# Performance Evaluation of the RLS Adaptive Beamforming Algorithm

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***Abstract*- The Recursive Least Square algorithm optimization method used in this paper for the synthesis of antenna array radiation pattern in adaptive beam forming. In this paper optimum value of weights of each antenna element is determined which produces radiation pattern with minimum side lobe level. Optimization is done using 8-elements array with an optimum inter-element spacing to avoid grating lobes. Simulation is done in MATLAB and can be taken into consideration, to obtain the desired beam in the lookup direction.**

*Keywords*—**RLS algorithm, array processing, adaptive array beam forming**

## I. INTRODUCTION

The term “smart antenna” generally refers to any antenna array, terminated in a sophisticated Signal processor, which can adjust or adapt its own beam pattern in order to emphasize signals of interest and to minimize interfering signals [1]. Numbers of array elements are used for the design of smart antenna and can be modified to give different radiation pattern in look up direction. The antenna array is a configuration of multiple antennas (elements) arranged to achieve a given radiation pattern and employs adaptive beam forming algorithms for recognize, track and suppress the interference. By combining the signals incident on the linear antenna array and by knowing their directions of arrival, a set of weights can be adjusted to optimize the radiation pattern. The adaptive algorithm allows for the calculation of continuously updated weights.RLS is one of the adaptive algorithms.Which also use weight updating technique. The performance of these adaptive algorithms is highly dependent on their filter order and signal condition. The performance of RLS algorithm, is depended on λ (commonly known as “forgetting factor” or exponential weighting factor” [2]).In adaptive beamforming, the radiation pattern of smart antenna is controlled through various adaptive algorithms. Adaptive algorithm dynamically optimizes the radiation pattern according to the changing electromagnetic environment. The number, geometrical arrangement, and relative amplitudes and phases of the array elements depend on the angular pattern that must be achieved. The array factor of a linear array is N (even) identical elements with uniform spacing. The combined relative amplitude and phase shift for each antenna is called a “complex weight” [3]. These weights are calculated using different algorithms. After every iteration weights present in adaptive array are being updated .After the number of iteration the weights are obtain which gives the desired narrow beam.

Adaptive array systems as shown in fig. 1 use antenna arrays controlled by strong signal process capability to dynamically vary the radiation pattern in accordance with the varying environment of the signal. Adaptive array systems provide maximum radiation in user’s direction and also nullify interferences at the same time [2].

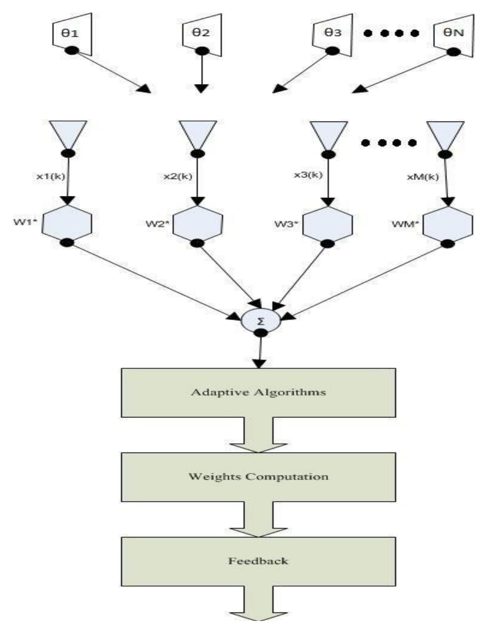


Fig 1. Block diagram for adaptive beamforming

III. RECURSIVE LEAST SQUARE ALGORITHM

The RLS algorithm recursively finds the filter coefficients that minimize a weighted linear least squares cost function relating to the input signals, i.e., given the least squares estimate of the tap weight vector of the filter at iteration (n-1),we compute the updated estimate of the vector at iteration n upon the arrival of the new data. This, in contrast to LMS algorithm aims to reduce the mean square error. In the derivation of the RLS, the input signals are considered deterministic, while for the LMS, they are considered stochastic. [1-3].Compared to most of its competitors, the RLS exhibits extremely fast convergence due to the fact that the RLS filter whitens the input data by using the inverse correlation matrix of the data, assumed to be of zero mean. However, this benefit comes at the cost of high computational complexity [4].

