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# Performance improvement in beamforming of Smart Antenna by using LMS algorithm

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## ABSTRACT
The smart antenna adaptive algorithms achieve the best weight vector for beam forming by iterative means. Whether the algorithm is good depends on the convergence rate and steady state error. Beam forming is directly determined by the two factors. The performance of the traditional LMS algorithm is analyzed in this paper. Then a new variable step size algorithm is proposed and is applied to beam forming with the software Matlab. The simulation result indicates that the algorithm improved could achieve faster convergence and lower steady state error.

## Keywords
Smart antenna, adaptive algorithm, LMS, beamforming, antenna arrays. .

## 1.INTRODUCTION
A smart antenna is a digital wireless communications antenna system that takes advantage of diversity effect at the source (transmitter), the destination (receiver), or both. Diversity effect involves the transmission and/or reception of multiple RF-waves to increase data speed and reduce the error rate. In conventional wireless communications, a single antenna is used at the source, and another single antenna is used at the destination. Such systems are vulnerable to problems caused by multipath effects.

When an electromagnetic field (EM field) is met with obstructions such as buildings the wavefronts are scattered, and thus they take many paths to reach the destination. The late arrival of scattered portions of the signal causes problems such as fading. In a digital communications system it can cause a reduction in data speed and an increase in the number of errors. Multi-path fading and delay spread lead to inter- symbol interference (ISI) and co-channel interference. The use of smart antennas can reduce or eliminate these problems resulting in wider coverage and greater capacity.

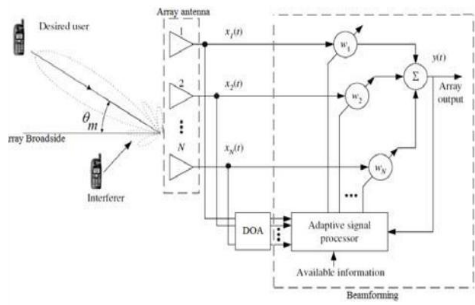


**Fig. 1. A functional block diagram of a smart antenna system.**

A smart antenna system at the base station of a cellular mobile system is depicted in Fig. 1. It consists of a uniform linear antenna array for which the current amplitudes are adjusted by a set of complex weights using an adaptive beamforming algorithm. The adaptive beamforming algorithm optimizes the array output beam pattern such that maximum radiated power is produced in the directions of desired mobile users and deep nulls are generated in the directions of undesired signals representing co-channel interference from mobile users in adjacent cells.

Prior to adaptive beamforming, the directions of users and interferes must be obtained using a direction-of- arrival (DOA) estimation algorithm [3]

Adaptive smart antennas are the array antennas whose radiation pattern is shaped according to some adaptive algorithms. Smart essentially means computer control of the antenna performance. The smart antenna radiation pattern directs the beam towards the users of interest only & nulls toward interference to improve the capacity of cellular system. The adaptive beam forming algorithms takes the fixed beam forming process one step further & allows for the calculation of continuously updated array weights. Fig. (2) shows the adaptive beam forming system.

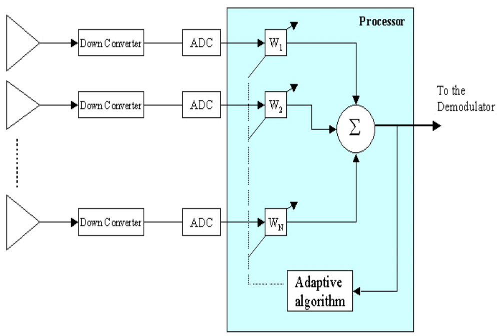


**Fig. 2. Block diagram of an adaptive beamformer.**

According to signal space information smart antenna can form directional beam in space with the adaptive beam forming algorithm, achieving that the main beam aims at the direction of the expected signal while the side lobe and nulls aims at the interference. Now many adaptive algorithms have been proposed on smart antenna. The LMS algorithm can be easily realized with the advantage of simple, less operations and robust for signal statistical characteristic. Then the convergence rate and steady state error of LMS algorithm is analyzed in this paper and in order to achieve faster convergence rate and less state error a new variable step size LMS algorithm is proposed.

