An Approach To Multi Stage And Modified VSSLMS Algorithm For Mobile Applications

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Abstract— In today's world number of users increasing day by day for using mobiles. With the limited spectrum accommodating many users is difficult. Smart Antenna will allocate user channels based on spatial separation reusing the same channel so bandwidth and capacity is hugely increased. In this paper a new innovative beam forming algorithm is used which makes use of modified variable step size least mean square algorithm (VSSLMS) in order to improve the convergence. In the previous approach of VSSLMS the step size is varied in order to improve convergence. In the Proposed method along with variation of step size the speed increase module and convergence improve module block are used in order to execute alternative weights so that convergence is further improved.

Keywords— **Smart antenna, Adaptive beam forming, VSSLMS, Modified VSSLMS, MATLAB**

I. INTRODUCTION

As the numbers of mobile users are increasing day by day, the spectrum has limited capacity. Within the limited capacity huge number of users must be occupied which degrades the quality of service. Hence an algorithm is needed which can send the radiation towards the mobile users with the reduced error and convergence faster, so that main beam can be formed towards desired user at a faster rate as well as with more accuracy. The aim of the algorithm is to form the main beam towards desired user and null or reduced radiation towards jammers using VSSLMS algorithm and also to improve the convergence capability of VSSLMS algorithm by using a novel four stage VSSLMS algorithm. The convergence of the existing LMS algorithm is improved with the help of variable step size least means square method. The VSSLMS method will compute the step size dynamically so that the convergence is improved. The convergence can be further improved by making use of Speed increase and Convergence improved module so that the speed of the weight computation is increased and then algorithm will converge for about N/4 number of iterations so that it is huge improvement for beam forming algorithm.

II. LITERATURE SURVEY

The robust minimum variance [1] algorithm is a distortion less response (MVDR) beam former. The algorithm makes use of kalman filter which reduces the computational cost. Smart antenna [2] concepts are described which increases the capacity by directing the beam in different directions on the same frequency using Least Mean Square (LMS), Recursive Least Mean Square Algorithm (RLS), Normalized Least Mean Square (NLMS) and Sample Matrix Inverse (SMI).The smart antenna [3] algorithms will increase the capacity and at the same time reduces the co channel interference using LMS, RLS and SMI. Multi Linear Filter [4] must determine a set of linear co-efficient which will minimize MSE and then computes the estimation of weights for the target signal in presence of noisy signals.

Variable step-size Griffiths' LMS (VGLMS) [5] algorithm makes use of a combination of step-size and gradient based on the cross-correlation between input and the desired signal. The algorithm performs better for both stationary and non stationary noise. In an application using ducts [6] if there is an error in microphone then it is placed at a far place from the control source to avoid effects of near fields. Due to which there will be delays which affects the convergence of the algorithm. By applying the x and u factor the convergence can be improved even in such environment. Lot of study has been performed on how to control the active noise and apply the practical implementation on a Texas instrument processor [7].

Many variations of beam forming have been presented which makes use of fixed beam formers. Vector-sensor arrays [8] contain crossed dipole pairs that can account for a signal's polarization along with DOA. A quaternion signal model is used in designing the weight coefficients for a fixed set of vector-sensor locations which can be achieved by minimizing the side lobe levels along with maintaining unitary response for the main lobe.

Sparse linear-phase finite-impulse-response multiple-notch filters[9] makes use a range of frequencies [0, π]. Iteratively reweighted orthogonal matching pursuit (IROMP), is based on the orthogonal matching pursuit performed under the weighted l2-norm whose weights are iteratively computed through the hybrid l1/l2-norm minimization. Vector signal modeling [10] can be used for quaternion algebra. Single value decomposition is used for approximation of linear algebra value. Co-prime arrays [11] are used to increase the area of freedom by offering larger apertures. The two properties namely robustness and efficiency are managed in a balance format. Covariance matrix is used to estimate desired signal steering. In order to maintain quality service [12] there should be more radio heads. The balanced transmission power and circuit power via RRH selection and beam forming. The fast baseband transmit [13] for distributed antennas are used to achieve better beam formation by applying the weight updates cyclically.

III. METHODOLOGY

i) Beam forming Approach

The block described in this module is responsible for sending the radiation towards the desired user and null or reduced radiation towards jammers. The beam forming can be described using the following block

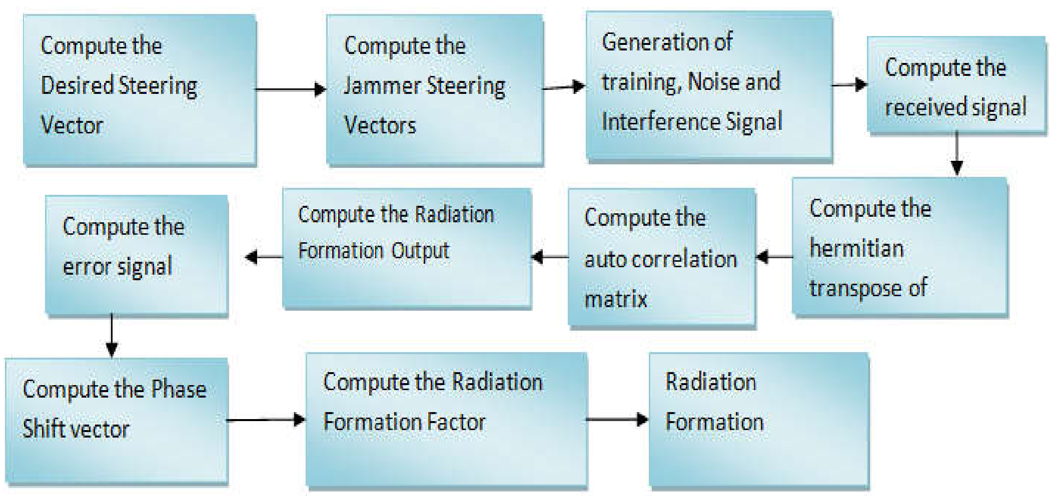

Figure1: Beam forming Algorithm

Compute the Desired Steering Vector: This module is responsible for computing the steering vector for the desired angle where the actual radio user is present.

