithm

LMS (Least Mean Square) Algorithm

In the analysis of this algorithm, we considered that the no. of antenna elements are $N = 10$, angle of arrival is 10 degree and angle of interference is 70 degree. The distance or spacing between the antenna elements of the array is 0.6λ.The Array Factor defines the positions of the antenna elements in the array and the weight used. The Array factor of the LMS based smart antenna w.r.t. AOA is shown below:-

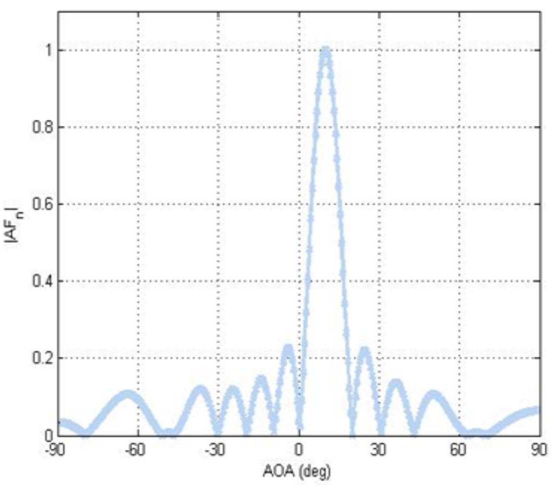

Figure 2. Array factor when DOA of desired user is 10 degree and interference is 70 degree

Figure Mean Square Error v/s No. of iterations when DOA of desired user is 10 degree and interference is 70 degree.

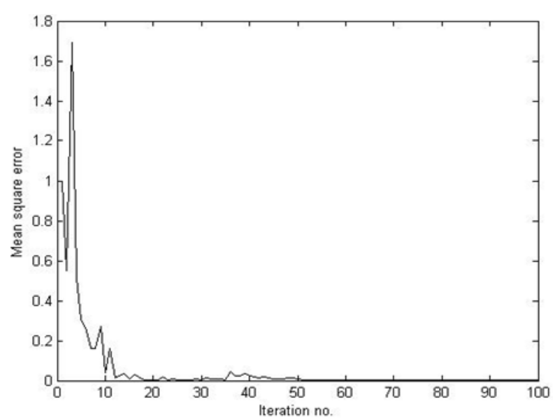

Figure 3. Mean Square Error v/s No. of iterations when DOA of desired user is 10 degree and interference is 70 degree

The weight updation of the LMS Algorithm is given in equation (3).In this analysis the weights for the N = 10 ULA are:

$w1 = 1$

$w2 = 1.0064 + 0.62254i$

$w3 = 0.22841 + 1.0108i$

$w4 = -0.29592 + 1.1036i$

$w5 = -0.97059 + 0.49151i$

$w6 = -1.0899 + 0.011474i$

$w7 = -0.76956 - 0.84212i$

$w8 = -0.26487 - 1.0037i$

$w9 = 0.60677 - 1.0146i$

$w10 = 0.88734 - 0.46312i$

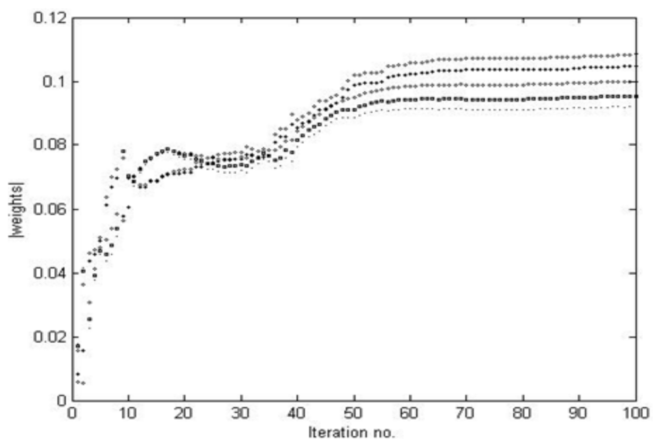

Figure 4. Weight updation of LMS Algorithm

The Mean Square Error of the algorithm defines the error between the desired and actual signal.

In this paper we will see the difference between both the algorithm mean square error and how much time is required to reduce it.

