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A New Modified Variable Steps Size Griffiths Beam Forming Algorithm with Feedback Loop

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Abstract: Antenna array is the set of antenna elements with each antenna element of type dipole separated by a distance. In this work a new algorithm is described which is combination of Variable Step Size Griffiths(VSSG) along with Speed Management , Convergence Management Module which increases the accuracy of beam forming algorithm as well as improve the convergence of the algorithm. The proposed method is compared against existing beam forming algorithms namely LMS, RLS, Griffiths and Variable Step Size Griffiths. The algorithms are simulated for various cases Low RF Sources and Single Interference, Large RF Source and Single Interference, Low RF Sources and Multiple Interference angles and finally for the case of Large RF sources and Multiple interference angles.

I. INTRODUCTION

In today's world the number of mobile users is increasing in an exponential format. With the limited electromagnetic spectrum many users have to be served with the same QOS. Multiple antennas used at the base station increases the capacity in an efficient way by serving multiple users at the same time with same frequency but different angle of orientation. The entire process is divided into transmission and reception dividends. The Reception is responsible for detecting the angles from which the sources are sending the electromagnetic waves and the transmission parts is responsible for sending the Radiation in the right direction and nullify the jammer or interference directions. The block diagram for adaptive antenna is as shown, figure1 shows the adaptive antenna which has N antenna elements and all the elements are connected to phase shifters and then these phase shifts are adaptive adjusted based on the weight vector computation which depends on the recovived signal from mobile station as well as the error signal.

Once the weights are computed from the processor the weights are applied to individual antenna elements. This weight are applied to individual antenna elements so that the radiation is directed towards the desired user.

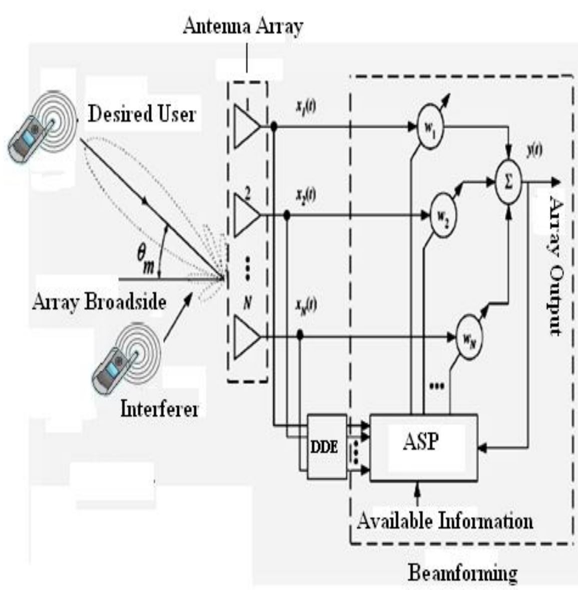

Figure1: Adaptive Beamforming Block

II. BACKGROUND

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 environments. Lot of study has been performed on how to control the active noise and apply the practical implementation on a Texas instrument processor [7].

Modeling [8] can be done either using an offline or online mode which control the active noise. It is also evident that such modeling will be equal to impulse response of secondary path. Once modeling is done faster accuracy and reduced prediction error can be achieved.

There is a non linear relationship between step size [9] and error signal based on the input signal. The step size can be modified based on error value of a set of 2 iterations current and previous which can bring a certain immunity to noise signal and improve MSE

In order to reduce the complexity and energy consumption and also maintain the performance a quaternion factor [10] is computed by modifying the LMS algorithm

Many variations of beam forming have been presented which makes use of fixed beam formers. Vector-sensor arrays [11] 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.

$\ell 1$ relaxation is applied to LMS [12] to improve its performance by deriving 2 kinds of variations zero-attracting LMS (ZA-LMS) and the reweighted zero-attracting LMS (RZA-LMS).l1 norm is applied in the LMS Cost function which accelerates convergence and achieves lower Mean Square Error. Sparse linear-phase finite-impulse-response multiple-notch filters[13] makes use a range of frequencies $[0, \pi]$. 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 [14] can be used for quaternion algebra .Single value decomposition is used for approximation of linear algebra value. Coprime arrays [15] 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 [16] there should be more radio heads. The balanced transmission power and circuit power via RRH selection and beam forming.

