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Adaptive Beam Forming Algorithms for MIMO Antenna

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Abstract*— MIMO antenna is a combination of multiple antenna elements. It has a signal processing capability to optimize its radiation reception pattern which automatically change in response to the signal environment. This paper provides comprehensive review on various evolutionary algorithms which are used for adaptation. The weights of the smart antenna array are adapted to maximize the output in desired direction and minimize the signals in undesired direction. Adaptive beam forming algorithm is used for track corresponding users automatically. This paper discuss about Non-blind beam forming algorithm i.e.. Least Mean Square, and Blind beam forming algorithm i.e.. Constant Modulus Algorithm and Sample Matrix Inversion. The algorithms are simulated for MIMO environment by using MATLAB. Beam forming can be used for either radio or sound waves. It has found numerous applications in radar, sonar, seismology, wireless communication, radio astronomy, speech and biomedicine.

***Keywords*— Smart antenna, Beam forming, Least Mean Square, Constant Modulus Algorithm , Sample Matrix Inversion.**

I. INTRODUCTION

The modern wireless communication services are spreading rapidly. Smart antenna also known as multiple antennas used to increase the efficiency of digital wireless communication systems [1]. Smart antenna is an array of antenna elements connected to a digital signal processor; such a configuration dramatically enhances the capacity of a wireless link through a combination of diversity gain, array gain, and interference suppression. Increased capacity translates to higher data rates for a given number of users or more users for a given data rate per user. Generally smart antennas is also known as adaptive array antennas [2]. Adaptive array antenna are able to adapt in changing traffic requirements. These antennas are used at the base stations which radiates narrow beams to serve different users. Users are well separated spatially same frequency reused even if the users are in the same cell. The process of combining the signals and then focusing the radiation in the particular direction is often referred to as digital beam forming. Beam forming in Smart antenna is recognized as a promising technology for higher user capacity in 3G wireless networks by effectively reducing multipath and co-channel interference.

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Beam forming is the term used to describe the application of weights to the inputs of an array of antennas to focus the reception of the antenna array in a certain direction, called the look direction or the main lobe. More importantly other signals of the same carrier frequency from other directions can be rejected. These effects are all achieved electronically and no physical movement of the receiving antennas is necessary. In addition, multiple beam formers focused in different directions can share a single antenna array one set of antennas can service multiple calls of the same carrier. Non blind algorithm- Least Mean Square, Recursive Least Square and Blind beam forming algorithm -Constant Modulus Algorithm and Sample Matrix Inversion are compared by using Code Division Multiple Access(CDMA). In CDMA, the signal from each user is spread across the entire channel by a unique spreading code [7]. The codes are chosen so that they are orthogonal to each other. They act as the key to access the message in the transmitted signal. To retrieve a particular message at the receiver, the corresponding code or key is used to extract the signal.

II. EXISTING SYSTEMS

A. Comparison of MVDR and LCMV:

The significance of the beam forming technique employed for the next generation broadband wireless mobile systems. The capacity, data rates, null steering and coverage of the cellular system are improved by using various beam forming techniques such as the Minimum variance distortion less response (MVDR) and Linear constraint minimum variance (LCMV). These two techniques depend on the received weight vector of the desired signa l[3]. The simulation result shows that for all the improved system parameters the MVDR technique shows better results than LCMV technique. The four elements of the linear array smart antenna are used in our simulation program with the operation frequency around 2.4 GHz, noise power is 0.5dB, and the spacing between elements is λ/2 d. Both modes give high output power but requires direction of all incoming sources which is difficult to obtain in practice MVDR beam forming mitigate the multipath fading problem by adding the multipath signal which increases strength of desired signal. Depending on the application requirements one of the beam forming algorithms is selected [3]. That mean the result by using MVDR algorithm is better from LCMV algorithm.

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B. Comparison of LMS and NLMS

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 [9]. Smart antennas combine the antenna array with signal processing to optimize automatically the beam pattern in response to the received signal. 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 [9]. 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.