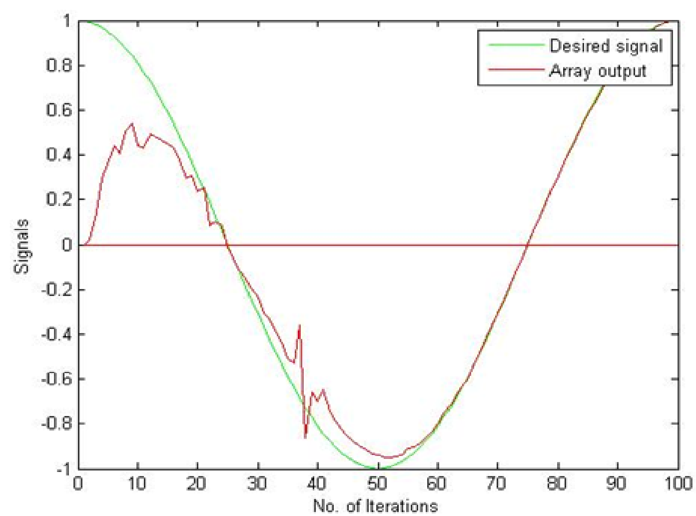

Figure 5. Difference b/w the desired signal and antenna array o/p

NLMS (Normalized Least Mean Square) Algorithm

The NLMS Algorithm, is same as LMS algorithm,it has fast convergence time and achieve the good calculation.The Difference between the LMS algorithm and NLMS is only the weight updation. The weight updation of the NLMS algorithm is given in equation(5).The Figure shows below the direction of arrival from the desired user

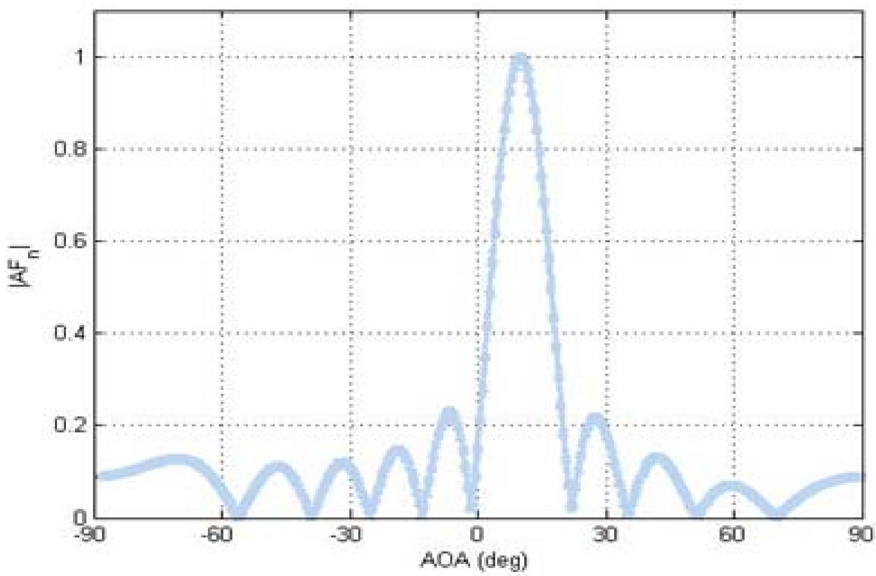

Figure 6. Array factor when DOA of desired user is 10 degree and interference is 70 degree

The difference between the desired and antenna o/p is shown below. The Antenna Output is more accurate in NLMS Algorithm as compared to the LMS algorithm**.**

