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PERFORMANCE ANALYSIS OF MODIFIED LEAST MEAN SQUARES (LMS) ALGORITHM FOR ADAPTIVE BEAMFORMING IN SMART ANTENNAS FOR 5G NETWORKS

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ABSTRACT: Adaptive beam forming is a crucial technique for enhancing the performance of 5G networks by mitigating interference and improving signal quality. This paper investigates the performance of a modified Least Mean Squares (LMS) algorithm with a variable step size for adaptive beam forming in smart antennas. The proposed algorithm dynamically adjusts the step size based on the instantaneous error, leading to improved convergence and reduced steady-state error compared to the standard LMS algorithm. The performance of the modified LMS algorithm is evaluated through simulations, considering various scenarios with different signal-to-noise ratios (SNRs) and angles of arrival. Simulation is done by using MATLAB software with uniform linear array as array geometry. The results demonstrate the effectiveness of the proposed algorithm in achieving faster convergence, better beam pattern formation, and lower mean squared error (MSE).
Keywords: *5G, Smart Antennas, Adaptive Beam forming, LMS Algorithm, SNR, Array Pattern, Convergence Analysis.*

1. INTRODUCTION

The rapid growth of wireless communication demands efficient utilization of available spectrum and improved signal quality. Smart antennas, enabled by adaptive beamforming techniques, offer a promising solution to address these challenges. Adaptive beamforming dynamically adjusts the antenna weights to steer the main lobe towards the desired signal and nullify interference. Among various adaptive algorithms, the Least Mean Squares (LMS) algorithm is widely used due to its simplicity and low computational complexity. However, the standard LMS algorithm suffers from slow convergence and sensitivity to the step size.

In 5G networks, the need for high data rates and low latency necessitates robust and efficient adaptive beamforming techniques. This paper focuses on enhancing the performance of the LMS algorithm by introducing a variable step size approach. The proposed modified LMS algorithm adjusts the step size based on the instantaneous error, enabling faster convergence and improved steady-state performance.

2. RELATED WORK

Adaptive beamforming has been extensively studied in the literature. Various algorithms, including Recursive Least Squares (RLS), Constant Modulus Algorithm (CMA), and LMS, have been investigated. RLS offers faster convergence but has higher computational complexity compared to LMS. Several modifications to the LMS algorithm have been proposed to improve its performance. These modifications include variable step size approaches, normalized LMS (NLMS), and sign-LMS.

Variable step size LMS algorithms aim to balance the trade-off between convergence speed and steady-state error. By dynamically adjusting the step size, these algorithms can achieve faster convergence during the initial stages and lower steady-state error in the later stages. Several methods for determining the step size have been proposed, including gradient-based methods and error-based methods. This paper focuses on an error-based variable step size approach.

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Zhou Yuanjian and Yang Xiaohui, proposed a new adaptive beamforming algorithm by improving on a projection of a gradient vector to a Uniform Linear Array (ULA). Its performance is compared to the conventional Least Mean Square (LMS) algorithm. The signal processing in smart antenna system mainly focuses on the Direction of Arrival (DOA) estimation and the development of the adaptive beamforming algorithm. Also, in A. Senapati and K. Ghatak performance of the LMS adaptive beamforming schemes for smart antennas, depend on the value of step size parameter used in the algorithm.

In the work by Mallaparapu et al, the advantage of the LMS algorithm is its low computational complexity. In addition, beamforming for smart antenna can be used to increase the channel bandwidth and capacity and at the same time minimize the channel interference in wireless communication.

3. MODIFIED LMS ALGORITHM

The standard LMS algorithm updates the weight vector as follows:

$$w(k+1) = w(k) + \mu e(k)x(k) \quad (1)$$

where $w(k)$ is the weight vector, μ is the step size, $e(k)$ is the error, and $x(k)$ is the received signal vector.

