



Comparative Analysis of MVDR & RLS Beamforming Algorithm for Smart Antenna

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ABSTRACT: Smart antenna attempt to enhance the received signal, suppress all interfering signals, and increase capacity. Beamforming is one of the mostly used antenna technique. It adjust the radiation beam in one specific direction also reduces multiple access interference. It also reduces common channel interference and multiple path fading, in result it increases capacity of mobile network. In this paper two antenna beam forming algorithms are compared. These two algorithms are Recursive Least Square (RLS) and Minimum Variance Distortionless Response (MVDR). Outputs of these two algorithms are in weights. By using these outputs weights, two parameters i.e. Mean Square Error and Power Beam Width are calculated and two algorithm are compared by this parameters and respective results are discussed.

KEYWORDS:Recursive Least Square (RLS), Minimum Variance Distortionless Response (MVDR), Mean Square Error, Power Beam Width;

I. INTRODUCTION

Beamforming algorithms are used in smart antenna array to find spatial signal signature and to calculate beamforming vectors to track the antenna beam on receiver. Smart antenna increases spectrum efficiency, coverage and channel capacity. It uses many other efficient method with the help of which it can track multiple user, which also reduces interference.

Smart antenna are classified into two types, one is switched beam while other is adaptive array system. Switched beam system uses multiple fixed beams to serve the user in desire directions. In this base station switches between several beams and selects the one who provides best performance and accuracy as the mobile user changes its position through cell [3]. To cover a certain area in a specific direction switched beam system uses multiple arrays. In case of phase shifting network multiple beams are used to search for desire signal in specific area and logic controller is used to control the selection of the beam which is governed by an algorithm. Based on the detection of the detector this algorithm decides and select the strongest signal. But this technique is less efficient in high interference region [2] [11].

Beamforming is a process of adapting magnitude and phase of the signal from every antenna element by the use of product of each user's signal and weight vectors [8]. Beamforming provides narrow beam in desire direction and also it reduces the interference. If arrival angles doesn't change with respect to time then fixed beamforming is used but if it changes then there is need of optimization scheme which will adjusts the weights of the arrival signal iteratively. So this technique intelligently adopts the weight with respect to time, hence called as adaptive beamforming. So in adaptive beamforming weights are adapted with respect to time which separates desired signal from interfering signal and maximizing the SNR ratio and array output [9].

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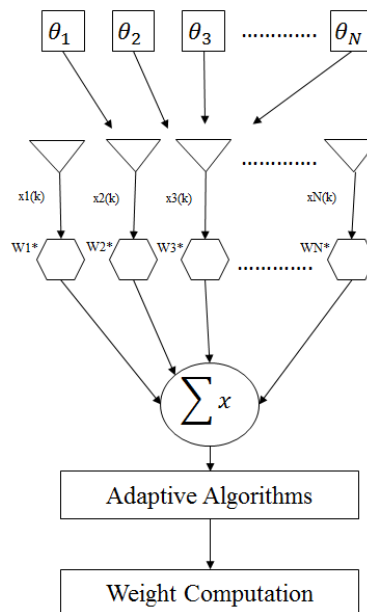


Fig. 1 Block diagram of adaptive beamforming

In adaptive array system strong signals which are capable of dynamically vary the radiation pattern are used by antenna arrays in accordance with the varying environment of the signal. It gives the user maximum radiation in desired direction and also nullify interference.[1].

Blind and non-blind are two types of adaptive algorithms. In non-blind algorithms pilot signal is required to detect the desired signal, which also updates the complex weights. Non-blind algorithm are LMS, RLS and MVDR. Blind algorithms are opposite to non-blind algorithms, it doesn't required pilot signal to find complex weights. Blind algorithms are CMA, Spectral Self-Coherence Restoral (SCORE) and Decision Directed algorithm (DD) [8] [15].