The fast baseband transmit [17] for distributed antennas are used to achieve better beam formation by applying the weight updates cyclically. The channel estimation [18] is based on received power measurements for multi antenna using energy transfer system. The key for beam forming is to maintain the low energy.

There must be an estimation of transmit and received beam forming weights for better channel estimation. Multi-group multicast beam forming[19] in wireless systems with large antenna arrays is a well known non-convex quadratically constrained quadratic programming (QCQP) problem. As the number of users in a group increases the performance of such a method decreases. The low-cost technique[20] for digital beamforming on receiver can be implemented which can be used to synthesize multiple beam patterns in different directions.

In a cloud [21] environment remote radio devices are connected to server in order to perform signal processing and resource allocation. Sigmoidal function is used to obtain better Signal to interference plus noise ratio. Secure transmit beamforming [22] in a Multiple Input and Single Output environment can be obtained by using legitimate receiver channel state information. The eaves dropping can be reduced by increasing the target secrecy

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Notation	Meaning
L	Number of Antenna Elements
$x(n)$	Received signal at the base station
d	Distance between antenna elements
$a(\theta_0)$	Steering Vector for an angle θ_0
A	Manifold vector for multiple steering vectors
S	Generated Signal Matrix at the Mobile Station of specific frequency
μ	Step Size
M	Number of Interference users
$y(n)$	Total received signal at the base station
$e(n)$	Error signal
$\theta_1, \theta_2, \ldots\ldots, \theta_M$	M interference angles
$d(n)$	Received signal vector

III. PROPOSED METHOD

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

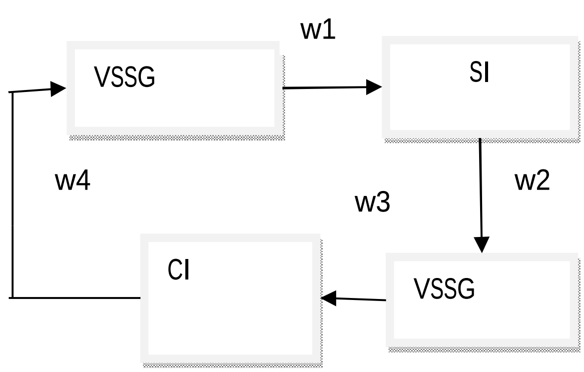

Figure2: Proposed Method

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 VSSG 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

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

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 VSSG 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

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$$\mu_{SI} = \frac{1}{3tr(R_{xx})} ---(2)$$

The weight equation for the Convergence Improvement module can be described as follows and is derived by applying the Aitkin method

$$w_{CI} = L_{value} - \frac{Nu_{VSSGMk}}{De_{VSSGMk}} ----(3)$$

Where,

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

$$De_{VSSGMk} = M_k M_k w_{VSSG1} + M_k N_k - 2M_k w_{VSSG1} - N_k + w_{VSSG1}$$

$$L_{value} = M_k M_k w_{VSSG1} + M_k N_k + N_k$$

$$M_k = I - 2\mu_{CI} R_{xx}$$

$$N_k = 2\mu_{CI} R_{xs}$$

Derivation of Weight Equation

As per Aitkin method the weight is given by

$$w_{sm} = \psi(\psi(w_k)) - \frac{power\{\psi(\psi(w_k)) - \psi(w_k)\}}{\psi(\psi(w_k)) - 2\psi(w_k) + w_k} --(4)$$

$$\psi(w_k) = M_K w_K + N_K ---(5)$$

Where $M_K = I - 2\mu R_K ---(6)$

$$N_K = 2\mu P_k ----(7)$$

Where R_k is correlation matrix and P_k is cross correlation matrix.

