International Journal of Electronics and Communication Engineering.
ISSN 0974-2166 Volume 5, Number 4 (2012), pp. 447-455

http://www.irphouse.com

Performance Study of A Non-Blind Algorithm for Smart Antenna System

[1]Umesh G. Chalva, [2]Dr. P.V. Hungund and [3]G.A. Bidkar

[1]M-phil Scholar, [2]Professor, [3]Ph.D. Student,
Dept. of Applied Electronics,
Gulbarga University, Gulbarga, India
E-mail: umeshchalva@gmail.com
prabhakar_hunagund@yahoo.co.in, gabidkar@rediffmail.com

Abstract

As the growing demand for mobile communications is constantly increasing, the need for better coverage, improved capacity, and higher transmission quality rises. Thus, a more efficient use of the radio spectrum is required. Smart antenna system is capable of efficiently utilizing the radio spectrum and is a promise for an effective solution to the present wireless system's problems while achieving reliable and robust high-speed high-data-rate transmission environments. The performance of a particular smart antenna system depends on how well-suited a chosen adaptive algorithm is to its operating signal environment. The best algorithm for a particular array system must not only account for the signal environment at hand, but also for a number of other practical considerations including synchronization, the presence or absence of carrier offsets, the reliability of array calibration data, and hardware cost. In this paper the Matlab simulation and performance study of a non-blind adaptive beamforming algorithm namely Least Mean Square (LMS) has been carried out. The simulation results are presented in the form of normalized array factor (NAF) by varying the number of elements in the array and the placing between the sensor elements.

Keywords: Smart Antenna; Diversity Reception; Spatial Filtering; Adaptive Arrays

Introduction

A smart antenna is an antenna array system aided by some smart algorithm designed to adapt to different signal environments. With the help of associated hardware and a computer controller, a smart antenna changes the array pattern in response to the radio frequency environment. Thus it can mitigate fading through diversity reception and beamforming. Fig.1. shows the block diagram representation of antenna array process [1].

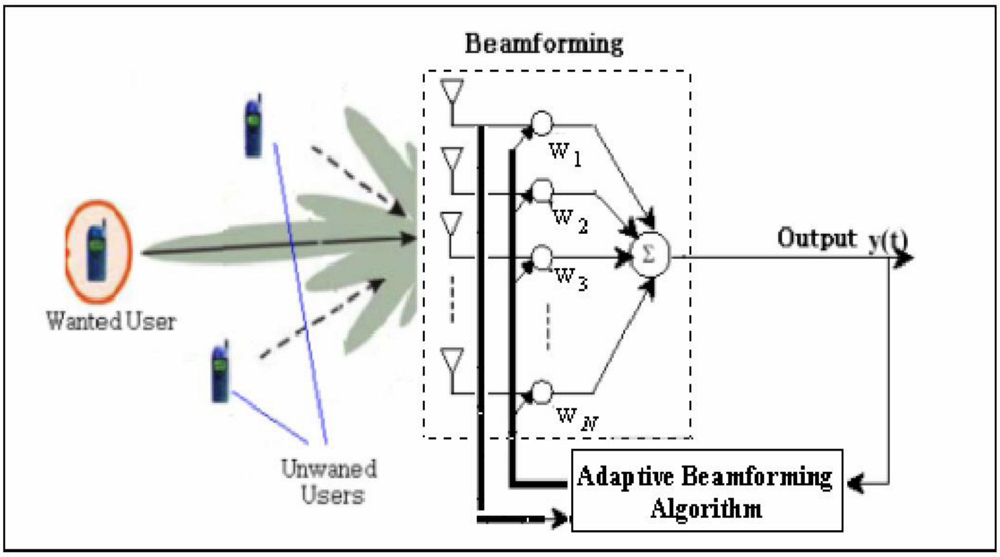

Figure 1: Block Diagram representation of Antenna Array processing.

The performance of a particular smart antenna system depends on how well-suited a chosen adaptive algorithm is to its operating signal environment [1]. Most of the algorithms either implicitly or explicitly estimate channel parameters, which may include but are not limited to the spatial signatures of both the desired and interfering signals, SNRs (Signal to Noise Ratio) time delays, and so forth [4]. If perfect channel estimates are available at the receiver, beamformer weights can be readily calculated to optimize some meaningful performance criterion, such as maximizing the SNR.

