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Analysis of LMS, NLMS and MUSIC Algorithms for Adaptive Array Antenna System

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As technology developed this decade proves communication is the most important factor for the data interchange. Smart antennas have been considered to be one of the most demanding communication technologies. It adapted as most demanding technology because of high-bit rate or high quality in broadband commercial wireless communication.

Direction-of-arrival (DOA) estimation is based on the MUSIC algorithm for identifying the directions of the source signals incident on the sensor array comprising the smart antenna system. Adaptive beam forming is achieved using the LMS algorithm for directing the main beam towards the desired source signals and generating deep nulls in the directions of interfering signals. The smart antenna system designed involves a hardware part which provides real data measurements of the incident signals received by the sensor array. Results obtained verify the improved performance of the smart antenna system when the practical measurements of the signal environment surrounding the sensor array are used. This takes the form of sharper peaks in the MUSIC angular spectrum and deep nulls in the LMS array beam pattern.

Keywords*: *Smart antenna, Angle of arrival, LMS, NLMS and MUSIC.

I. INTRODUCTION

Smart antennas are also known as adaptive array antennas [1], multiple antennas and recently MIMO are antenna arrays with smart signal processing algorithms used to identify spatial signal signature such as the direction of arrival (DOA) of the signal. It is mainly used to calculate beam forming vectors, to track and locate the antenna beam on the mobile/target. The antenna could optionally be any sensor. Smart antenna techniques are used in acoustic signal processing, track and scan RADAR, radio astronomy and radio telescopes and mostly in cellular systems like W-CDMA and UMTS. Smart antenna [2] is defined as an antenna array system that is aided by a processing system that processes the signals received by the array or transmitted by the array using suitable array algorithms to improve wireless system performance. Its array consists of a set of distributed antenna elements (dipoles, monopoles or directional antenna elements) arranged in certain geometry of desired signal strength and reduces the interference from other signals. Hence they can be viewed as a combination of regular or conventional antenna elements whose transmit or received signals are processed using smart algorithms. Generic implementation of Smart Antenna system shows a generic implementation smart antenna system.

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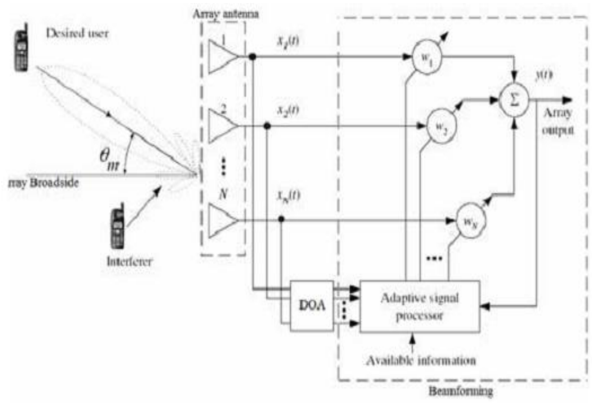

Fig. 1. A functional block diagram of a smart antenna system.

The antenna arrays have input or output as RF signals in the analog domain. These signals are passed to/from the RF analog front end which usually consists of low noise amplifiers, mixers and analog filters. In the receive mode, the RF signals are converted to digital domain by analog to digital converters and in transmit mode, the base band digital signals are converted to RF using digital to analog converters . The down-conversion from RF to base band or up-conversion from base band to RF can involve the use of IF signals. The base band signals received from each antenna is then combined using the smart algorithms in a digital processing section. Each antenna element hence has a RF chain going from the antenna element to RF front end to digital conversion for receiver and vice-versa for transmitter.

II. MATHEMATICAL BACKGROUND OF LMS ALGORITHM

An Adaptive Beam forming using least mean square algorithm consists of multiple antennas, complex weights, the function of which is to amplify (or attenuate) and delay the signals from each antenna element and a summer to add all of the processed signals, in order to tune out the signals of interest. Hence it is sometimes referred to as spatial filtering. The output response of the uniform linear array is given by

$$Y_{(n)} = w^H X_{(n)} \quad (1)$$

Where w is the complex weight vector and X is the received signal vector given. The complex weight vector w is obtained using an adaptive Beam forming algorithm. The least mean square algorithm is a gradient based approach in which an error, ε (n) is formed as

$$\in (n) = d_{(n)} - w^H X(n) \quad (2)$$

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Where d (n) denotes the sequence of reference or training symbols known a priori at the receiver at time n. This error signal ε is used by the beamformer to adaptively adjust the complex weight vector w so that the mean squared error (MSE) is minimized. The choice of weights that minimize the MSE is such that the radiation pattern has a beam in the reference signal and that there are nulls in the radiation pattern in the direction of the interferers.

