Performance Analysis of LMS Adaptive Beamforming Algorithm for Smart Antenna System

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ABSTRACT
As the growing need for wireless communications is constantly increasing, the demand for better coverage, enhance user capacity, and higher transmission quality rises. To provide interference mitigation and enhance user capacity the smart antenna system is one of the promising technologies. This paper presents performance analysis of LMS (Least Mean Square) adaptive beamforming algorithm for smart antenna system. Use different spacing between array element, increase number of array elements and also use different array geometry i.e. linear array, circular array, and planar array. Simulation is done by using MATLAB software.

Keywords
Smart antenna, Adaptive beamforming, LMS

1. INTRODUCTION
In modern era, there are many innovations related to the applications of wireless services increases all over the world; hence the numbers of users are rises. This has produced the need of wider service area and higher data rates to satisfy the each users need. Demanding of higher coverage and data rates can be achieved using smart antenna (SA) system. Smart antenna system consists of array antenna and signal processing ability to reject interfere signal. In the view of fact that today's evolution of powerful digital signal processor and MATLAB software based algorithms makes the smart antenna systems accepted commercially. In Smart antenna system the optimum weights for array antenna elements are computed using algorithm for different parameters. According to the processed and calculated weights array antenna generates the radiation pattern in which the main lobe of radiation pattern is in the direction of the desired user and generate the null in the direction of the undesired users. Thus smart antenna eliminate the interfere and enhancing the desired user by providing the increase gain. In this paper, LMS (Least Mean Square) algorithms are used to achieve the complex optimum weights of the array elements. The performance of the algorithm is investigated in terms of parameters related to radiation pattern like side lobe level and beam width for uniform linear array antenna in specific signal environment.

Section 2 gives Smart antenna. In Section 3 discuss Adaptive beamforming, Section 4 gives Array Geometry, Section 5 gives LMS algorithm, then Section 6 gives Simulation setup and Results, And 7 gives Conclusion and future work. Section 8 shows references.

2. SMART ANTENNA
Smart antenna is subdivided in two types first one is switch beamforming. Switch beamforming contain set of radiating elements which are arranged in the form of array. By combining that array elements form a switchable beam pattern that follows the desired user. Smart antenna is antenna which can adjust or adapt its own beam pattern in particular direction with minimizing interference from undesired user. Smart antenna has two objective DOA (direction of arrival estimation) and beamforming [7].The process of combining the signals and then focusing the radiation pattern in a particular direction called as digital beamforming [3],[4],[8].Most advanced type of smart antenna is "adaptive beamforming". Adaptive Beamforming uses antenna arrays backed by strong signal processing capability to automatically change the beam pattern in accordance with the changing signal environment. Forming beam in desired direction and nulling the pattern in undesired direction. It is obtain by continuously multiplying the incoming signal with complex weights and then summing them together to obtain the desired radiation pattern. These weights are computed by using different adaptive beamforming algorithms [7]. So for adaptive beamforming adaptive algorithms are very important.

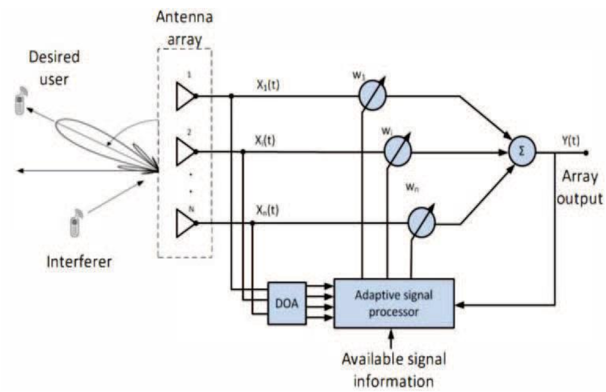
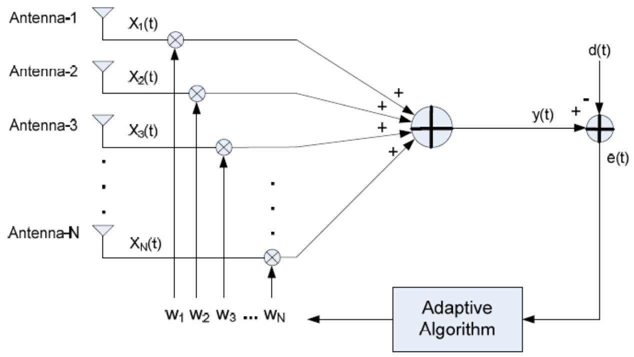


Fig 1: Smart Antenna System

3. ADAPTIVE BEAMFORMING
An adaptive beamformer is a device that is able to separate signals collected in the frequency band but separated to the spatial domain. This provides means for separating a desired signal from interfacing signal. An adaptive beamformer able to automatically optimize the array pattern by adjusting the elemental control weights until prescribed objective function is satisfied. The means by which the optimization is achieved is specified by an algorithm designed for that purpose.

