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Research Article

Adaptive Beamforming Approach with Robust Interference Suppression

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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 Variable Step Size Normalized Least Mean Square (VSSNLMS) method to direct the main beam towards the desired user. We shall take into consideration, the already existing algorithms for beamforming such as Sample Matrix Inverse (SMI) and Least Mean Square (LMS) in order to compare the performance level of the new algorithm. However the weight expression of the SMI algorithm involves inversion of the array correlation matrix and the LMS algorithm enters damped modes, both of which are highly undesirable. To overcome this, a new approach for adaptive beamforming called VSSNLMS is introduced. With the help of simulation results, it can be proved that the VSSNLMS approach converges faster than SMI and LMS along with reduced noise and better interference suppression. The Simulation tool used is Matrix Laboratory.

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

1. 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. 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.

2. Literature Survey

Ali Hakam *et al* in the paper titled ‘Robust Interference Suppression Using a New LMS Based Adaptive Beamforming Algorithm’ introduce a robust variable step size NLMS algorithm to improve interference suppression in smart antenna system.

Kerim Guney *et al* 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 ‘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’, explains implementation of LMS and SMI algorithms for the interference rejection of the adaptive antenna array with three-elements.

3. 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.

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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.

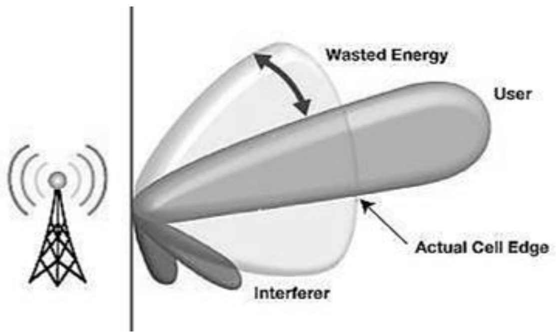

Fig.1 Designing the beam in the required direction and simultaneously nulling interference

In this paper we present the performance of three algorithms ie., SMI, LMS and VSSNLMS 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.

3.1 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

$$W_{SMI} = R^{\wedge} r \quad (1)$$

$R^{\wedge}$ → 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.

3.2 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 μ 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:

$$\begin{aligned} & w(n+1) = w(n) + \mu e(n) x^{*}(n) \\ & e(n) = error\ signal \\ & x^{*}(n) = recieved\ signal \\ & \mu = step\ size \end{aligned} \quad (2)$$

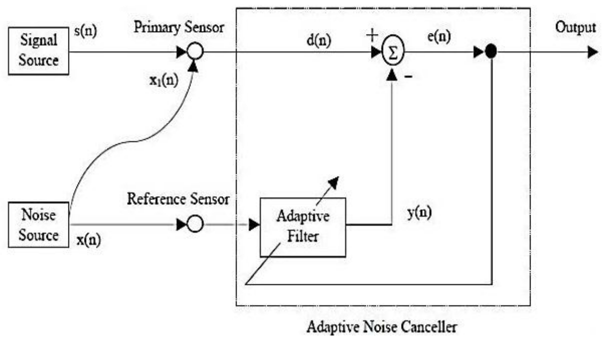

Fig.2 LMS with Adaptive Filter Block Diagram

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.

3.3 Variable Step size Normalized Least Mean Square Algorithm

The main aim of the developed Variable Step Size (VSS) NLMS algorithm is to replace the fixed step size μ that is used in LMS by a variable one. The array weight (Ali Hakam *et al*, 2014) is given by

$$w(n+1) = w(n) + \frac{\mu e(n) x(n)}{\sigma + \|x(n)\|^{2}} \quad (3)$$

The VSSNLMS possess the advantage of updating the stepsize μ in every iteration and therefore flexibily managaing the main beam in look direction untill the communication channel is used.

4. Simulation Results

4.1 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.