RLS is a deterministic algorithm in which the performance index is the sum of weighted error squares for the given data. The tap weight vector update equation is, [8]

$$w(n) = w(n-1) + k(n) * e_n(n) \quad (1)$$

Where

$e_{n-1}(n)$ is error estimate given by,

$$e_{n-1}(n) = d_n - y_{n-1}(n) \quad (2)$$

$k(n)$ is gain vector given by,

$$k(n) = \frac{u(n)}{(\lambda + X^T(n) * u(n)} \quad (3)$$

Where

$$\mathrm{u(n)} = \psi\lambda^{-1}(\mathrm{n}-1) * \mathrm{X(n)} \quad (4)$$

Where is updated through the equation

$$\psi\lambda^{-1}(\mathrm{n}) = \lambda^{-1}(\psi\lambda^{-1}(\mathrm{n}-1) - \mathrm{k(n)} * \left(\mathrm{X}^{\mathrm{T}}(\mathrm{n}) * \psi\lambda^{-1}(\mathrm{n}-1)\right) \quad (5)$$

Where λ is known as forgetting factor that determines the emphasis put by the algorithm on the previous samples of the received data [8].

IV Result and Discussion

The performance of beamforming algorithm RLS has been studied by means of MATLAB simulation. In this simulation we have considered three cases with different look direction and interference which gives finest beam. For Simulation the following parameter have been considered

1. Mutual Coupling effects are zero between antenna elements.

2. Distance between antenna elements is λ/2 an optimum value to avoid grating lobes.

3. Number of array elements=8.

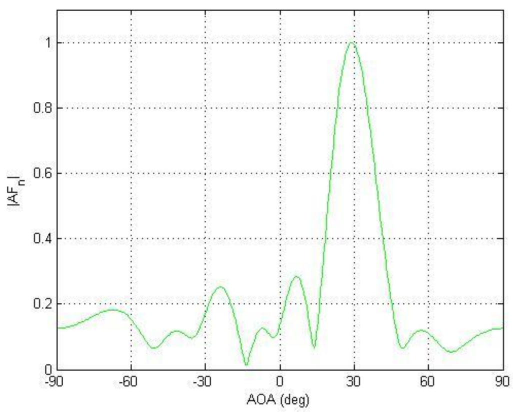
4. Forgetting factor (**λ**) (for RLS) = 0.9

5. Number of data samples: 100

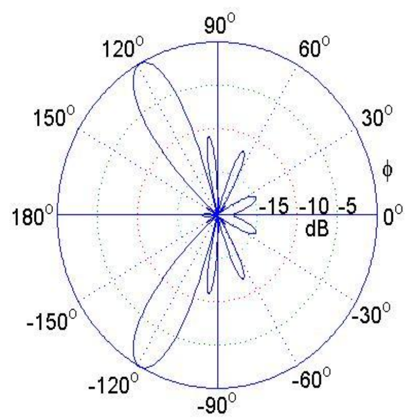
In three different cases the parameters are same and consideration of optimized beam has been done on the basis of their look up direction and interference. In all three cases the direction of arrival for beam is different. According to that the finest beams will is obtain.