Adaptive array algorithms are often classified into two types: blind and non-blind as indicated in Fig.2 [5]. Many wireless standards specify that users should periodically transmit a known signal, often called a training sequence, over a specified interval for channel estimation. These known signals can be exploited with a non-blind adaptive algorithm. However, if these sequences are unavailable or unusable, a number of blind beamforming algorithms can be used. Blind algorithms require no training sequences.

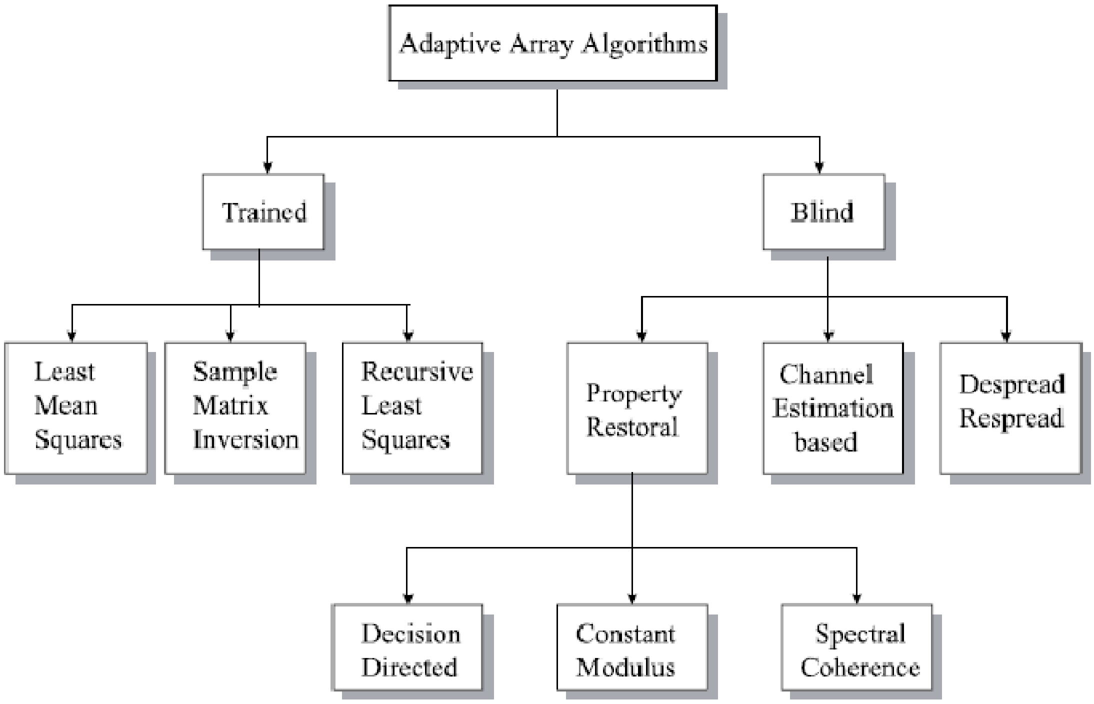

Figure 2: Classification of adaptive array algorithms.

Least Mean Square Algorithm

LMS algorithm a non-blind adaptive algorithm, in which a training signal, d (t), which is known to both the transmitter and receiver, is sent from the transmitter to the receiver during the training period[6]. LMS algorithm uses the estimates of the gradient vector from the available data. It incorporates an iterative procedure that makes successive corrections to the weight vector in the direction of the negative of the gradient vector which eventually leads to the minimum mean square error. Compared to other algorithms LMS algorithm is relatively simple; it does not require correlation function calculation nor does it require matrix inversions [3]

LMS Algorithm and Adaptive Arrays

Consider a Uniform Linear Array (ULA) with N isotropic elements, which forms the integral part of the adaptive beamforming system as shown in the Fig.3 [5] below.