A. Recursive Least Square Algorithm (RLS):

To calculate weight vectors $w(k)$, RLS algorithm uses method of Least Squares. In RLS weight vector is selected to reduce the cost function which includes sum of error squares over a time window. Weights are calculated using following equations;

$$R^{-1}(0) = \delta^{-1}I,$$

Where δ is small positive constant and I the $N * N$ identity matrix.

for each k

$$\begin{cases} k(k) = R^{-1}(k-1) x(k) \end{cases}$$

$$g(k) = k(k) / (\lambda + x^H(k)k(k))$$

$$R^{-1}(K) = \frac{1}{\lambda} [R^{-1}(k-1) - \frac{K(k)k^H(k)}{\lambda + x^H(k)g(k)}]$$

$$e(k) = \delta(K) - w^H(k)X(k)$$

$$W(k+1) = w(k) + e(k)g(k)$$



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Where $x(k)$ = input data vector,

$w(k)$ = weight vector,

$e(k)$ = error signal,

k = block length

μ = step size.

$g(k)$ = direction vector

λ is forgetting factor or weighting factor. Its value is such that, $0 \leq \lambda \leq 1$ which shows that it is a positive constant. $\lambda = 1$ indicates infinite memory and also ordinary least square algorithm is restored [5] [6] [10].

B. MVDR:

One of the beamforming algorithm used in smart antenna is MVDR. In MVDR desired signal is determine by using calculated weight vector from interference. More specifically MVDR provides maximum sensitivity in only one direction. MVDR beamformer is also known as Capon beamformer because it minimizes the output power of the beamformer depending upon the response of the array towards the desired signal [12].

For weight vector calculation the MVDR beam former algorithm does not require knowledge of the direction of the interference. It only takes the value of direction of desired signal. MVDR weight vector is given by:

$$W_{MVDR} = \frac{R^{-1}a(\theta)}{a^H(\theta)R^{-1}a(\theta)}$$

Where R is covariance matrix should be $(N,1)$ for receive signal. H is the hermitian matrix and $a(\theta)$ is the steering vector which is given by;

$$a(\theta) = \begin{bmatrix} 1 \\ \exp\left\{j\frac{2\pi}{\lambda}(\sin\theta_i)d\right\} \\ \exp\left\{j\frac{2\pi}{\lambda}(\sin\theta_i)(N-1)d\right\} \end{bmatrix}$$

Where d is the space between the elements of the antenna, θ_i is the desired angle, and N is the number of elements [7] [13] [14] [16].

Step 1: Calculating Transmission Energy:

The transmission energy (TE_{node}) of each node relative to its distance with another node is calculated by using eq.(1)[8].

$$\begin{aligned} TE_{node} &= \alpha d^n \\ TE_{node} &= k d^n \end{aligned} \quad \text{eq. (1)}$$

where k is constant and n is path loss factor which is generally between (2-4) [8].

II. SIMULATION RESULT

Simulation for an adaptive antenna array is done in MATLAB software. In simulation we analyse radiation patterns, mean square error and power beamwidth for adaptive beamforming algorithms RLS and MVDR. The parameters used for our simulation are shown in Table 1.

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TABLE 1: SIMULATION PARAMETERS

Number of antenna elements(N)	10
Element Spacing(d)	0.5λ
Noise Variance(σ)	0.001
Total number of data sample(K)	50
Forgetting factor (α) for (RLS)	0.9
DOA of desired signal	0°
DOA of interferer signal(I_1)	-30
DOA of interferer signal(I_2)	-60
DOA of interferer signal(I_3)	45

In Figure 2-11, radiation patterns of the two algorithms are shown. Firstly 'N' is kept constant at 8 and value of 'd' is varied in two values 0.25 and 0.5. Then value of 'd' is kept constant at 0.5 and value of 'N' varied in three values 8, 10. It can be seen that RLS algorithm is the best choice among the two algorithms because it has least power in the side lobes and has narrowest beamwidth.

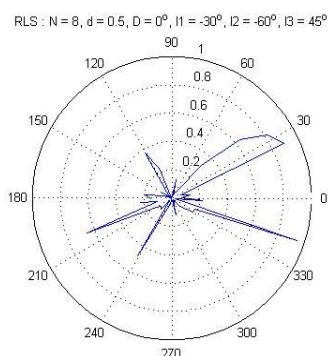


Fig. 2 for d=0.5(RLS)

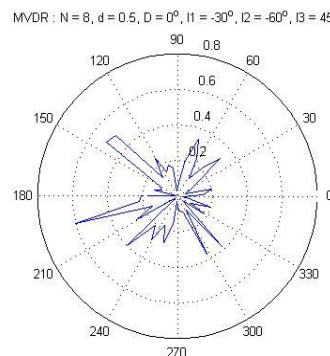


Fig. 3 for d=0.5(MVDR)