The proposed modified LMS algorithm introduces a variable step size, $\mu(k)$, which is adjusted based on the instantaneous error as shown below

$$\mu(k) = \frac{\mu_{max}}{1+|e(k)|^2} \quad (2)$$

where μ_{max} is a predefined maximum step size. This approach reduces the step size when the error is large, preventing instability, and increases the step size when the error is small, accelerating convergence.

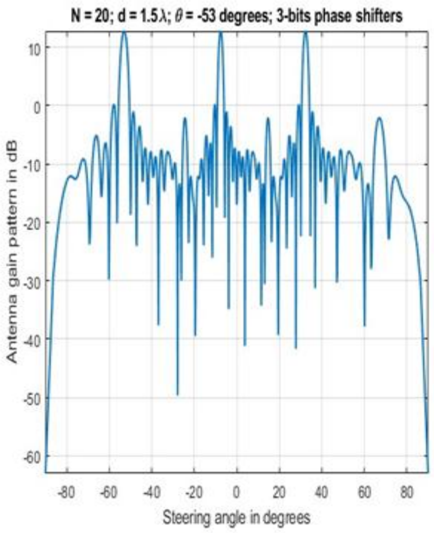
The updated weight vector for the modified LMS algorithm is:

$$w(k+1) = w(k) + \mu(k)e(k)x(k) \quad (3)$$

In the LMS algorithm, the computation of the weight vector is based on Minimum Squared Error (MSE). The minimum mean squared error (MMSE) algorithm minimizes the error with respect to a reference signal.

4. SIMULATION RESULTS AND DISCUSSION

The performance of the modified LMS algorithm is evaluated through simulations using MATLAB. A uniform linear array (ULA) with N antenna elements is considered. The desired signal and interference signals are modeled as complex Gaussian signals. Additive white Gaussian noise (AWGN) is added to the received signal. Figure 1(a) shows polar array factor plot for different angles of arrival. Figure 1(a) to (i) shows rectangular array factor plot for different angles of arrival. The uniform linear array for N=20 elements is used



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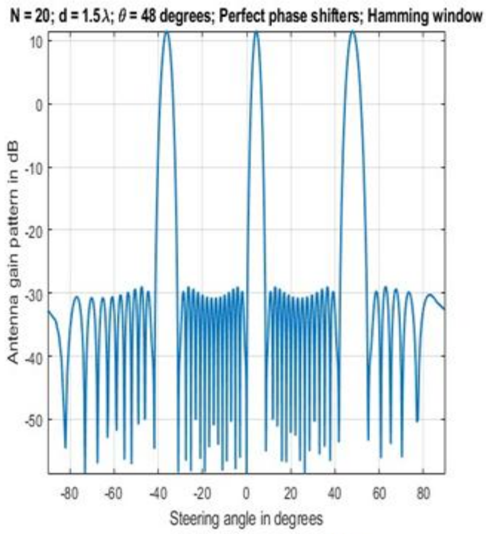

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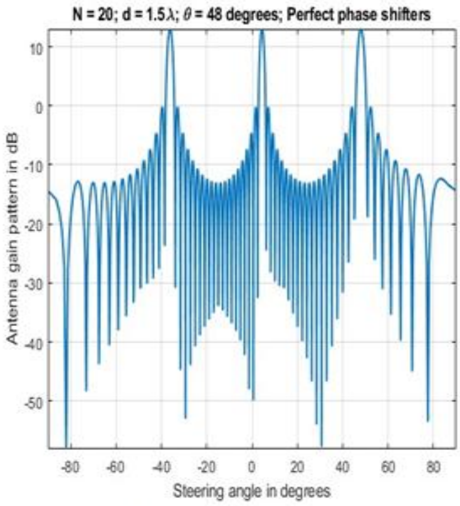

