Implementation of Adaptive Beam Forming Algorithm for Smart Antenna

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Abstract

The smart antenna is a new technology and has been applied to the mobile communication system such as GSM and CDMA. Advent of powerful, low-cost, digital processing components and the development of software-based techniques has made smart antenna systems a practical reality for both base station and mobile station of a cellular communications systems in the next generation. The core of smart antenna is the selection of beam forming algorithms. Using beam forming algorithms the weight of antenna arrays can be adjusted to form certain amount of adaptive beam to track corresponding users automatically and at the same time to minimize interference arising from other users by introducing nulls in their directions. Thus interferences can be suppressed and the desired signals can be extracted. In this project adaptive beam forming algorithm is implemented using Wiener Hopf steepest descent method for broadside antenna array of a base station receiver (Uplink). Assuming narrow band desired signal.

Key words: Switched Beam, Adaptive Array, Steepest Descent Algorithm

Introduction

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. This is achieved by focusing the radiation only in the desired direction and adjusting itself to changing traffic conditions or signal environments. The process of combining the signals and then focusing the radiation in a particular direction is often referred to as digital beam forming [1], [2].

Smart antennas are defined as arrays of antenna elements that change their antenna pattern dynamically to adjust to the noise, interference in the channel and mitigate multipath fading effects on the signal of interest. The main difference between the smart antenna and fixed antenna is the property of having an adaptive and fixed lobe pattern.

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

1. Switched beam antenna
2. Adaptive Array Antenna

Switched beam Antenna

The Switched beam approach is simpler compared to the fully adaptive approach. It provides a considerable increase in network capacity when compared to traditional omnidirectional antenna systems or sector-based systems.

Adaptive Array Antenna

This system tracks the mobile user continuously by steering the main beam towards the user and at the same time forming nulls in the directions of the interfering signal. Like switched beam systems, they also incorporate arrays. Typically, the received signal from each of the spatially distributed antenna elements is multiplied by a weight. These signals are combined to yield the array output. These complex weights are computed by a complicated adaptive algorithm, which is pre-programmed into the digital signal-processing unit that manages the signal radiated by the base station.

Adaptive Beam Forming Algorithm

Beam forming is generally accomplished by phasing the feed to each element of an array so that signals received or transmitted from all elements in phase in a particular direction. The adaptive algorithms can be classified into categories based on different approaches based on adaptation and based on information required as follows.

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Based on adaptation

1. Continuous adaptation
   Examples: The Least Mean Square (LMS) algorithm
   The Recursive Least square (RLS) algorithm
2. Block adaptation
   Example: The Sample Matrix Inversion (SMI) algorithm

Based on information required

1. Reference signal based algorithms:
   Examples: The Least Mean Square (LMS) algorithm
   The Recursive Least square (RLS) algorithm
   The Sample Matrix Inversion (SMI) algorithm
2. Blind adaptive algorithms
   Examples: The Constant Modulus Algorithm (CMA)
   The Cyclostationary algorithm
   The Decision-Directed algorithm

Implementation Using Steepest Descent Algorithm

The steepest descent procedure uses the knowledge of this direction to move to a lower point on the surface and find the bottom of the surface in an iterative manner. In matrix notation [3], induced signal can be written as

$$X = A_{\theta 0} S + A_{in} I_i + N$$

where, X represents L x Ns induced signal matrix. L corresponds to number of elements in an array. Ns is total number of samples. S represents reference signal samples. $A_{\theta 0}$ is desired steering vector of order Lx1. Ii represents interference signal samples matrix of order 1xNs, N represents Gaussian noise matrix of order LxNs and in A_{in} is Lx1 column vector that is obtained by adding all columns of array manifold vector as shown

$$A_{in} = \begin{bmatrix} 1 \\ e^{j2\pi d\cos\theta 1} \\ \vdots \\ . \\ e^{j2\pi d(L-1)\cos\theta 1} \end{bmatrix} + \begin{bmatrix} 1 \\ e^{j2\pi d\cos\theta 2} \\ \vdots \\ . \\ e^{j2\pi d(L-1)\cos\theta 2} \end{bmatrix} + \dots\dots\dots\dots\dots\dots\dots + \begin{bmatrix} 1 \\ e^{j2\pi d\cos\theta M} \\ \vdots \\ . \\ e^{j2\pi d(L-1)\cos\theta M} \end{bmatrix}$$

Where, d is the distance between antenna elements, $\theta_1 \theta_2 \dots\dots\dots\dots \theta_M$ are directions of jamming signals and M is number of jamming signals.

