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Least Mean Square (LMS) for Smart Antenna

D. M. Motiur Rahaman[1], Md. Moswer Hossain[2], Md. Masud Rana[2,*]

[1]Dept. of Electrical, Electronics &Telecommunication Engineering, Dhaka International University, 66 Green Road, Dhaka1205, Bangladesh
[2]Dept. of Electronics & Communication Engineering,Khulna University of Engineering and Technology Bangladesh
Corresponding Author: mamaraece28@yahoo.com

Abstract The demand **for** increased capacity in wireless communication networks has motivated recent research activities toward wireless systems that exploit the concept of smart antenna and space selectivity. Efficient utilization of limited radio frequency spectrum is only possible to use smart/adaptive antenna system. Smart antenna radiates not only narrow beam towards desired users exploiting signal processing capability but also places null towards interferers, thus optimizing the signal quality and enhancing capacity. We analysis the performance of adaptive (LMS) algorithm for smart antenna systems which very important for smart antenna design. The SA incorporates this algorithm in coded form which calculates complex weights according to the signal environment. The performance of LMS algorithm is compared on the basis of normalized array factor and Mean Square Error (MSE) for SA systems. It is observed that an LMS algorithm is converging after 50 iteration.

Keywords Beam Forming, Smart Antenna, Least Mean Squre

1. Introduction

A smart antenna (SA) is an antenna system, which dynamically reacts to its environment to provide better signals and frequency usage for wireless communications [1-3]. SA also known as adaptive array antennas, multiple antennas and recently multiple input multiple output (MIMO) are antenna arrays with smart signal processing algorithms used to identify spatial signal signature such as the direction of arrival (DOA) of the signal and use it to calculate beamforming vectors to track and locate the antenna beam on the target [4-7]. Radio frequency (RF) spectrum is limited and its efficient use is only possible by employing smart/adaptive antenna array system to exploit mobile systems capabilities for data and voice communication [8]. The SA supported by signal processing capability, point's narrow beam towards desired users but at the same time introduces null towards interferers, thus optimizing the service quality and capacity [9-10]. Adaptive beamforming scheme that is least mean square (LMS) and normalized LMS (NLMS) is used to control weights adaptively to optimize signal to noise ratio (SNR) of the desired signal in look direction and minimize the mean square error.

A smart antenna system are capable of efficiently utilizing the radio spectrum and is a promise for an effective solution to the present wireless systems problems while achieving reliable and robust high speed high data rate transmission [3]. The LMS and NLMS are two adaptive beamforming algorithms use the estimate of the gradient vector from the available data. Adaptive beamforming is a technique in which an array of antennas is exploited to achieve maximum reception in a specified direction by estimating the signal arrival from a desired direction (in the presence of noise) while signals of the same frequency from other directions are rejected. This is achieved by varying the weights of each of the sensors (antennas) used in the array. The word adaptive array was first coined by Van Atta in 1959, to describe a self phased array. Adaptive algorithms form the heart of the array processing network [5]. These algorithms make successive corrections to the weight vector in the direction of the negative of the gradient vector which finally concludes to minimum mean square error (MMSE) [11-13].

In this paper, we analysis the performance of adaptive (LMS) algorithm for smart antenna systems which very important for smart antenna design. The SA incorporates this algorithm in coded form which calculates complex weights according to the signal environment. The performance of LMS algorithm is compared on the basis of normalized array factor and mean square error (MSE) for SA systems. It is observed that an LMS algorithm is converging after 50 iteration.

The paper is organized as follows: Adaptive smart antennas are described in section II, goals of a smart antenna system are described in section III, general methodology of beamforming are described in section IV, the adaptive algorithms for smart antenna systems are described in section V. The simulation results are discussed in section VI. And the conclusion is given in section VII.

2. Adaptive Smart Antennas

For an intuitive grasp of how an adaptive antenna system works, close your eyes and converse with someone as they move about the room. You will notice that you can determine their location without seeing them because of the following:

- You hear the speaker's signals through your two ears, your acoustic sensors.
- The voice arrives at each ear at a different time.
- Your brain, a specialized signal processor, does a large number of calculations to correlate information and compute the location of the speaker.

Your brain also adds the strength of the signals from each ear together, so you perceive sound in one chosen direction as being twice as loud as everything else.

