Mitigating the Effect of CCI and Multipath in Mobile Communication using Smart Antenna

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ABSTRACT

In mobile communication systems, capacity and performance of network are usually limited by two major impairments. They are multipath and co-channel interference. Smart antenna is one of the most promising technologies that will enable a higher capacity in wireless networks by effectively reducing multipath and co-channel interference Smart Antenna use adaptive beam forming algorithms in a dynamic environment continuously adjusting the weight of antenna arrays for creating a beam to track desired users automatically, and minimize interference from other users by placing nulls in their directions. This paper provides comparative analysis to results of LMS and SMI adaptive algorithms for one desired angle and three undesired angles using MATLAB software Results of simulation will help in beam forming and antenna design.

Keywords – **Beam former, LMS, SMI, Smart Antenna**

I. INTRODUCTION

Existing base station antennas in cellular communication are normally Omni directional. Omni direction antenna radiates its energy in all directions will results waste of frequency band because majority of transmitted signal power radiates in other directions instead of desired user . Signal power radiated throughout the cell area that will increase in interference and reduce SNR due to undesired users. Although sector antenna will increase capacity of system by dividing entire cell into sector but have the same problem of interface.

Emerging trends of mobile communication and ever growing demand of mobile users with high speed data requirements and migrating towards 4G, Co-Channel interference and multipath in urban/dense urban environment will limit the capacity of the network**.** Multipath is a condition which arises when a transmitted signal undergoes reflection from various obstacles in the propagation environment. This gives rise to multiple signals arriving from different directions. Since the multipath signals follow different paths, they have different phases when they are arrive at the receiver. The result is degradation in signal quality when they are combined at the receiver due to the phase mismatch. Co-channel interference

is the interference between two signals that operate at the same frequency. In cellular communication the interference
is usually caused by a signal from a different cell occupying the same frequency band.

Organization of paper is; In Section II the Smart Antenna model is reviewed. In Section III Basics of beam forming Section IV Adaptive Beam forming algorithms (LMS & SMI) discussed ,Section V Smart antenna simulation and Results, Section VI conclusion and References

II. SMART ANTENNA

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 RF-waves to increase data speed and reduce the error rate. In conventional wireless communications, a single antenna is used at the source, and another single antenna

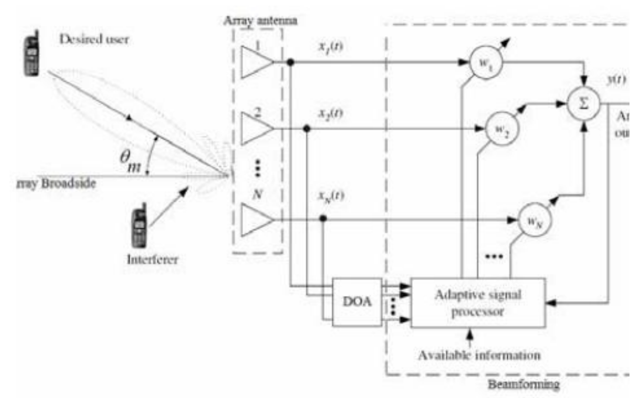


Fig.1.A functional block diagram of a smart antenna system.

is used at the destination. Such systems are vulnerable to problems caused by multipath effects .When an electromagnetic field (EM field) is met with obstructions such as buildings the wave fronts are scattered, and thus they take many paths to reach the destination. The late arrival of scattered portions of the signal causes problems such as fading. In a digital communications system it can cause a reduction in data speed and an increase in the number of errors. Multi-path fading and delay spread lead to inter symbol interference (ISI) and co-channel interference. The use of smart antennas can reduce or eliminate these problems resulting in wider coverage and greater capacity.