Compute the Jammer Steering Vectors: This module is responsible for computing the steering vectors for the direction of jammers. The jammers can be a single jammer or multiple jammers across different directions.

Generation of training, Noise and Interference Signal: The training signal is responsible for generation of wave at the mobile station with a certain sampling period. Noise and Interference signal are the signals which are generated randomly.

Compute the Base Station Total signal: The Base Station total signal is the combination of signal at the mobile station, interference signal and noise signal.

Compute the hermitical transpose of received signal: The received signal transpose is found out by taking the transpose and then applying the conjugate of each of the values.

Compute the auto correlation matrix: The auto correlation matrix is used to find the relation between the signal and its delayed version. It is defined as the multiplication of signal and its hermitical transpose.

Compute the Array Output: The Array Output is computed by adding all the electromagnetic waves and its delayed version with the phase shifts.

Compute the error signal: The error signal is defined as the subtraction of total sum of signal at base station with that generated at the mobile station.

Compute the Phase Shift vector: The Phase Shift vector is the phase shifts responsible for forming the radiation which are given to the radio elements.

Compute the Radiation Formation Factor: The Radiation Formation factor is responsible for finding the radiation pattern of antenna array. It is computed in two ways one is using polar coordinates and then using Cartesian coordinates.

Radiation Formation: The radiation formation is performed based on the MATLAB usage.

ii) **Methodology of VSSLMS Algorithm**

The Methodology for VSSLMS algorithm can be described using the following steps

1. The steering vector $S_v(\theta)$ for an antenna array comprising of N_{antena} elements is calculated by using

$$S_v(\theta) = \begin{bmatrix} 1 \\ e^{-j\frac{2\pi}{\lambda}d\sin(\theta)} \\ . \\ . \\ . \\ e^{-j(N_{antenna}-1)\frac{2\pi}{\lambda}d\sin(\theta)} \end{bmatrix}$$

Where,

θ = angle at which signal is falling

λ = operating wavelength for antenna

d = distance between antenna elements

In order to avoid grating lobes the value of d must be multiple of $\frac{\lambda}{2}$. Hence the following is considered assuming each antenna used in the array is a dipole antenna $d = \frac{\lambda}{2}$

After substitution,

$$S_v(\theta) = \begin{bmatrix} 1 \\ e^{-j\frac{2\pi}{\lambda}\frac{\lambda}{2}\sin(\theta)} \\ . \\ . \\ . \\ e^{-j(N_{antenna}-1)\frac{2\pi}{\lambda}\frac{\lambda}{2}\sin(\theta)} \end{bmatrix}$$

Simplifying equation

$$S_v(\theta) = \begin{bmatrix} 1 \\ e^{-j\pi\sin(\theta)} \\ . \\ . \\ . \\ e^{-j\pi(N_{antenna}-1)\pi\sin(\theta)} \end{bmatrix}$$

2. The array manifold vector is computed for the set of N_{users} and is the combination of steering vectors across interference users N_{users} directions $\{\theta_1, \theta_2, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\theta_{N_{users}}\}$

$$A_M = \begin{bmatrix} 1 & 1 & 1 \\ e^{-j\pi\pi\sin(\ _1)} & e^{-j\pi\pi\sin(\ _2)} & e^{-j\pi\pi\sin(\ _{N_{users}})} \\ . & & \\ . & & \\ . & & \\ e^{-j\pi\pi(\ _{antennas}-1)\sin(\theta_1)} & e^{-j\pi\pi(\ _{antennas}-1)\sin(\theta_2)} & e^{-j\pi\pi(\ _{antennas}-1)\sin(\theta_{N_{users}})} \end{bmatrix}$$

3. The training signal is generated at the mobile station for N_s samples and is generated at an appropriate frequency of the baseband signal. As per Nyquist criteria the sample frequency must satisfy the condition.

$$f_s >= \frac{1}{2T}$$

Where,

T = sampling period

The signals are generated as below

$$ts(n) = \cos(\frac{\pi n}{T})$$

Where,

$0 \leq n \leq N_s$

4. The following factors are computed sample by sample for each sample of the training signal generated

$$rs(n)_{signal} = S_v(\theta_0)\ ts(n) + is(n) * \sum_{i=1}^{N_{jammers}} S_v(\theta_i) + n(n)$$

Where,

$S_v(\theta_0)$ = steering vector for an angle θ_o

$ts(n)$ = training signal sample for the n^{th} sample

$is(n)$ = interferen ce signal sample

$n(n)$ = noisy signal for the n^{th} sample across all antenna elements

$S_v(\theta_i)$ = steering vector for angle θ_i correspond ing to jammer direction θ_i

