

# Beamforming Algorithms using Smart Antenna

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**Abstract** — Array antennas which are smart enough to distinguish between the desired and interference signal are nothing but Smart Antennas. They work on Space Division Multiple Access and are used in mobile communication to increase the capacity of communication channels. DOA and Beamforming together make a Smart Antenna. We shall restrict our discussion to Beamforming.

This paper explains the Sample Matrix Inverse (SMI) method to direct the main beam towards the desired user. However the weight expression of the SMI algorithm involves inversion of the array correlation matrix and to overcome this, a new approach for adaptive beamforming called Least Mean Square (LMS) is introduced. With the help of simulation results, it can be proved that the LMS approach converges faster than SMI with improved noise and interference suppression. The Simulation tool used is Matrix Laboratory.

**Keywords** — Beamforming, Least Mean Square, Sample Matrix Inverse and Smart Antenna.

## I. INTRODUCTION

A smart antenna is a directional antenna which works to achieve high efficiency network by exploiting the spatial domain of the mobile radio channel.

A smart antenna which is held in the base station of a mobile system comprises of a uniform linear array antenna where the amplitudes are accustomed by a group of complex weights using an adaptive beamforming algorithm. The adaptive beamforming algorithm improves the output of the array beam pattern in a way which it maximizes the radiated power where it will be produced in the directions of the desired mobile users. Moreover, deep nulls are produced in the directions of undesired signals which symbolize co-channel interference from mobile users in the adjacent cells [4,5]. Before adaptive beamforming, direction of arrival estimation is used to specify the main directions of users and interferers. The function of adaptive beamforming algorithms is used to direct main beam towards look direction and nulls towards jammer directions.

## II. LITERATURE SURVEY

Kerim Guney *et al*[1] in the paper '*Interference Rejection of Adaptive Array Antennas by Using LMS and SMI Algorithms*'

explains that interference rejection of adaptive array antennas is achieved by optimally determining the array weights.

In the paper titled [2] '*Adaptive Beamforming for Efficient Interference Suppression Using Minimum Variance Distortion less Response*', the author presents a comparative study of minimum variation distortion less algorithm and LMS algorithm. Results show that LMS is a better performer.

The paper '*Smart Antenna its Algorithms and Implementation*', [3] explains implementation of LMS and SMI algorithms for the interference rejection of the adaptive antenna array with three-elements.

## III. SMART ANTENNA AND PROPOSED ALGORITHMS

Smart antennas involve processing of signals induced on an array of sensors such as antennas, microphones, and hydrophones. The type of multiple accesses they work on is Space Division Multiple Access. They have applications in the areas of radar, sonar, medical imaging and mobile communication.

Smart antennas have the property of spatial filtering, which makes them possible to receive energy from a particular direction while simultaneously block energy from other direction. This property is extensively exploited in spatial domain of mobile radio channel.

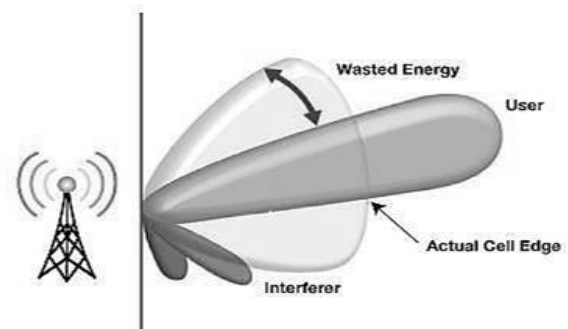


Fig.1. Designing the beam in the required direction and simultaneously nulling interference.

In this paper we present the performance of two algorithms i.e., SMI and LMS with the help of simulation to demonstrate

the adaptive ability of these algorithms to direct a main beam towards the desired user and nulls towards interferers.

A. Sample Matrix Inversion Algorithm

A Sample Matrix Inverse (also known as direct matrix inverse) is a sample based algorithm which requires computation of array correlation matrix and its inverse.

The array weights in SMI is computed using the array weight equation

$$W_{SMI} = R^{-1}r \tag{1}$$

$R^{-1}$  → Inverse of Array Correlation Matrix

$r = uS^H$ , Cross Correlation Matrix

$S^H$  → Hermitian transpose of signal Correlation Matrix

$u$  → Received signal

The disadvantage with this algorithm is that it requires computation of matrix inversion of correlation matrix which cannot be done for large antenna elements. Hence to overcome this, we introduce LMS algorithm.

