NON-BLIND ADAPTIVE BEAM FORMING ALGORITHMS FOR SMART ANTENNAS

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ABSTRACT
The number of mobile users are increasing tremendously all over the world .It is necessary to increase the channel bandwidth and capacity and at the same time minimize the channel interference .Smart antennas are considered as an effective counter measure to achieve these requirements because they offer wide bandwidth, less electromagnetic interference, flexibility, less weight, high speed, phase control independent of frequency and low propagation loss .Smart antennas combine the antenna array with signal processing to optimize automatically the beam pattern in response to the received signal. Beam forming can be used for either radio or sound waves; it has found numerous applications in radar, sonar, seismology, wireless communications, radio astronomy, speech and biomedicine.This paper discuss about two non-blind beam forming algorithms i.e Least Mean square(LMS) and Normalized Least Mean Square (NLMS) algorithms. The algorithms are compared using MATLAB.

keywords: *Beam forming, Smart Antennas, LMS, NLMS.*

1. INTRODUCTION

As the number of users and demand for wireless services are increasing at an exponential rate, the need for wider coverage area, improved capacity and higher transmission quality rises. Thus a more effective use of the radio spectrum is required. A Smart antenna system are capable of efficiently utilizing the radio spectrum and is a promise for an effective solution to the present wireless systems problems while achieving reliable and robust high speed high data rate transmission.

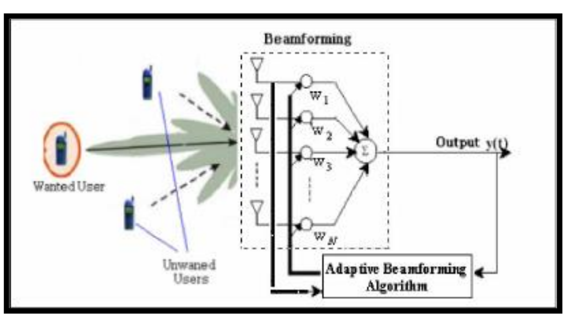
The two main functions of Smart antennas are :

1. Direction of arrival .
2. Adaptive Beam forming.

In this project antenna array with adaptive beam forming technique is used to achieve the high capacity, wider coverage and efficient spectrum utilization, by using the smart signal processing algorithms such as 1.Least mean square algorithm 2. Normalized least mean square algorithm. These adaptive signal processing algorithms shape the beam of array antennas for more directives in signal of interest and nullify the signal not of use.The NLMS algorithm has better performance in robustness, convergence rate, computational complexity compared to LMS and also perform in less time.

1.2. Blind and Non-Blind Algorithm

In Blind algorithms training signal d(t), is not used where as in Non blind algorithm signal d(t), known to both the transmitter and receiver during the training period .



The beam former in the receiver uses the information of the training signal to compute the optimal weight vector. After the training period, data is sent and the beam former uses the weight vector computed previously to process the received signal. Typical non blind algorithms used are least mean square(LMS), Normalized Least mean square(NLMS).

2. LEAST MEAN SQUARE (LMS) ALGORITHM

The Least mean square algorithm is a gradient based quadratic approach. Gradient algorithms assume an established quadratic performance surface which is a function of the array weights, the Performance surface J(W') is in the shape of an elliptic parabola having one minimum. One of the best ways to establish the minimum is through gradient method. We can establish the performance surface (cost function) by again finding the MSE. Therefore, the spatial filtering problem involves estimation of signal from received signal(i.e., the array output). by minimizing error between the reference signal d(t)(which closely matches or has some extent of correlation with the desired signal estimate) and the beam former output y(t) equal to Wx(t). This is a classical wiener filtering problem for which solution can be iteratively found using the LMS algorithm. The signal x(t) received by multiple antenna elements is multiplied with the coefficients in a weight vector w (series of amplitude and phase coefficients) which adjusted the phase and the amplitude of the incoming signal accordingly. The weighted signal is summed up, resulted in the array output

y(t). An adaptive algorithm is then employed to minimize the error e(t) between a desired signal d(t) and the array output y (t) given by linear combination of the data at the k sensors.