C. Comparison of LMS and RLS

Smart antennas possess the capability of suppressing jamming signal, so they can improve signal to interference plus noise ratio (SINR). Array processing utilizes information regarding locations of signal to aid in interference suppression and signal enhancement and is considered promising technology for anti-jamming. In this paper we studied three beam forming algorithms, Least Mean Square (LMS) algorithm, Optimized-LMS algorithm and Recursive Least Squares (RLS) algorithm [2]. RLS algorithm provides fastest convergence, Optimized LMS algorithm also shows fast convergence but LMS algorithm lacks the convergence speed. In beam forming results, RLS showed the best beam forming capability placing deeper nulls in case of all the three interference positions i-e 40◦, 60◦and 90◦. The significant difference between the results of LMS and Optimized-LMS in case of beam forming was the presence of many minor lobes in Optimized-LMS. The dependency on SNR and SIR showed that in better conditions. But in poor conditions i-e low SNR and SIR its performance deteriorates [2]. LMS and RLS almost showed equal dependency on SNR and SIR. As the recent developments in digital signal processor (DSP) kits and field-programmable gate arrays (FPGA) have made it possible to implement RLS algorithms in real time systems, and complexity to an extent is not a problem anymore. So RLS algorithm is proposed as it provides deeper nulls in the direction of interferences and faster convergence.

III. Multipath And Co Channel Interference

A. Multipath

Multipath is a effect where the transmitting signal is reflected by a object or block, which create multiple signal paths between the base station and the user. Figure 1 shows the multipath effect of the signal [8].

Problems Associated with Multipath

a. Fading — Waves of multipath signals are being to out of phase, the reduction in signal strength can also occur. This type of reduction is called a fade. The phenomenon is known as "Rayleigh fading". A fade is constantly changing, three-dimensional phenomenon. Fade zones tend to be small, multiple areas of space within a multipath environment that cause periodic attenuation of a received signal for users passing through them. In other words, the received signal strength will fluctuate the signal in downward direction, causing a momentary, but periodic, worst in quality.

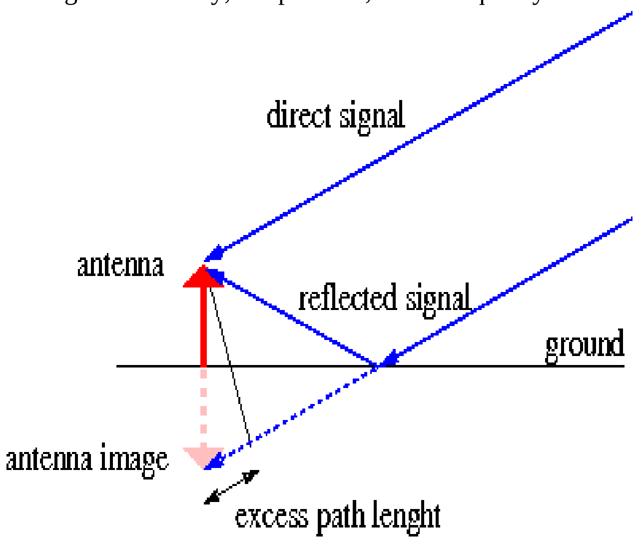

Figure 1: The Effect of Multipath

b. Phase cancellation — Waves of two multipath signals are rotated to exactly 180° out of phase, the signals will cancel each other. While this sounds severe, it is rarely sustained on any given call (and most air interface standards are quite resilient to phase cancellation). In other words, a call can be maintained for a certain period of time while there is no signal, although with very poor quality [4]. The effects of more concern when the control channel signal is canceled out, resulting in a black hole, a service area in which call set-ups will occasionally fail.

c. Delay spread — The effect of multipath on signal quality for a digital air interface (e.g., TDMA) can be slightly different. Here, the main concern is that multiple reflections of the same signal may arrive at the receiver at different times. This can result in inter symbol interference that the receiver cannot sort out [5]. While switched diversity and combining systems do improve the effective strength of the signal received, their use in the conventional macro cell propagation environment has been typically reverse-path limited due to a power imbalance between base station and mobile unit. This is because macro cell-type base stations have historically put out far more power than mobile terminals were able to generate on the reverse path.

B. Co Channel Interference

One of the primary forms of man-made signal degradation associated with digital radio, co channel interference occurs when the same carrier frequency reaches the same receive from two separate transmitters.

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As we have seen, both broadcast antennas as well as more focused antenna systems scatter signals across relatively wide areas. The signals that miss an intended user can become interference for users on the same frequency in the same or adjoining cells [8]. While sectorized antennas multiply the use of channels, they do not overcome the major disadvantage of standard antenna broadcast—co channel interference. To combat effects of co channel interference, smart antenna systems not only focus directionally on intended users, but in many cases direct nulls or intentional noninterference toward known, undesired users.