Types of Smart Antenna

There are basically two approaches to implement antennas that dynamically change their antenna pattern to mitigate interference and multipath effects while increasing coverage and range. They are

- Switched beam
- Adaptive Arrays

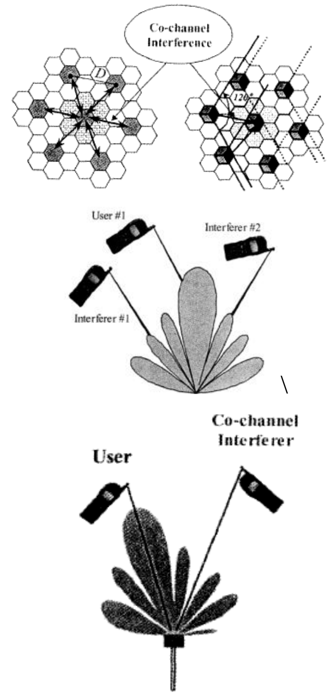


Fig.2. Cochannel Interference pattern of Switched Beam and Adaptive arrray antenna system

Switched beam employs an antenna array which radiates several overlapping fixed beams covering a designated angular area. It subdivides the sector into many narrow beams. Each beam can be treated as an individual sector serving an individual user or a group of users. Adaptive array systems are smart because they are able to dynamically react to the changing RF environment. They have a multitude of radiation patterns compared to fixed finite patterns in switched beam systems to adapt to the ever-changing RF environment. An Adaptive array, like a switched beam system uses antenna arrays but it is controlled by signal processing. This signal processing steers the radiation beam towards a desired mobile user, follows the user as he moves, and at the same time minimizes interference arising from other users by introducing nulls in their directions. This is illustrated in a Fig.2

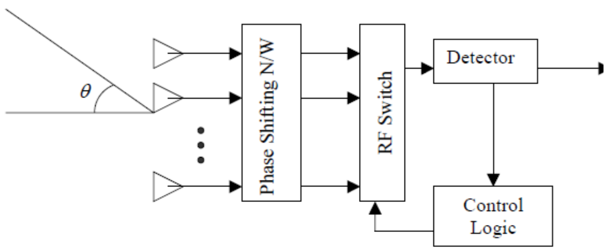


Fig.3. Switched Beam Antenna system.

III.BASICS OF BEAMFORMING

Beam forming is an advanced signal processing technique which, when employed along with an array of transmitters or receivers, is capable of controlling the 'directionality of' or 'sensitivity to' a particular radiation pattern. This method creates the radiation pattern of the antenna array by adding the phases of the signals in the desired direction and by nulling the pattern in the unwanted direction. The phases and usually amplitudes are adjusted to optimize the received signal.

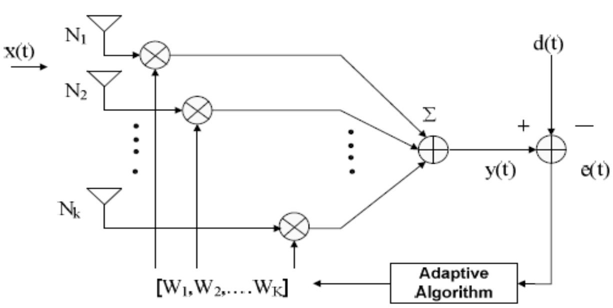


Fig.4 Beam formation

IV. ADAPTIVE BEAM FORMING ALGORITHM

The fixed beam-forming approaches mainly used for fixed arrival of angle, if the angles of arrival do not change with respect to time, the optimum array weights would not need to be adjusted again and a gain. In a dynamic environment, if the desired angle of arrival rapidly change, it is necessary to choose an optimization weight/scheme that update on real time basis so recalculating the optimum array weights again and again. Some examples of popular optimization techniques include LMS (Least Mean Square), SMI (sample Matrix Inversion), conjugate gradient, and waveform diverse algorithms .The main purpose of adaptive Beam-forming algorithm is to generate beam towards desired users while minimizing the interferers at the same time, by adjustment of beam former's weights. It is the process of changing the complex weight on real time basis for the maximization of quality of the communication channel.