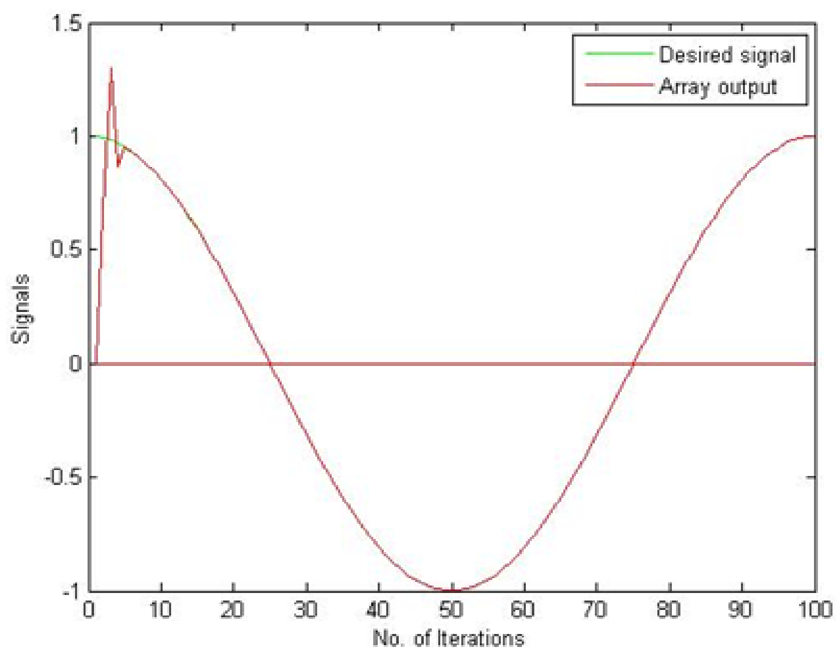

Figure 7. Difference b/w the desired signal and antenna array o/p

The updation of Weights of NLMS Algorithm is faster than LMS algorithm. The updation of weights in NLMS Algorithm is shown in figure 8.

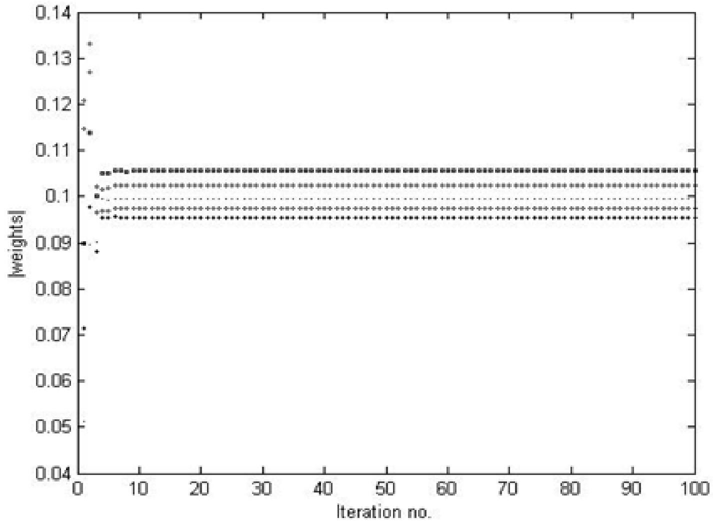

Figure 8. Weight updation of LMS Algorithm

The Updation of weights in NLMS algorithm in 10 ULA Elements in given below:-

w1 = 1

w2 = 1.002 + 0.62029i

w3 = 0.22946 + 1.0102i

w4 = – 0.29612 + 1.099i

w5 = –0.96845 + 0.49263i

w6 = –1.0865 + 0.0093512i

w7 = – 0.76945 – 0.83869i

w8 = – 0.26211 – 1.0022i

w9 = 0.60315 – 1.0124i

w10 = 0.88738 – 0.46105i

The Mean Square Error in the NLMS reduces very fast as compared to LMS. The plot between the Mean Square error and No. of Iterations is shown below:-

4. Conclusion

From the analysis of both algorithms ,it is concluded that the NLMS Algorithm is much better as compared to LMS Algorithm in the mobile communication, But the NLMS Algorithm requires a min. of one additional multiply, divide and addition as compared to LMS. The LMS Algorithm is basic method for updating the weight vectors and NLMS is an improved LMS Algorithm for fast convergence. So finally, we can say that the NLMS is more useful for mobile communication system.

5. References

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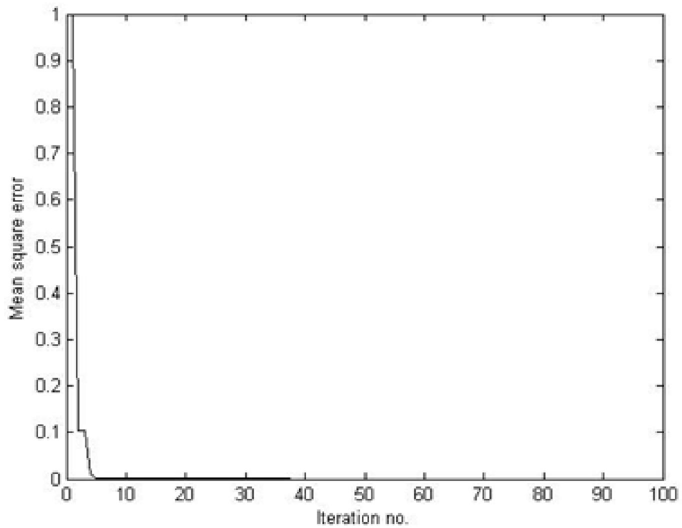

Figure 9. Mean Square Error v/s No. of iterations when DOA of desired user is 10 degree and interference is 70 degree

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