Adaptive antenna systems do the same thing, using antennas instead of ears. As a result, 8, 10, or 12 ears can be employed to help fine-tune and turn up signal information. Also, because antennas both listen and talk, an adaptive antenna system can send signals back in the same direction from which they came. This means that the antenna system cannot only hear 8 or 10 or 12 times louder but talk back more loudly and directly as well. Going a step further, if additional speakers joined in, your internal signal processor could also tune out unwanted noise (interference) and alternately focus on one conversation at a time. Thus, advanced adaptive array systems have a similar ability to differentiate between desired and undesired signals[14,15].

Adaptive antenna technology represents the most advanced smart antenna approach to date. Using a variety of new signal-processing algorithms, the adaptive system takes advantage of its ability to effectively locate and track various types of signals to dynamically minimize interference and maximize intended signal reception. Both systems attempt to increase gain according to the location of the user; however, only the adaptive system provides optimal gain while simultaneously identifying, tracking, and minimizing interfering signals.

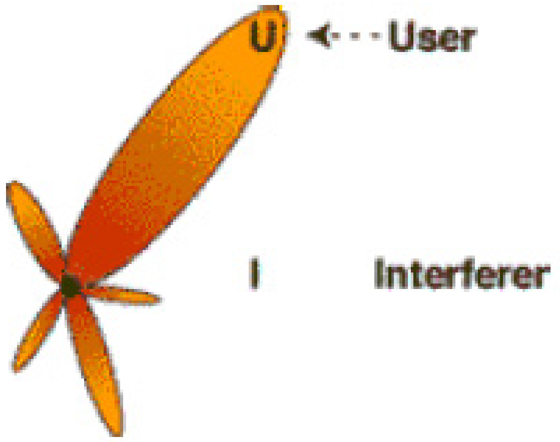

Figure 1. Adaptive Array Coverage: A Representative Depiction of a Main Lobe Extending Toward a User with a Null Directed Toward a Cochannel Interferer

3. Goals of a Smart Antenna System

The dual purpose of a smart antenna system is to augment the signal quality of the radio-based system through more focused transmission of radio signals while enhancing capacity through increased frequency reuse. More specifically, the features of and benefits derived from a smart antenna system include those listed in Table 1[16,17].

4. General Methodology of Beamforming

The general methodology of beamforming is shown in Fig. 1, which consists of an array of M antenna elements or beamformer. A beamformer is a collection of sensors or antennas which are linearly arranged so that their output can be steered electronically. The received signal at these sensors is used to compute the complex weights which are adaptively updated based on signal samples.

Feature	Benefit
Sgnal gain-Inputs from multiple antennas are combined to optimize available power required to establish given level of coverage.	better range/coverage- Focusing the energy sent out into the cell increases base station range and coverage. Lower power requirements also enable a greater battery life and smaller/lighter handset size.
Interference rejection- Antenna pattern can be generated toward cochannel interference sources, improving the signal to-interference ratio of the received signals.	increased capacity- Precise control of signal nulls quality and mitigation of interference combine to frequency reuse reduce distance (or cluster size), improving capacity. Certain adaptive technologies (such as space division multiple access) support the reuse of frequencies within the same cell.
Spatial diversity- Composite information from the array is used to minimize fading and other undesirable effects of multipath propagation.	multipath rejection- can reduce the effective delay spread of the channel, allowing higher bit rates to be supported without the use of an equalizer
Power efficiency- combines the inputs to multiple elements to optimize available processing gain in the downlink (toward the user)	reduced expense- Lower amplifier costs, power consumption, and higher reliability will result

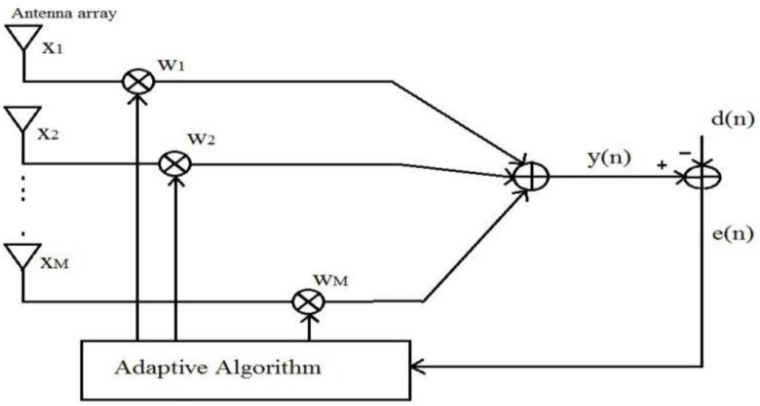

Figure 2. Smart antenna receiver

As shown in fig.2, the output of the array $y(n)$ is the weighted sum of the received signals $X_k(n)$ at the array elements and the array weights $W_k\ (n)$, where k=1,2, …… , M and M is number of antenna elements. The array weights (W_1, $W_{2,}$ ……, W_M) are iteratively computed based on array output $y(n)$, a reference signal $d(n)$ that approximates the desired signal and previous weights. The array output is given by