B. Least Mean Square Algorithm

It is one of the most widely used adaptive beamforming algorithm being employed in several communication applications.

In LMS approach, the weights of the antenna array can be changed according to a step size  $\mu$  and the weight vector  $w(n)$  changes along the direction of the estimated gradient based on the steepest descent method. In this method the assumption is that there's enough information of the reference signal. The adaptive weights can be calculated from the equation:

$$w(n+1) = w(n) + \mu e(n) x^*(n) \tag{2}$$

$e(n)$  = error signal

$x^*(n)$  = received signal

$\mu$  = step size

The LMS algorithm has low computational complexity and performs very well in noise suppression and interference reduction. Figure.2 shows the block diagram of LMS algorithm. The trade-off for the designer would be on convergent rate since LMS is quite a slow convergent.

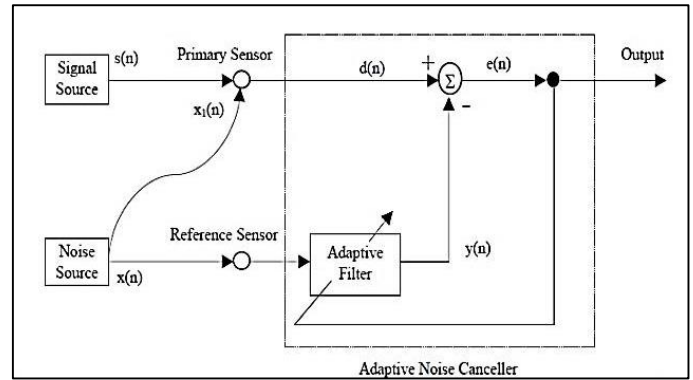


Fig.2. LMS with Adaptive Filter Block Diagram

IV. SIMULATION RESULTS

A. Sample Matrix Inversion Algorithm.

First let us consider the scenario of fewer antenna elements (say 8), we can clearly see that the algorithm successfully distinguishes user and the jammers.