**Case (I)**

Beamforming Result for RLS
Direction of Arrival (DOA) = 30 deg
Directions of Interference (DOI) = 70deg




(a)Beam Plot of RLS algorithm

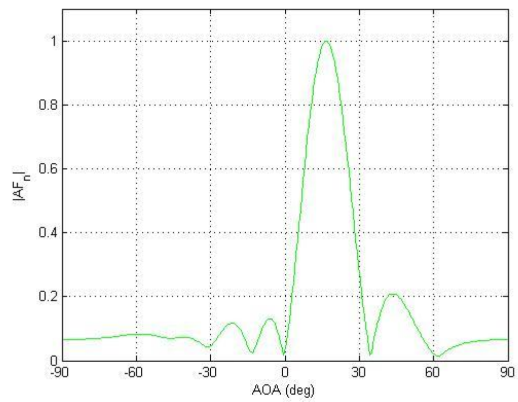



(b)Spatial spectrum with 8 antennas

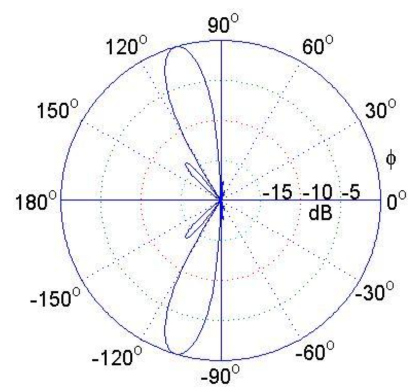
Fig. 2 Radiation pattern of RLS algorithm (When DOA=$30^0$ & DOI=$70^0$)

**Case (II)**

Beamforming Result for RLS
Direction of Arrival (DOA) =-15 deg
Directions of Interference (DOI) = 60deg




(a)Beam Plot of RLS algorithm

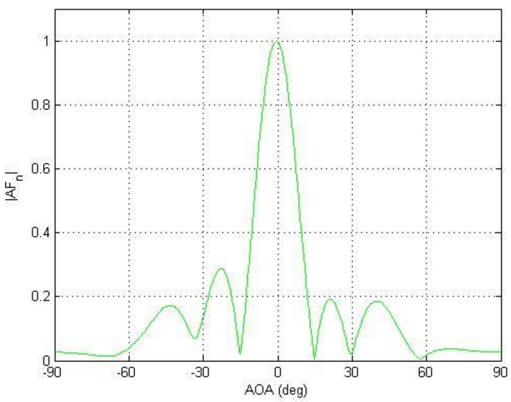



(b)Spatial spectrum with 8 antennas

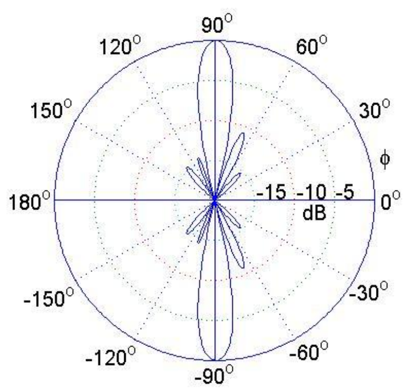
Fig. 3 Radiation pattern of RLS algorithm (When DOA=$15^0$ & DOI=$60^0$)

**Case (III)**

Beamforming Result for RLS
Direction of Arrival (DOA) =-0 deg
Directions of Interference (DOI) = 30deg




(a)Beam Plot of RLS algorithm




(b)Spatial spectrum with 8 antennas

Fig. 4 Radiation pattern of RLS algorithm
(When DOA=$0^0$ & DOI=$30^0$)

In the case study all the three patterns are obtain according to their DOA and DOI given. In comparisons with all the three cases Fig.3 with DOA=$15^0$ & DOI=$60^0$ has sharp beam with no back lobes present .while that of the beam obtain in Fig.4 with DOA=$0^0$ & DOI=$30^0$ and Fig.2 beam with DOA=$30^0$ & DOI=$70^0$ is a sharp beam but with more sidelobes. As per the requirement of low side lobes beam Fig .3 gives the required result.

## IV. CONCLUSION

A number of different cases have been observed keeping different look direction and Interference direction. It is observed that these three cases give the best beam forming pattern using RLS algorithm. An approach has been accomplished to obtain complex weights through RLS algorithm. Among three cases the weights obtain by beam with DOA=$15^0$ & DOI=$60^0$ in Fig.3 show the best result with no back lobes. This can be further used for optimization of beamforming in the desired direction by steering the beam and reducing the interference by comparing the weights with the different algorithm.

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