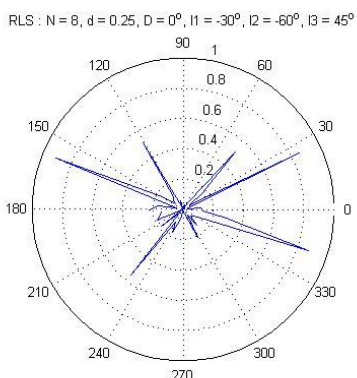


Fig. 4 for d=0.25(RLS)

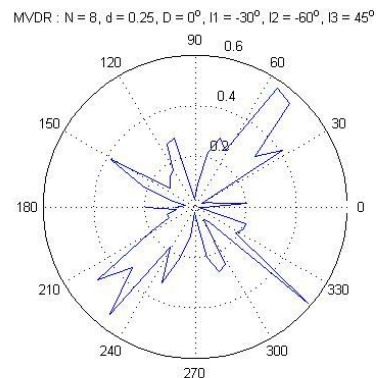


Fig. 5 for d=0.25(MVDR)

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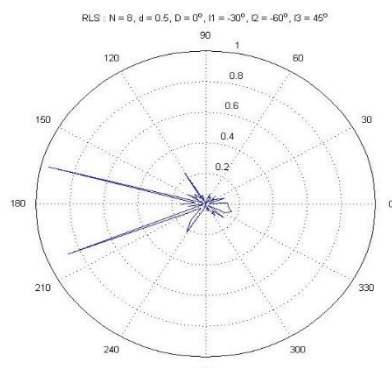


Fig. 6 for N=8 (RLS)

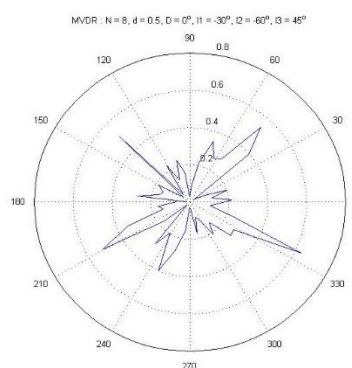


Fig. 7 for N=8 (MVDR)

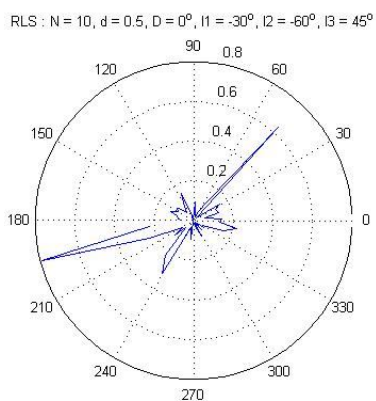


Fig. 8 for N=10 (RLS)

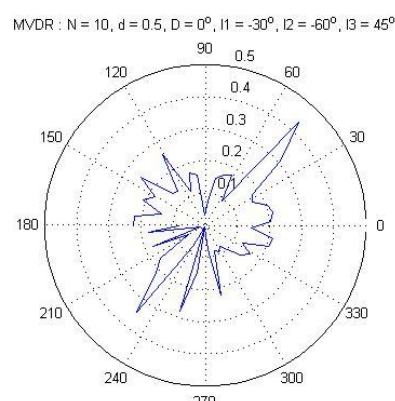


Fig. 9 for N=10 (MVDR)

In Figure 12-21, mean square error of the two algorithms are shown. Firstly 'N' is kept constant at 8 and value of 'd' is varied in two values 0.25 and 0.5. Then value of 'd' is kept constant at 0.5 and value of 'N' varied in three values 8, 10, and 12. It can be seen that mean square error for MVDR is constant in all the cases, while it became zero in first iteration in case of RLS.