Substituting the value of $\psi(w_k)$

$$w_{sm} = \psi(M_K w_K + N_K) - \frac{power\{\psi(M_K w_K + N_K) - (M_K w_K + N_K)\}}{\psi(M_K w_K + N_K) - 2\psi(M_K w_K + N_K) + w_k} --(9)$$

if we can replace wk by $M_k W_k + N_k$

$$\psi(M_K w_K + N_K) = M_K(M_K w_K + N_K) + N_K = M_K M_K w_K + M_K N_K + N_K --(10)$$

Substituting the above value on can obtain

$$w_{sm} = M_K M_K w_K + M_K N_K + N_K - \frac{power\{M_K M_K w_K + M_K N_K + N_K - M_K N_K - N_K\}}{M_K M_K w_K + M_K N_K + N_K - 2M_K w_K - 2N_K + w_k} \_\_(11)$$

Simplifying the denominator by cancelling NK,

$$w_{sm} = M_K M_K w_K + M_K N_K + N_K - \frac{power\{M_K M_K w_K + M_K N_K + N_K - M_K N_K - N_K\}}{M_K M_K w_K + M_K N_K - 2M_K w_K - N_K + w_k} -(12)$$

IV. RESULTS

In this section the proposed method is compared with several algorithms namely Least Mean Square (LMS), Recursive Least Square (RLS), Griffiths and finally Variable Step Size Griffiths (VSSG) .

Set Up

Parameter Name	Parameter Value
Type of Antenna	Dipole
Type of Array	Uniform Linear Array
Variability	$-90^0 \le \theta \le 90^0$
Antenna Separation	$\frac{\lambda}{2}$
Noise	Random Noise
Frequency of Operation	1MHz

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A. Parameters for Simulation

1) Radiation Pattern Polar Plots: This determines whether the algorithms are capable of forming the main beam at the look direction an then reduced or zero radiation at interference directions

B. Mean Square Error

Mean Square is defined as the difference between actual signal and total received signal at the base station

$$MSE = |y(n) - s(n)|^2 \;---(13)$$

Where,

$$s(n) = generated\ signal$$

$$y(n) = recieved\ signal\ at\ base\ station$$

C. Root Mean Square Error (RMSE)

If the beam forming algorithm is repeated for a range of angles then the RMSE is the square root sum of all MSE values

$$RMSE = \sqrt{|y_\theta(n) - s_\theta(n)|^2} \;---(14)$$

$$\theta = direction\ of\ desired\ user$$

$$10 \le \theta + 5 \le 70$$

1) Case1: Low RF Elements and Single Interference User

Parameter Name	Parameter Value
Number of Antenna Elements	8
Desired Angle	45
Number of Interference Angle	1
Direction of Interference Angle	60

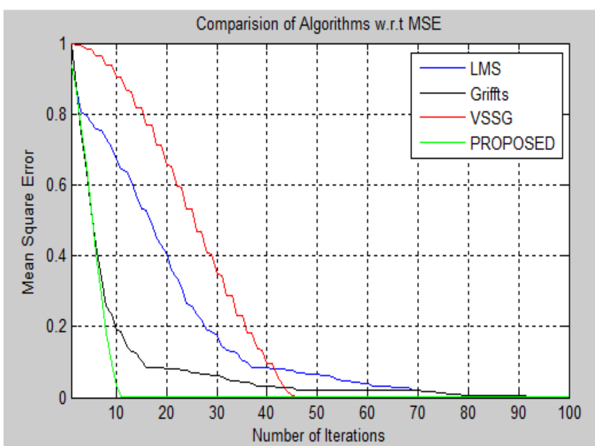

Fig3: MSE Comparison

Fig3 shows the MSE comparison between Proposed Method, LMS, Griffiths and VSSG. Proposed Method has the lowest MSE as compared to VSSG, Griffiths and LMS algorithm. The proposed method also converges at the faster rate.

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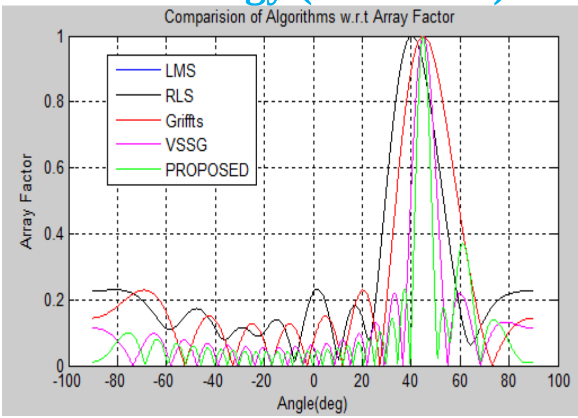

Fig4: Beam forming algorithm

Fig4 shows the radiation pattern for the beam forming algorithms as shown in the fig all the algorithms are capable of forming the main beam towards the desired user. As shown in the fig the proposed method has the sharper beam as compared to other methods.