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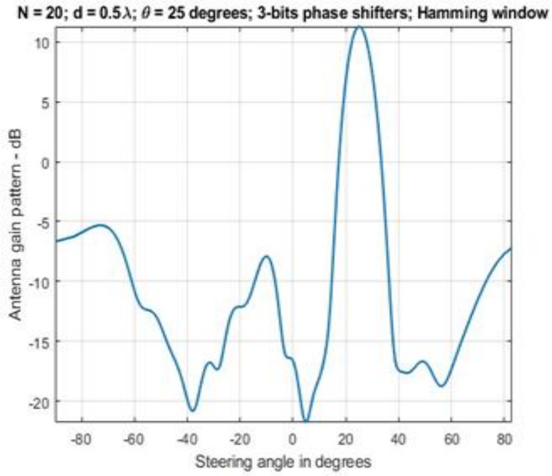

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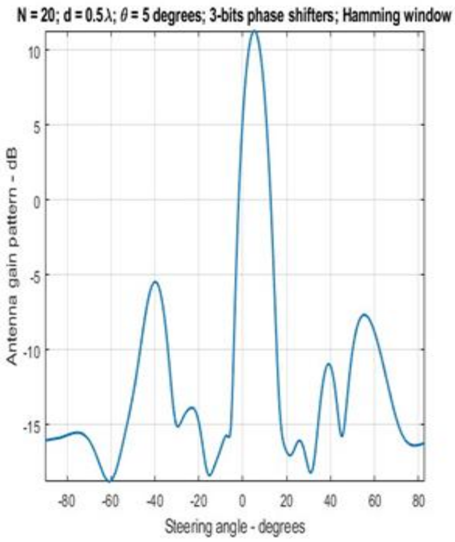

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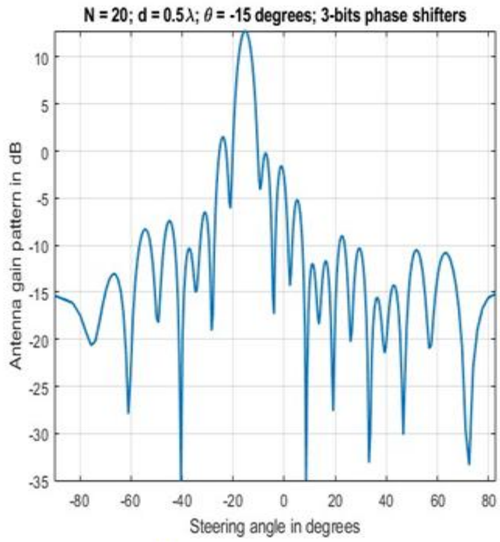

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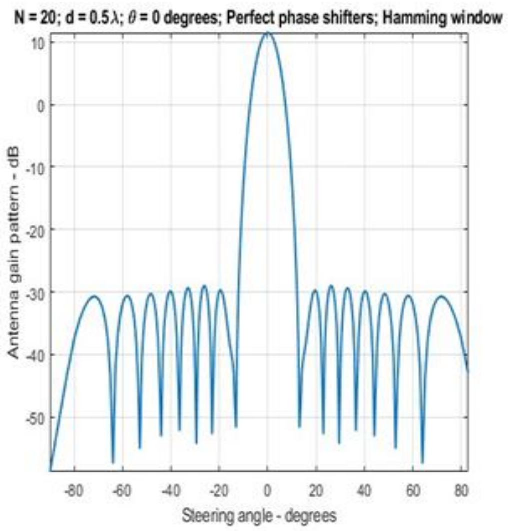

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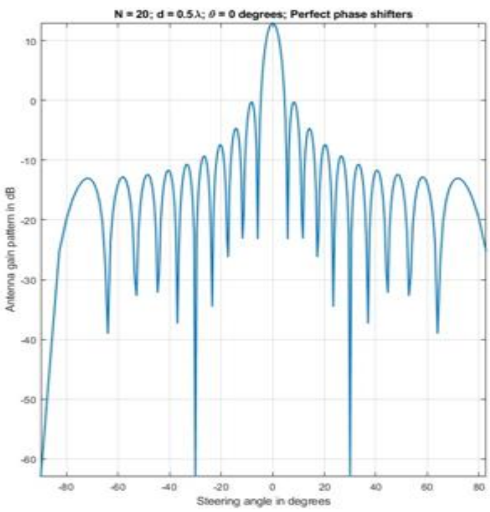