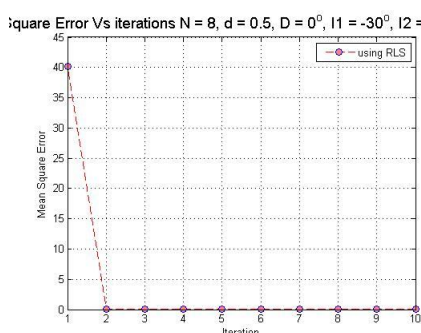


Fig. 10 for d=0.5(RLS)

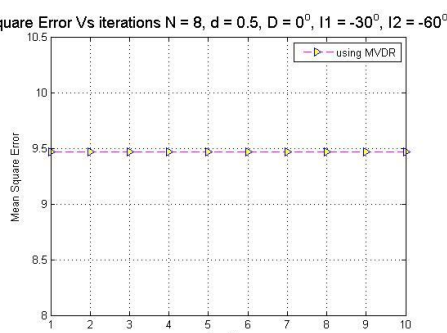


Fig. 11 for d=0.5(MVDR)

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quare Error Vs iterations N = 8, d = 0.25, D = 0°, I1 = -30°, I2 = -60°

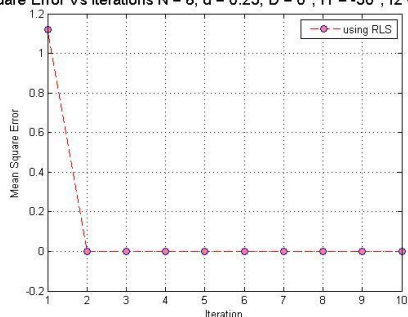


Fig. 12 for d=0.25(RLS)

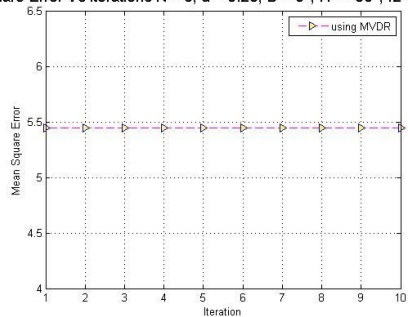


Fig. 13 for d=0.25(MVDR)

quare Error Vs iterations N = 8, d = 0.5, D = 0°, I1 = -30°, I2 = -60°

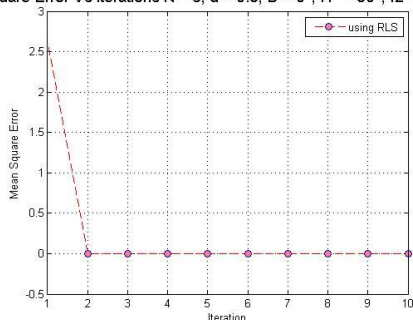


Fig. 14 for N=8(RLS)

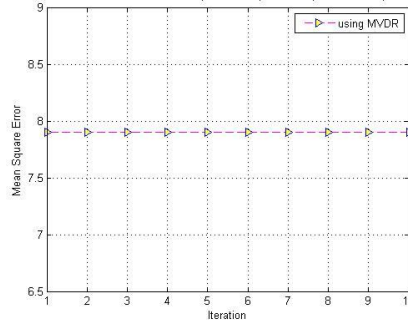


Fig. 15 for N=8(MVDR)

quare Error Vs iterations N = 10, d = 0.5, D = 0°, I1 = -30°, I2 = -60°

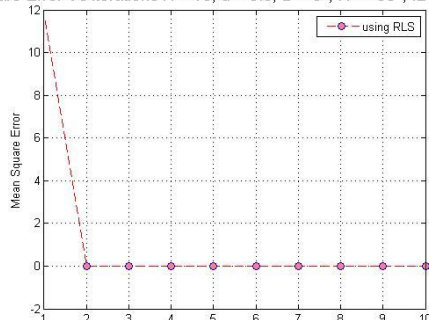


Fig. 16 for N=10(RLS)

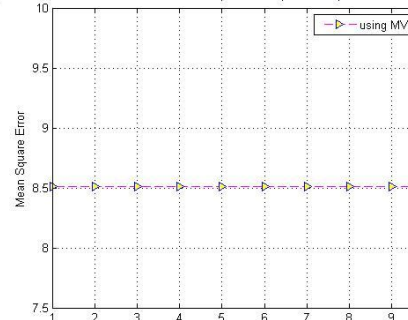


Fig. 17 for N=10(MVDR)

In figure 20-24, power beamwidth of two algorithms are shown. Firstly 'N' is kept constant at 8 and value of 'd' is varied in two values 0.25 and 0.5. Then value of 'd' is kept constant at 0.5 and value of 'N' varied in three values 8, 10.