$$y(n) = W^H\ (n)\ x(n)$$

where, W^H denotes the hermitian transpose of the weight vector W.

The received signal $x(n)$ is given by

$$x\ (n) = a\theta\ d\ (n) + \sum_{K=1}^{M} a(\theta_i)\ i(n) + n_k(n)$$

where, a_θ is the desired steering vector, $d(n)$ is the reference signal, $a(\theta i\ )$is the interference steering vector, $i(n)$ is the interference signal and $nk\ (n)$ is the noise signal. The error $e\ n$ is used to calculate new weights and is given by

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

5. Adaptive Algorithms for Smart Antenna Systems

Wireless communication is one of the most rapidly growing industries. The high demand for wireless communication services had led to an increase in system capacity. Then most elementary solution would be to increase bandwidth; however, this becomes ever more challenging as the electromagnetic spectrum is becoming increasingly congested. The ever-increasing demand for increased capacity in wireless communications services has led to developments of new technologies that exploit space selectivity. This is done through smart-antenna arrays and the associated adaptive beamforming algorithms. SA systems provide opportunities for higher system capacity and improved quality of service among other things [14,18,19]

The SA can atomically combine multiple antenna elements with a signal-processing capability to optimize its radiation and/or reception pattern. The SA is either switched beam or adaptive array systems [15]. In switched beam SA, a finite number of fixed, predefined patterns or combining strategies. On the other hand, in adaptive array SA system has infinite number of patterns that are adjusted in real time. It provides optimal gain while simultaneously identifying, tracking, and minimizing interfering signals as shown in Fig. 3.

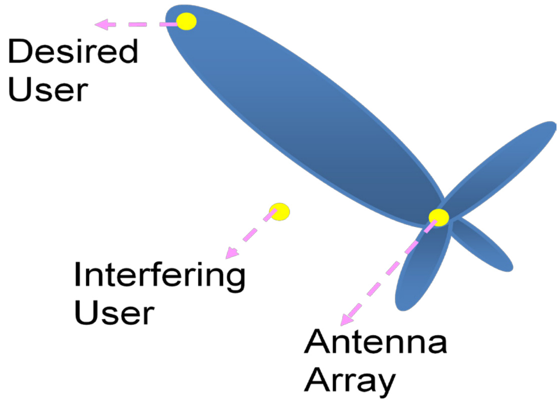

Figure 3. An adaptive array

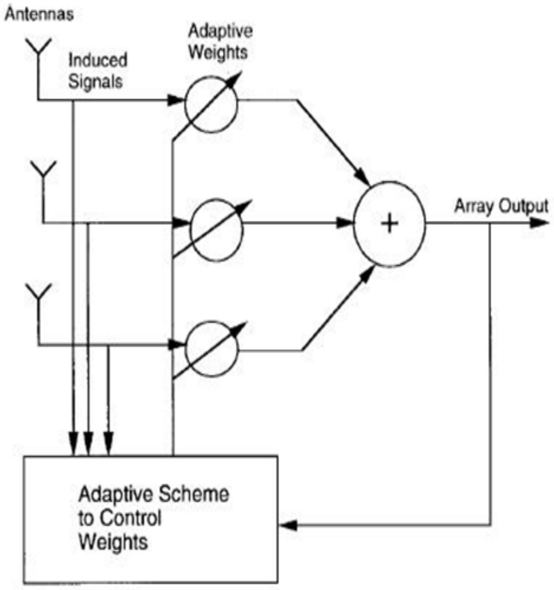

Figure 4. Block diagram of an adaptive array system [3].