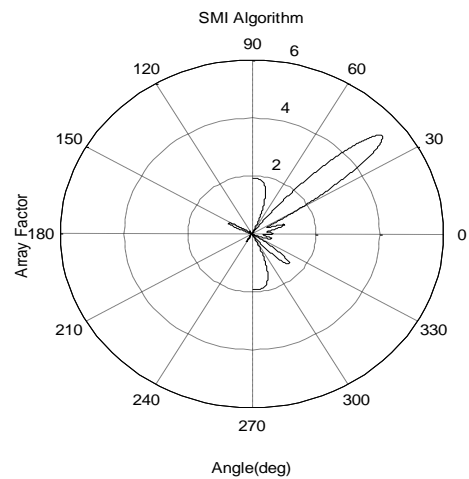


Fig.3. Radiation pattern having main beam at 45°

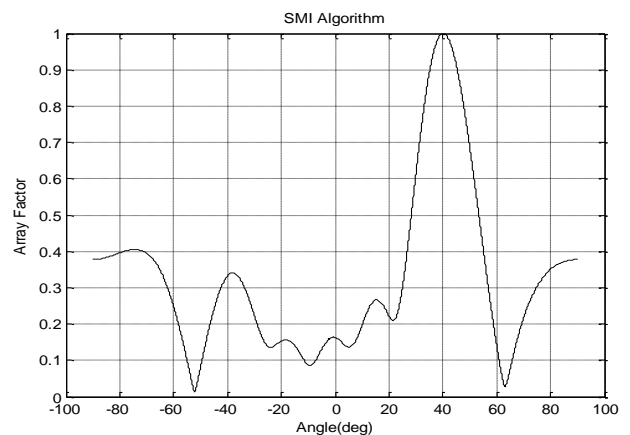


Fig.4. Plot of array factor v/s angle showing main beam at 45°

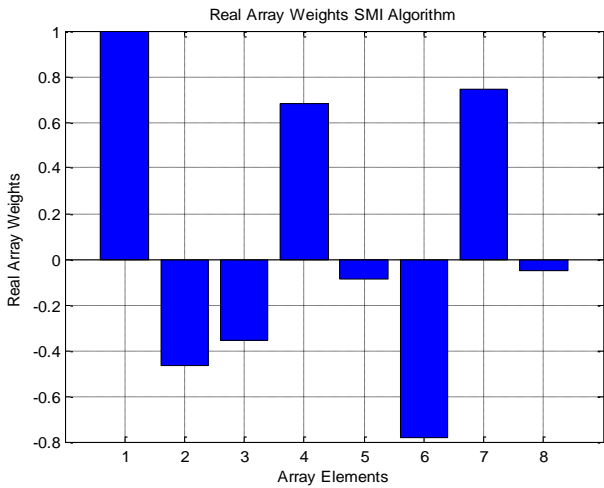


Fig.5. Real array weights of SMI Algorithm

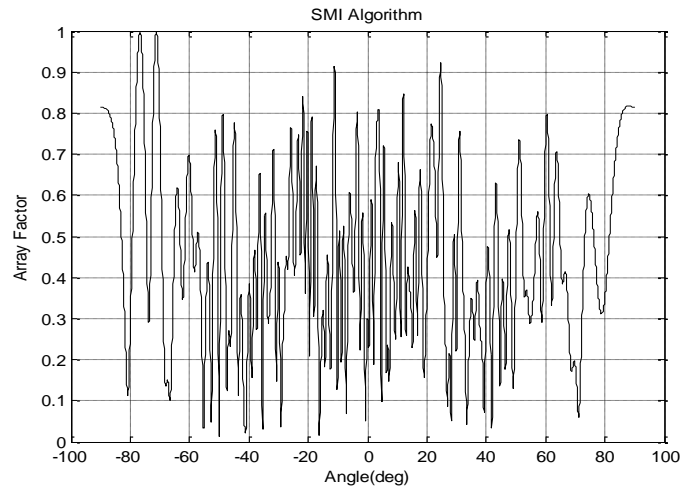


Fig.8. Plot of array factor v/s angle.

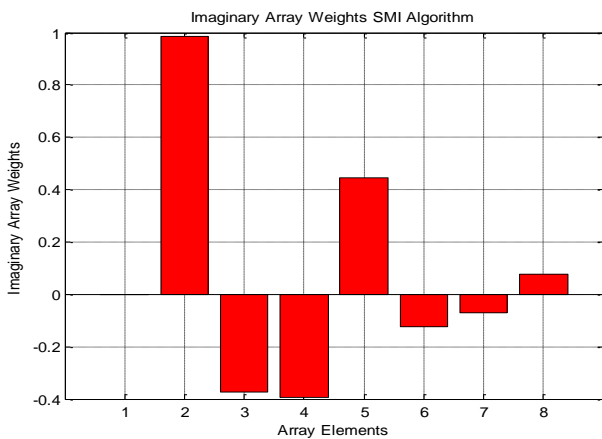


Fig.6. Imaginary array weights of SMI Algorithm

We had to get main beam at  $45^{\circ}$  but due to antenna elements being more, the algorithm fails to distinguish user and jammers direction causing high interference and signal distortion. Figure 9 and 10 show the real and imaginary array weights for the same.