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Power Beam Width N = 8, d = 0.5, D = 0°, I1 = -30°, I2 = -60°, I3 = 0° Power Beam Width N = 8, d = 0.25, D = 0°, I1 = -30°, I2 = -60°, I3 = 0°

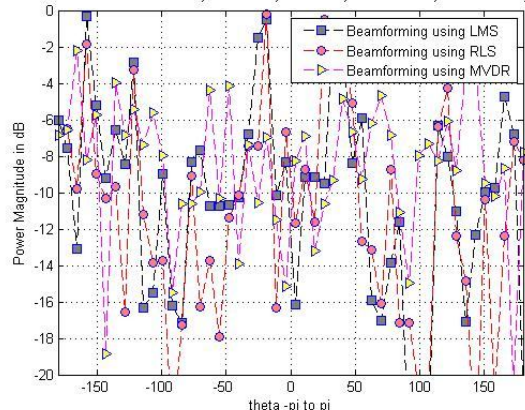


Fig. 18 for d=0.5

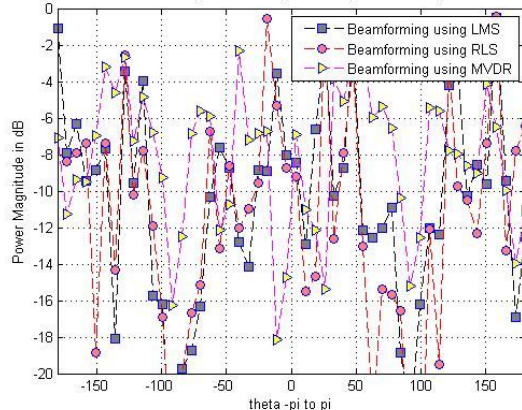


Fig. 19 for d=0.25

Power Beam Width N = 12, d = 0.5, D = 0°, I1 = -30°, I2 = -60°, I3 = 0° Power Beam Width N = 10, d = 0.5, D = 0°, I1 = -30°, I2 = -60°, I3 = 0°

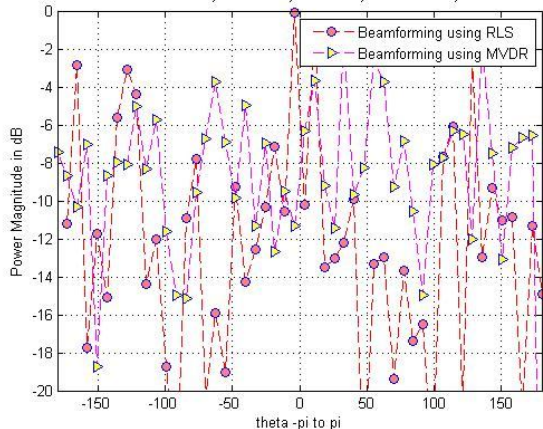


Fig. 20 for N=8

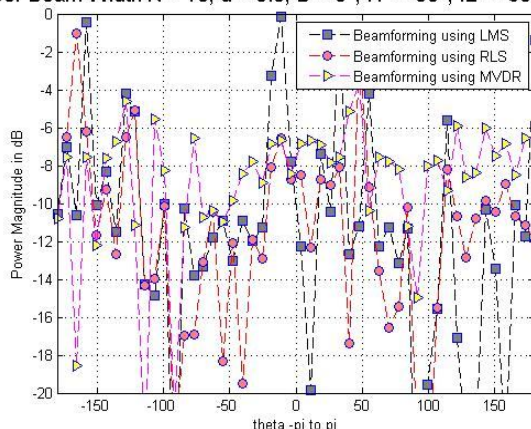


Fig. 21 for N=10

III. CONCLUSION AND FUTURE WORK

In smart antenna adaptive algorithms are used to control radiation pattern. Adaptive algorithm dynamically optimizes the radiation pattern according to the changing electromagnetic environment. Here we analyse two popular adaptive techniques RLS and MVDR through simulation of various parameters like radiation pattern, mean square error and absolute weights. Comparative analysis of the two algorithms

RLS have narrowest beamwidth, complete rejection of interference and fastest convergence at the cost of high computational burden but has greater power in side lobes. RLS is the best choice where quick tracking of the signal is required. MVDR beamforming requires only desired user direction. It produces the undistorted output with unity gain in desired direction and nulls in direction of interferences. It is not suitable for multipath arrivals as it produces beam only in one desired direction and cancel out signals in other directions.

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