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An Overview of LMS Adaptive Beamforming Algorithm for Smart Antenna

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ABSTRACT: Smart antennas use antenna arrays with signal processing algorithms for identifying signals spatially. The direction of arrival (DOA) estimation has a significant role in the implementation of a smart antenna. This is a new and promising technology in the field of wireless communications in which capacity and performance are usually limited by two major impairments multipath and co-channel interference. This paper presents brief account on smart antenna system. Smart antennas can place nulls in the direction of interferers via adaptive updating of weights linked to each antenna elements. DOA estimation gives the maximum peak of spectrum with respect to angle of arrival where the desired user is supposed to exist. In this paper we use LMS beamforming algorithms to steer the antenna beam in particular desired direction. This simulation are carried out using MATLAB.

KEYWORDS:. Smart Antenna, LMS, Beamforming,

I. INTRODUCTION

A smart antenna consists of several antenna elements, whose signal is processed adaptively in order to exploit the spatial domain of the mobile radio channel. The smart antenna technology can significantly improve wireless system performance and economics for a range of potential users. It enables operators of PC's cellular and wireless local loop networks to realize significant increase in signal quality, network capacity and coverage.

In actual, antennas are not Smart Antenna, systems are smart. Generally co- located with a base station, a smart antenna system combines an antenna array with a digital signal-processing capability to transmit and receive in an adaptive, spatially sensitive manner. In other words, such a system can automatically change the directionality of its radiation patterns in response to its signal environment. This can dramatically increase the performance characteristics (such as capacity) of a wireless system.

This is a new and promising technology in the field of wireless and mobile communications in which capacity and performance are usually limited by two major impairments multipath and co-channel interference. Multipath is a condition that arises when a transmitted signal undergoes reflection from various obstacles in the environment. This gives rise to multiple signals arriving from different directions at the receiver. Smart antennas (also known as adaptive array antennas and multiple antennas) are antenna arrays with smart signal processing algorithms to identify spatial signal signature such as the Direction of arrival (DOA) of the signal and use it to calculate beam forming vectors, to track and locate the antenna beam on the mobile targets. The antenna could optionally be any sensor. Smart antenna techniques are used notably in acoustic signal processing, track and scan Radar, Radio astronomy and Radio Telescopes and mostly in Cellular Systems like W-CDMA and UMTS.

A smart antenna is a digital wireless communications antenna system that takes advantage of diversity effect at the source (transmitter), the destination (receiver) or both. Diversity effect involves the transmission and/or reception of multiple radio frequency (RF) waves to increase data speed and reduce the error rate. The result is bad signal quality at the receiver due to phase mismatch. Co-channel interference is interference between two signals that operate at the same frequency. A smart antenna enables a higher capacity in wireless networks by effectively reducing multipath and

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co-channel interference. This is achieved by focusing the radiation only in the desired direction and adjusting itself to changing traffic conditions or signal environments. Smart antennas employ a set of radiating elements arranged in the form of an array.

First, the direction of arrival of all the incoming signals including the interfering signals and the multipath signals are estimated using the Direction of Arrival algorithms. Secondly, the desired user signal is identified and separated from the rest of the unwanted incoming signals. Lastly, a beam is steered in the direction of the desired signal and the user is tracked as he moves while placing nulls at interfering signal directions by constantly updating the complex weights.

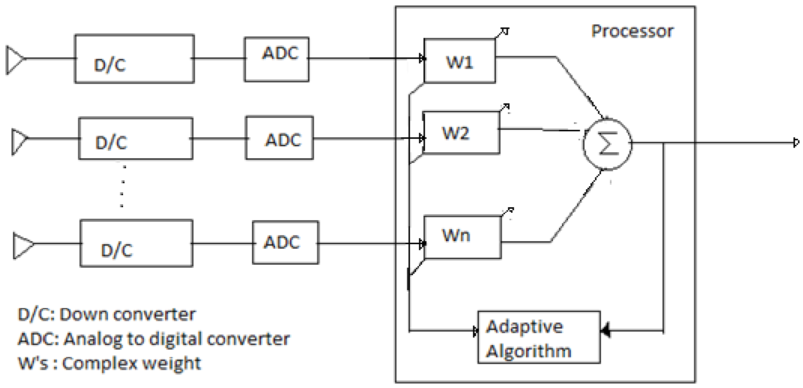

Fig. 1 Block diagram of smart antenna

II.TYPES OF SMART ANTENNA

Two of the main types of smart antennas include switched beam smart antennas and adaptive array smart antennas. Switched beam systems have several available fixed beam patterns. A decision is made as to which beam to access, at any given point of time, based upon the requirements of the system. Adaptive arrays allow the antenna to steer the beam to any direction of interest while simultaneously nullifying interfering signals. Beam direction can be estimated using the so-called Direction-of-Arrival (DOA) estimation methods.

A. Switched Beam Antennas :

Switched beam antenna systems form multiple fixed beams with heightened sensitivity in particular directions. These antenna systems detect signal strength, choose from one of several predetermined, fixed beams and switch from one beam to another as the mobile moves throughout the sector. Instead of shaping the directional antenna pattern with the metallic properties and physical design of a single element, switched beam systems combine the outputs of multiple antennas in such a way as to form finely directional beams with more spatial selectivity than can be achieved with conventional, single-element approaches.

