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LMS Algorithm for Smart WIMAX Antenna

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Abstract— Desired signal convergence of high spatial resolution for wireless communication (mainly in WiMAX) estimation is the main problem in antenna application. This paper consists of smart antenna for WiMAX application is analyzed by detecting the main beam towards the desired source signal (by adjusting the weighted array values) using adaptive beamforming algorithm –Least Mean Square (LMS) algorithm of 3.5 GHz frequency and it also deals with the generation of deep nulls in the direction of interference signals by using MATLAB software. The algorithm for smart WiMAX antenna provides best quality of the desired signal with maximum convergence rate.

Keywords— LMS, beamforming, Smart Antenna, WiMAX, Adaptive Beamforming.

I. INTRODUCTION

Wireless communication is the important technology. WiMAX is the next generation of wireless communication, which provides high speed rates of communicating signals for long distance. In communicating the signals errors are main problems. The detection of exact arrival angle is done through MUSIC and ESPRIT algorithm but this estimation leads to minimize the signal to noise ratio due to the more noise presents. The noise is eliminated by using preprocessor. Hence it tends to increase in manufacturing cost [1]. The MUSIC (Multiple Signal Classification) algorithm determine the multiple array elements at the desired signal received by various terms like polarization, elements count used, signal direction. Spatial estimation is done through MUSIC but it does not reduce the interference problems [8]. ESPRIT (Estimation of Signal Parameters via Rotational Invariant Techniques) applied to various problems like presence of noise in the signal, estimation of accurate detection. This technique also includes the problem of interference and the convergence rate [9].

To eliminate these problems adaptive algorithms are used. The adaptive algorithms are used to optimize the weights in order to get best output. And these algorithms are analyzed for smart antenna [2]. The application of mobile communication provides a comprehensive and detailed treatment of different beam-forming schemes, adaptive algorithms to adjust the required weighting on antennas, direction-of-arrival estimation methods and the effects of errors on the performance of an array system and also deals with all aspects of array signal processing [5][7]. The combination of matrix inversion and normalized LMS leads to MI-NLMS algorithm which estimates optimal weights by SMI and updates the weights by normalized LMS algorithm and also increase in reduction of interference, gain enhancement [6]. Hence smart antenna and its algorithm are used for WiMAX application.

This paper contains mainly six captions. First caption explains theme of the project. Second caption explains the operation and advantages of smart antenna and WiMAX and it also explain the integrated system of both smart antenna and WiMAX technique. Third caption explains the adaptive beamforming and their conditions to form beam at desired angle and effects of reducing the interference noise signal. Fourth caption explain briefly about the determination of beamforming output, error signal by which Mean Square error can be estimated, the estimation optimal weight vectors using LMS algorithm and its application over adaptive beamforming. Fifth caption consist of simulation results for the implementation of smart WiMAX antenna through its various results as shown. Finally, conclusion caption deals with the summary of this paper.

II. SMART WIMAX ANTENNA

The adaptive antenna technology integrated with the modulators and the base station terminals of WiMAX technique for more convenient wireless communications with high speed rates.

A. Smart Antenna

Smart antenna systems are becoming one of the important technologies for the overall wireless communication systems performance. There are two types of smart antenna. First type is phased array antenna which describes the multi beam with one beam turned on towards the desired signal or a single beam by adjusting phase of the desired signal. Next type is Adaptive antenna array, which is an array of multiple antenna elements, with the weighted received signals and combines to produce maximum signal to interference and noise power ration. The adaptive antenna array forms main beam towards the desired signal and nullifies the interference signal patterns with the advantages as, it excessively reduce the interference pattern, increases the system capacity, increase in power efficiency and reduce the construction cost of the system.

B. WiMAX

WiMAX (Worldwide Interoperability for Microwave Access) is an upgrading a wireless communication standard designed to provide 30 to 40 mega bit-per-second data rates. It is a base transceiver station, a central antenna communicates with the subscriber's antenna. WiMAX communication is based on the term point-multipoint link. It is classified in two categories and they are, First is Fixed WiMAX provides for a fixed-line connection with the antenna within the 2-11 GHz of frequency range and the other one is Mobile WiMAX allows the mobile machine to be connect to the internet within the range 2-6 GHz of frequency range.

III. ADAPTIVE BEAMFORMING

The beamforming which is used differentiate the spatial properties between signal and noise. The system used for beamforming is beamformer, which is mainly used in antenna applications. The system receives a source signal radiating from a specific direction and to attenuate signals originating from other directions that were of no interest. In order to achieve beamforming, the system has to satisfy two conditions and they are Steering Capability and Cancellation of interference.