An adaptive algorithm is an algorithm that changes its behaviour based on the resources available. The SA can adjust the direction pattern adaptively and reduce the interference signals using some adaptive interference algorithms, and thus enhances the performance of mobile telecommunication systems. It especially enlarges the user system capacity [14-16]. The block diagram of an adaptive array system is shown in fig. 4.

The LMS is an iterative beamforming algorithm that uses the estimate of the gradient vector from the available data. This algorithm makes successive corrections to the weight vector in the direction of the negative of the gradient vector which finally concludes to minimum MSE. This successive correction to the weight vector is the point at which optimum value is obtained that relies on autocorrelation matrix R and cross correlation matrix P of the filter.

The LMS adaptive beamforming algorithm is [13]:

$$y(n)=\omega^T(n-1)u(n), \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

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

$$\omega(n)=\omega(n-1)+\mu e(n)u^*(n), \ldots\ldots\ldots\ldots\ldots(3)$$

where y(n) is the filter output, e(n) is the error signal between filter output and desired signal d(n) at time n, and u(n) is the transmitted signal. In addition, w (n) is the update function for the LMS algorithm, where μ is the rate of adaptation, controlled by the processing gain of the antenna array and denotes the complex conjugate of the input signal u(n).The convergence conditions imposed on step size μ is given by

$$0 \le \mu \le \frac{1}{\lambda max}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where λ_{max} is the largest eigen value of autocorrelation matrix R i.e., R=E[u(n)u^T (n)], where E is expectation. If μ is chosen to be very small, then convergence becomes slow. If μ is kept large, then convergence becomes fast, but stability becomes a problem.

The LMS algorithm is initiated with an arbitrary value of $w\ (0)$ for the weight vector at time n=0. The successive corrections of the weight vector eventually leads to minimum value of the mean squared error. The next section, we describe the simulation results for SA sytems.

6. Simulation Results

The LMS algorithm was simulated using Matlab software. An N=10 element array with spacing d=0.5 has received a signal arriving at an angle θ=0°,an interferer at the angle θ1=-60°.

From Fig. 5 it is observe that the final weighted array which has a peak at the desired direction of 0º and a null at the interfering direction of -60º.

Another simulation is as shown in fig. 6 it is observe that the array output acquires and tracks the desired signal after 50 iterations. If the signal characteristics are rapidly changing, the LMS algorithm may not allow tracking of the desired signal in a satisfactory manner.