$N_{jammers}$ = Number of Jammers

$rs(n)$ = recieved signal for n^{th} signal

The array output is computed using the following equation

$$AO(n) = Aw^H(n)\ tr(n)$$

Where,

$Aw^H(n)$ = hermitian transpose of array weights which are applied to individual phase shifters

$tr(n)$ = total recieved signal for n^{th} signal

The error signal is computed at the base station using the following equation

$$es(n) = |ts(n) - AO(n)|$$

The Step Size is computing using the following equation

$$S_s(n+1) = \alpha\ S_s(n) + \gamma\ |es(n)|^2$$

Where,

α = correlatio n factor

γ = convergenc e factor

$es(n)$ = error signal

$S_s(n)$ = step size in the previous iteration

$S_s(n+1)$ = step size in the next iteration

The Step Size will be varying within the limits of 0 to $S_{s\ upper}$

$$S_s(n+1) = \begin{cases} S_{s\ upper} & \text{if } S_s(n+1) > S_{s\ upper} \\ 0 & \text{if } S_s(n+1) < 0 \\ S_s(n+1) & \text{otherwise} \end{cases}$$

The array weights are computed using the following equation

$$Aw_{VSSG}(n+1) = A\,w_{VSSG}(n) + \frac{S_s\ CC_{ts,rs}}{|rs|}$$

Where

$Aw(n)$ = phase shifts applied to antenna elements

S_s = Step Size

$CC_{ts,rs}$ = cross correlation between traning signal and recieved signal

$|rs|$ = magnitude of recived signal

5. The array factor is computed for the array weights in order to generate the radiation pattern.

$$AF = \sum_{i=1}^{N_{antennas}} Aw^{H}(i)\ e^{-j\pi \sin(\theta i}$$

Where,

$AF =$ array factor

$Aw =$ array weights

$N_{antennas} =$ Number of antennas used in the array

$\theta =$ direction of scanning

$-90^{0} \leq \theta \leq 90^{0}$

iii) Modified VSSLMS Algorithm with Feedback Loop

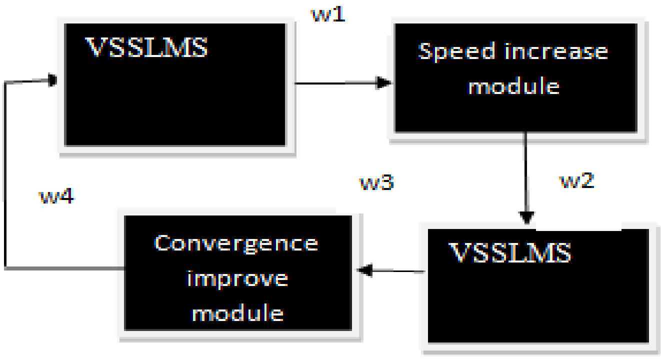

Figure 2: Modified VSSLMS Method Architectur

In the Proposed method the combination of VSSLMS and two additional blocks which provide the feedback for the VSSLMS algorithm. The additional 2 blocks are used to increase the speed as well as increase the convergence rate.

The w1, w2, w3 and w4 acts as a feedback to each of the blocks. Each block handles its own sample of the signal. The weight equation in such a case will be picked up in such a way that w1 and w3 are computed using VSSLMS and w2 and w4 are computed using Speed Increase and Convergence Improve module to increase the convergence rate and make the algorithm converge faster

The weight vector for the SI module is computed using the following equation

$$w_{SI}(n+1) = w_{SI}(n) + ([I - 2\mu_{SI} R_{xx}]^{-1}[w_{VSSG} - 2\mu_{SI} R_{xs}])$$

Where,

$w_{SI}(n+1)$ are theLx1 updated array weights , I is LxL identity matrix, μ_{SI} is the step size, R_{xx} is the LxL autocorrelation matrix of induced signal x(n) . w_{VSSG} are Lx1 array weights obtained from VSSLMS module initially this value is zero and R_{xs} is the cross-correlation between signal generated at mobile station and base station

The step size for the Speed Increase module is given by

$$\mu_{SI} = \frac{2}{3tr(R_{xx})}$$

The weight equation for the Convergence Improvement module can be described as follows and is derived by applying the Aitkin method in the next section and finally the following is obtained

$$w_{CI} = L_{value} - \frac{Nu_{VSSGMk}}{De_{VSSGMk}}$$

Where,

$$Nu_{VSSGMk} = M_k M_k w_{VSSG1} + M_k N_k - M_k\ w_{VSSG1}$$

$$De_{VSSGMk} = M_k M_k w_{VSSG1} + M_k N_k - 2M_k w_{VSSG1} - N_k + w_{VSSG1}$$
$$L_{value} = M_k M_k w_{VSSG1} + M_k N_k + N_k$$
$$M_k = I - 2\mu_{CI} R_{xx}$$
$$N_k = 2\mu_{CI} R_{xs}$$

IV. RESULTS AND DISCUSSION

Case1: Performance with Less number of Antenna Elements and Single Interference

Parameter Name	Parameter Value
Number of Antenna Elements	8
Desired Angle	30
Number of Interference Angle	1
Direction of Interference Angle	10