## 2. LMS ALGORITHM

By combining the signals incident on the linear antenna array and by knowing their directions of arrival, a set of weights can be adjusted to optimize the radiation pattern. The application of the LMS algorithm to estimate the optimum weights of an antenna array is widespread and its study has been of considerable interest. The emphasis of previous work has been on the convergence behavior of such an algorithm rather than the effect of various parameters used in the design of the beamformer. Some of these parameters are related to the array structure in terms of its size and element spacing. Others are related to the incident signals including their number and angular separation. Moreover, the SNR has an effect on the performance of the LMS beamformer. The LMS algorithm involves the adjustment of a set of weights to minimize the difference between a reference signal and the antenna array output. The reference signal is used by the array to distinguish between the desired and interfering signals at the receiver . A block diagram of an adaptive beamformer is shown in Figure 1. It consists of an antenna array of N elements used for receiving M signals incident at angles $\varphi_1^d,\ldots,\varphi_M^d$, relative to the array axis. There are also m interfering signals incident at angles.

$\varphi_1^i,\ldots,\varphi_m^i$

The total signal that is received by the linear array is expressed, in vector form, as:

$$(t) = (t) + (t) \qquad (1)$$

where the signal vector (t), representing the desired signals, is given by:

$$(t) \quad = \sum_{k=1}^{M} A^d(\varphi_k{}^d) S_k{}^d(t) \qquad (2)$$

where $s^d(t)$ is an M×1 vector of source waveforms representing the reference or desired signals, and $A^d(\varphi)$is an NxM matrix formed by combining the array steering vectors each of which corresponds to one direction of the incident signals. In a similar fashion, the vector (t), which represents the interfering signals can be expressed as:

$$x\,(t) = \sum_{k=1}^{M_i} A^i(\varphi_k{}^i)\, S_k{}^i(t) \qquad (3)$$

The output (t) of the beamformer is then given by:

$$(t) = {}^T(t) + (t) \qquad (4)$$

where is a vector of the weights that need to be adjusted to optimize the radiation pattern. In the LMS algorithm, this is achieved by minimizing the difference between the beamformer output (t) and the reference signal s(t) . This difference is expressed in the form of Minimum Mean Squared Error given by:

$$\varepsilon^2\,(t) = |\,(t) - s^d\,(t)|^2 \qquad (5)$$

Since the mobile environment is time-variable, solution for the weight vectors must be updated continuously. Also, since the data required to estimate the optimal solution is noisy, it is desirable to use a technique which uses previous solutions for the weight vector to smooth the estimate of the optimal response and reduce the effects of noise. In the LMS algorithm, the weights are updated using the equation:

$$(n+1) = (n) + \mu\,(n)\,\varepsilon\,(n) \qquad (6)$$

where (n+l) denotes the weights to be computed at iteration n+l. μ is a positive scalar (gradient step-size) that controls the convergence of the algorithm, i.e., how fast and how close the estimated weights approach the optimasolution that minimizes the error, $\varepsilon^2$ (t).

# 3. A NEW VARIABLE STEP LMS

## 3.1 Principle and Realization of Variable Step LMS

The variable step LMS has been proposed based on the relationship between the performance and step μ. The basic principle of variable step-size LMS is that at the stage of beginning to converge or change of system parameter for the weight of adaptive algorithm is far away from the optimal weight, choose a bigger value for μ to ensure it has faster convergence rate and tracing rate. When the weight of algorithm is near to the optimal one, in order to reduce the steady state error choose a smaller value for μ

During the adaptive process in smart antenna, the error between the output of antenna array and expected signal will be affected by the noise and interference. When there is serious noise and interference if μ is adjusted by only making use of the error signal LMS performance will be greatly affected. The result is that the instantaneous weight can not be near to the optimal one, instead, it can only wave around the optimal weight [5]. So in this paper we update the weight through the self correlation estimate of the current error and the previous to eliminate influence of irrelevance noise [6]. At the same time the unitary LMS is introduced to minish sensitivity of the algorithm depending on the received signal. In this paper a new variable step μ is proposed as follows:

$$\mu(n) = \frac{\alpha\,(1-e^{-\beta\,|\,e(n)\,e(n-1)\,|})}{x^H(n)\,x(n)}$$

|e(n)e(n-1) |introduced to adjust the weight at the stage of beginning to converge with big error, so the step (μ)*n* is big too. But for the noise is not relative and it has little impact on (μ)*n*, the steady

state error caused by noise for the adaptive algorithm will be effectively reduced and the algorithm will has good performance with faster convergence rate and less error. The unitary method introduced monishes sensitivity of the algorithm depending on the received signal

