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A LMS and NLMS Algorithm Analysis for Smart Antenna

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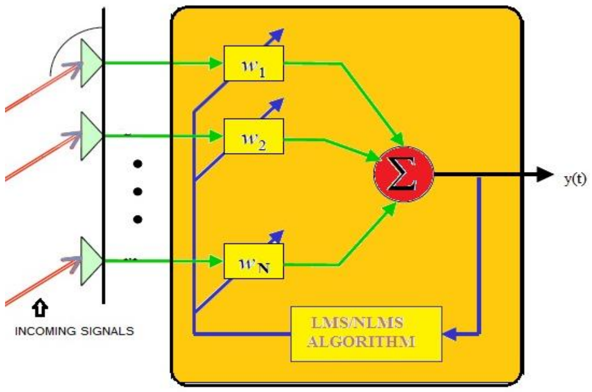
Abstract:-The demand of new communication techniques arising day by day, due to the increasing the numbers of users. There are many techniques which are used to increase the efficiency of the communication system like cell sectoring, cell splitting, directional antenna etc. The smart antenna is used where interference is critical problem in the communication system. The smart antenna plays an important role to reduce the 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. Smart antenna can place nulls in the direction of interference via adaptive updating of weights linked to each antenna element. Smart antenna cancels out the co-channel interference resulting in better quality of reception and reduces the no. of dropped calls. In this paper, we analyze the performance of smart antenna system on LMS and NLMS algorithm and comparative analysis is done using MATLAB.

Keywords:-Smart Antenna, NLMS, LMS, Beamforming, convergence speed.

I. 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. Smart antenna techniques are used in track and scan RADAR, radio astronomy and radio telescopes and more useful in mobile communication system like W-CDMA and UMTS. We analyze the weight of smart antenna and receive the desired signal using different algorithms.

The performance of the algorithm can be measured with different parameters such as effect of number of antenna elements, the spacing between antenna array elements, the different angles of interference etc. Beamforming is technique in which each user's signal is multiplied by complex weight that adjusts the magnitude and phase of the signal to and from each antenna. For Adaptive Beamforming, some of these criteria are implemented by Least Mean-Square (LMS) Recursive Least Squares (RLS), Constant Modulus Algorithm (CMA), Sample Matrix Inversion (SMI), Normalized least Mean Square(NLMS) algorithm etc. Beamforming algorithms create the radiation pattern of the antenna in the particular desired direction and by placing nulls in the unwanted direction. The smart antenna basic diagram is shown in fig(1).In figure weights updation by LMS and NLMS algorithm according to the output signal. The algorithm block adapts the weights multiplier and then gives output radiation pattern in desired direction.



Fig(1). Basic diagram of smart antenna

This paper is organized as follows: Section-II provides the detailed information regarding LMS and NLMS algorithm. Section-III represents the simulation of both algorithms with different parameters in MATLAB and section-IV presents the conclusion.

II. MATHEMATICAL BACKGROUND OF LMS AND NLMS ALORITHM

A) LMS (LEAST MEAN SQUARE) Algorithm:-

Least Mean Square (LMS) algorithm, was 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. 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,

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

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

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

where μ is a gain constant and control the rate of adaptation, e(n) is the error between desired and output signal, y(n) is the output signal, x(n) represents the input signal and d(n) is the desired signal.

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:-

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

The phase shift 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 μ=1/4trace(R), where R is the correlation matrix.

B). NORMALIZED LEAST MEAN SQUARE (NLMS) ALGORITHM:-

Normalized Least Mean Square Algorithm is an extension of the LMS algorithm being directly proportional to the input vector x(n), which overcomes the limitation of LMS algorithm. The stability problem occurs in LMS due to its weight vectors w(n+1).

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.

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

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

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

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

μ(n) 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*).