Implementation of the LMS algorithm

The least mean square algorithm is a gradient based approach.

The error is given by

$$\varepsilon(k) = d(k) - \bar{w}^H(k)\bar{x}(k) \quad \text{...(eq 2.1)}$$

The squared error is given as

$$|\varepsilon(k)|^2 = \left|d(k) - \bar{w}^H(k)\bar{x}(k)\right|^2 \quad \text{...(eq 2.2)}$$

The cost function is given as

$$J(\bar{w}) = D - 2\bar{w}^H\bar{r} + \bar{w}^H\overline{R}_{xx}\bar{w} \quad \text{...(eq 2.3)}$$

The array correlation matrix (Rxx) is given by

$$\hat{R}_{xx}(k) \approx \bar{x}(k)\bar{x}^H(k)$$

$$\hat{r}(k) \approx d^*(k)\bar{x}(k) \quad \text{...(eq 2.4)}$$

The signal correlation vector ($\bar{r}$) minimum occurs when the gradient is zero

$$\nabla_{\bar{w}}\left(J(\bar{w})\right) = 2\overline{R}_{xx}\bar{w} - 2\bar{r} \quad \text{......(eq 2.5)}$$

The solution for the weights is the optimum wiener solution given by

$$\bar{w}_{\text{opt}} = \overline{R}_{xx}^{-1}\bar{r} \quad \text{.....(eq 2.6)}$$

The steepest descent iterative approximation is given as

$$\bar{w}(k+1) = \bar{w}(k) - \frac{1}{2}\mu\nabla_{\bar{w}}\left(J(\bar{w}(k))\right) \quad \text{...(eq. 2.7)}$$

Where *μ is the step size parameter and* $\Delta\bar{w}$ is the gradient of the performance surface Lms solution is given by

$$\begin{aligned}\bar{w}(k+1) &= \bar{w}(k) - \mu[\hat{R}_{xx}\bar{w} - \hat{r}] \\ &= \bar{w}(k) + \mu e^*(k)\bar{x}(k) \quad \text{......(eq.2.8)}\end{aligned}$$

$$e(k) = d(k) - \bar{w}^H(k)\bar{x}(k) \quad \text{......(eq.2.9)}$$

The convergence of the LMS algorithm is directly proportional to the step-size parameter μ. LMS algorithm is based on three factors step size parameter , number of weights and Eigen value of correlation matrix of the input data. The advantage is in terms of least computational complexity.

3. NORMALISED LEAST MEAN SQUARE (NLMS) ALGORITHM

The NLMS algorithm is the improved version of LMS algorithm in terms of slow convergence rate so that the acquisition and tracking problem for cellular systems is solved for better. The gradient noise amplification problem that occurs in standard form of LMS algorithm is due to the product vector e*(k)x(k) at iteration n applied to the weight vector w(n) directly proportional to input vector x(k).

$$\bar{w}(k+1) = \bar{w}(k) - \mu[\hat{R}_{xx}\bar{w} - \hat{r}]$$
$$= \bar{w}(k) + \mu e^*(k)\bar{x}(k) \quad \text{(eq 3.1)}$$

Now here comes the application of NLMS algorithm that
Normalizes the product vector at iteration n+1 with the square Euclidean norm of the input vector x (n) at iteration n. The final weight vector can be updated by

$$\hat{\mathrm{h}}(n+1) = \hat{\mathrm{h}}(n) + \frac{\mu e^*(n)\mathbf{x}(n)}{\mathbf{x}^H(n)\mathbf{x}(n)} \quad \text{(eq 3.2)}$$

Here
w(k+1) represented as h^(n+1)
This equation helps in updating weight vectors from diverging so that the algorithm gets more stable and faster converging than when a fixed step size is used. This represents the normalized version of Lms (NLMS) because the step size is divided by the norm of the input signal. For both correlated and whitened data this algorithm better performs than LMS in terms of potentially-faster convergence speeds , but not efficient in computational complexity.

