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Performance Comparison of LMS and NLMS Beamforming Algorithms for Smart Antenna System in Mobile Communication

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Abstract: Due to the great increase in the number of users in mobile communication various problems arise such as improper sectorization, frequency reusability, handling complexity etc. So the use of Smart Antennas is indispensible. Smart Antennas includes the concept of adaptive signal processing to efficiently get the desired radiation pattern to accommodate more number of users in the limited frequency spectrum. Least Mean Square (LMS) and Normalised Least Mean Square (NLMS) Algorithms are the adaptive beamforming algorithms used in Smart Antenna systems. This paper compares the performance of these algorithms on the basis of radiation pattern and the number of iterations performed to minimize the mean square error to reach the optimum values of antenna weight vector which are the essential factors for any adaptive beam forming algorithm. The results depict NLMS as a better adaptive beamforming algorithm.

Keywords: Smart Antenna, Adaptive beam forming, LMS algorithm, NLMS algorithm.

I. INTRODUCTION

As the number of users is increasing rapidly in the field of mobile communication, the efficient use of the available spectrum is a requisite. For this Smart Antennas provide a flexible solution. Smart Antenna is a system of antenna array which have the capability to steer the main lobe of the radiation pattern towards the desired signal and simultaneously nullifies the undesired signal to obtain sufficient high quality. So the spatial separation of the signal of interest and interferer is exploited in adaptive beamforming, which adaptively sets the weights of smart antenna array elements to optimal values. Adaptive Beamforming algorithms are mainly classified in two forms viz. Blind Algorithms and Non-Blind Algorithms [1-3].

A. *Blind Algorithms*

As the name suggests, the blind algorithms do not require any temporal reference for the computation of the optimal weight vectors. The Blind algorithm which is commonly used is Constant Modulus Algorithm (CMA)[1-3].

B. *Non Blind Algorithms*

In the Non-Blind Algorithm, temporal reference is used i.e. the training signal. This signal is known to both the transmitter and the receiver during the training period. The beamforming is done at the receiver using this information and computing the optimal weight vector. When the training period is over the beam former uses the weight vector computed previously to process the received signal. Typical Non-Blind Algorithms used are Least Mean Square (LMS) and Normalised Least Mean Square (NLMS) Algorithms. The Fig.2 shows the structure of the Non Blind Algorithm [4] Where, d(n) is the training sequence.

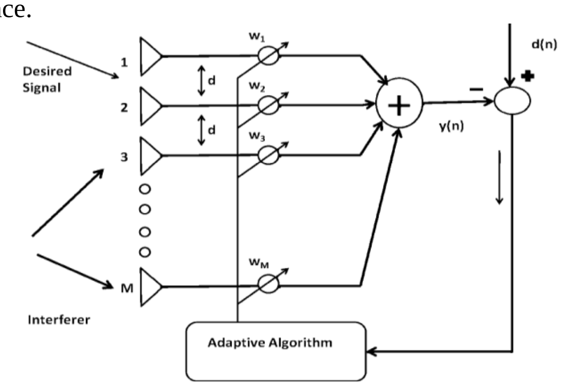

Fig.1 Structure of Non Blind Algorithm

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II. Least Mean Square Algorithm

The LMS algorithm is a widely used adaptive beamforming algorithm in the mobile communication. It is basically a gradient based quadratic approach. Gradient algorithms assume an established quadratic performance surface J(W') which is in the shape of an elliptic parabola having one minimum. Eq(1) shows the formula for the Steepest Descent Method used in LMS algorithm which updates the weight vector as

.

$$\mathbf{w}(k+1)=\mathbf{w}(k)-\tfrac{1}{2}*\mu\,\nabla_w(J(\mathbf{w}(k))) \qquad ...(1)$$