III. ANALYSIS OF LMS AND NLMS ALGORITHM:-

LMS(LEAST MEAN SQUARE) ALGORITHM:-

In the analysis of this algorithm, the input signal is S=cos(2*pi*t/T),the snr is 10db,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 0.5λ.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. angle of arrival is shown below:-

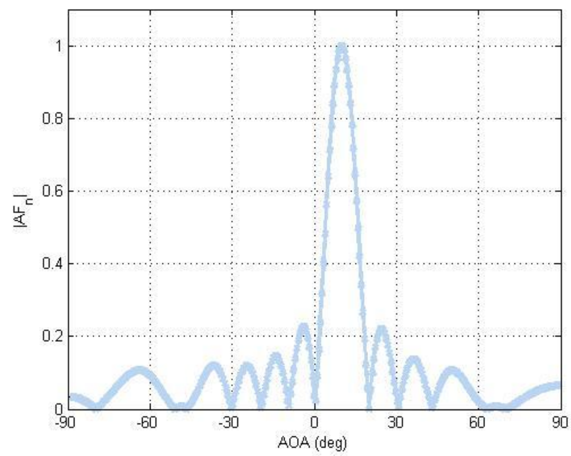


Fig.(2) Array factor when AOA of desired user is 10 degree and interference is 70 degree.

In the above figure, antenna places deep nulls in the direction of interfering signal and maximum in the direction of the desired signal.

The Mean Square Error (MSE) of the algorithm defines the error between the desired and actual signal. Fig. (3) shows Mean Square Error v/s No. of iterations when DOA of desired user is 10 degree and interference is 70 degree.

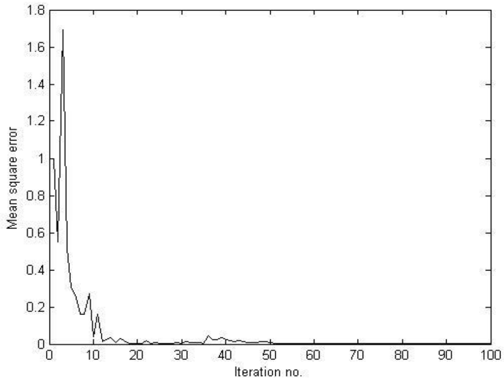


Fig.(3) Mean Square Error v/s No. of iterations when DOA of desired user is 10 degree and interference is 70 degree.

In the above plot, the MSE reduces as the numbers of iterations increases. Convergence time also defines by this plot because it defines the time at which the error converges and comes in real condition.

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

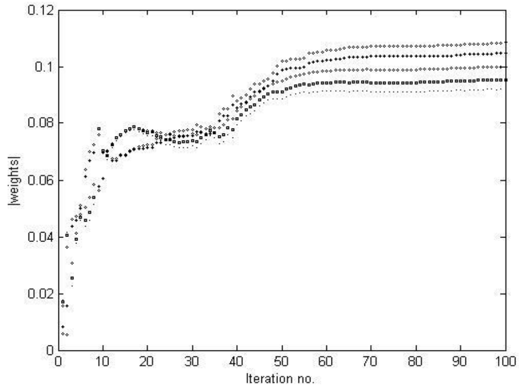


Fig.(4) Weight updation of LMS Algorithm

After updation of weights, the final output converges according to our desired direction. The difference between the desired and antenna output is shown below.

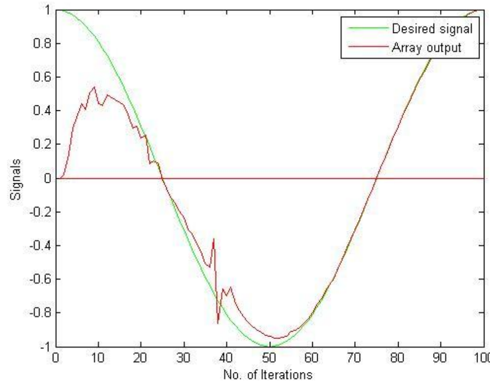


Fig.(5) Difference b/w the desired signal and antenna array o/p

NLMS (Normalized Least Mean Square) Algorithm:-

The NLMS algorithm is same as LMS algorithm but it has fast convergence time and achieves 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 Fig(6) shows the direction of arrival from the desired user:-

