© 2017 IJSRST | Volume 3 | Issue 2 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X

National Conference on Advances in Engineering and Applied Science (NCAEAS)
16th February 2017
In association with
International Journal of Scientific Research in Science and Technology

Adaptive Smart Antenna using Neural Network (SMI Algorithm)

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ABSTRACT

Smart antenna systems are of great importance in wireless communications and RADAR applications ,They effectively enhance the system capacity and reduce the co-channel interference. Smart antenna is an array antenna that uses adaptive beam forming algorithms to steer the main beam towards the desired signal direction and reject the interfering signals of the same frequency from other direction without moving the antenna. This is achieved by continuously updating the weights of each radiating element (antenna). An algorithm with low complexity, low computation cost, high speed convergence rate and better performance is usually preferred. This paper introduces a new performance investigation and comparison between five different beam forming algorithms : Least Mean Square(LMS), Normalised Least Mean Square(NLMS),Sample Matrix Inversion(SMI),Recursive Least Square(RLS) and Hybrid Least Mean Square/ Sample Matrix Inversion (LMS/SMI). In this investigations, the number of array element and the displacement among them are changed in each algorithm is optimized and demonstrated using MATLAB software package.

Keywords: MATLAB, LMS, NLMS, RADAR, CDMA, SMI

I. INTRODUCTION

Due to the globalisation, the modern wireless communication services are spreading rapidly. This necessitates to improve the coverage area, quality of the signal, and capacity of present network by the service providers. The upcoming technologies (Third Generation-3G and Fourth Generation-4G) are adopting the Space Division Multiple Access (SDMA) technique with smart antenna system. With this antenna architecture, the weights of the antennas are adopted to point the main beam in the desired directions and place nulls in the interference directions. Different algorithms are used to adjust the weights in the Smart Antenna Systems. A comparision of Least Mean Square(LMS) and Recursive Least Square (RLS) algorithms for smart antennas in a Code Division Multiple Access(CDMA) mobile communication environment has been presented.

II. Mathematical Model

A Smart antenna system consists of a number of element which are arranged in different geometries (like Linear, Circular etc.,) and whose weights are adjusted with signal processing technique and evolutionary algorithm to exploit the spatial parameter of wireless channel characteristics under noisy environment. Fig.1 shows the block diagram of smart antenna system.

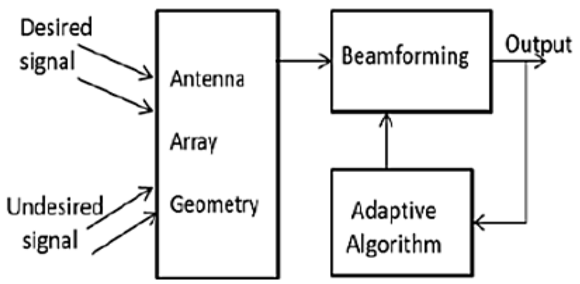


Figure 1. Block diagram of Smart antenna system

III. SMI Algorithm

One of the drawback of the LMS algorithm is the rate of convergences of weights is slow since it must go through many iteration before satisfactory convergence is achieved. So we have another algorithm called SMI algorithm, The sample matrix is a time average estimates of the array correlation matrix using K-time sample. If the random process is ergodics in the correlation, the time average estimate will equal the actual correlation matrix. The SMI algorithm has a faster convergences rate since it employ direct inversion of the correlation matrix Rxx

$$\text{where } \bar{R}_{XX} = \mathrm{E}[\overline{xx}^{\mathrm{H}}]$$

Here x represent array signal vector of size 1xM, where M represent number of antennas in array. H represents Hermitian transpose of x . SMI is also known as Direct Matrix Inversion (DMI). The samples matrix is a time average estimate of the array correlation, matrix using K-time sample. In this algorithm, the input samples

$$\text{where } \bar{r} = \mathrm{E}[d * .\bar{x}]$$

are divided into "k" number of block and each number of block is of length K. The optimum weights can be calculated directly by calculating correlation matrix R and cross-correlation vector r ,
The optimum weight vector is given by

$$\bar{w}_{opt} = \bar{R}_{xx}^{-1}\bar{\gamma}$$

wopt = it is the Wieners solution. We can estimate the correlation matrix by calculating the time average such that

$$\mathrm{R}_{\mathrm{XX}} = \frac{1}{k}\sum_{k=1}^{k} \bar{x}(\mathrm{k})\bar{x}^{\mathrm{H}}(\mathrm{k})$$