1. Compute the Lx1 steering vector for desired direction θ_0

$$a_\theta = \begin{bmatrix} 1 \\ e^{j2\pi d\cos\theta} \\ \vdots \\ . \\ e^{j2\pi d(L-1)\cos\theta} \end{bmatrix}$$

2. Compute the LxM array manifold vector corresponding to M interference source directions

$$a_\theta = \begin{bmatrix} 1 & & \dots & \dots & 1 \\ e^{j2\pi d\cos\theta} & \dots & \dots & & e^{j2\pi d\cos\theta_{m-1}} \\ & & \dots & & \\ e^{j2\pi d(L-1)\cos\theta} & \dots & \dots & & e^{j2\pi d(L-1)\cos\theta_{m-}} \end{bmatrix}$$

3. Obtain signal samples S by sampling continuous time signal of baseband
   frequency.
4. Compute the autocorrelation matrix R_{xx}
5. Compute the step size by using

$$\mu = \frac{1}{\lambda_{max}}$$

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6. Compute the following for all signal samples $0 \leq n \leq NS$

$$x(n) = s(n)a(\theta_0) + i(n)\sum_{i=1}^{M} a(\theta_i) + n_0(n)$$

7. The array factor is computed by using equation

$$AF = \sum_{i=1}^{L} w_{(i)}^{H} e^{j2\pi d cos\theta}$$

where $-90^{o} \leq (\theta + 0{:}001) \leq +90^{o}$

8. Array factor versus angles are plotted.

Results and Discussions

Fig 5.1, 5.2, 5.3 and 5.4 shows the plot for input signal x(t), error plot, radiation pattern and output pattern for adaptive antenna array consisting of number of antenna elements = 5.