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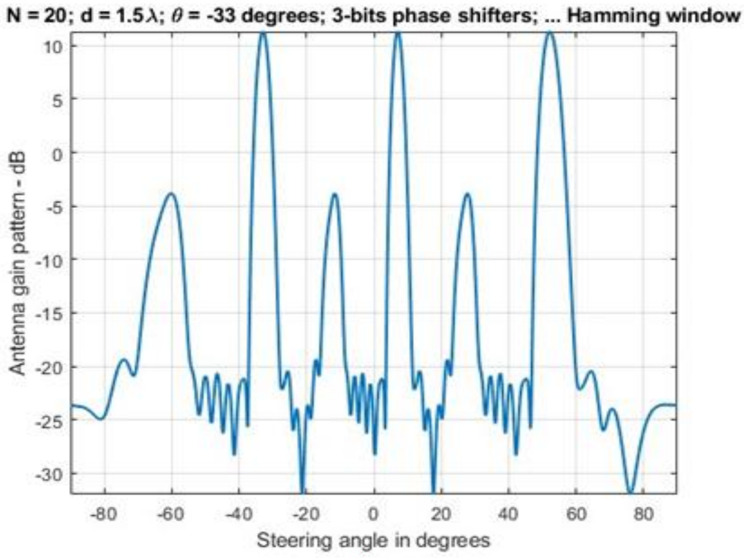

(i)

Figure 1. Array pattern for different angles of arrival

The effect of different SNR for the desired signal and the interference signal on the performance of the modified LMS adaptive beamforming algorithm are given in figures 2 to 4. These figures are plotted using the same array parameters such as spacing between arrays (0.5λ), and number of array elements (N=20).The desired signal is arriving at an angle of 30°, and the interference signal at an angle 60°.The performance metrics used are Mean Squared Error (MSE) and Beam pattern.

Fig.2 shows the Mean Squared Error (MSE) and beam pattern for LMS and modified LMS algorithms for the simulation parameters:

- Number of antenna elements (N): 20
- Number of iterations(M): 1000
- Maximum step size (μ_{max}): 0.05
- SNR: 20 dB,
- Desired angle of arrival: 30 degrees
- Interference angle of arrival: 60 degrees

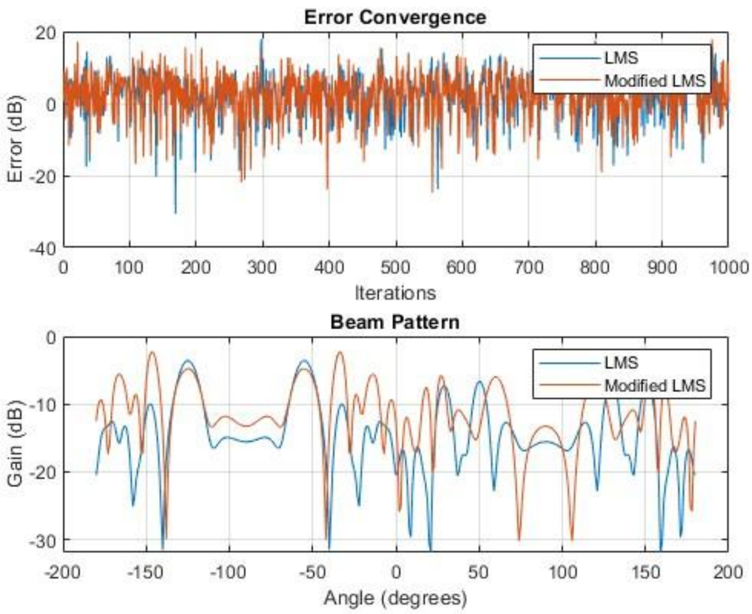

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Fig.3 Iteration number versus Mean Square Error and beam pattern vs angle when desired signal is at 20dB and interferer signal is at 10dB