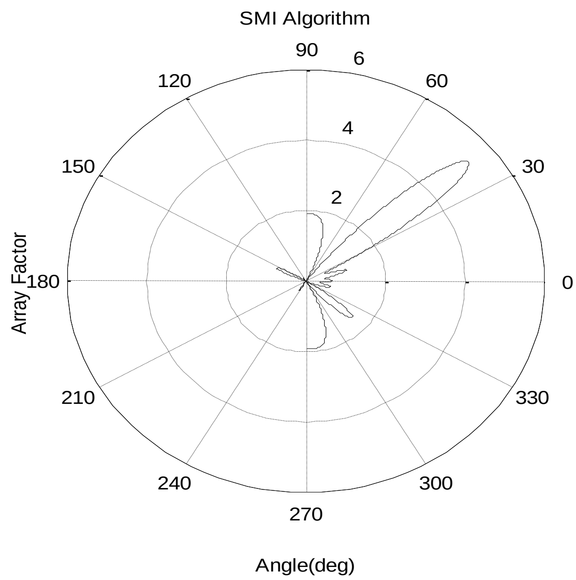

Fig.3 Radiation pattern having main beam at 45^0

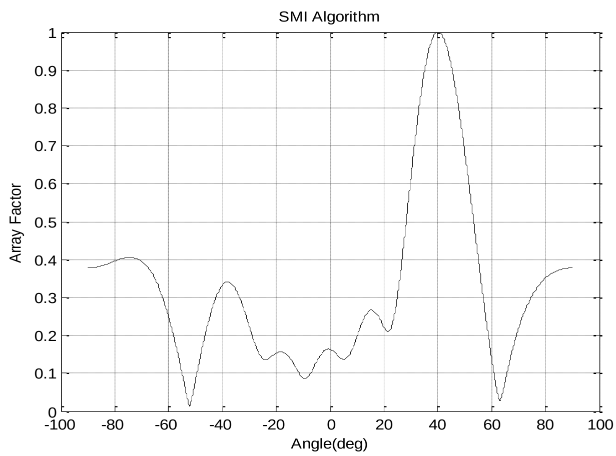

Fig.4 Plot of array factor v/s angle showing main beam at 45^0

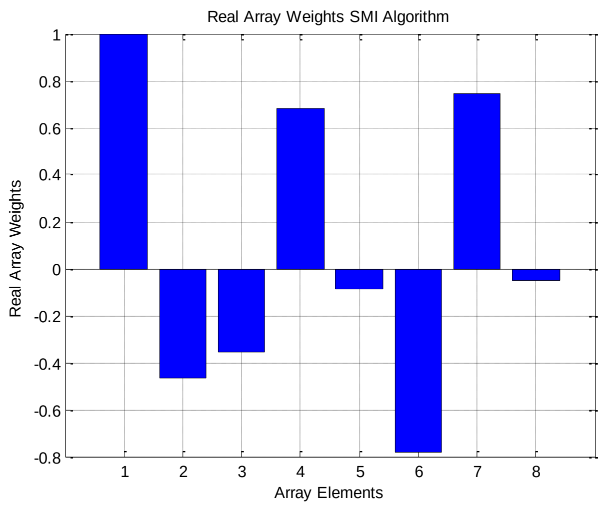

Fig.5 Real array weights of SMI Algorithm

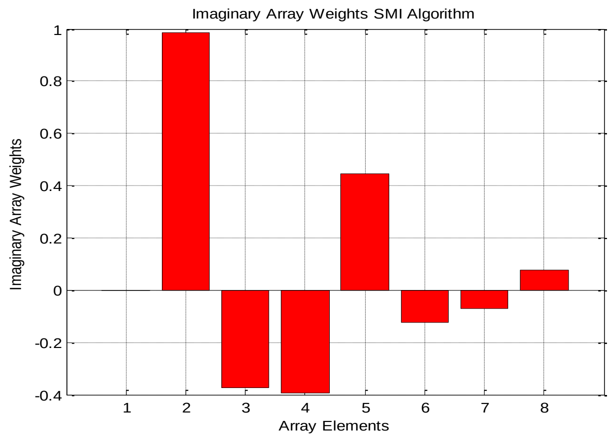

Fig.6 Imaginary array weights of SMI Algorithm

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.