Traditionally adaptive beamforming has been employed primarily in sonar, radar system. It started with the invention of the intermediate frequency side lobe canceller in 1959 by Howells [3]. The concept of a fully adaptive array developed in 1965 by Applebaum. He derived control law governing operation. This algorithm is based on the general problem of maximization of SNR at the array output. The SLC was included as a special case in Applebaum's work. Another independent approach to adaptively uses the least mean squares (LMS) algorithm, which was invented by Widrow and Hoff.



. **Fig 2: Adaptive beamforming**

In this figure uniform linear array antenna receive the incoming signal x(t).Then input signal multiplied with weight factor W, which basically modify the phase and amplitude of incoming signal x(t).This modified weighted signals are added together and give the output signal y(t). Then adaptive beamforming algorithm is used to observe the error between output signal y(t) and reference signal d(t).The e(t) is the error between output signal y(t) and reference signal d(t) so, minimizing this error adaptive algorithm updating the weight vector.

4. ARRAY GEOMETRY

4.1 Uniform linear array

Array Factor

$$AF = \sum_{n=0}^{N-1} W_n e^{jnkd\cos\theta} \tag{1}$$

Where

Wn=Complex array weight at element n,

Ɵ =angle of incidence of electromagnetic plane wave from array axis.

K =Wave number (2π/λ).

λ = Wavelength.

d = Inter-element spacing.

4.2 Uniform circular array

Array Factor

$$AF = \sum_{n=1}^{N} W_n e^{-j(ka\hat{\varrho}\hat{r}+\delta_n)}$$
$$= \sum_{n=1}^{N} W_n\, e^{-j(ka\sin\theta\cos(\emptyset-\emptyset_n)+\delta_n)} \tag{2}$$

Where

Wn =excitation coefficients (amplitude and phase) of nth element. [2]

Øn=2π (n/N) = angular position of each element on x-y plane.

4.3 Planar array

Array Factor

$$AF = \sum_{m=1}^{M}\sum_{n=1}^{N} w_{mn} e^{j[(m-1)(kd_x\sin\theta\cos\emptyset+\beta_x)+(n-1)(kd_y\sin\theta\sin\emptyset+\beta_y)]}$$

Where (3)

$$\beta_x = -kd_x \sin\theta_0\cos\emptyset_0$$
$$\beta_y = -kd_y \sin\theta_0\sin\emptyset_0$$

5. LMS ALGORITHM

Least mean square algorithm is first type of non blind algorithm; it was first developed by Widrow and Hoff [2],[3]. The design of this algorithm was stimulated by the Wiener-Hoff equation. This algorithm is based on gradient approach, uses to estimate of the gradient vector from the available data. LMS algorithm does not require correlation function calculation and also not require matrix inversions so as compared to other adaptive beamforming algorithm LMS algorithm is relatively simple. Following are the steps for LMS algorithm [7].

$$e(t) = d(t) - y(t) \tag{4}$$

The output signal y(t) is,

$$y(t) = w^H * x(n) \tag{5}$$

The weight vector w shown in the above equation is a complex vectors. The LMS algorithm the weight vector update according to the instantaneous gradient vector$\nabla J(n)$. The updated value of the weight vector w is written as,

$$w(n+1) = w(n) + \frac{1}{2}\mu[-\nabla J(n)] \tag{6}$$

In above equation μ is the step sizes which regulate the speed of convergence. The value of step size μ is very small generally varies between 0 and 1. Initial value of the covariance matrix R and the cross-correlation vector r requires computing the precise value of instantaneous gradient vector. So the gradient vector is given by,

$$\nabla j(n) = -2r(n) + 2R(n) * w(n) \tag{7}$$

Where $R(n) = x(n) * x^H(n)$ (8)