A. Least Mean Square

The Least Mean Square (LMS) algorithm, uses a gradient-based method of steepest decent , LMS algorithm uses the estimates of the gradient vector from the available data. LMS 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.

Considering a Uniform Linear Array (ULA) with N isotropic elements, which forms the integral part of the adaptive beam forming system.

The output of the antenna array is given by,

$$\xi(k) = d(k) - \overline{W}^{H}(k)\overline{x}(k) \quad \textbf{(1)}$$

Taking square error

$$|\xi(k)|^2 = \left|d(k) - \overline{W}^{H}(k)\overline{x}(k)\right|^2$$

(2)

By solving above equations,

$$|\xi(k)|^2 = |d(k)|^2 - 2d(k)w^{H}(k)\overline{x}(k) - w^{H}\overline{x}(k)x^{H}k\overline{w}$$

Taking the expected value of both sides and simplifies the expression and suppresses the time dependence notation k.

$$E[|\xi|^2] = E[|d|^2] - 2\overline{w}^{H}\overline{r} + 2\overline{w}^{H}\overline{R}_{xx}\overline{w} \quad \textbf{(3)}$$

B. Sample Matrix Inversion

When the transmission is discontinuous, a block adaptive approach would give a better performance than a continuous approach. One such algorithm is the Sample Matrix Inversion (SMI) which provides good performance in a discontinuous traffic. However, it requires that the number of interferers and their positions remain constant during the block acquisition. the Sample Matrix Inversion (SMI) algorithm initially estimates the array weights, and updates when new samples arrives resulting a new estimates of matrix. When number of samples grows, the matrix updates approaching its true value, and then the estimated weights approach to the optimal weight.of the block acquisition. LMS the optimal solution is

$$\bar{W}_{optimal} = \bar{R}_{xx}^{-1}\,\bar{r} \quad (4)$$

Where

$$\bar{r} = E[\,d^{*}\bar{x}\,] \quad (5)$$

$$\bar{R}_{xx} = E[\,\bar{x}\bar{x}^{H}\,] \quad (6)$$

The correlation matrix by calculating the time average with an observational interval K

$$\hat{R} = \frac{1}{K}\sum_{K=1}^{K}\bar{x}(k)\bar{W}^{H}(k) \quad (8)$$

The correlation vector wills

$$\hat{r} = \frac{1}{K}\sum_{K=1}^{K}\bar{x}(k)d^{*}(k) \quad (9)$$

Since we use a *K*-length block of data, this method is called a block adaptive approach. We are thus adapting the weights block-by-block . The SMI weight can be calculated for the kth block of length K as

$$\bar{W}_{SMI}(k) = R_{xx}^{-1}(\bar{k})\; r(k) \quad (10)$$

$$W_{SMI}(k) = [\,X_k(k)\,]\,R_{xx}^{-1}(k)\; r(k) \quad (11)$$

V. SIMULATION AND RESULTS

Consider 4 element antenna array and 100 samples, there is a desired user at 0°, while interference/undesired user at 30°, -30° and 60°, by generating the simulation for 4 array element of Least Mean Square (LMS) algorithm using MATLAB version 7.5, Simulation result in figure.3 shows that there is a big variation before 20 samples, some small variation between 35 to 45 samples, and almost constant after about 50 to 55 samples. That result describe the fact that adaptive array cannot acquire the signal of interest fast enough to track the environment change.

For same condition ,simulation result of Sample Matrix Inversion (SMI) algorithm in 20 samples, some small variation between 35 to 45 figure4 shows that there are some variation before samples, and almost constant after about 50 samples. The result describes the fact that information will update block-by-block will reduce the errors. Reduction of error results in high signal to interference ratio for mitigating the effect of multipath and cochannel.