Where, μ is the step-size parameter and ∇_w is the gradient of the performance surface and w(k) is the weight vector.
The Eq(2) shows the computational process as

$$\mathbf{w}(k+1)=\mathbf{w}(k)+\mu e^*(k)\mathbf{x}(k) \qquad ...(2)$$

where e(k) is given in Eq(3) as

$$e(k) = d(k) - \mathbf{w}^{\mathbf{H}}(k)\mathbf{x}(k) \qquad ...(3)$$

LMS algorithm is based on three factors step size parameter, number of weights and Eigen value of correlation matrix of the input data.
On the basis of the Step Size parameter, two cases regarding the convergence of the LMS algorithm arises. The first is the Over-damped case when the step size is too small which results in slow convergence and hence cannot acquire the signal of interest fast enough to track the changing signal. Secondly the Under-damped case in which if the step-size is too large, the LMS algorithm will overshoot the optimum weights of interest. It can be shown that stability is insured provided that the following condition is met.

$$0\leq\mu\leq 1/2\lambda_{max}$$

Where λ_{max} is the largest eigen value of the autocorrelation function of the input signal.

III. Normalised Least Mean Square Algorithm

The setback for the pure LMS algorithm is that it is sensitive to the scaling of its input x(k). This makes it very hard to choose a learning rate μ that guarantees stability of the algorithm. The gradient noise amplification problem that occurs in standard form of LMS algorithm is due to the product vector e*(k)x(k) at iteration n applied to the weight vector w(k) directly proportional to input vector x(k) shown in Eq(2).
Now here comes the application of NLMS algorithm that normalizes the product vector at iteration k+1 with the square Euclidean norm of the input vector x(k) at iteration n. The updated weight vector is given in Eq(4).

$$\mathbf{w}(k+1)=\mathbf{w}(k)+\mu e^*(k)\mathbf{x}(k)/\mathbf{x}^{H}(k)\mathbf{x}(k) \qquad ...(4)$$

where e(k) is same as shown in Eq(3)

The Eq(4) helps in updating weight vectors from diverging so that the algorithm gets more stable and faster converging than when a fixed step size is used. This represents the normalized version of LMS (NLMS) because the step size is divided by the norm of the input signal [4, 7, 8].

IV. Data Model

a) To analyze the LMS algorithm we give the following parameters (inputs):
Number of elements in linear smart antenna array are 8, the spacing d (in terms of wavelength λ) between adjacent elements is 0.5, the Pilot signal direction is 60^o, number of interfering signal is 1, the direction of interference signal is 30^o, the mean of the noise taken is 0, the variance of the noise is 0.1, the number of data samples are 500, the value for μ of LMS algorithm is 0.001 and Array Factor threshold (in dB) is -40.

b) To analyze the NLMS algorithm we give the following parameters (inputs):
Number of elements in linear smart antenna array are 8, the spacing d (in terms of wavelength λ) between adjacent elements is 0.5, the Pilot signal direction is 60^o, number of interfering signal is 1, the direction of interference signal is 30^o, the mean of the noise taken is 0, the variance of the noise is 0.1, the number of data samples are 500, the value for μ of NLMS algorithm is 0.15 and Array Factor threshold (in dB) is -40.

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Here the input signal is Random signal which after taking samples down converted into BPSK signal thus we have a random sequence of 1 & -1 bits of given data samples.

V. SIMULATION RESULT AND COMPARATIVE STUDY

In the fig 1, it shows the graph of time Vs throughput of receiving packet. Throughput is the average rate of successful message delivery over a communication channel.

A. *Radiation Pattern:*

After defining the input parameters which are same for LMS and NLMS algorithms. The two algorithms are compared on the basis of their radiation pattern as shown in Fig.3 where it can be seen that there are improved radiation pattern in the case of NLMS algorithm.