The correlation vector r can be estimated by

$$r = \frac{1}{k}\sum_{k=1}^{k} d^*(\mathrm{k})\,\bar{x}(\mathrm{k})$$

where d(k) represents the desired signal. Since we use a K-length block of data, this methods is called a block-adaptive approach. We are thus adapting the weights block-by-block. It is easy in MATLAB to calculates the array correlation matrix and the correlation vector by the followings procedure. Define the matrix x K(k) as the kth block of x vectors ranging over K-data snapshots

$$\bar{X}_k(k) = \begin{bmatrix} x_1(1+kK) & x_1(2+kk) & \cdots & x_1(\mathrm{K}+kK) \\ x_2(1+kK) & x_2(2+kk) & & \vdots \\ \vdots & & \ddots & \\ x_M(1+kK) & \cdots & & x_M(\mathrm{K}+kK) \end{bmatrix}$$

Here where k is the block numbers and K is the block length. Thus, the estimate of the array correlation matrix is given by

$$\hat{R}_{xx}(k) = \frac{1}{K}\bar{X}_K(k)\bar{X}_K^H(k)$$

the desired signal vector can be define by

$$d(k) = [d(1+kK)\ d(2+kK)\ \ldots d(K+kK)]$$

the estimate of the correlation vector is given by

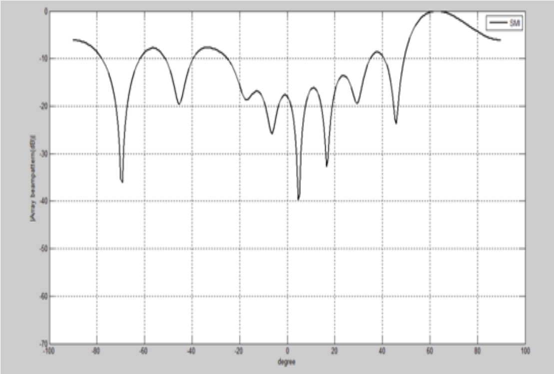
$$f(k) = \frac{1}{K}d^*(k)\bar{X}_K(k)$$

for the k th block of length K The SMI weights can then be calculated as

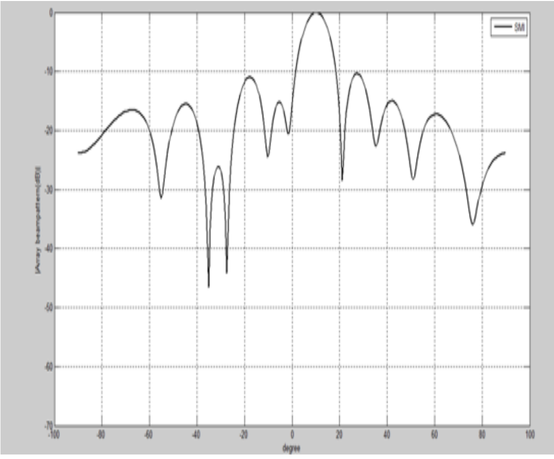
$$\bar{w}\,SMI^{(k)} = \bar{R}_{xx}^{-1}(k)\bar{r}(k) = [\bar{X}_K(k)\bar{X}_K^H(k)]^{-1}\,d^*(k)\bar{X}_K(k)$$

The SMI algorithm was simulated using MATLAB Software. Let us take Case1: An array of antenna with 8 element, N = 8. Let the spacing between each antenna in the array be d = 0.25. Suppose that the desired signal is arriving at an angle θ0 = 25° and an interferer is arriving at an angle θ1 = –65°. Case2: An array of antenna with 30 element, N = 30, d = 0.25. the desired signal is arriving at an angle θ0 = 25° and an interferer is arriving at an angle θ1 = –65°. Case3: An array of antenna with 30 elements, N = 30, d = 0.15, then the desired signals is arriving at an angle θ0 = 25° and an interferer is arriving at an angle θ1 = –65°. Case4: An array of antennas with 30 elements, N = 30, d = 0.15, then the desired signal is arriving at an angle θ0 = 45° and an interferer is arriving at an angle θ1 = –65°. Case5:An array of antennas with 30 elements, N = 30, d = 0.15, the desired signal is arriving at an angle θ0 = 45° and an interferer is arriving at an angle θ1 = –85°. Now calculate the beam strength at those angles by applying optimum weights to received signals and also observe the beam patterns at different angles in a Cartesian plot.

IV. Output of SMI



At =60°



At =10°

V. CONCLUSION

In this work, SMI algorithms are used for interference rejection by an adaptive antenna array with various numbers of elements. The effect of number of elements in the array of antenna on the interference rejection is observed. As expected from antenna theory, the main lobe and other lobes widths are reduced. The Simulation results show that SMI is capable of nullifying the interference sources and its convergence is faster than LMS algorithm. The null depth performance of the SMI algorithm is better than that of the LMS algorithm.

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