The output of the antenna array is given by,

$$x(t) = s(t)a(\theta_0) + \sum_{i=1}^{N_u} u_i(t)a(\theta_i) + n(t)$$

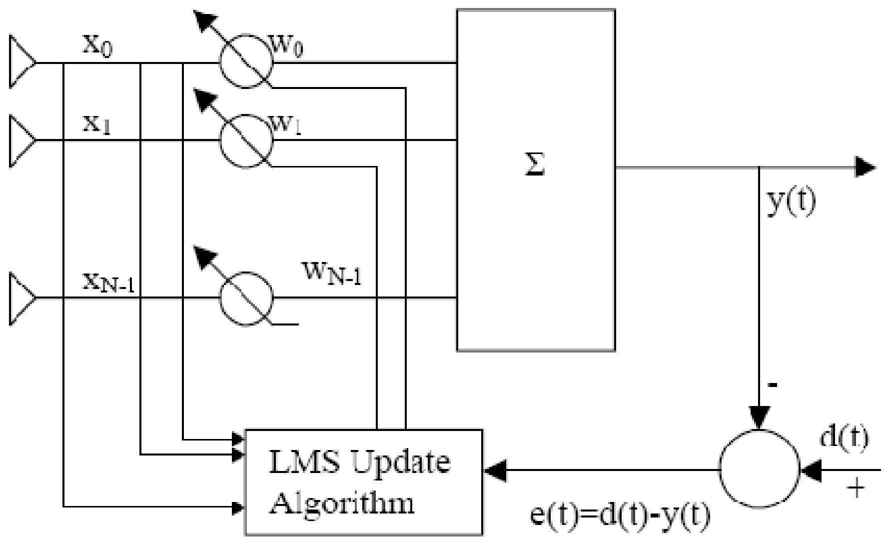

Figure 3: Adaptive beamforming network

S (t) denotes the desired signal arriving at angle θ_0 and $u_i(t)$ denotes interfering signals arriving at angle of incidences θ_i respectively. $a(\theta_0)$ and $a(\theta i)$ represents the steering vectors desired signal and interfering signals respectively. Therefore it is required to construct signal from the received signal amid the interfering signal and additional noise n (t).

As shown above the outputs of the individual sensors are linearly combined after being scaled using corresponding weights such that the antenna array pattern is optimized to have maximum possible gain in the direction of the desired signal and nulls in the direction of the interferers. The weights here will be computed using LMS algorithm based on Minimum Squared Error (MSE) criterion. Therefore the spatial filtering problem involves estimation of signal from the received signal x(t) (i.e. the array output) by minimizing the error between the reference signal d(t), which closely matches or has some extent of correlation with the desired signal estimate and the beamformer output y(t) (equal to wx(t)). This is a classical Weiner filtering problem for which the solution can be iteratively found using the LMS algorithm.

The output response of the uniform linear array is given by LMS as follows:

$y(n)= W^H x(n)$ ………….. (1)

Where, 'w' is the complex weight vector and 'x' is the received signal vector

Optimal weights are calculated as follows:

$w(n+1) = w(n)- \mu\, g[w(n)]$ ………….. (2)

where, w(n+1) denotes new weights computed at (n+1) iteration, μ is the gradient step size that controls the convergence characteristics of the algorithm, that is, how fast and close the estimated weights approach the optimal weights, g(w(n)) is estimate of gradient of the Mean Square Error (MSE);

MSE(w(n))=E[*3r(n+1)ï²]+w^H (n)R w(n)-2w^H (n)z (3)

Convergence and Stability of the LMS algorithm

The LMS algorithm initiated with some arbitrary value for the weight vector is seen to converge and stay stable for

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

Where λ_{max} is the largest eigenvalue of the correlation matrix R [2]. The convergence of the algorithm is inversely proportional to the eigenvalue spread of the correlation matrix R. When the eigenvalues of R are widespread, convergence may be slow. The eigenvalue spread of the correlation matrix is estimated by computing the ratio of the largest eigenvalue to the smallest eigenvalue of the matrix. If μ is chosen to be very small then the algorithm converges very slowly. A large value of μ may lead to a faster convergence but may be less stable around the minimum value.

Simulation results for the LMS algorithm

The desired signal s(t) arriving at θ_s is a simple complex sinusoidal-phase modulated signal of the following form.

$$s(t) = e^{j\sin(\omega t)}$$

The interfering signals $u_i(t)$ arriving at angles θ_i are also of the above form. By doing so it can be shown in the simulations how interfering signals of the same frequency as the desired signal can be separated to achieve rejection of co-channel interference.

For simulation purpose in case1, case2 and case3 linear array with different number of elements is used with its individual elements spaced at half-wavelength distance and the corresponding results are indicated in the form of NAF plots.