4. RESULTS OF LMS ALGORITHM

The LMS algorithm was simulated using Matlab. An N=8 element array with spacing d=0.5λ has received a signal arriving at an angle θ_0=70°,an interferer at the angle θ_1=30°.
Figure 4.1 shows the. Weighted LMS array for which array factors are plotted for different angle of arrivals.
Figure 4.2. shows the Acquisition and tracking of desired signal.the signal level is plotted for the number of iterations.
Figure 4.3 . shows the Magnitude of array weights.In which the weights are calculated and plotted for particular iteration number.
Figure 4.4 shows the mean square error.here for number of iterations mean square error is calculated and plotted

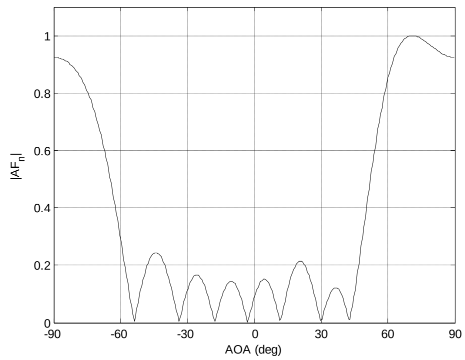


Figure 4.1 Weighted LMS array

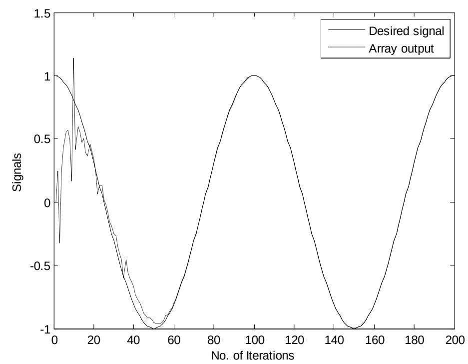


Figure 4.2. Acquisition and tracking of desired signal

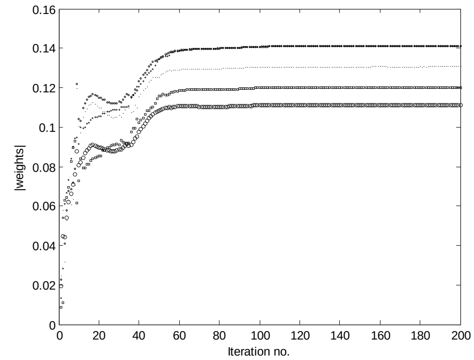


Figure 4.3 .Magnitude of array weights

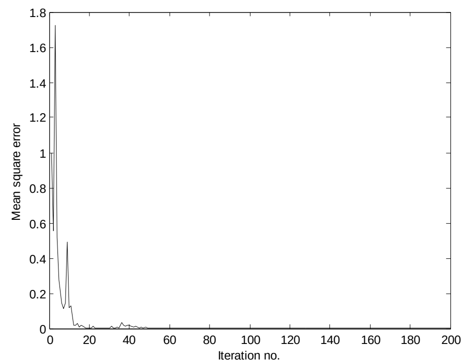


Figure 4.4 mean square error.

5. RESULTS OF NLMS ALGORITHM

The NLMS algorithm was simulated using Mat lab. An N=8 element array with spacing d=0.5λ has received a signal arriving at an angle θ0=70 °,an interferer at the angle θ1=30°.