The method to satisfy Steering and elimination of interference is to minimize the variance of the output of the system during the process of adaptation, the M-by-1 weight vector w (n) satisfies the condition

$$W^H(n)s(\theta) = 0 \text{ , for all } n \ \& \ \theta = \theta_t \qquad (1)$$

and whereas s(θ) is M-by-1 steering vector, which is defined by

$$s(\theta) = [1, e^{-j\theta}, \ldots . e^{-j(M-1)\theta}]^T \qquad (2)$$

where θ is the electrical angle determined by the direction of target

$$\theta = (2\pi d) * \text{Sin } \Phi / \boldsymbol{\lambda}, \quad -\pi/2 \leq \theta \leq \pi/2 \qquad (3)$$

where d is the spacing between adjacent arrays, ($d<(\boldsymbol{\lambda}/2)$) and $\boldsymbol{\lambda}$ is the wavelength of incident wave. If the requirement $d< (\boldsymbol{\lambda}/2)$ is not satisfied, then the radiation pattern exhibits the grating lobe. The radiation pattern is the plot of the output power of the system versus the direction of angle arrival. The adaptive beamforming can be achieved by different adaptive algorithms like LMS, NLMS, RLS, etc. These are also called smart antenna algorithms.

IV. LMS ALGORITHM

The LMS algorithm is from the family of stochastic gradient algorithms. It consists of two basic processes. First is the filtering process, which computes the output of the filter and generates the error by comparing the output with the desired inputs. Second, an Adaptive process which automatically adjust the parameters in order to estimate the error from the output. The LMS algorithm is used to estimate the weight vectors for each iteration values and it also estimates the error by using filter output.

The step size (μ) is a constant for each iteration values to estimate the optimal weights which leads to characterize the convergence, transient response and covariance. It is a main issue in practical application.

$$0<\mu<2/ (M\ S_{max}) \qquad (4)$$

where M is the number of array elements and S_{max} is the power spectral density of the signal.

The error signal (e(n)) is determined by the difference between the original signal and output of the beamformer.

$$e(n) = d(n)-w^H(n)u(n) \qquad (5)$$

where d(n) is the desired signal and the tap-weight vectors are calculated for each iteration and it is mentioned as below equation.

$$w(n+1) = w(n)+\mu u(n)e^*(n) \qquad (6)$$

Finally, by estimating the error signal, the mean square error is estimated as

$$J(n) = E(|e(n)|^2) \qquad (7)$$

This deals with the convergence of the desired signal and interference signal.

A. Adaptive beamforming using LMS

The LMS algorithm is used for the application of beamforming. In order to achieve this, there are two steps to be considered. First one is to imposition of linear multiple constraints which preserve an incident signal along a

direction of interest. Second, adjust the weights, in accordance with the LMS algorithm, so as to eliminate/minimize the effects of interference and noise at the beamformer output.

The vector of assigned to the linear array antenna elements is represented by,

$$w(n) = w_q - C_a w_a(n) \quad (8)$$

$$w_q = C(C^H C)^{-1} g \quad (9)$$

where $w_a(n)$ is the adjustable – weight vector and w_q is the quiescent-weight vector. C is the constraint matrix and g is a gain vector.

The beamformer output is

$$\begin{aligned} e(n) &= w^H(n)u(n) \\ &= (w_q - C_a w_a(n))^H \\ &= w_q{}^H u(n) - w_a{}^H(n) C_a{}^H u(n) \end{aligned} \quad (10)$$

The adaptation of weight vector $w_a(n)$ in LMS algorithm can be written as,

$$\begin{aligned} w_a(n+1) &= w_a(n) + \mu x(n) e^*(n) \\ &= w_a(n) + \mu C_a{}^H u(n)(w_q{}^H u(n) - w_a{}^H(n) C_a{}^H u(n))^* \\ &= w_a(n) + \mu C_a{}^H u(n)(w_q - C_a w_a(n)) \end{aligned} \quad (11)$$

V. SIMULATION RESULTS AND ANALYSIS

Simulation for an adaptive WiMAX antenna is done through MATLAB software. This simulation dealt with the radiation pattern (beamforming), mean square error and the absolute weights for adaptive beamforming algorithm, LMS. The parameters used for this simulation are shown in the table below,

TABLE I
SIMULATION PARAMETERS

S.No	Parameter Used	Range
1	Number of array elements	16
2	WiMAX frequency	3.5GHz
3	Step size (μ)	0.211
4	Desired Signal Angle	0^0
5	Interference Signal Angle (I_1)	$\pm 30^0$
6	Interference Signal Angle (I_2)	$\pm 60^0$

In table 1, it describes the parameter used in simulation process in order to get the desired output. And the parameters are number of array elements, WiMAX frequency value is used for its application, Step size , a constant parameter is used in order estimate the optimal weights, Desired signal angle and interference angles are used to estimate the direction of the arrival the angle. Simulation result figures shown below describe the optimal output of the beamforming and convergence of the signal.