The LMS algorithm is based on the steepest descent method which recursively computes an updates the sensor array weights vector w. It is reasonable that successive corrections to the weights vector in the direction of the negative of the gradient vector should eventually lead to minimum MSE, which point the weights vector assume its optimum value. In a standard LMS algorithm, the array weights vector w is initialized arbitrarily, and is then updated using the LMS equation given below [6].

$$w(n+1) = w(n) + \mu X(n)\epsilon^*_{(n)} \quad (3)$$

Where w (n + 1) denotes the weights vector to be computed at iteration n + 1 and μ is the LMS step size which is related to the rate of convergence. In order to ensure the stability and convergence of the algorithm, the adaptive step size should be chosen within the range specified as

$$0 \le \mu \le \frac{1}{2\lambda max} \quad (4)$$

where λ_{max} is the maximum Eigen value of the input correlation matrix.

III. MATHEMATICAL BACKGROUND OF NLMS ALGORITHM

This algorithm uses data-dependent step size at each iteration and avoids the requirement for calculating the Eigen value of autocorrelation matrix or its trace for selection of the maximum permissible step size. In case of this algorithm, only weight update function changes and all other equations remains the same as described for LMS [2] [3] [4]. The weight update equation for the NLMS algorithm is defined as:

$$w_{(n+1)} = w_{(n)} + \mu e_{(n)} \frac{x^*_{(n)}}{\epsilon + x^H_{(n)} x_{(n)}} \quad (5)$$

Where H denotes the Hermitian transpose, used for complex conjugate of the input signal x(n). μ is the step size used for convergence to obtain optimum solution for smart/adaptive antenna consisting of number of elements N spaced equally d that ultimately leads to get minimum MSE. A small positive constant epsilon used for controlling instability in updating of weights.

IV. MATHEMATICAL BACKGROUND OF MUSIC

Music stands for Muiltiple Signal Classification, one of the high resolution subspace DOA algorithms, which gives the estimation of number of signals arrived, hence their direction of arrival. MUSIC [5] [6]deals with the decomposition of covariance matrix into two orthogonal matrices, i.e., signal-subspace and noise-subspace. Estimation of DOA is performed from one of these subspaces, assuming that noise in each channel is highly uncorrelated. This makes the covariance matrix diagonal. The covariance matrix is given by:

$$S_x = F(\Theta)S_S\, F(\Theta)^H + \sigma_w^2 \quad (6)$$

Where $F(\Theta) = [F(\Theta_1): F(\Theta_2): \ldots : F(\Theta_D)]$ is a M x D array steering matrix. σ is noise variance and Ss is an identity matrix of size M x M.

Writing the spatial covariance matrix in terms of Eigen values and eigenvectors gives:

$$S_X = \sum_{i=0}^{M} \text{Pi}\, \emptyset\text{i}\, \emptyset_\text{i}^\text{H} \quad (7)$$

The noise subspace Eigen values and eigenvectors are..

P_i and $\emptyset_i$; I = D+1, D+2, …. ,M.

The noise subspaces can be written in the form of M x (M-D):

$$U_N = [\,\emptyset_{D+1,}\, \emptyset_{D+2,} \ldots, \emptyset_{M,}]$$

Above Equation indicates that we can find out the desired value DOA of teta1, teta2,……, D by finding a set of vectors that span and projecting array manifold matrix onto for all values of and evaluating the D values of , where the projection is zero .