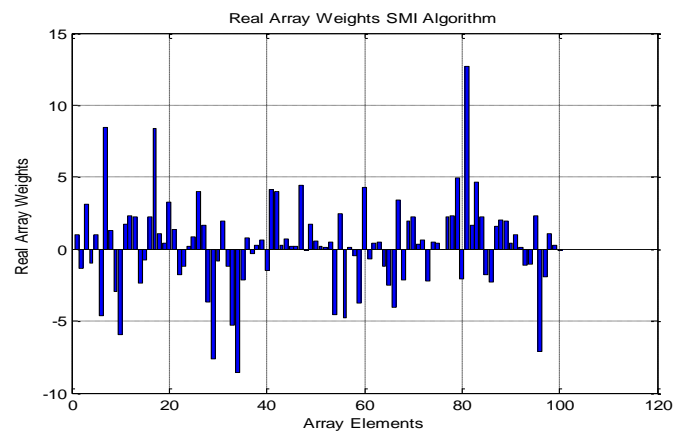


Fig.9. Real array weights of SMI Algorithm

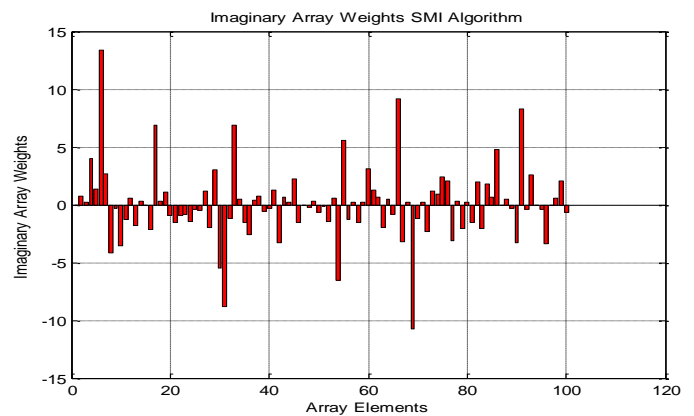


Fig.10. Imaginary array weights of SMI Algorithm

Secondly let's consider the scenario with more antenna elements (say 100). Here we see that as the number of antennas increase, it becomes difficult for the algorithm to distinguish between user and jammers. Hence it fails to provide the user with the main beam.

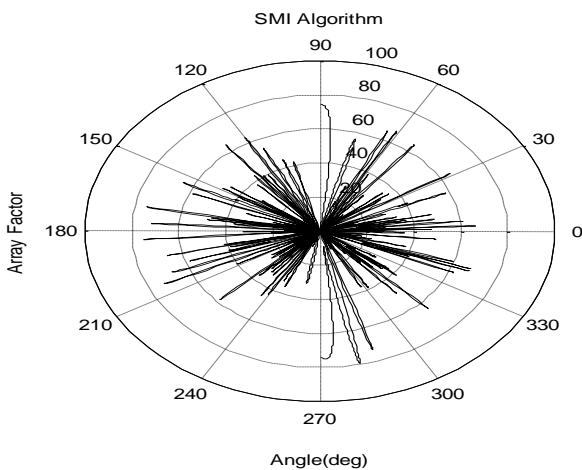


Fig.7. Radiation pattern with no proper distinction

**B. Least Mean Square Algorithm**

In case of LMS algorithm, we shall consider the scenario of the user at  $45^{\circ}$  and having jammers at different directions (say 10, 30 and 90). The results below prove that the desired user is provided with main beam at the desired angle and nulls are given to the interferers or jammers. LMS produces a sharp main beam at the desired angle and minimizes interference to a great extent as shown in figures 11 and 12.

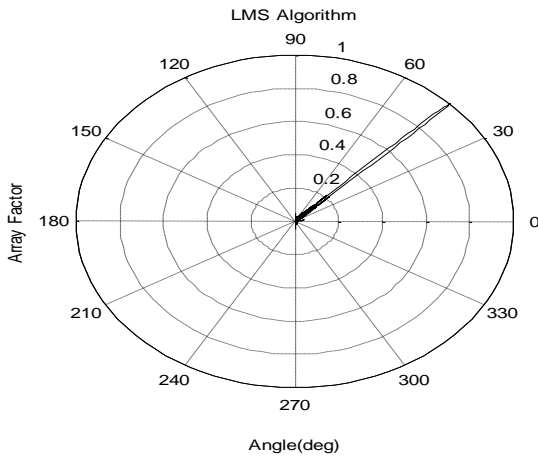


Fig.11. Radiation pattern having main beam at  $45^{\circ}$

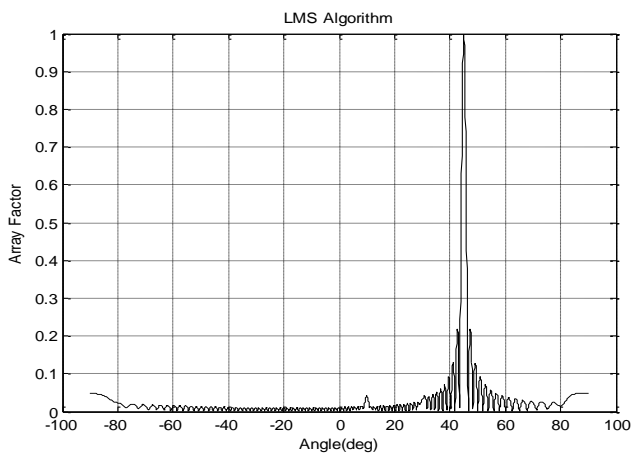


Fig.12. Plot of array factor v/s angle.