Case: 1

Number of elements in the array = 5
Spacing between the elements d = 0.5λ
The angle of arrival of desired signal = 60 degrees
Interferers angle = -30 degrees

Case: 2

Number of elements in the array = 8
Spacing between the elements d = 0.5λ
The angle of arrival of desired signal = 60degrees
Interferers angle = -30 degrees

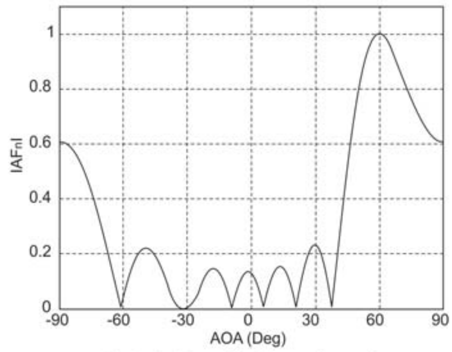

Figure 4a: Normalized Array Factor plot for N=5, θs = 60°, θi = -30°

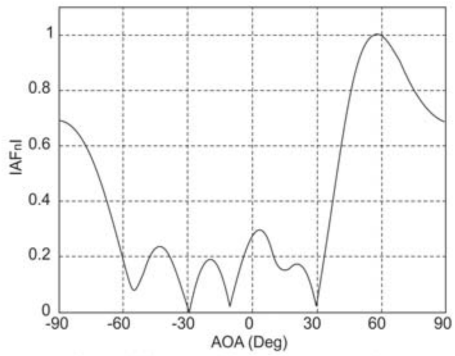

Figure 4b: Normalized Array Factor plot for N=5, θs = 60°, θi = -30°

Case: 3
Number of elements in the array = 32
Spacing between the elements d = 0.5λ
The angle of arrival of desired signal = 60 degrees
Interferers angle = -30 degrees

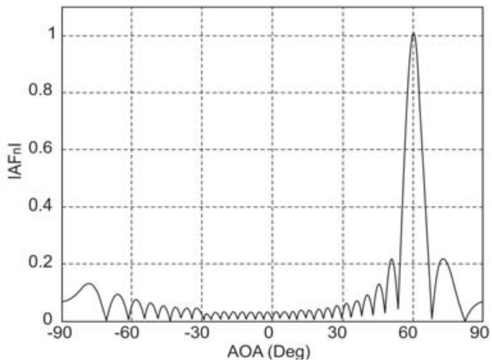

Figure 4.c: NAF Plot of LMSA, N=32, θs=60°, θi=-30°

The normalized array factor plots for case 1, case 2, case3, are indicated in the Fig. 4(a), Fig.4(b) and Fig.4(c).

The array factor plots in Fig.4 (a), Fig.4 (b) and 4(c) show that the LMS algorithm is able to iteratively update the weights to force deep nulls at the direction of the interferer and achieve maximum in the direction of the desired signal. By increasing the number of elements it is observed that the array factor is maximum for the desired signal and minimum for the interferer. Also the array factor falls steeply for the N=32.

The performance of the algorithm is also studied by varying the distance d between the antenna elements. The normalized array factor plot for case 5 and case 6 are indicated in the Fig.5 (a) and Fig.5 (b) below.

Case: 4
Number of elements in the array = 4
Spacing between the elements d = 0.25λ
The angle of arrival of desired signal = -30 degrees
Interferers angle = 60 degrees

Case: 5
Number of elements in the array = 8
Spacing between the elements d = λ
The angle of arrival of desired signal = -30 degrees
Interferers angle = 60 degrees