Fig.3 shows the Mean Squared Error (MSE) and beam pattern for LMS and modified LMS algorithms for the simulation parameters:

- Number of antenna elements (N): 20
- Number of iterations(M): 1000
- Maximum step size (μmax): 0.05
- SNR: 30 dB,
- Desired angle of arrival: 30 degrees
- Interference angle of arrival: 60 degrees

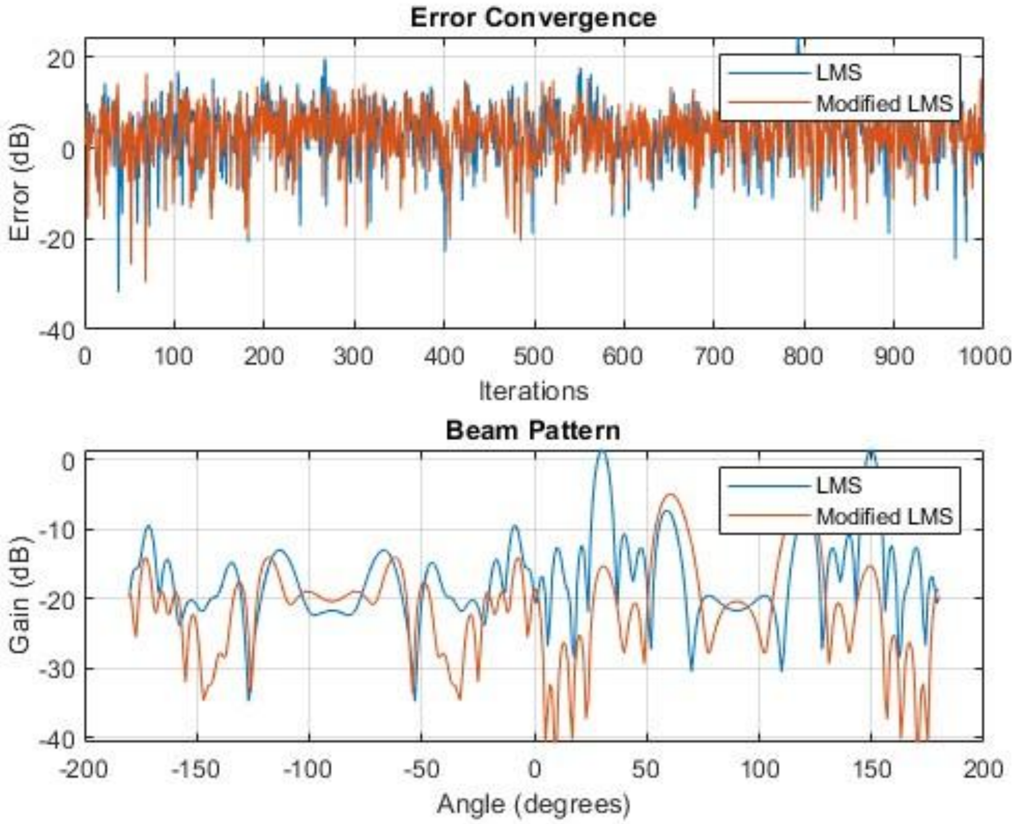

Fig.3 Iteration number versus Mean Square Error and beam pattern vs angle when desired signal is at 30dB and interferer signal is at 10dB

Fig.4 shows theMean Squared Error (MSE) and beam pattern for LMS and modified LMS algorithms for the simulation parameters for the simulation parameters:

- Number of antenna elements (N): 20
- Number of iterations(M): 1000
- Maximum step size (μmax): 0.05
- SNR: 40 dB,
- Desired angle of arrival: 30 degrees
- Interference angle of arrival: 60 degrees