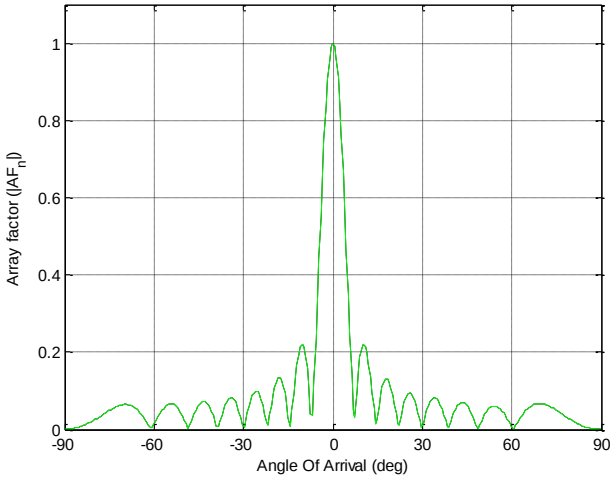

Fig. 1. Main beam formation towards the source signal and deep nulls at interferences

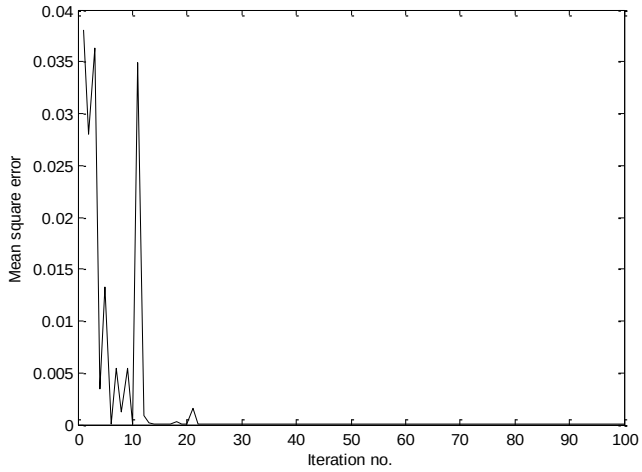

Fig 2. Mean Square Error analysis

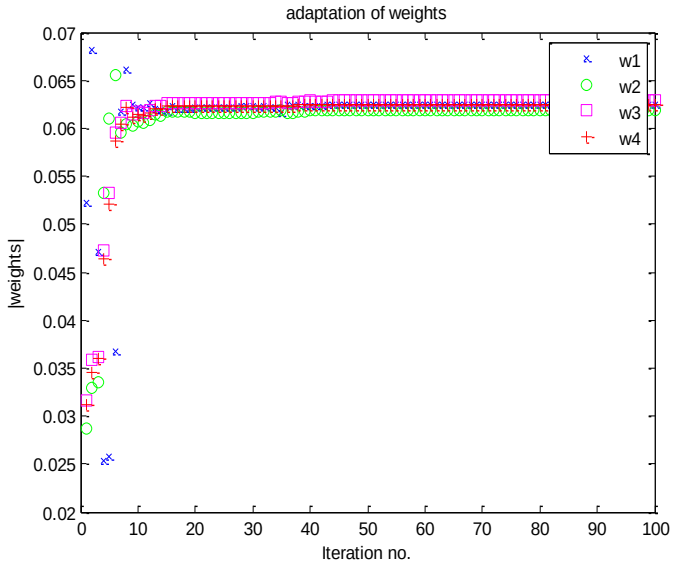

Fig. 3. Absolute adaption weights

In figure 1, the main beam at 0^0 is the desired signal angle and deep nulls are formed at the direction of $\pm 30^0$ and $\pm 60^0$ in both axis with respect to the absolute array weight factors for each iteration. It rejects the other signals and from the figure 1, it describes main beam towards is the desired signal angle which has a strong arrival the signal is detected. In figure 2, the signal over the axis dealt with the mean square error which is used to estimate the convergence rate of the signal for each iteration weight values.

In figure 3, it shows the absolute weight values which is calculated for each iteration values. The legend is shown in figure; it describes the first four weight values (w_1, w_2, w_3, w_4) for example.

VI. CONCLUSION

The adaptive beamforming for both directions of desired angle and the interference signal angle is estimated by using LMS algorithm and also dealt with the convergence by the estimation of mean square error for Wimax application. It also considered the equations dealt for the application of beamforming for wimax application in order to get better communication over internet.

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