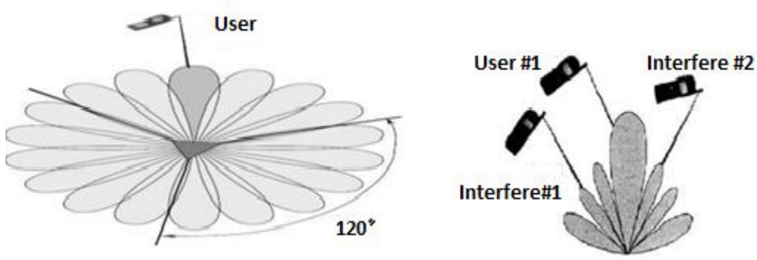

Fig. 2 Switched Beam System Coverage Pattern

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B. Adaptive Array Antennas :

Adaptive antenna technology represents the most advanced smart antenna approach as on date. Using a variety of new signal-processing algorithms, the adaptive system takes advantage of its ability to effectively locate and track various types of signals to dynamically minimize interference and maximize intended signal reception. Both systems attempt to increase gain according to the location of the user, however, only the adaptive system provides optimal gain while simultaneously identifying, tracking and minimizing interfering signals.

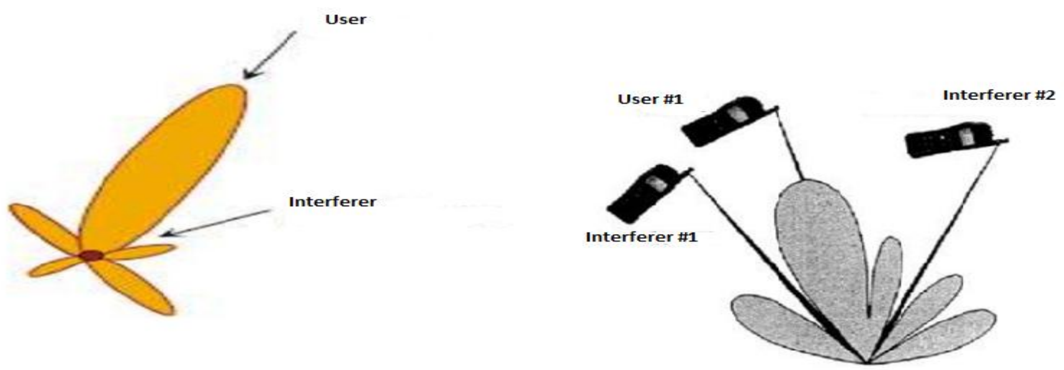

Fig. 3 Adaptive array system coverage pattern

III. BEAMFORMING

It is the method used to create the radiation pattern of the antenna array by adding constructively the phases of the signals in the direction of the targets/mobiles desired and nullifying the pattern of the targets/mobiles which are undesired/interfering targets. This can be done with a simple FIR tapped delay line filter. The weights of the FIR filter may also be changed adaptively and used to provide optimal beam forming and actual beam pattern formed. Typical algorithms are the steepest descent and LMS algorithms. There is an ever-increasing demand on mobile wireless operators to provide voice and high-speed data services. At the same time, these operators want to support more users per base station to reduce overall network costs and make the services affordable to subscribers. As a result, wireless systems that enable higher data rates and higher capacities are a pressing need.

IV. LMS ALGORITHM

Least Mean Square (LMS) algorithm, was introduced by Widrow and Hoff in 1959, is an adaptive algorithm which uses a gradient based method of steepest decent.
The least-mean-square (LMS) is a search algorithm in which a simplification of the gradient vector computation is made possible by appropriately modifying the objective function [1]-[2]. The LMS algorithm, as well as others related to it, is widely used in various applications of adaptive filtering due to its computational simplicity [3]-[7]. The convergence characteristics of the LMS algorithm are examined in order to establish a range for the convergence factor that will guarantee stability. The convergence speed of the LMS is shown to be dependent on the eigen value spread of the input signal correlation matrix
The LMS algorithm can be described by the following three equations,

$$y(n) = w(n).x(n) \quad \ldots\ldots\ldots\ldots\ldots(1)$$

$$e(n) = d(n) - y(n) \quad \ldots\ldots\ldots\ldots\ldots(2)$$

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$$w(n+1)= w(n) +\mu.x(n).e^*(n)\ldots\ldots\ldots\ldots(3)$$

where μ is a gain constant and control the rate of adaptation, e(n) is the error between desired and output signal, y(n) is the output signal, x(n) represents the input signal and d(n) is the desired signa

LMS algorithm uses continuous adaptation and weight vector sequence converges to the optimum solution when the weight adjusts. The array factor for N element equally spaced linear array is given by:-

$$AF(\theta)= w\ N\ n{=}1\ n\ e(j(n-1)\{2\pi d/\lambda.(\cos\theta)+\alpha\}\ldots\ldots..(4)$$

The phase shift between the elements of antenna α is given as:-

$$\alpha= -2\pi d\ \lambda\ .\cos\theta$$

and the weight vector is seen to converge and stay stable for:

$$0<\mu<1/\lambda max$$

where λmax is largest Eigen value of correlation matrix .

The step size is given by

$$\mu=1/4trace(R)$$

where R is the correlation matrix.

The convergence of the algorithm is inversely proportional to the Eigen value spread of the correlation matrix R. When the Eigen values of R are widespread, convergence may be slow. The Eigen value spread of the correlation matrix is estimated by computing the ratio of the largest Eigen value to the smallest Eigen value 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.

V. CONCLUSION

This paper discussed the adaptive beamforming LMS algorithm.LMS algorithm is proposed by making step size variable. The performance of LMS algorithm is analysed in this paper for different number of array element and different spacing between elements are considered for simulation. This paper studied the results for direction of arrival for LMS it was found that beams are directed towards desired signals as more elements are used in antenna array, it shows system error is less and steady, the radiation pattern has faster convergence rate and can form deeper nulls in the direction of interference. The result obtain for error curve, beamforming, SNR curve plot achieves faster convergence and lower steady state error.

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