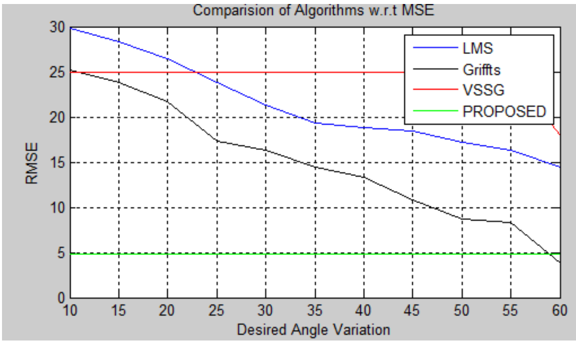

Fig5: RMSE Error

Fig5 shows the RMSE plot, the RMSE of Proposed algorithm is the lowest as compared to VSSG, Griffiths and LMS algorithms.

2) Case2: Low RF Elements and Multiple Interference Users

Parameter Name	Parameter Value
Numberof Antenna Elements	8
Desired Angle	45
Number of Interference Angle	3
Direction of Interference Angle	[10 30 60]

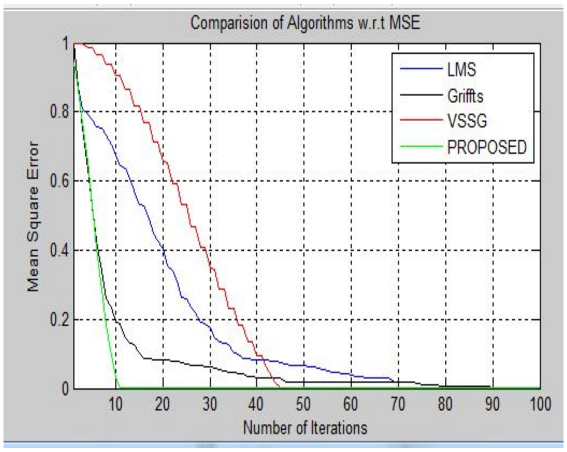

Fig6: MSE for Case2

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Fig6 shows the MSE comparison between Proposed, LMS, Griffiths and VSSG where Proposed method has the lowest MSE as compared to VSSG, Griffiths and LMS algorithm. The Proposed Method has the lowest MSE. For the case of low RF sources and multiple interference angles

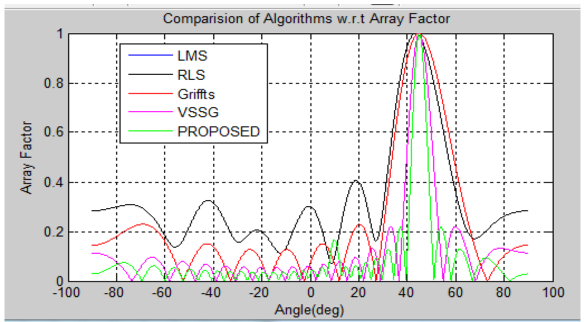

Fig7: Beamforming Algorithm Case2

Fig7 shows the beam forming algorithm where the Proposed method is the best as compared to other 4 algorithms namely VSSG, LMS, RLS and Griffiths.

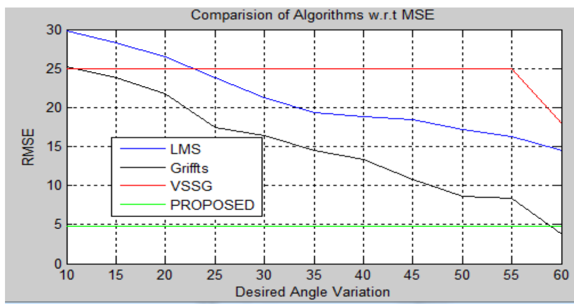

Fig8: RMSE Case2

Fig8 shows the RMSE for VSSG is the best as compared to LMS and Griffiths.