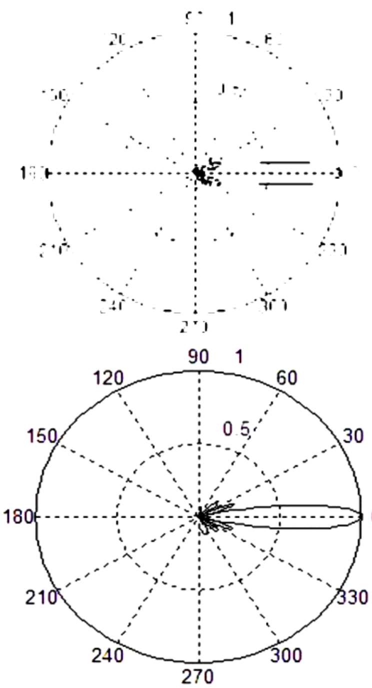
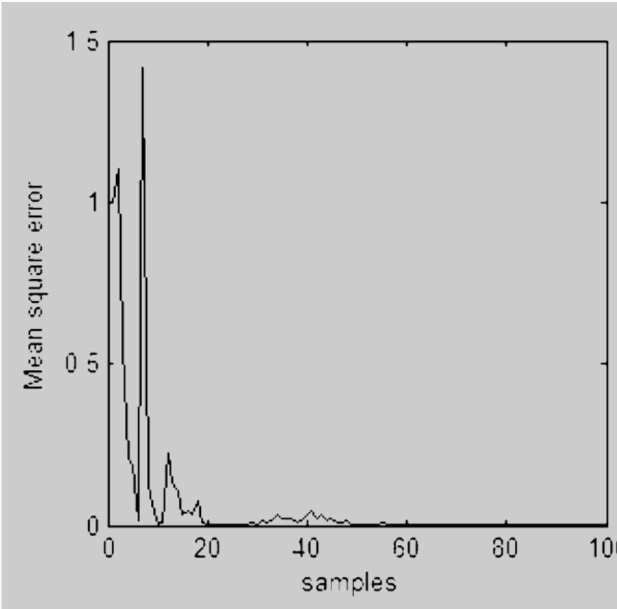


Fig .5 Radiation pattern for LMS and SMI Algorithm



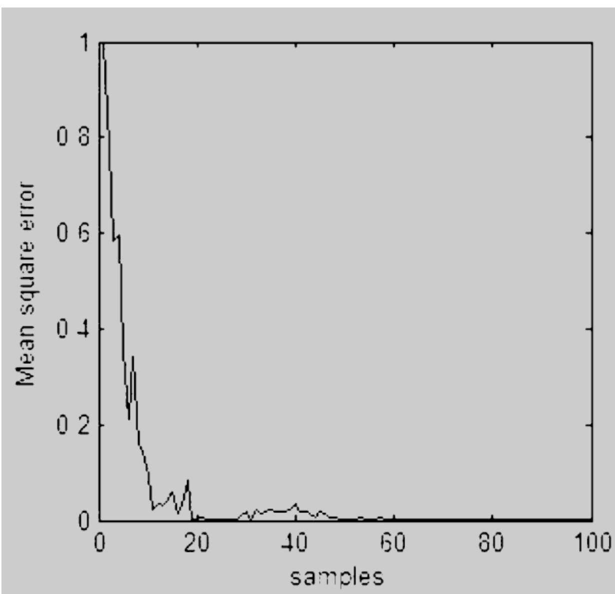


Fig.6 Mean square error pattern of LMS and SMI

VI. CONCLUSION

Simulated result shows that LMS and SMI beam forming algorithm results in multipath and CCI rejection. LMS is easy to adopt but it has slow convergence as changes happen in the dynamic environment, and required knowledge of reference signal. SMI has a fast convergence rate. It is suitable for bursty traffic adaptation where it is unlikely that signal environment will change during block acquisition. SMI algorithm is based on matrix inversion, which tends to be computationally intensive. The high convergence rate property of the SMI algorithm is based on matrix inversion, which tends to be computationally intensive. The high convergence rate property of the SMI algorithm is best made use of when it is used in conjunction with other algorithms. Again like LMS, SMI algorithm requires information about the desired signal.

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