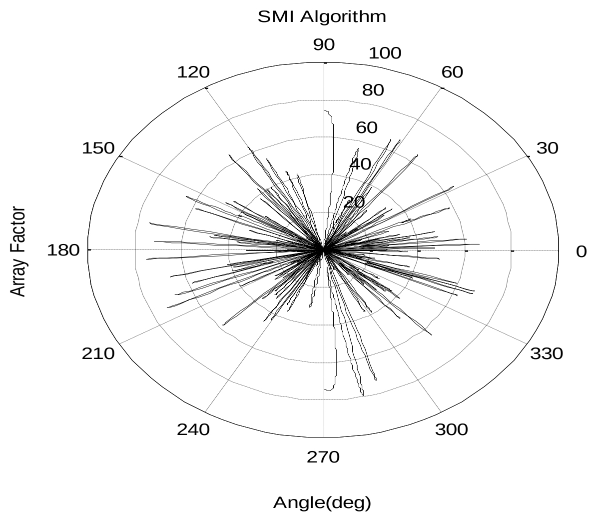

Fig.7 Radiation pattern with no proper distinction

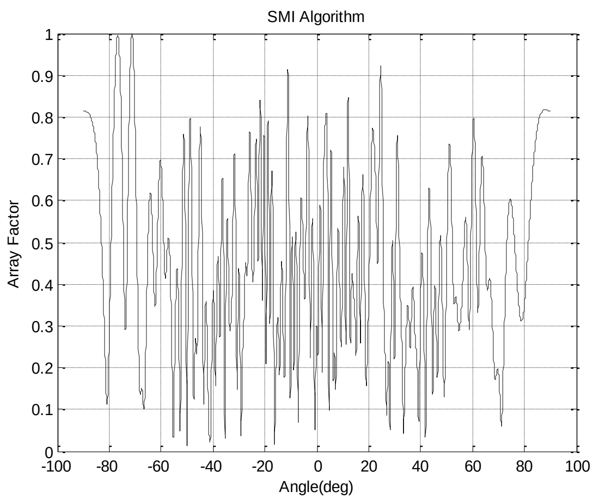

Fig.8 Plot of array factor v/s angle.

We had to get main beam at 45^0 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.

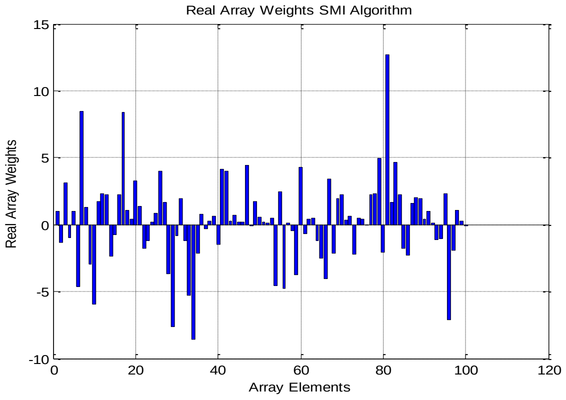

Fig.9 Real array weights of SMI Algorithm

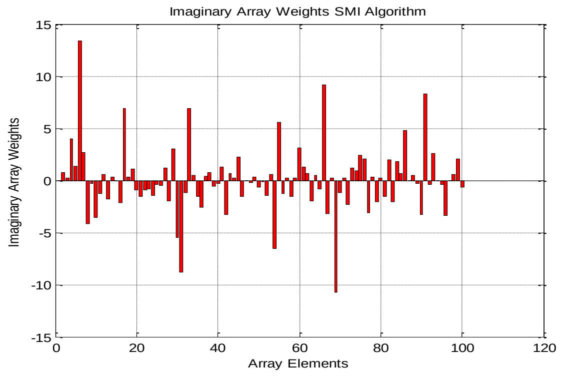

Fig.10 Imaginary array weights of SMI Algorithm

4.2 Least Mean Square Algorithm

In case of LMS algorithm, we shall consider the scenario of the user at 45^0 and having jammers at different directions (say 10, 30 and 90).

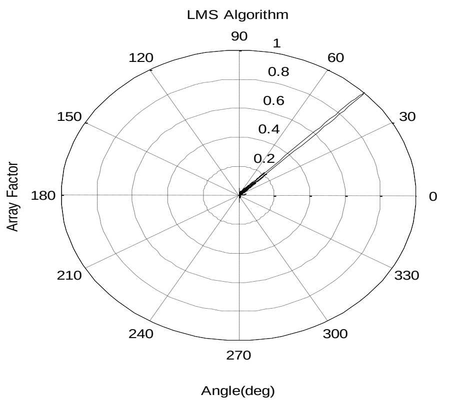

Fig.11 Radiation pattern having main beam at 45^0

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.

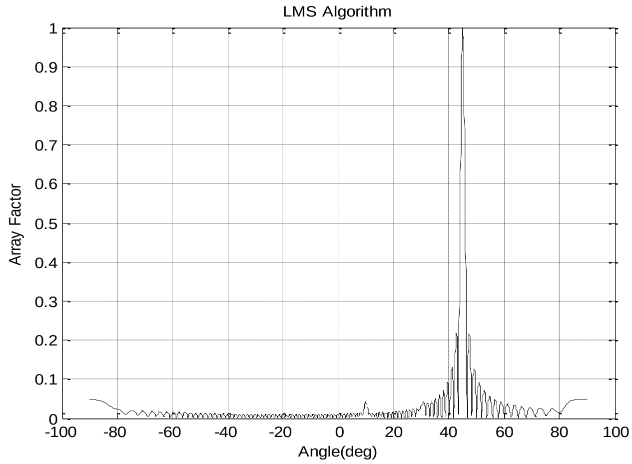

Fig.12 Plot of array factor v/s angle.