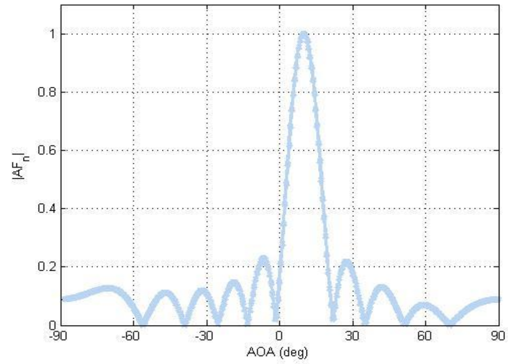


Fig.(6) Array factor when DOA of desired user is 10 degree and interference is 70 degree.

The figure(6) shows the antenna main beam in the desired direction and nulls are fitted in the interference direction. The difference between the desired and antenna output is shown below(in fig(7)). The antenna output is more accurate in NLMS Algorithm as compared to the LMS algorithm.

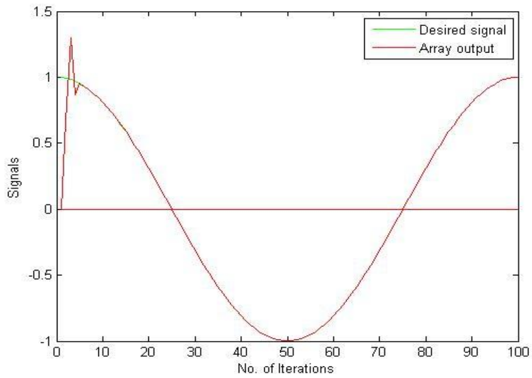


Fig.(7) Difference b/w the desired signal and antenna array o/p

The updation of weights of NLMS Algorithm is faster than LMS algorithm which is shown in fig(8):-

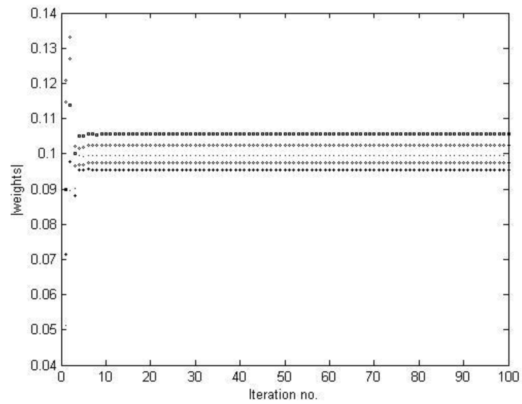


Fig.(8)Weight updation of NLMS Algorithm

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

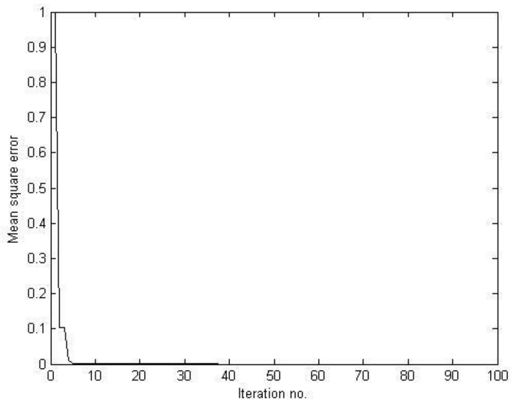


Fig.(9) Mean Square Error v/s No. of iterations when DOA of desired user is 10 degree and interference is 70 degree.

The above figure also shows that the convergence speed of the NLMS is more as compared to LMS.

IV. 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 minimum 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. The NLMS algorithm gives better convergence characteristics than the LMS algorithm, because it can reduce the increase of the noise by dividing the step size parameter by input vector power. So finally, we can say that the NLMS is more useful for mobile communication system.

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