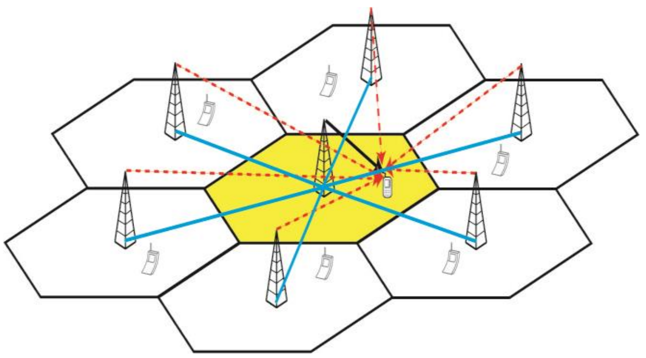

Figure 2: Co Channel Interference

IV. Adaptive Filter Approach And Algorithms

The adaptive antenna systems approach communication between a user and base station in a different way, in effect adding a dimension of space. By adjusting to an RF environment as it changes, adaptive antenna technology can dynamically alter the signal patterns to near infinity to optimize the performance of the wireless system. Adaptive arrays utilize sophisticated signal-processing algorithms to continuously distinguish between desired signals, multipath, and interfering signals as well as calculate their directions of arrival. This approach continuously updates its transmit strategy based on changes in both the desired and interfering signal locations [2]. The ability to track users smoothly with main lobes and interferers with nulls ensures that the link budget is constantly maximized because there are neither micro sectors nor predefined patterns. The relative coverage area for conventional sectorized, switched beam, and adaptive antenna systems. Both types of smart antenna systems provide significant gains over conventional sectored systems [5]. The low level of interference on the left represents a new wireless system with lower penetration levels. The significant level of interference on the right represents either a wireless system with more users or one using more aggressive frequency reuse patterns. In this scenario, the interference rejection capability of the adaptive system provides significantly more coverage than either the conventional or switched beam system.

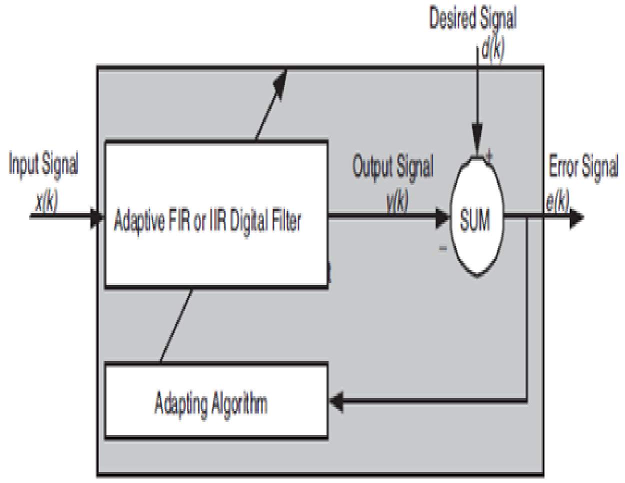

Figure 3: Adaptive Filter Approach

The above block diagram shows the adaptive filter approach. It shows that how the error is separated from the signal. The adaptive filter is used to filtering and smoothening the input signal and also it predict the signal parameter. This filter steps are followed for all the number of elements which is antenna. The output of the each antenna is collected and combined to form a radiation pattern. The adaptive algorithm used in the signal processing has a profound effect on the performance of a Smart Antenna system. Although the smart antenna system is sometimes called the "Space Division Multiple Access", it is not the antenna that is smart. The function of an antenna is to convert electrical signals into electromagnetic waves or vice versa but nothing else. The adaptive algorithm is the one that gives a smart antenna system its intelligence. Without an adaptive algorithm, the original signals can no longer be extracted. Different adaptive algorithms were developed for different purposes and tasks. The task of the algorithm in a Smart antenna system is to adjust the received signals so that the desired signals are extracted once the signals are combined. Various methods can be used in the implementation of an adaptive algorithm. In this project, the adaptive algorithm is implemented in MATLAB code.

1. *Least Mean Square Algorithm*

This algorithm was first developed by Widrowand Hoff in 1960. The design of this algorithm was stimulated by the Wiener-Hopf equation. By modifying the set of Wiener-Hopf equations with the stochastic gradient approach, a simple adaptive algorithm that can be updated recursively was developed. This algorithm was later on known as the least-mean-square (LMS) algorithm. The algorithm contains three steps in each recursion: the computation of the processed signal with the current set of weights, the generation of the error between the processed signal and the desired signal, and the adjustment of the weights with the new error information [2,7,8,9]. The following equations summarize the above three steps.

$$\epsilon(k) = d(k) - Y(k) \quad (1)$$

$$Y(k) = W^H X(k) \quad (2)$$

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$$W(k+1) = W(k) + \mu X(k)\left[d(k) - X^H(k)W(k)\right] \quad (3)$$

The w in the above equations is a vector which contains the whole set of weights. The H represents the Hermitian transpose of a vector. Here, we have taken eight elements, so there are eight for each symbol received at time n. All eight weights are updated according in each recursion. At time zero, all weights are initialized to have a value of zero. The symbol μ is called the step size parameter. The value of this parameter affects the settling time and the steady state error of the LMS algorithm. A large step-size allows fast settling but causes poor steady state performance.