$$r(n) = d^*(n) * x(n) \tag{9}$$

The weight vector is

$$w(n+1) = w(n) + \mu[-r(n) + R(n) * w(n)] \tag{10}$$

$$w(n+1) = w(n) + \mu[d^*(n) - x^H(n) * w(n)] \tag{11}$$

$$w(n+1) = w(n) + \mu[x(n) * e^*(n)] \tag{12}$$

In equation (12) convergence of the LMS algorithm is directly proportional to the step-size parameter μ. The convergence speed of LMS calculations relies upon step size μ and remains stable at,

$$0 < \mu < \frac{1}{\lambda_{max}}$$

λ_{max} is maximum eigenvalue of the correlation matrix R which is the boundary for step size value. If the value of step size μ is very small then the convergence speed of algorithm is slow [2]. And for large value of μ speed of convergence is fast but it may be less stable around the minimum value [7].

6. SIMULATION RESULT

In this section, MATLAB platform is used to process the results of the adaptive beamforming LMS algorithm discussed in section 5.

6.1 LMS for different spacing between array elements

Rectangular plots are given, which are DOA=30°, DOI=10° Number of Array Elements N = 8

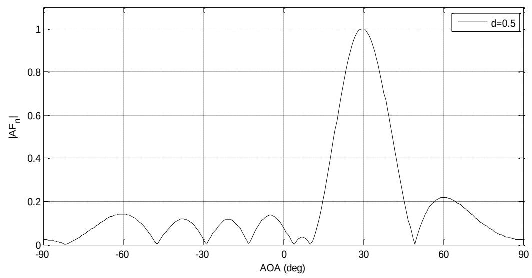


Fig 3: Angle of arrival vs. array factor: Beam steered at 30° (Signal of interest) and interferer nulled at 10° using LMS algorithm for d=0.5

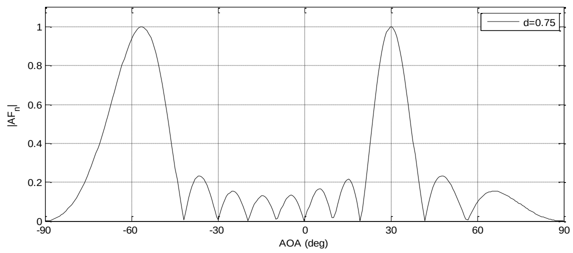


Fig 4: Angle of arrival vs. array factor: Beam steered at 30° (Signal of interest) and interferer nulled at 10° using LMS algorithm for d=0.75

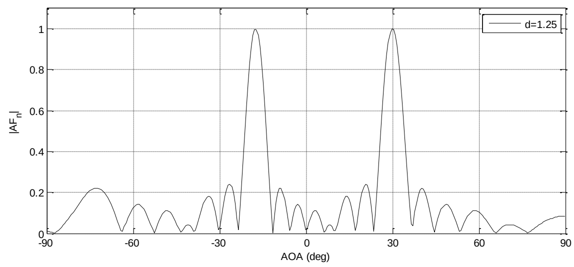


Fig 5: Angle of arrival vs. array factor: Beam steered at 30° (Signal of interest) and interferer nulled at 10° using LMS algorithm for d=1.25

Simulation results of Angle of arrival vs. array for different inter element spacing is shown in the Fig. 3, 4 and 5. This shows that when increase spacing between elements beam width becomes narrower but for higher values sidelobe level. So consider the most appropriate separation distance between two antenna elements is d= 0.5 λ.

6.2 LMS for different number of array elements

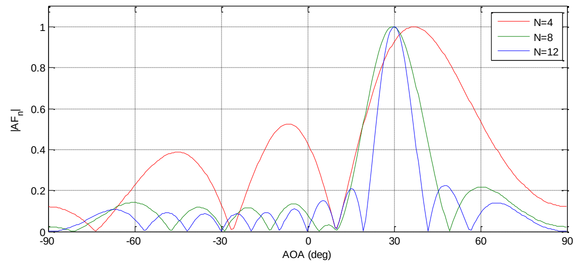


Fig 6: Angle of arrival vs. array factor: Beam steered at 30° (Signal of interest) and interferer nulled at 10° using LMS algorithm for N=4, N=8 and N=12

In Fig 6 simulation is carried out for different cases, number of elements of array are considered as N=4, 8 and 12. The inter-element spacing is considered to be d=0.5 and step size is μ=0.01. Signal of desired user is arriving at an angle of 30° and interfere signal is arriving at an angle of 10°. In this when increase number of elements beamwidth becomes narrower and also sidelobes are decreases.