Figure 4.1 shows the Weighted LMS array. for which array factors are plotted for different angle of arrivals. Figure 4.2.Acquisition and tracking of desired signal the signal level is plotted for the number of iterations Figure 4.3 .Magnitude of array weights. In which the weights are calculated and plotted for particular iteration number Figure 4.4 shows the mean square error. Here for number of iterations mean square error is calculated and plottedFigure 4.1 shows the Weighted NLMS array

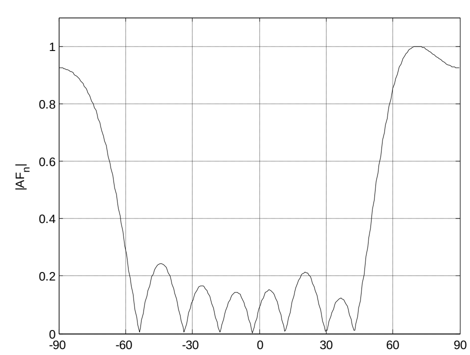


Figure 4.1 shows the Weighted LMS array

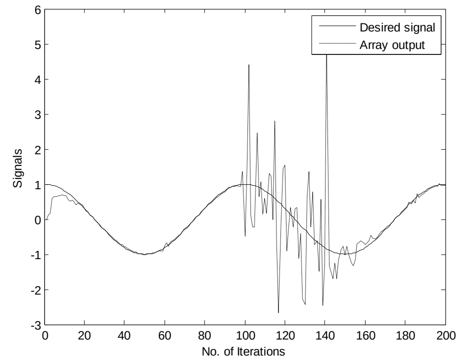


Figure 4.2. Acquisition and tracking of desired signal

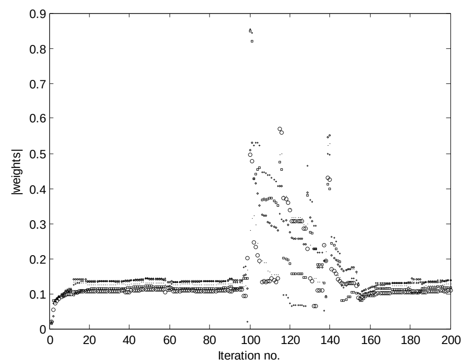


Figure 4.3 .Magnitude of array weights.

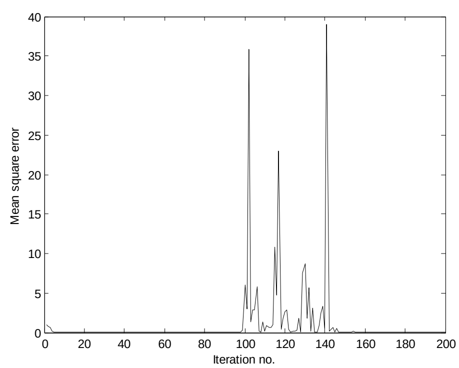


Figure 4.4 shows the mean square error.

Desired users AOA (in degrees)= 70, Interferers AOA(in degrees) =30 ,mu =0.0159,N=8		
weights	LMS	NLMS
W1	1	1
W2	-0.84637+0.090005i	-0.84701+0.09087i
W3	0.91259-0.11205i	0.9122-0.11367i
W4	-1.0109+0.38024i	-1.0096+0.38089i
W5	0.82288-0.69956i	0.82231-0.6993i
W6	-0.54067+0.74369i	-0.5408+0.74419i
W7	0.48926-0.69646i	0.48843-0.69763i
W8	-0.48508+0.87447i	-0.4834+0.87459i

Table 1: Summary of adaptive algorithms Performance

6. CONCLUSION

The analysis of LMS and NLMS is done using eight antennas with half wavelength spacing.LMS algorithm is less stable as variation of weight values is more. LMS algorithm shows output with more fluctuations. While in case of NLMS number of iterations needed for errors to converge is less. So convergence takes more time in the case of LMS than NLMS. The error convergence is more stable and shows quick convergence for NLMS algorithm. The attractive quality of LMS algorithm is less computational complexity. So NLMS is very good for smart antenna systems. Due to best features NLMS has been largely used in real-time applications and best for Mobile industry.

7. REFERENCES

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