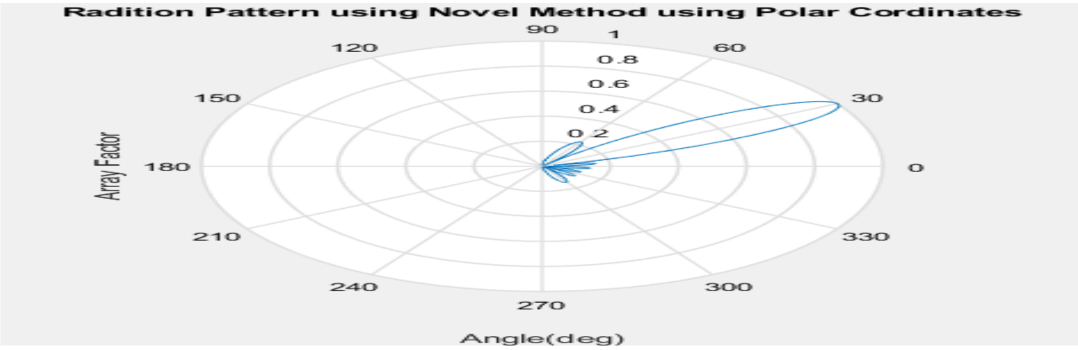

Figure 3: Radiation Pattern for Feedback Loop VSSLMS Algorithm in Polar Format

Figure 3 shows the radiation pattern for Feedback Loop VSSLMS Algorithm in polar format. As shown in the figure the Feedback Loop VSSLMS algorithm is able to send radiation for the user present at an angle of 30 degree.

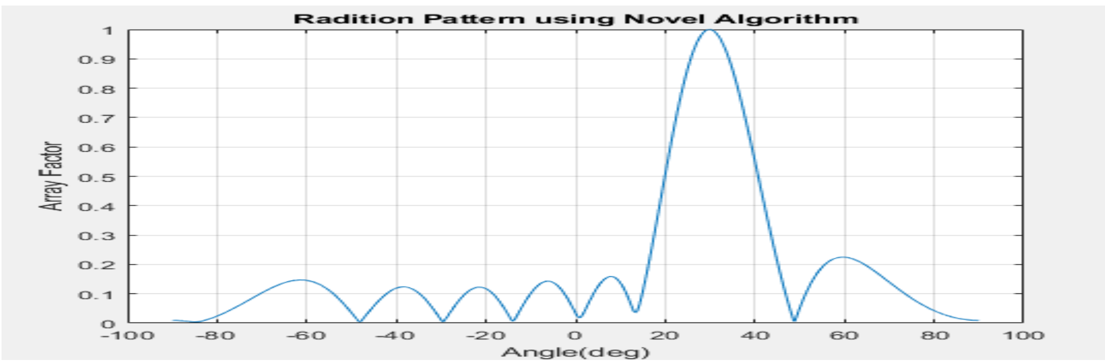

Figure 4: Radiation Pattern for Feedback Loop VSSLMS Algorithm in Beam Plot Format

Figure 4 shows the radiation pattern for Feedback Loop VSSLMS Algorithm in beam plot format. As shown in the figure the Feedback Loop VSSLMS algorithm is able to send radiation for the user present at an angle of 30 degree. The VSSLMS Feedback Loop algorithm converges faster as compared to VSSLMS algorithm.

Case2: Performance with Less number of Antenna Elements and Multiple Interference

Parameter Name	Parameter Value
Number of Antenna Elements	8
Desired Angle	45
Number of Interference Angle	3
Direction of Interference Angle	[10 15 20]

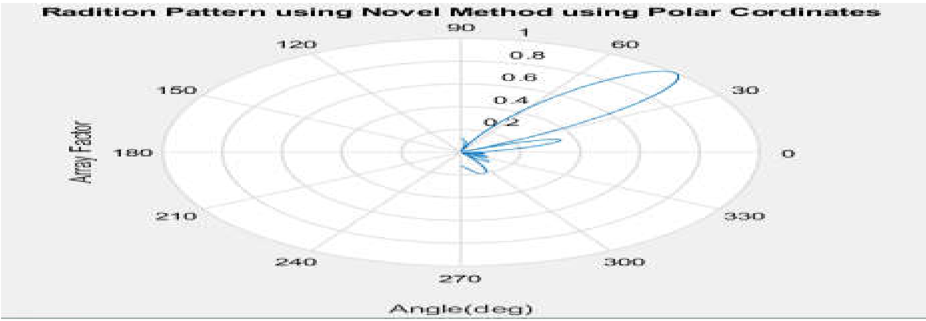

Figure 5: Radiation Pattern of VSSLMS Feedback Algorithm in Polar Format Less number of Antenna Elements and Single Interference

Figure 5 shows the radiation pattern for VSSLMS Feedback Algorithm in Polar Format for Less number of Antenna Elements and Multiple Interference. As shown in the figure the VSSLMS Feedback algorithm is able to send radiation for the user present at an angle of 45 degree.