2. Constant Modulus Algorithm

Many adaptive beam forming algorithms are based on minimizing the error between reference signal and array output. In the case where a reference signal is not available one must resort to an assortment of optimization techniques that are blind to exact content of the incoming signals. The constant modulus algorithm (CMA) is used for blind equalization of signals that have a constant modulus .The minimum shift key (MSK) signal, for example, is a signal that has the property of a constant modulus [7,8]. The algorithm contains three steps in each recursion: the computation of the processed signal with the current set of weights, the generation of the error , and the adjustment of the weights with the new error information.

3. Sample Matrix Inversion

For a N-element antenna array, the baseband received signal vector X is given by

$$x(t) = \sum_{i=1}^{M} Si(k)ai(\theta i) + n(k) \quad (4)$$

The sensor outputs are each multiplied by a complex weight $w_i(k)$ which may vary with time, and then summed to produce the output y(k) [8]. The goal is to adjust the complex weights w_i to improve reception of the signal of interest (SOI). The array output is expressed as

$$y(t) = \sum_{i=1}^{N} Wi(k)xi(k) \quad (5)$$

$$y(t) = x(k)w(k) \quad (6)$$

Where w(k) is the Nx1 column vector of beam-former weights.

V. Simulation Results

Simulations for different algorithms are done by using MATLAB. The simulation result shows the radiation pattern for the MIMO antenna. Each algorithm gives different pattern based on number of elements, pi and theta value. Number of elements is eight, and spacing element distance is 0.5.

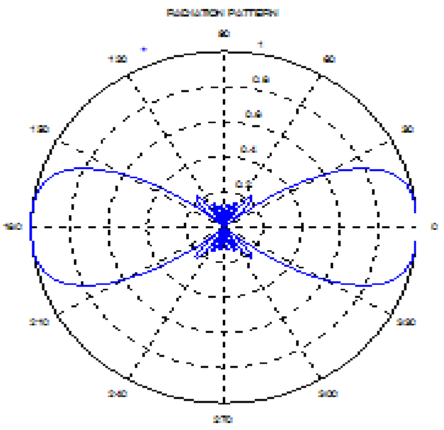

Figure 4: Radiation Pattern using LMS

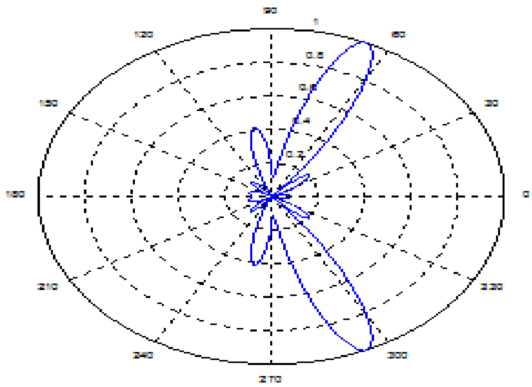

Figure 5: Radiation Pattern using CMA

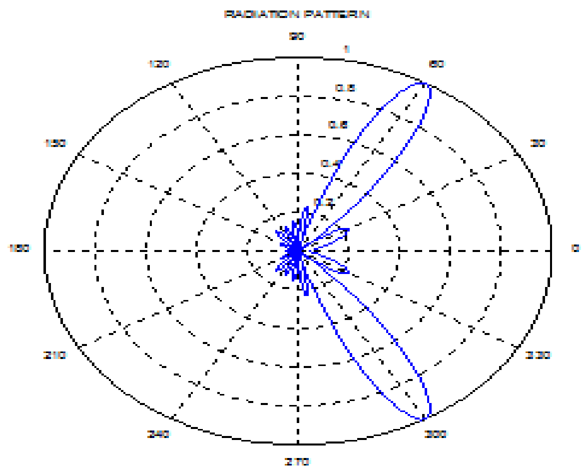

Figure 6: Radiation Pattern using SMI

VI. Conclusion

In Beamforming approach, LMS gives better performance and easy to work but it has slow convergence for few number of element and we are using eight element in our research so the convergence is too slow. In SMI algorithm there is a necessary to invert a large correlation.CMA has low convergence time which limits the usefulness of the algorithm in dynamic environments where the signal must be captured quickly.

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By comparing three algorithms CMA and SMI is selected randomly for the application depend on its environment.

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