3) Case3: Large RF Elements and Single Interference User

Parameter Name	Parameter Value
Number of Antenna Elements	100
Desired Angle	30
Number of Interference Angle	1
Direction of Interference Angle	45

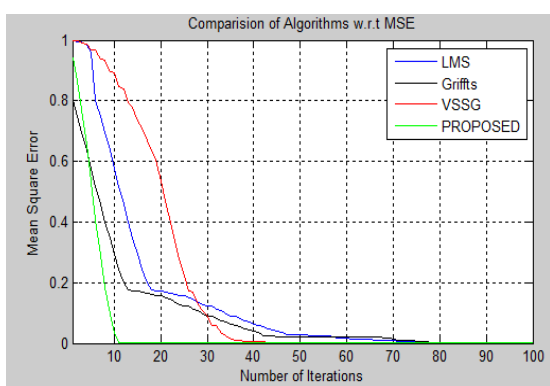

Fig9: Performance MSE Case3

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Fig9 shows the MSE Performance where the proposed method converges for around 10 iterations followed by VSSG converges for about 22 iterations as compared to LMS and Griffiths.

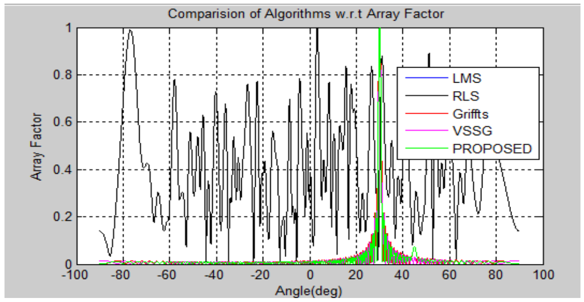

Fig10: Beam forming Algorithm Comparison Case3

Fig10 shows the radiation pattern as shown in the fig the RLS algorithm performance is worst as compared to the remaining algorithms and also the beam is becoming sharper for other algorithms as number of antennas increases.

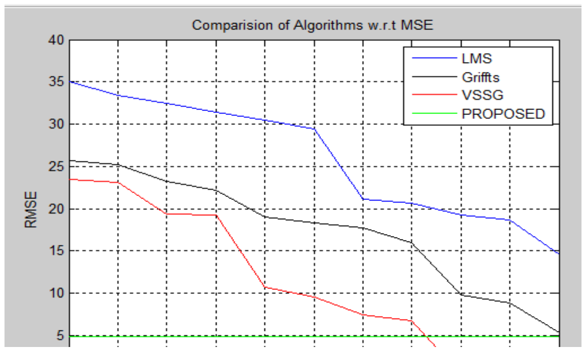

Fig11: RMSE Algorithm Results Case3

Fig11 shows the RMSE comparison the proposed is lowest followed by VSSG, Griffiths and last is LMS.

4) *Case4: Large RF Elements and Multiple Interference Users*

Parameter Name	Parameter Value
Number of Antenna Elements	100
Desired Angle	30
Number of Interference Angle	3
Direction of Interference Angle	[10 45 60]

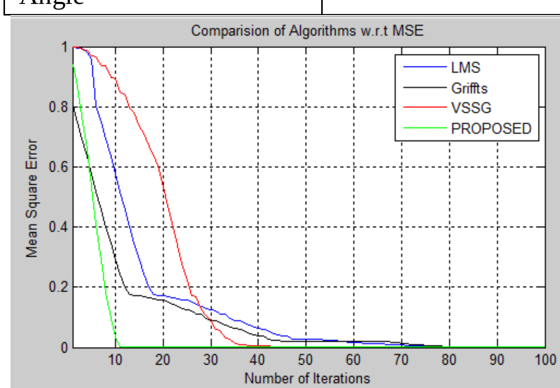

Fig12: MSE Performance Analysis Case4

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Fig12 shows the MSE Performance where the proposed method converges for 10 iterations then VSSG converges for about 22 iterations as compared to LMS and Griffiths. VSSG performs better than LMS and Griffiths.