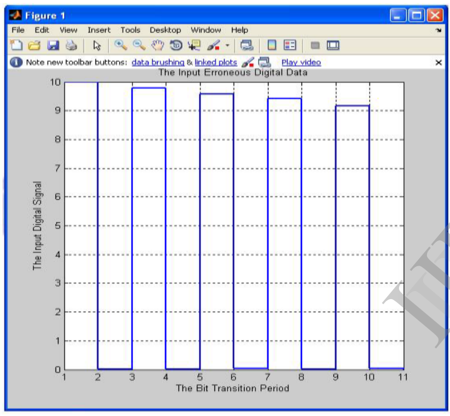

Figure 5.1: The input erroneous digital data

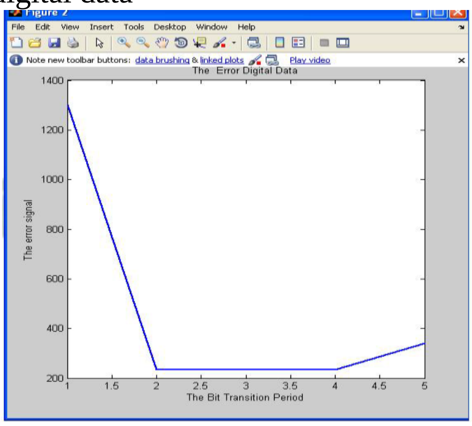

Figure 5.2: The error polt

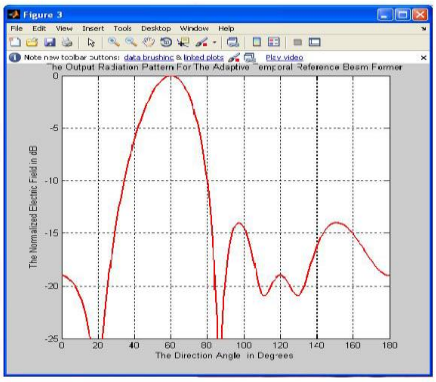

Figure 5.3: The output radiation pattern

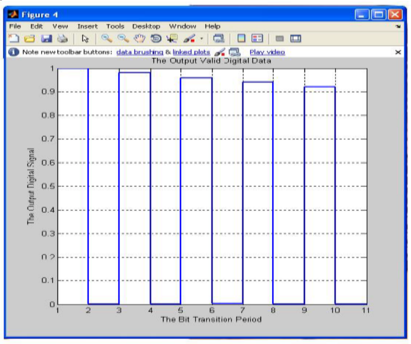

Figure 5.4: The output digital data

Fig 5.5, 5.6, 5.7 and 5.8 shows the plot for input signal x(t), error plot, radiation pattern and output pattern for adaptive antenna array consisting of number of antenna elements = 10.

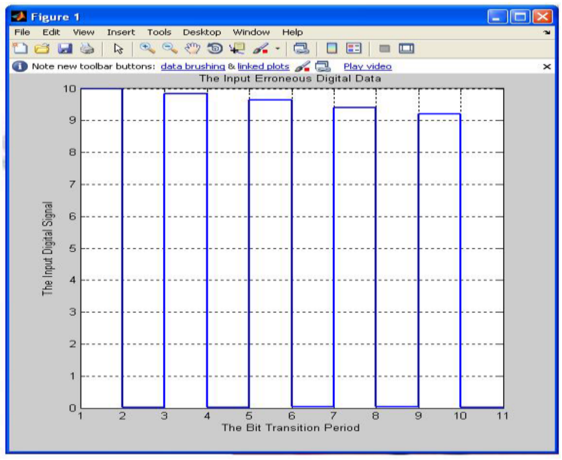

Figure 5.5: The input erroneous digital data

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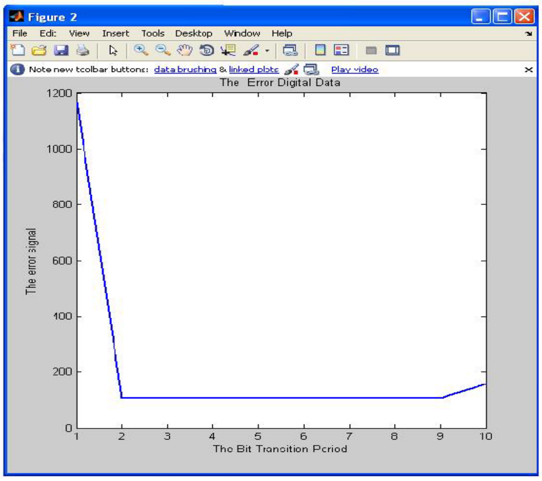

Figure 5.6: The error polt

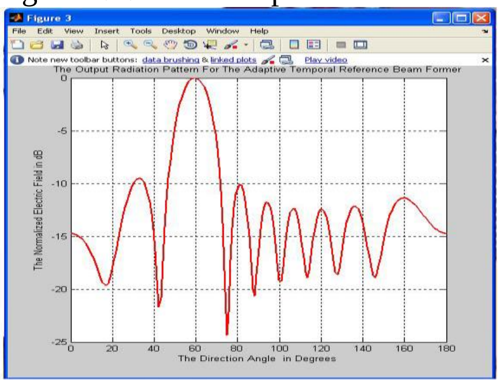

Figure 5.7: The output radiation pattern

It is also observed that as the number of antenna elements increases in array the beam becomes more narrower which indicates that if more numbers of antenna elements are included in array covers more area and hence increases coverage capacity and thus reduces the co-channel interference.

Conclusion

This project discussed adaptive beamforming for adaptive array antenna i.e a smart antenna using wiener Hopf steepest descent method. The convergence speed of this method depends on eigenvalues of array correlation matrix. It was found that the performance of adaptive beamformer improves as more elements are used in the antenna array. This improvement can be seen in the form of sharper beams directed towards the desired users .

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