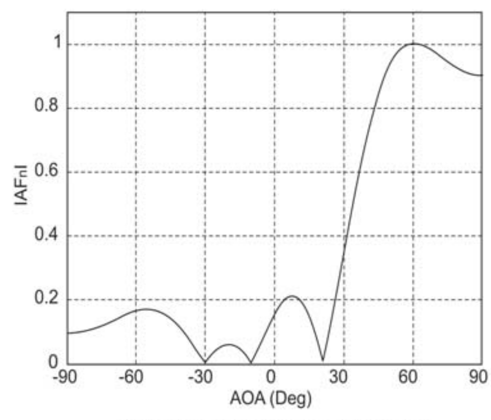

Figure 5a: NAF plot for d=0.25λ

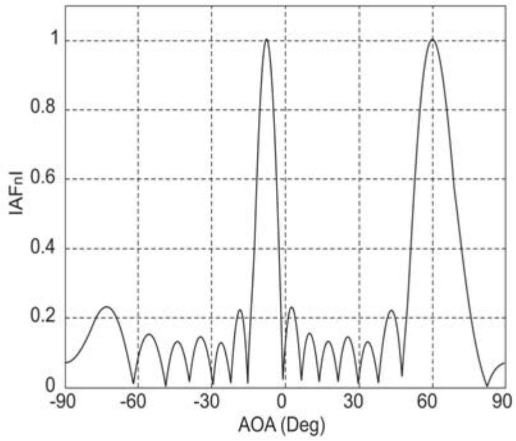

Figure 5b: NAF plot for d=λ

Case: 6
Number of elements in the array = 8
Spacing between the elements d = 0.75λ
The angle of arrival of desired signal = -30 degrees
Interferers angle = 60 degrees

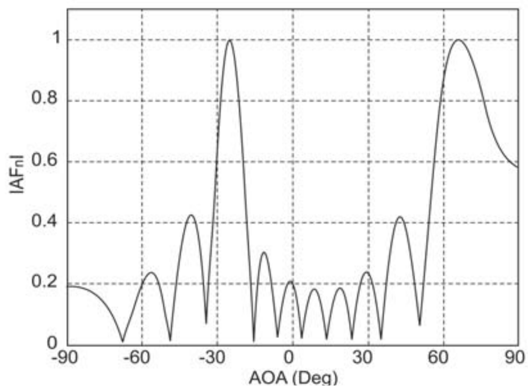

Figure 5 c: NAF plot for d=0.75λ

Fig.5 (a), Fig.5 (b) and Fig.5(c) shows the NAF plots for different value of'd'i.e the spacing between the elements. For d=0.25λ the maximum NAF is obtained at the desired user's angle. But it will not fall immediately for other angles. For d=0.75λ a peak is obtained at an unwanted angle. Hence it can be inferred that the algorithm performs well for d=0.5λ. Hence it can be inferred that, the element spacing cannot be greater than 0.5λ to avoid spatial aliasing. Even the element spacing cannot be made arbitrarily small since two closely spaced antenna elements will exhibit mutual coupling.

The performance of the antenna array using LMS algorithm is found to be satisfactory at d = 0.5λ and the performance is found to degrade for d = 0.25λ and d = 0.75λ. Any way the performance is not much affected for d =1λ except an unwanted peak at the undesired direction.

Conclusion

In this paper a non-blind LMS algorithm has been implemented in matlab and the simulation results are presented in the form of the normalized array factor plots. It is observed that a maximum can be achieved at the angle of the desired signal and nulls can be directed at the undesired interferers. The simulation results show that with the increase in number of elements, deeper nulls are obtained in the direction of interferer and the array factor which is maximum in the direction of desired angle falls of steeply for the other angles. By varying the distance between the elements it can be observed that, the algorithm performs well for d=0.5λ and performance degrades for other values.

References

[1] Chulajata, T.; Kwon, H.M.; Min, K.Y. "Adaptive Antenna Array With no Phase Calibration for CDMA Reverse Link", Vehicular Technology Conference, 2000, IEEE VTS Fall VTC 2000, 52 nd, Vol: 1, 2000, Page(s): 127- 134.

[2] Sandgchoon Kim; Miller, S.L. "An Adaptive Antenna array based Propagation Delay Estimation for DS-CDMA Communication Systems", Military Communications Conference, 1998. Milcom 98, Proceedings of the IEEE. Vol: 1, 1998, Page(s):333-337

[3] LAL C. GODAR4, Application of Antenna Array to Mobile Communications, Part U: Beam-Forming and Direction-of-Arrival Considerations". Proceedings of the IEEE, Vol. 85, No. 8, 1997, Page(s): 1213-1218.

[4] Jeffrey H. Reed, Software Radio – A modern approach to radio engineering, Pearson Education, 2006.

[5] Paul Petrus, "Novel Adaptive Array Algorithms and Their Impact on Cellular System Capacity", Ph.D dissertation, Virginia Polytechnic Institute and State University, 1997.

[6] Zhigang Rong, "Simulation of Adaptive Array Algorithms for CDMA Systems", M.S. Thesis, Virginia Polytechnic Institute and State University, 1996.