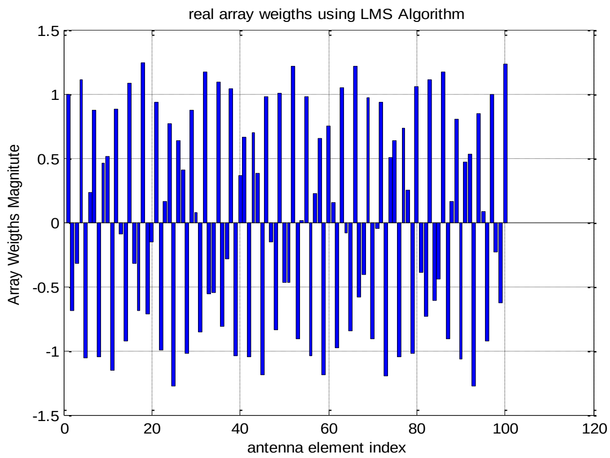

Fig.13 Real array weights of LMS Algorithm

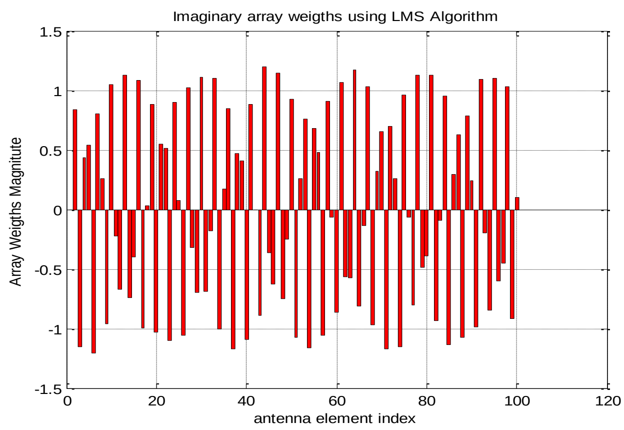

Fig.14 Imaginary array weights of LMS Algorithm

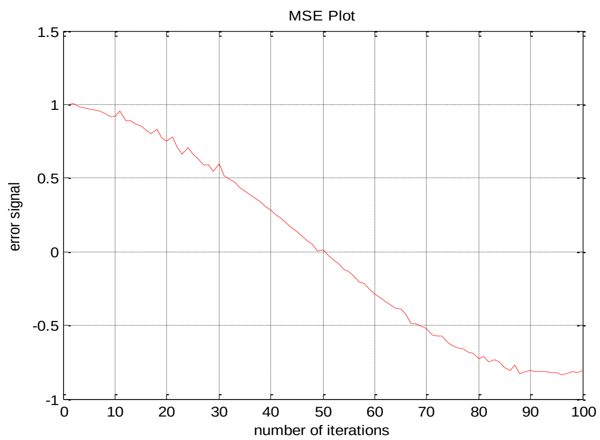

Fig.15 Plot of MSE

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.