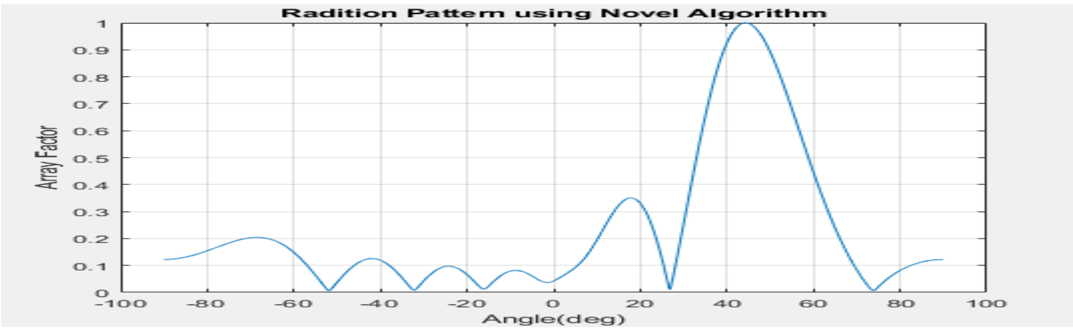

Figure 6: Radiation Pattern of VSSLMS Feedback Algorithm in Beam Plot Format for Less number of Antenna Elements and Multiple Interference

Figure 6 shows the radiation pattern for VSSLMS Feedback Algorithm in Beam Plot Format for Less number of Antenna Elements and Multiple Interference. As shown in the figure the VSSLMS Feedback algorithm is able to send radiation for the user present at an angle of 45 degree.

Case3: Performance with More number of antenna elements and single interference

Parameter Name	Parameter Value
Number of Antenna Elements	100
Desired Angle	30
Number of Interference Angle	1
Direction of Interference Angle	10

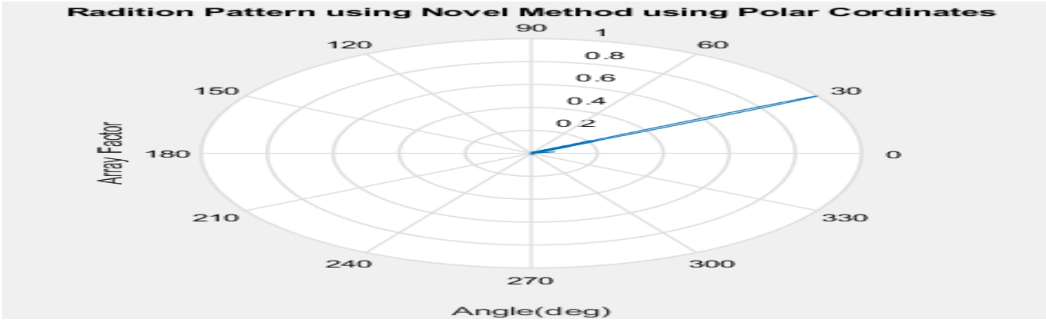

Figure 7: Radiation Pattern of VSSLMS Feedback Algorithm in Polar Format for More number of Antenna Elements and Single Interference

Figure 7 shows the radiation pattern for VSSLMS Feedback Algorithm in Polar Format for More number of Antenna Elements and Single Interference. As shown in the figure the VSSLMS Feedback algorithm is able to send radiation for the user present at an angle of 30 degree.

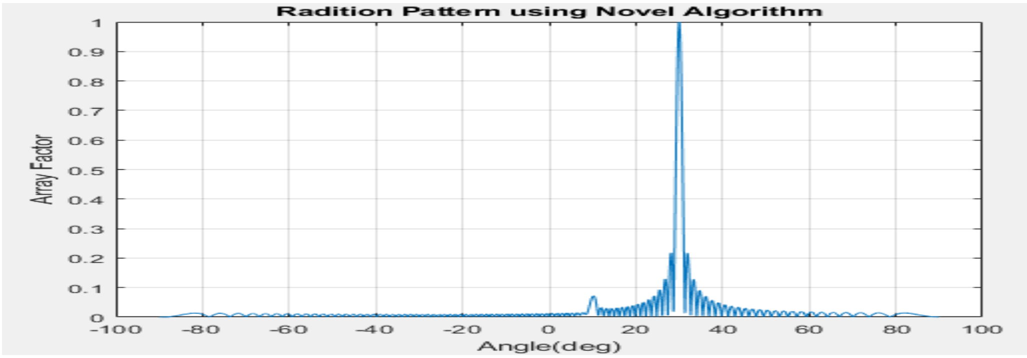

Figure 8: Radiation Pattern of VSSLMS Feedback Algorithm in Beam Plot Format for More number of Antenna Elements and Single Interference

Figure 8 shows the radiation pattern for VSSLMS Feedback Algorithm in Beam Plot Format for More number of Antenna Elements and Single Interference. As shown in the figure the VSSLMS Feedback algorithm is able to send radiation for the user present at an angle of 30 degree. The Proposed Feedback Loop VSSLMS has narrow beam as compared to other algorithms and hence is most accurate.

Case4: Performance with More number of antenna elements and multiple interference

Parameter Name	Parameter Value
Number of Antenna Elements	100
Desired Angle	45
Number of Interference Angle	3
Direction of Interference Angle	[10 15 20]

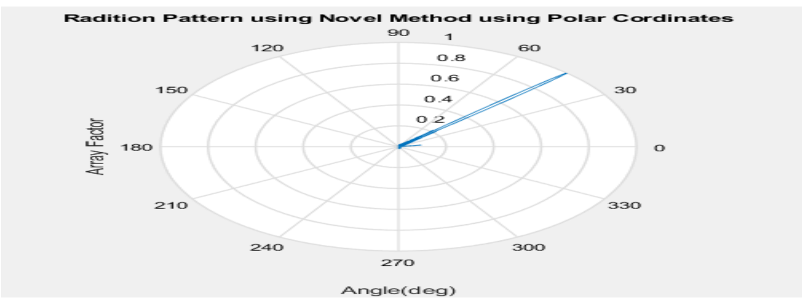

Figure 9: Radiation Pattern of VSSLMS Feedback Algorithm in Polar Format for More number of Antenna Elements and Multiple Interference

Figure 9 shows the radiation pattern for VSSLMS Feedback Algorithm in Polar Format for More number of Antenna Elements and Multiple Interference. As shown in the figure the VSSLMS Feedback algorithm is able to send radiation for the user present at an angle of 45 degree.