6.3 LMS for different array geometry

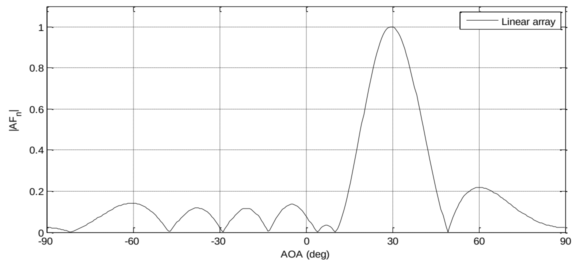


Fig 7: Angle of arrival vs. array factor: Beam steered at 30° (Signal of interest) and interferer nulled at 10° using LMS algorithm for uniform linear array

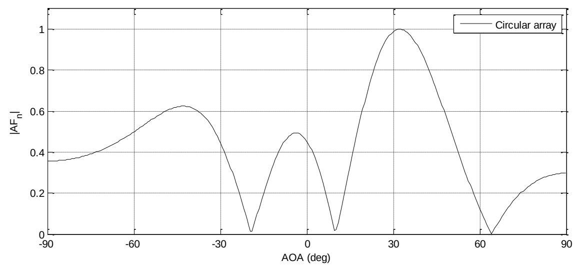


Fig 8: Angle of arrival vs. array factor: Beam steered at 30° (Signal of interest) and interferer nulled at 10° using LMS algorithm for uniform circular array

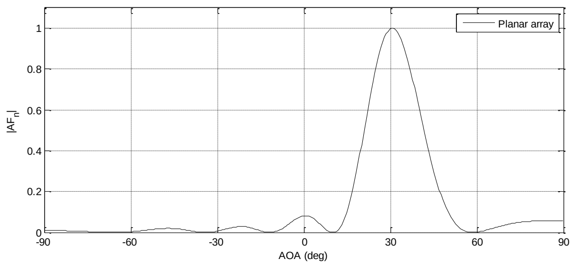


Fig 9: Angle of arrival vs. array factor: Beam steered at 30° (Signal of interest) and interferer nulled at 10° using LMS algorithm for uniform planar array

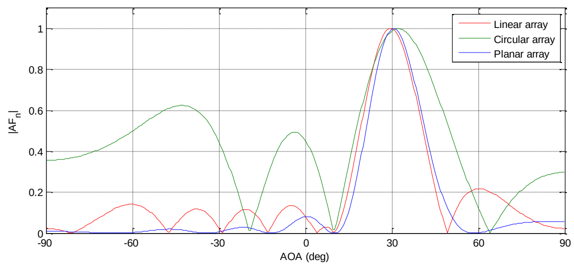


Fig 10: Angle of arrival vs. array factor: Beam steered at 30° (Signal of interest) and interferer nulled at 10° using LMS algorithm comparison with different array geometry

Figure 7 shows result of LMS with using linear array with N=8 and d=0.5. In this beamwidth is narrower and also sidelobes are also less. In figure 8 with using circular array beamwidth is becomes wider and side lobes are also increases. Figure 9 shows result of rectangular planar array. Beamwidth of planar array is narrower than linear array and circular array. And also sidelobes decreases than other geometry. Result of figure 10 shows comparison between array geometry. In this planar array geometry gives good array factor compare to other geometries.

7. CONCLUSION AND FUTURE WORK

LMS algorithm is type of non blind adaptive beamforming. The simulation results of LMS algorithm is presented in above section. In this first simulation is done using different spacing between array elements. This shows that when increase spacing between elements beam width becomes narrower but for higher values sidelobe level. So consider the most appropriate separation distance between two antenna elements is d= 0.5 λ for LMS algorithms. Next shows result of LMS algorithm with increase the number of array elements i.e. N=4, N=8, N=12. So, when increase number of elements beamwidth becomes narrower and also sidelobes are decreases. Next figures shows simulation result of LMS for different array geometry i.e. linear array, circular array, and rectangular planar array. In this beamwidth of planar array is narrower than linear array and circular array. And also sidelobes decreases than other geometry. Comparison between this array geometry shows planar array geometry gives good array factor compare to other geometries.

Adaptive beamforming algorithms improve the directivity of antenna. In future, these beamforming algorithms can be implemented for Smart antenna system .Also these algorithms can be implemented for other applications such as SONAR, RADAR etc. Further, simulation results can be tested for different channels such as Racian and Rayleigh Channel.

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