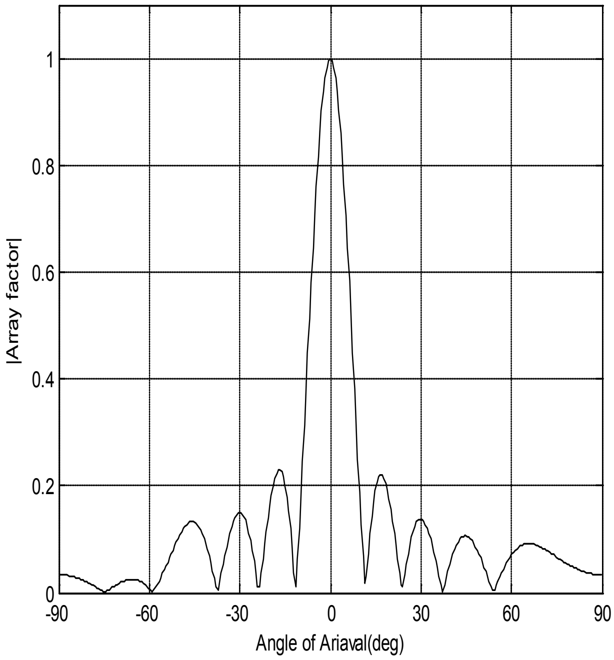

Figure 5. Shows the array factor using LMS algorithm

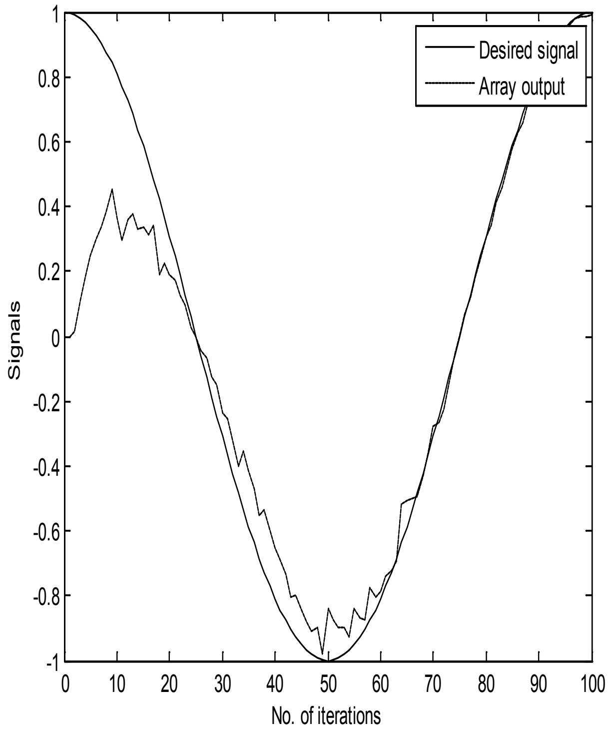

Figure 6. Acquisition and tracking of desired signal using LMS algorithm

Another simulation result is describes the algorithmic changing the weighting in each iteration. From fig.7 it is observed that this algorithm converge after 50 iterations.

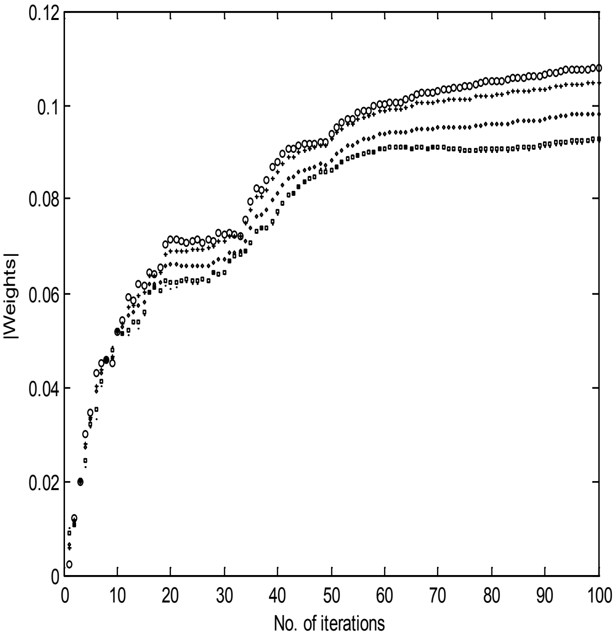

Figure 7. Magnitude of array weights using LMS algorithm

Finally, we simulated the MSE error in each iteration. From fig. 8 it is observed that MSE is decreases each iteration and it is converge after 50 iterations.

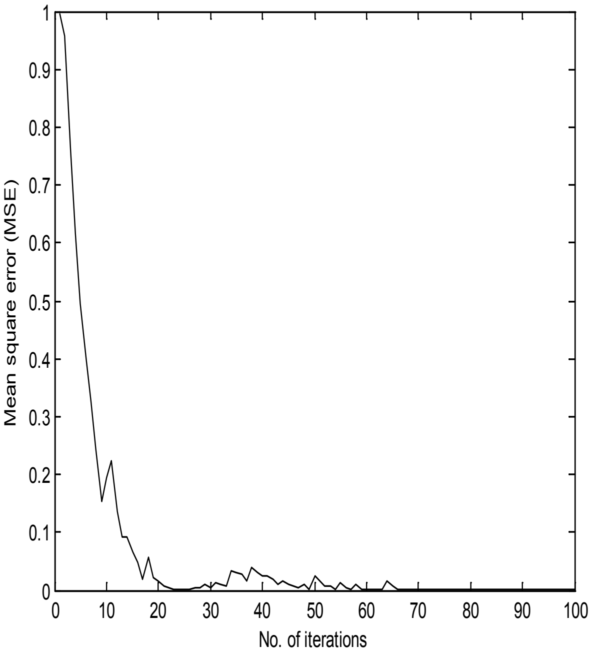

Figure 8. Shows the mean square error using LMS algorithm.

7. Conclusion

This work, we analysis the performance of adaptive LMS algorithm for smart antenna systems which very important for smart antenna design. The performance of LMS algorithm is compared on the basis of normalized array factor and mean square error (MSE) for SA systems. It is observed that an LMS algorithm is converging after 50 iteration. The attractive quality of LMS algorithm is less computational complexity. Our findings are explained in details in the above result and analysis section with graphs. Our next target is to simulated recursive least square (RLS) algorithm for SA systems.

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