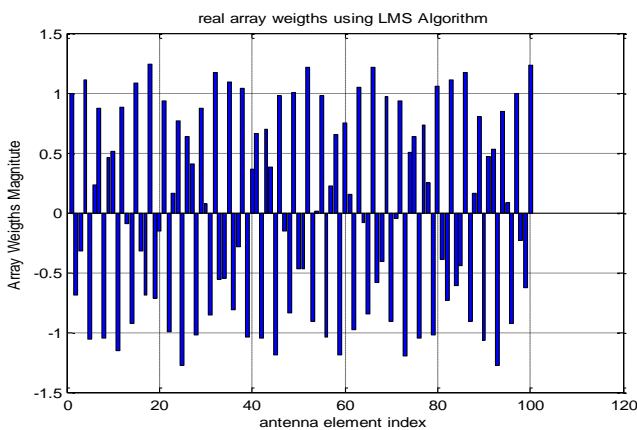


Fig.13. Real array weights of LMS Algorithm

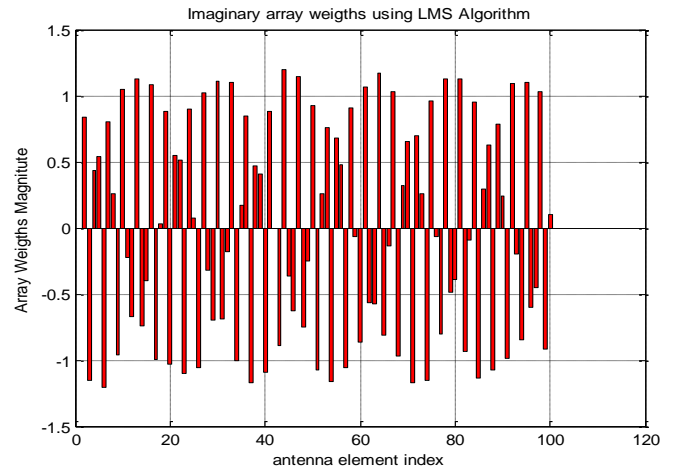


Fig.14. Imaginary array weights of LMS Algorithm

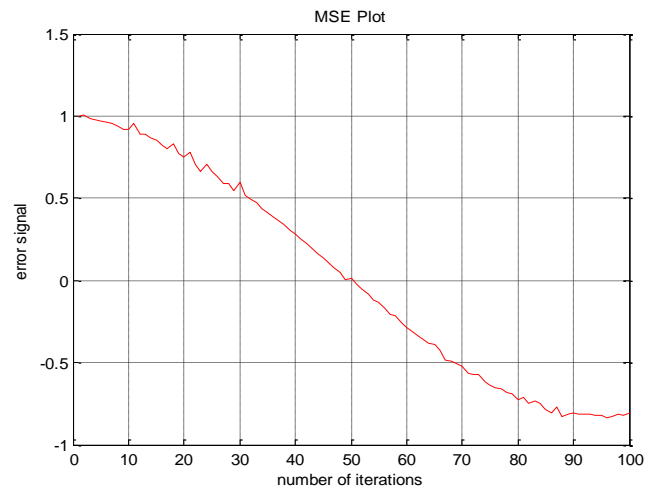


Fig.15. Plot of MSE

The Figure.15 shows the plot of Mean Square Error (MSE). This is the parameter which determines the rate of convergence. As we can see in the figure above that the MSE is becoming zero at 50 iterations. Thus we say that LMS converges at this rate.

**V. CONCLUSION**

From the above results we can conclude that the SMI algorithm works well for fewer antenna elements. But when the antenna elements are more, as is the practical scenario, the computation of inverse of correlation matrices become quite difficult and the algorithm fails.

Thus, as proved above, a better choice is LMS algorithm which successfully identifies the user even with increased antenna elements and provides it with the main beam simultaneously giving nulls to jammers. In LMS, as the number of antenna elements increase, the width of main beam reduces, providing a sharper and powerful beam to the user.

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