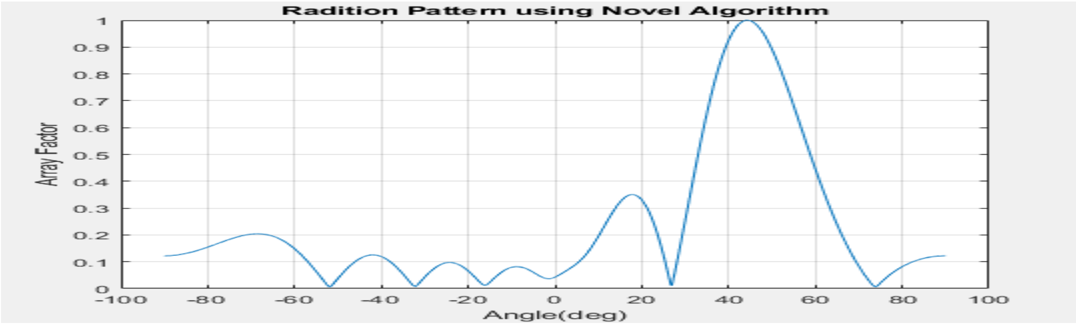

Figure 10: Radiation Pattern of VSSLMS Feedback Algorithm in Beam Plot Format for More number of Antenna Elements and Multiple Interference

Figure10 shows the radiation pattern for VSSLMS Feedback Algorithm in Beam Plot Format for More number of Antenna Elements and Multiple Interference. As shown in the figure the VSSLMS Feedback algorithm is able to send radiation for the user present at an angle of 45 degree. The Proposed Feedback Loop VSSLMS has narrow beam as compared to other algorithms and hence is most accurate.

COMPARISON RESULTS

Case1: Performance with Less number of antenna elements and single interference

Parameter Name	**Parameter Value**
Number of Antenna Elements	8
Desired Angle	30
Number of Interference Angle	1
Direction of Interference Angle	10

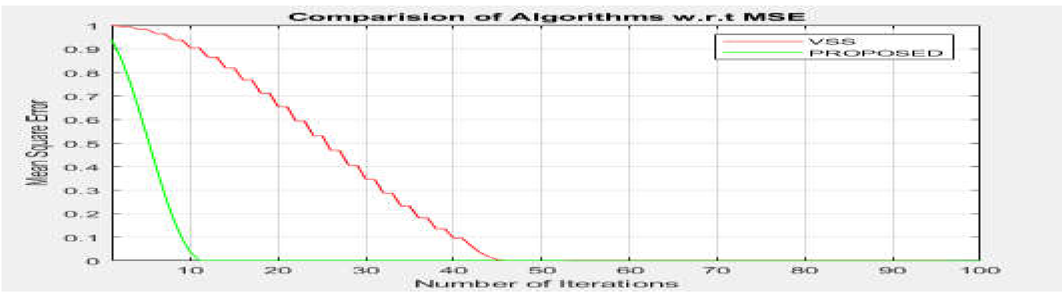

Figure 11: Mean square Error comparison

Figure 11 shows the Mean Square Error comparison by taking number of iteration in the x axis and mean square error in the y axis. As shown in the figure VSSLMS converges for about 45 iterations where as proposed method converges for about 11 iterations. This shows that the Mean Square Error of the Proposed Feedback Loop VSSLMS algorithm gives better results and also it converges faster.

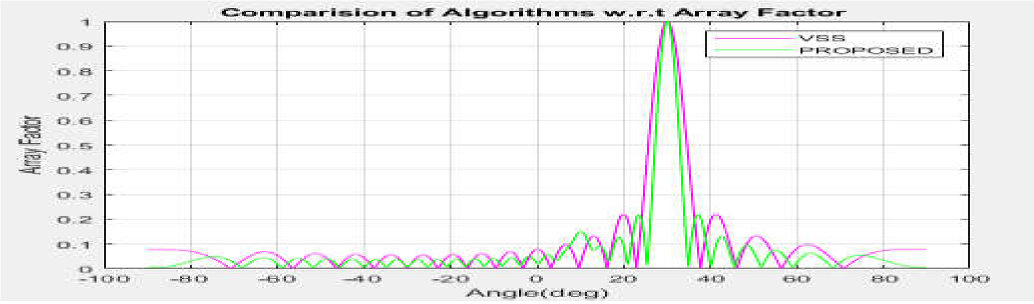

Figure 12: Beam forming algorithm results

Figure12 shows the beam forming algorithm results. As shown in the figure both VSSLMS and VSSLMS Feedback algorithm is able to send radiation for the user present at an angle of 30 degree. The Proposed Feedback Loop VSSLMS has narrow beam as compared to other algorithms and hence is most accurate.