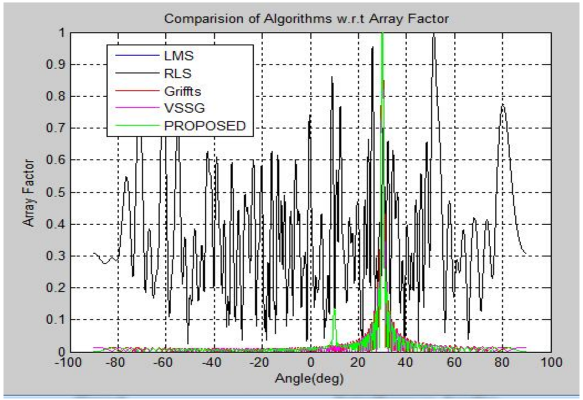

Fig13: Beam Forming Performance Analysis Case4

Fig13 shows the beam forming plots comparison where the Proposed method, VSSG, LMS and Griffths are better as compared to RLS Algorithm

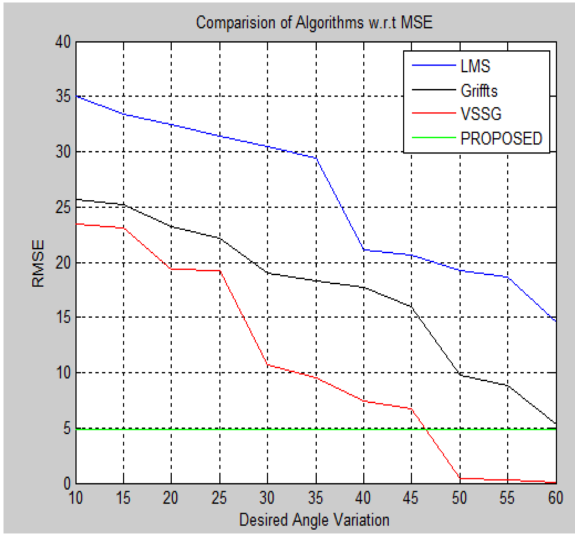

Fig14: Performance RMSE Case4

Fig14 shows the Performance of Proposed method algorithm is best as compared to VSSG, LMS and Griffiths for the case of large elements and multiple interference angles.

V. CONCLUSION

From the simulation results for the various cases the following conclusions can be drawn.

Algorithm Name	Convergence point
LMS	80
Griffiths	80
VSSG	45
Proposed	10

From the above table one can find that the LMS and Griffiths algorithm converges for 80 iterations, VSSG convergences for 45 iterations and Proposed method converges for 10 iterations

A. Case1: Low RF Sources and Single Interference Angle.

1) The MSE of Proposed Method is the best followed by VSSG, Griffiths and last is the LMS
2) The Beam forming works in a nice manner for all the 5 algorithms namely Proposed, LMS, RLS , Griffiths and VSSG
3) The RMSE of Proposed is the best as compared to all the remaining algorithms namely VSSG, LMS and Griffiths

B. Case2: Low RF Sources and Multiple Interference Angles.

1) The MSE of Proposed method is the best followed by VSSG, Griffiths and last is the LMS
2) The Beam forming works in a nice manner for all the 5 algorithms namely Proposed, LMS, RLS, Griffiths and VSSG
3) The RMSE of Proposed Method is the best as compared to all the remaining algorithms namely VSSG, LMS and Griffiths

C. Case3: Large RF Sources and Single Interference Angle.

1) The MSE of Proposed Method is the best followed by VSSG, Griffiths and last is the LMS
2) The Beam forming works in a nice manner for algorithms namely Proposed Method. LMS, Griffiths and VSSG where as for RLS it is worst
3) The RMSE of Proposed and VSSG are the best as compared to all the remaining algorithms namely LMS and Griffiths

D. Case4: Large RF Sources and Multiple Interference Angles.

1) The MSE of Proposed is the best followed by VSSG, Griffiths and last is the LMS
2) The Beam forming works in a nice manner for algorithms namely Proposed, LMS, Griffiths and VSSG where as for RLS it is worst
3) The RMSE of Proposed and VSSG are the best as compared to all the remaining algorithms namely LMS and Griffiths.

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