## 3.2. Algorithm Simulation

Condition of simulation: the experiment is based on uniform linear array and the number of elements is M=16. We assume that there are three signal from far space, their incidence angle is -45,0,30. The signal coming from 0 is the expected signal, the others are interference. The SNR is 30 dB and the noise is gauss white noise. The equal value of noise is 0 and the square error is 1. The step μof traditional LMS is 0.000005, and the parameters of new algorithm are α=0.225, β=0.25. The simulation results are shown in thecfigure 3 and 4. The figure 3 shows the relationship between SNR and snap shots and the figure 4 shows the beam pattern with the different algorithm. In the figure 3 we can see that when the snap shot is about 30 the new algorithm has obtained the optimal weight. In addition from the beam pattern in the figure 4 we can draw the conclusion that they all can implement the function that the main beam aims at the expected signal and the nulls aim at the interference. In addition in the direction of interference the new algorithm can form much deeper nulls comparing with the traditional one and has better performance of restraining the interference. The results indicate that the convergence rate of the new algorithm is faster than the traditional LMS.

When the simulation conditions change compare two algorithm performances. Now the parameter is SNR=INR=20dB, while others are invariable. The results shown in the figure 5 and 6 indicate that when the SNR and INR decrease to 20dB the error become bigger than the previous simulation but the new algorithm still has faster convergence rate than the traditional LMS

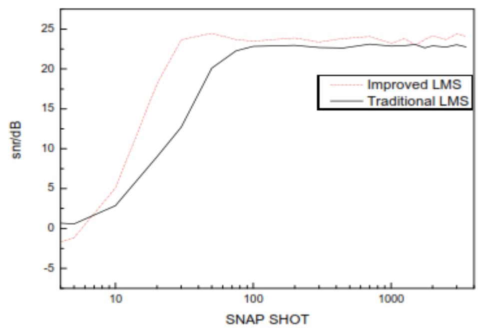


**Fig.3 SNR=INR=30db curve for SNR**

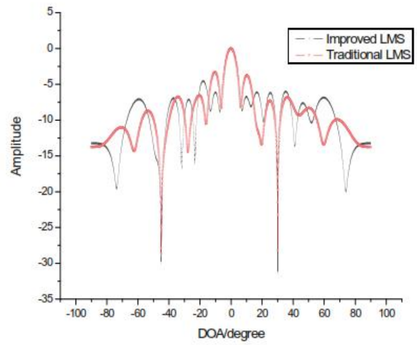


**Fig.4 SNR=INR=30db Beam Pattern**

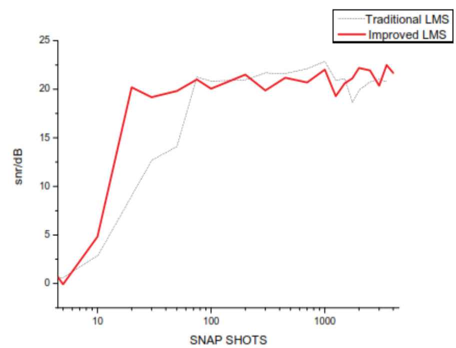

**Fig.5 SNR=INR=20db curve for SNR**

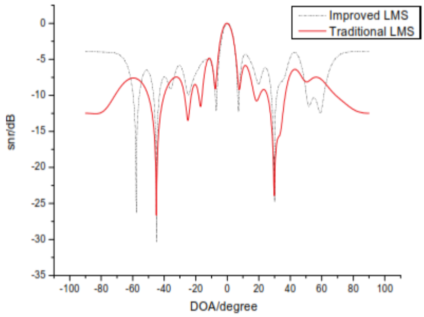


**Fig.6 SNR=INR=20db Beam Pattern**

# 4 .CONCLUSION

In this paper the factors which affect the performance of the traditional LMS algorithm are analyzed. Then on the basis of the variable step a new variable formula is proposed to improve the LMS algorithm for acquiring faster convergence rate and lower steady state error. The simulation results with the Matlab show that the new algorithm has faster convergence rate and can form deeper nulls in the direction of interference.

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