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Performance Analysis of Adaptive Beamforming Algorithms for Smart Antennas

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Abstract

In this paper, adaptive beamforming techniques for smart antennas based upon Least Mean Squares (LMS), Sample Matrix Inversion (SMI), Recursive Least Squares (RLS) and Conjugate Gradient Method (CGM) are discussed and analyzed. The beamforming performance is studied by varying the element spacing and the number of antenna array elements for each algorithm. These four algorithms are compared for their rate of convergence, beamforming and null steering performance (beamwidth, null depths and maximum side lobe level).

Keywords: Smart antenna; adaptive beamforming algorithms; null steering

1. Introduction

A smart antenna system is a multi-element antenna where the signals received at each antenna element are intelligently combined to improve the performance of the wireless system. Smart antennas can increase signal range, reduce signal fading, suppress interfering signals, and increase the capacity of wireless systems. The block diagram of a smart antenna system is shown in Fig.1 where signals received by the antenna array are multiplied by adjustable weights and then combined to produce the system output. The processor receives

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array signals, system output, and direction of the desired signal as additional information. These are used by the processor to calculate the weights to be used for each channel [2][9].

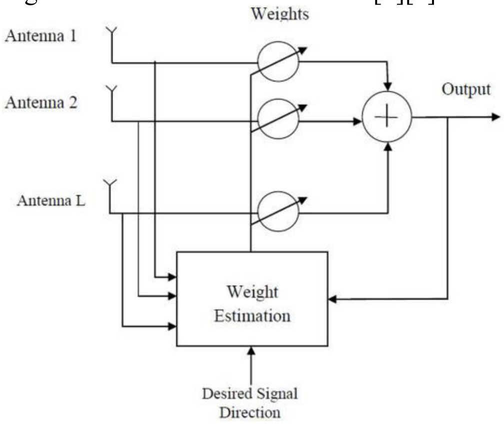

Fig. 1. Basic Adaptive Beamformer

Beamforming is the process of forming the radiation pattern of the antenna array by nulling out the interference and pointing the beam in the direction of the user. Fixed beamforming is applied to fixed arrival angle sources. However, if the angles of arrival of the sources change with time, fixed beamforming cannot be used. The optimum array weights need to be continuously adapted to the ever-changing environment. This process is known as adaptive beamforming. An adaptive array system consists of antenna array elements terminated in an adaptive processor which is designed to update and compensate the array weights as the source moves. There are two basic adaptive approaches [1]: 1. Block Adaptation, where a temporal block of data is used to estimate the optimum array weights and 2. Continuous Adaptation, in which the weights are adjusted as the data is sampled such that the weight vector converges to the optimum solution. Beamforming algorithms used to control the smart antenna patterns are based upon certain criteria like minimizing the variance, maximizing the signal to interference ratio, minimizing the mean square error, etc. In this paper, adaptive beamforming techniques based upon Least Mean Squares (LMS), Sample Matrix Inversion (SMI), Recursive Least Squares (RLS) and Conjugate Gradient Method (CGM) are discussed and analyzed in section 2. Section 3 presents MATLAB simulations of these algorithms and discusses the advantages and disadvantages of each algorithm. Section 4 concludes the paper.

2. Adaptive beamforming algorithms

2.1. LMS Algorithm

The LMS algorithm [2-8] was introduced by Widrow. In this algorithm, the weights are updated at every iteration by estimating the gradient of the quadratic Mean Square Error (MSE) surface, and then moving the weights in the negative direction of the gradient by a small amount, known as the step size. The convergence of this algorithm is directly proportional to the step-size parameter μ. When the step size is within a range that ensures convergence, the process leads the estimated weights to the optimal weights. Stability is ensured provided that the following condition is met [3].

$$0 \le \mu \le \frac{1}{2\lambda_{\max}} \tag{1}$$