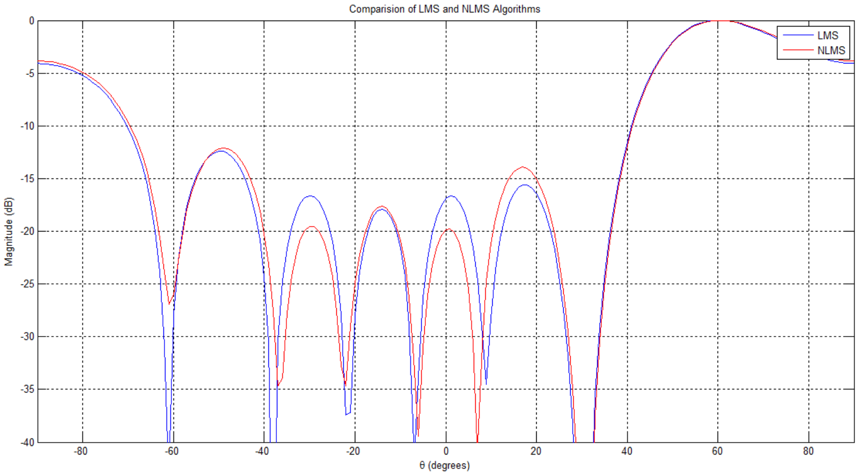

Fig. 2 Comparison of LMS & NLMS in terms of Radiation Pattern

B. Mean Square Error:

With the equally provided parameters for LMS and NLMS algorithms it is observed from the Fig.4 that the number of iterations for minimizing the Mean Square Error is very less in the case of NLMS algorithm as compared to the LMS algorithm.

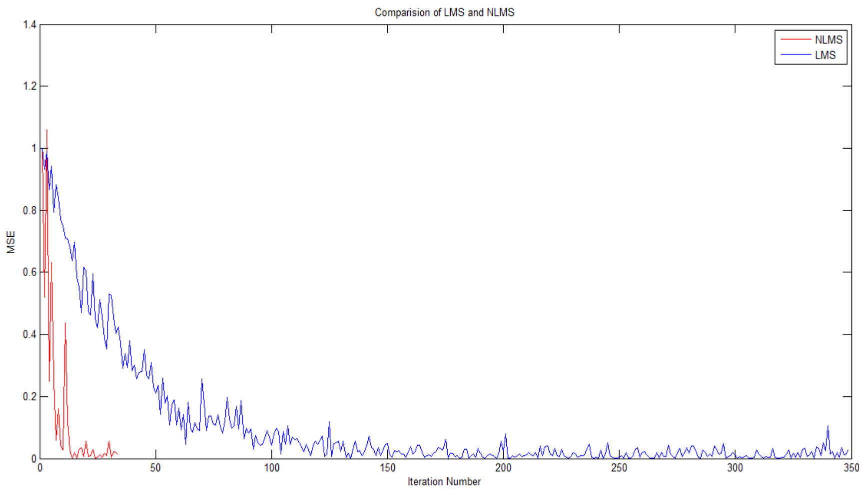

Fig. 3 Comparison of LMS & NLMS in terms of MSE

VI. CONCLUSION

From the results obtained by the two figures it can be concluded that the improved radiation patterns were obtained in the case of the NLMS algorithms whereas the mean square error was computed in lesser number of iterations then in the LMS algorithm case. For both correlated and whitened data NLMS algorithm better performs than LMS in terms of potentially-faster convergence speeds, but not efficient in computational complexity. Hence NLMS is a better Adaptive Beamforming algorithm over LMS.

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BIOGRAPHY

Mr. Koushal Singh Mourya received his B.E. degree in Electronics and Communication Engineering from Rajiv Gandhi Technical University, Bhopal in 2010, the M.Tech degree in Electronics and Communication Engineering from Acropolis Institute of Technology and Research, Indore, (RGPV Bhopal) in 2015. Presently he is working as an Assistant Professor at Malwa Institute of Science and Technology, Indore since. His research interests include Antenna Design, Microwave Engineering, Transmission Lines and Smart Antenna. He is also a co-guide of second Author[2] (Ms. Roshni Thakur).