The MUSIC Pseudo spectrum is given as,

$$P_{MU\,(\Theta)} = 1/abs[F(\Theta)^H\; U_N\, U_N^H\; F(\Theta)] \quad (8)$$

V. SIMULATION RESULTS:

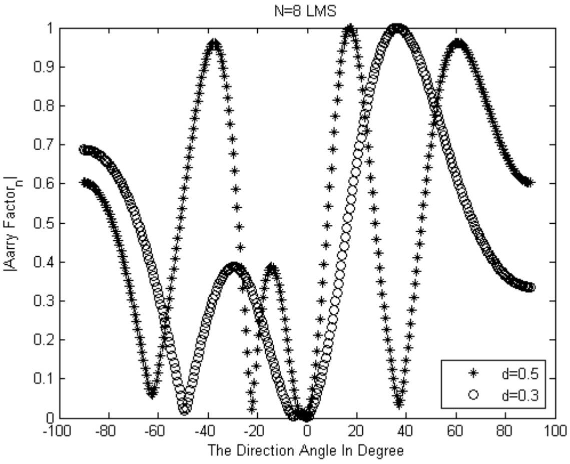

Figure: 1

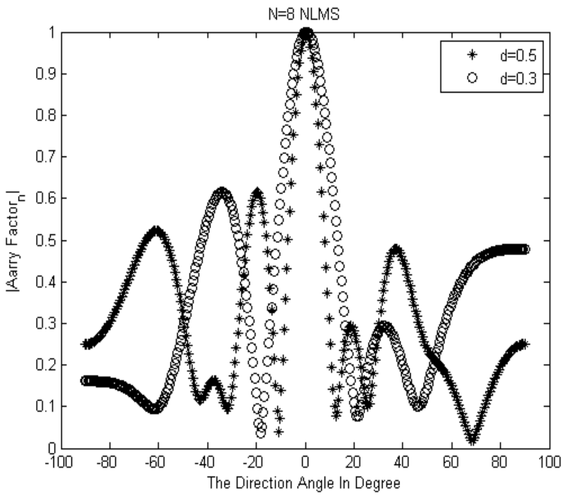

Figure: 2

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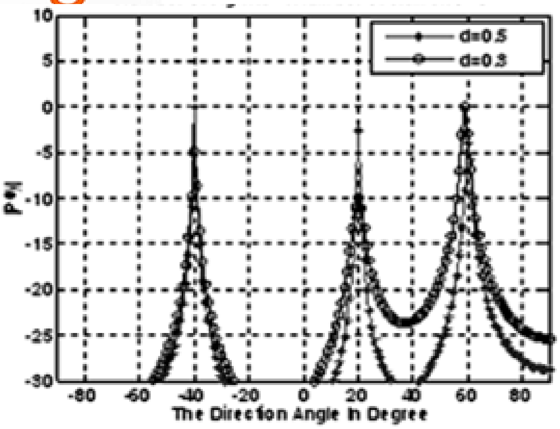

Figure: 3

VI. CONCLUSION

This paper presents the performance analysis of the popular algorithm using Matlab. LMS algorithm has good response towards desired direction and has better capability to place null towards interferer than NLMS. But the convergence speeds of NLMS algorithm is good than LMS as the speed of convergence for NLMS does not depend on Eigen value of input correlation matrix that play significant role in optimum solution in case of LMS. Sharper peaks in the MUSIC angular spectrum indicate locations of desired users. This paper provides references to studies where array beam-forming and DOA schemes are considered for mobile communications systems. Peaks of LMS are formed in the same desired direction and deep null in the direction of the undesired interference. This takes the form of sharper peaks in the MUSIC angular spectrum indicating locations of desired users, and deep nulls in the LMS array beam pattern indicating the location of the undesired interference signals.

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CONFERENCE

Paper presented on Cooperative Beam Forming For Wireless Ad Hoc Networks in International Conference on Sunrise Technologies (ICOST), 13-14-15 January 2011.

Paper presented on Digital Beam Forming For Adaptive Antenna Array System in International Conference on Resent Technologies (ICORT), 13-14 February 2012.

Paper presented on Analysis of LMS and MUSIC algorithm For Adaptive Antenna Array in International Conference on Emerging Intelligent Sustainable Technologies (ICEIST), 20th January 2013, ISBN: 978-93-81693-78-3.

INTERNATIONAL, NATIONAL CONFERENCES & PUBLICATION OTHER THAN RESEARCH

Presented a paper on Global Precipitation Measurement with Advanced Estimation Technique in a International Conference on Sunrise Technologies (ICOST) at SSVPSBSD COE, Dhule.

Presented a paper on Multi resolution direction filter using Wavelets basis in an International Conference on Science, Engineering & Spirituality (ICSES) at SESCOE, Naval Nagar.

Presented a paper in an International conference on VLSI and Communication at Saintgits COE, Kottayam, Kerala.

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Presented a paper in a national conference on Adhoch Mobile Network switching at JTM COE, Faizpur.

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PROFESSIONAL DEVELOPMENTS

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Description: The problems in 3G systems can be effectively tackled by using smart antennas. This project aims to design and develop an advanced antennas test-bed to serve as a common reference for testing adaptive antennas arrays and signal combining algorithms, as well as complete systems.
A flexible suite of offline processing software should be written to perform system calibration, test-bed initialization data acquisition control, data storage/transferring, offline system processing and analysis and graph plotting.

b] Now as a Principal Investigator on the R&D project "Design and analysis of semi-smart antenna array, funded by BCUD, Pune University, Pune (worth Rs.2.5 Lakhs), (April 2012 onwards)
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To study a detailed evaluation of the technical, standard and business issues raised by employing smart antenna systems.
To study of semi-smart antenna systems and traffic load balancing algorithms.
To develop a novel optimization algorithm and system level simulations.
Also to study the hardware aspects of this technology and built a prototype system to demonstrate the feasibility of this technique.

AS A REVIEWER FOR JOURNALS AND CONFERENCES
Worked as Reviewer for the following Journals and Conferences :

Journal of Engineering and Technology Research (ISSN: 2006 9790), Mauritius.

Journal of Electromagnetic Waves and Applications (JEMWA), Progress in Electromagnetic Research (PIER, PIER B,C,M, PIER Letters), Concord Avenue Cambridge, MA 02138, USA

International Journal of Computer and Engineering Research, Nairobi, Victoria Island, Lagos.

2nd International Conference on Electronics and Optoelectronics, (ICEOE 2012), July 2012, Shenyang, China.

2nd International conference on Advances in Computing, Communications and Informatics, August 2013, Mysore, India.

International Conference on Advances in Computing, Communication and Control, January 2013, Mumbai, India.
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HONORS AND AWARDS

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