Case2: Performance with Less number of Antenna Elements and Multiple Interference

Parameter Name	Parameter Value
Number of Antenna Elements	8
Desired Angle	45
Number of Interference Angle	3
Direction of Interference Angle	[10 15 20]

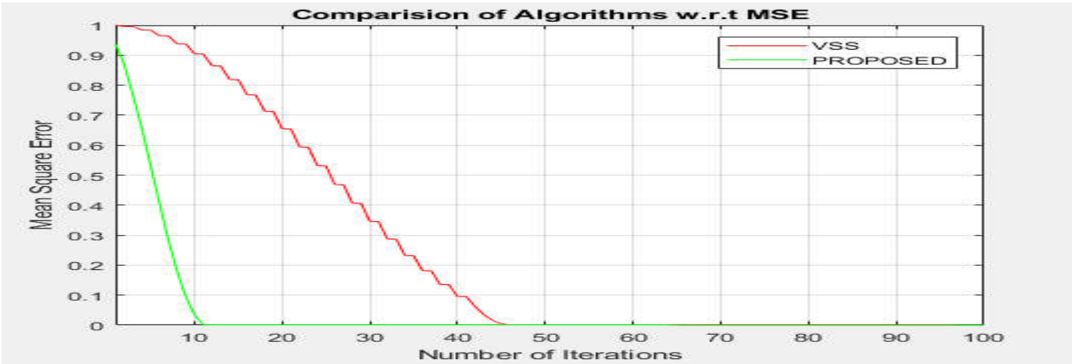

Figure 13: Mean square Error comparison

Figure 13 shows the Mean Square Error comparison by taking number of iteration in the x axis and mean square error in the y axis. As shown in the figure VSSLMS converges for about 45 iterations where as proposed method converges for about 11 iterations. This shows that the Mean Square Error of the Proposed Feedback Loop VSSLMS algorithm gives better results and also it converges faster.

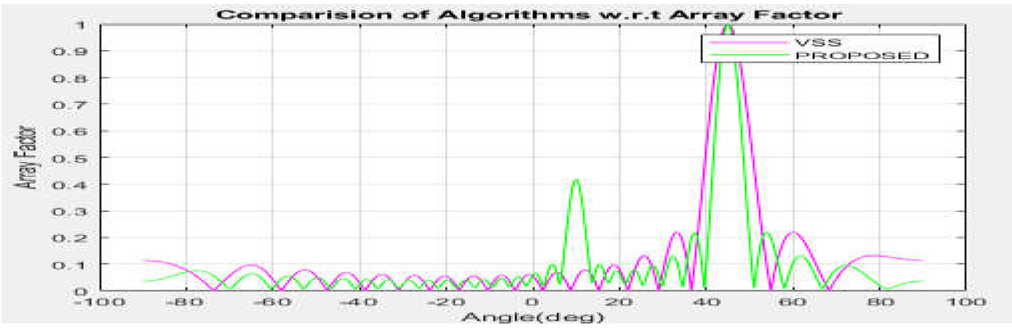

Figure 14: Beam forming algorithm results

Figure14 shows the beam forming algorithm results. As shown in the figure both VSSLMS and VSSLMS Feedback algorithm is able to send radiation for the user present at an angle of 45 degree. The Proposed Feedback Loop VSSLMS has narrow beam as compared to other algorithms and hence is most accurate.

Case3: Performance with More number of Antenna Elements and Single Interference

Parameter Name	Parameter Value
Number of Antenna Elements	100
Desired Angle	30
Number of Interference Angle	1
Direction of Interference Angle	10

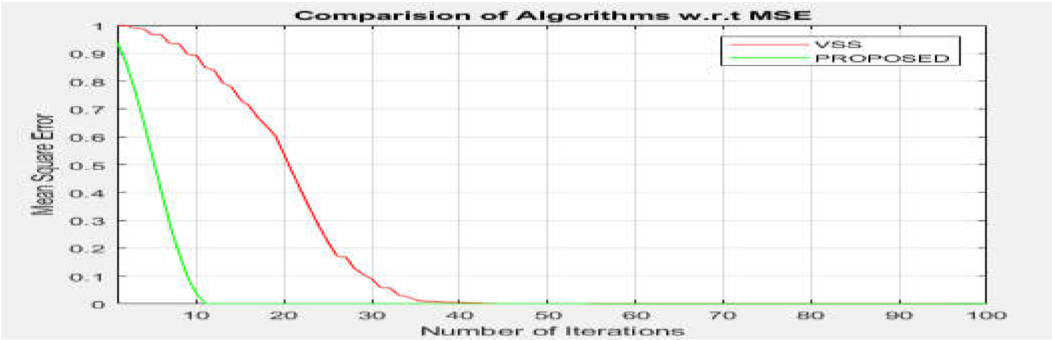

Figure 15: Mean Square Error Comparison

Figure 15 shows the Mean Square Error comparison by taking number of iteration in the x axis and mean square error in the y axis. As shown in the figure VSSLMS converges for about 35 iterations where as proposed method converges for about 10 iterations. This shows that the Mean Square Error of the Proposed Feedback Loop VSSLMS algorithm gives better results and also it converges faster.