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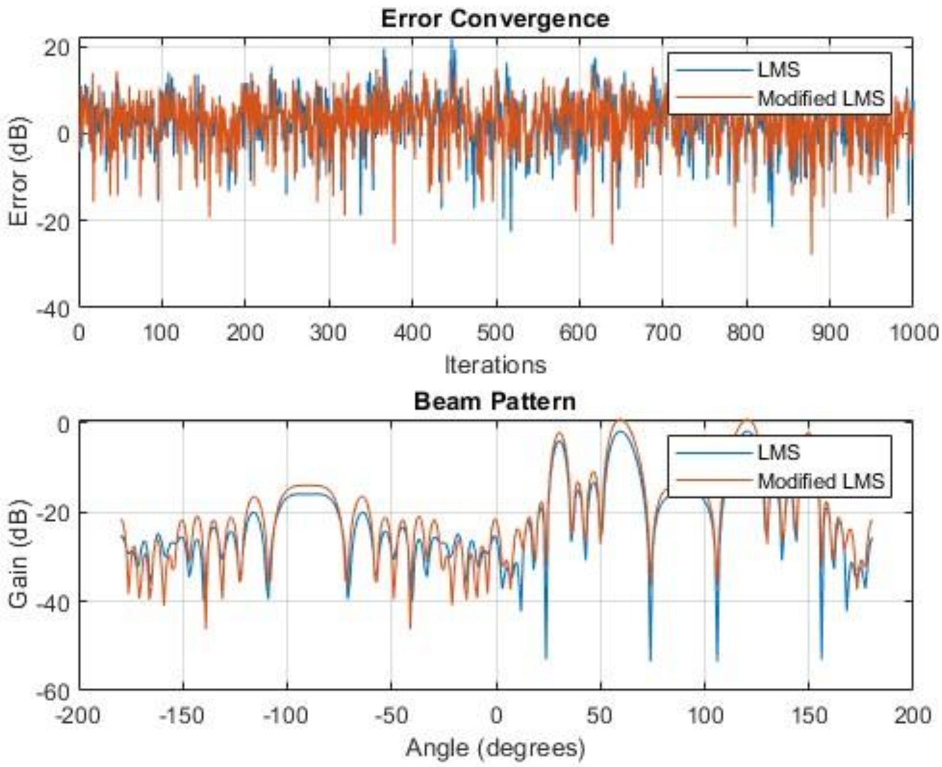

Fig.3 Iteration number versus Mean Square Error and beam pattern vs angle when desired signal is at 40dB and interferer signal is at 10dB

The simulation results demonstrate the effectiveness of the modified LMS algorithm. The MSE curves for the standard LMS and modified LMS algorithms are compared for different SNRs. The results show that the modified LMS algorithm achieves faster convergence and lower steady-state MSE compared to the standard LMS algorithm. The variable step size approach allows the algorithm to adapt to the changing error conditions, resulting in improved performance.

The beam patterns for the standard LMS and modified LMS algorithms are compared. The modified LMS algorithm exhibits better beam pattern formation, with a sharper main lobe towards the desired signal and deeper nulls towards the interference signal. This indicates that the modified algorithm effectively suppresses interference and improves signal quality.

The performance of the modified LMS algorithm is evaluated for different SNRs. The results show that the algorithm performs well across a range of SNRs, demonstrating its robustness. As the SNR increases, the MSE decreases, and the beam pattern becomes sharper. The results are presented in Table 1.

Table 1: Values of MSE for the standard LMS and modified LMS algorithms

SNR (dB)	LMS MSE	Modified LMS MSE
20	0.002186	0.001188
30	0.002815	0.000981
40	0.003514	0.000883

6. CONCLUSION

This paper presented a modified LMS algorithm with a variable step size for adaptive beamforming in smart antennas for 5G networks. The proposed algorithm dynamically adjusts the step size based on the instantaneous error, leading to improved convergence and reduced steady-state error compared to the standard LMS algorithm. Simulation results demonstrate the effectiveness of the modified LMS algorithm in achieving faster convergence, better beam pattern formation, and lower MSE. Future work will focus on exploring more sophisticated variable step size approaches and evaluating the performance of the algorithm in more complex channel conditions.

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