4.3 VSSNLMS Algorithm

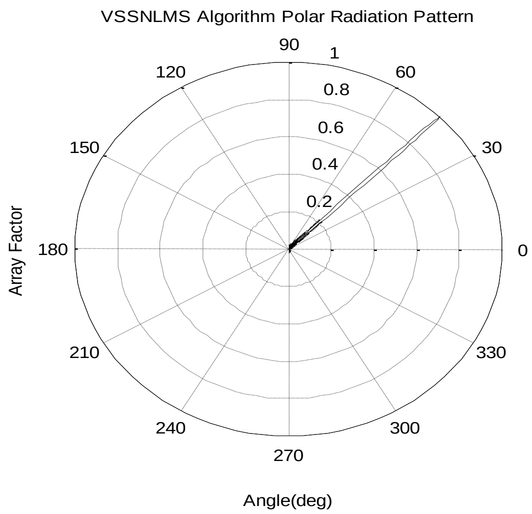

Fig.16 Radiation pattern having main beam at 45^0

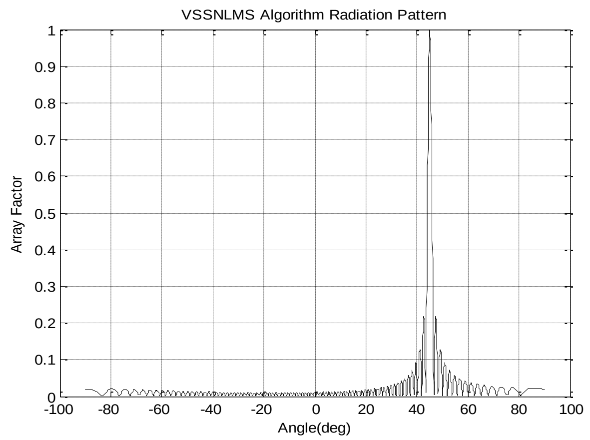

Fig.17 Plot of array factor v/s angle

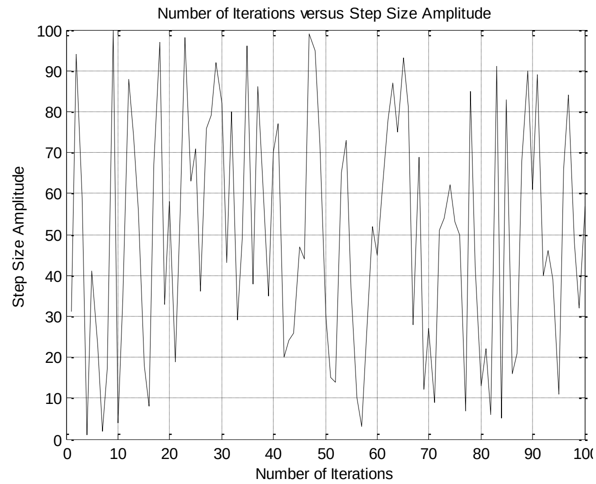

Fig.18 Plot of Iterations v/s amplitude of μ.

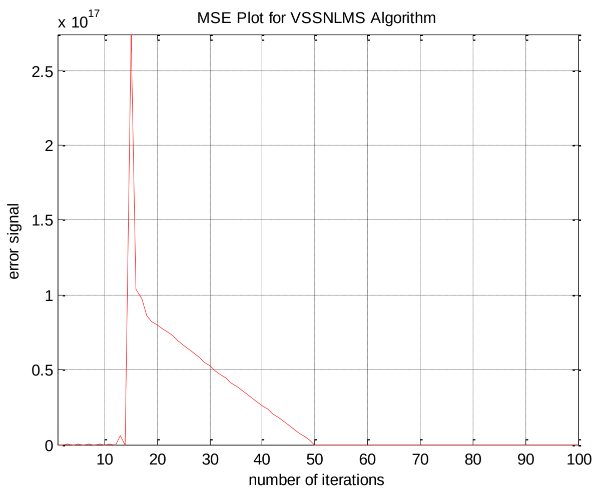

Fig.19 Plot of MSE

As we can clearly see from the above graph that VSSNLMS converges better and early than other algorithms.

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.

Though LMS performs very well compared to SMI given that there's no complex computing but the disappointing factor is LMS entering damped modes. All the disadvantages of SMI and LMS are overcome in VSSNLMS.

Thus, as proved above, a better choice is VSSNLMS algorithm which successfully identifies the user even with increased antenna elements and provides it with the main beam simultaneously giving nulls to jammers.

References

Ali Hakam, Raed Shubair, Shihab Jimaa, and Ehab Salahat, (2014), Robust Interference Suppression using a New LMS Based Adaptive Beamforming Algorithm, 17th IEEE Mediterranean Electrotechnical Conference, Beirut, Lebanon, 13-16.

Kerim Guney, Bilal Babayigit and Ali Akdagli, Interference Rejection Of Adaptive Array Antennas By Using LMS And SMI Algorithms, 38039, Kayseri, Turkey.

I Kaushik Jyoti Das & Kandarpa Kumar Sarma, (2012) Adaptive Beamforming for Efficient Interference Suppression using Minimum Variance Distortionless Response, International Conference on Advancement in Engineering Studies & Technology, ISBN : 978-93-81693-72-8, 15th JULY, , Puducherry.

Suraya Mubeen, Dr. Am.Prasad, Dr.A.Jhansi Rani, (2012) Smart Antenna its Algorithms and Implementation, in IJARCSSE, vol2, issue4, ISSN: 2277 128x.

S. Haykın, (2002) Adaptive Filter Theory, 4th ed., Prentice Hall.

Frank Gross, (2005), Smart antennas for wireless communication, McGraw Hill, New York.

H. Tsuji, M. Mizuno, (2000) Applications of Adaptive Array Antennas in Mobile Communications, Electronics and Communications in Japan, Part 3, Vol. 83, No. 12.