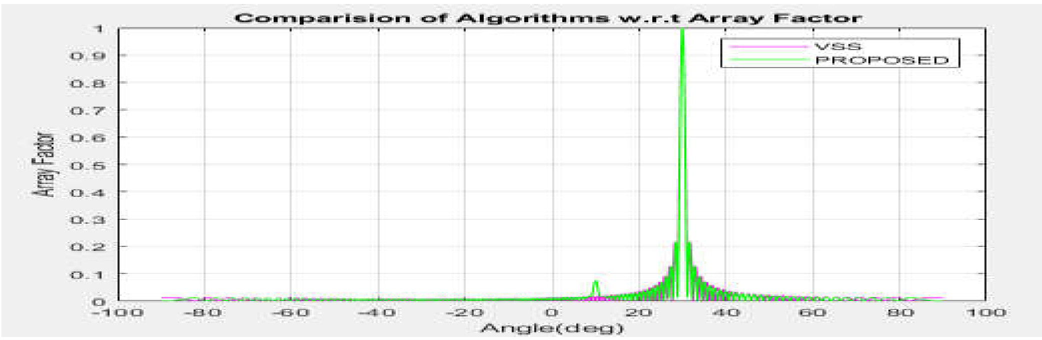

Figure16: Beam forming Algorithm results

Figure 16 shows the beam forming algorithm results. As shown in the figure both VSSLMS and VSSLMS Feedback algorithm is able to send radiation for the user present at an angle of 30 degree. The Proposed Feedback Loop VSSLMS has narrow beam as compared to other algorithms and hence is most accurate.

Case4: Performance with More number of Antenna Elements and Multiple Interference

Parameter Name	Parameter Value
Number of Antenna Elements	100
Desired Angle	45
Number of Interference Angle	3
Direction of Interference Angle	[10 15 20]

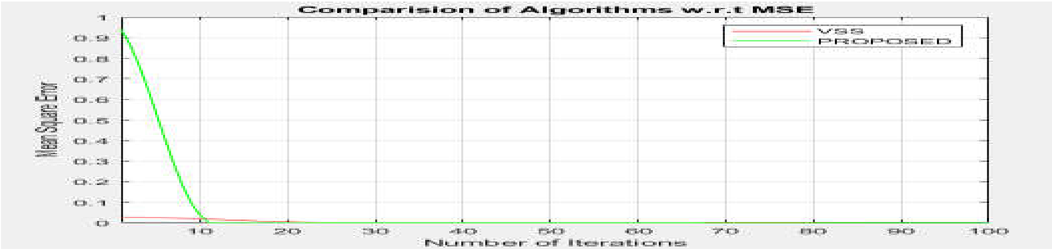

Figure17: Mean Square Error Comparison

Figure 17 shows the Mean Square Error comparison by taking number of iteration in the x axis and mean square error in the y axis. As shown in the figure VSSLMS converges for about 20 iterations where as proposed method converges for about 10 iterations. This shows that the Mean Square Error of the Proposed Feedback Loop VSSLMS algorithm gives better results and also it converges faster.

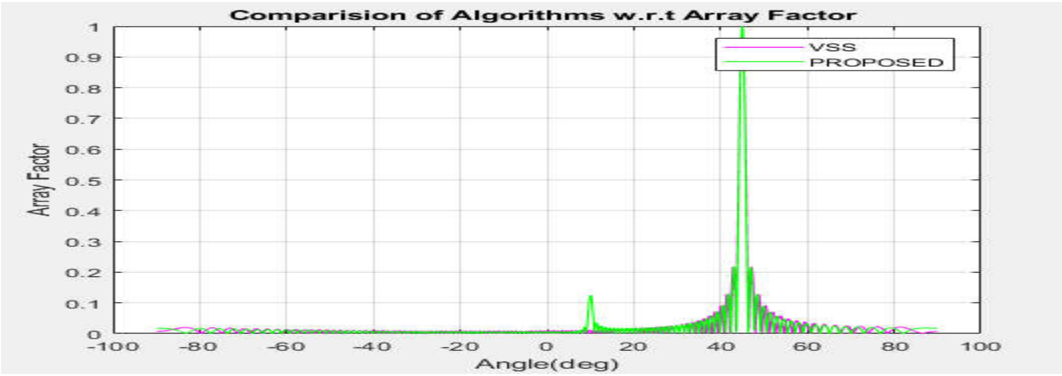

Figure 18: Beam forming Algorithm results

Figure18 shows the beam forming algorithm results. As shown in the figure both VSSLMS and VSSLMS Feedback algorithm is able to send radiation for the user present at an angle of 45 degree. The Proposed Feedback Loop VSSLMS has narrow beam as compared to other algorithms and hence is most accurate.

DISCUSSION: For Less or more number of antenna with single or multiple interference angles, the VSSLMS feedback loop converges for less number of iteration compared to existing approaches.

V. CONCLUSION AND FUTURE SCOPE

Modified VSSLMS algorithms are compared for the various cases namely Less number of Antenna Elements and Single Interference Angle, Less number of Antenna Elements and Multiple Interference Angles, More number of Antenna Elements and Multiple Interference Angles and finally More number of Antenna Elements and Multiple Interference Angles. The Proposed Feedback Loop VSSLMS algorithm gives better results compared to VSSLMS algorithms. The Mean square error (MSE) of the proposed method is the least and also algorithm converges for lesser number of iterations.

FUTURE SCOPE

The algorithms can be modeled for beam steering in RADAR systems for detecting the enemy vehicles. The algorithms can be used in Mobile Communication towers to improve the capacity and include more number of users in the electromagnetic spectrum with high Quality of Service.

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